**EXHIBIT L – PART 2**

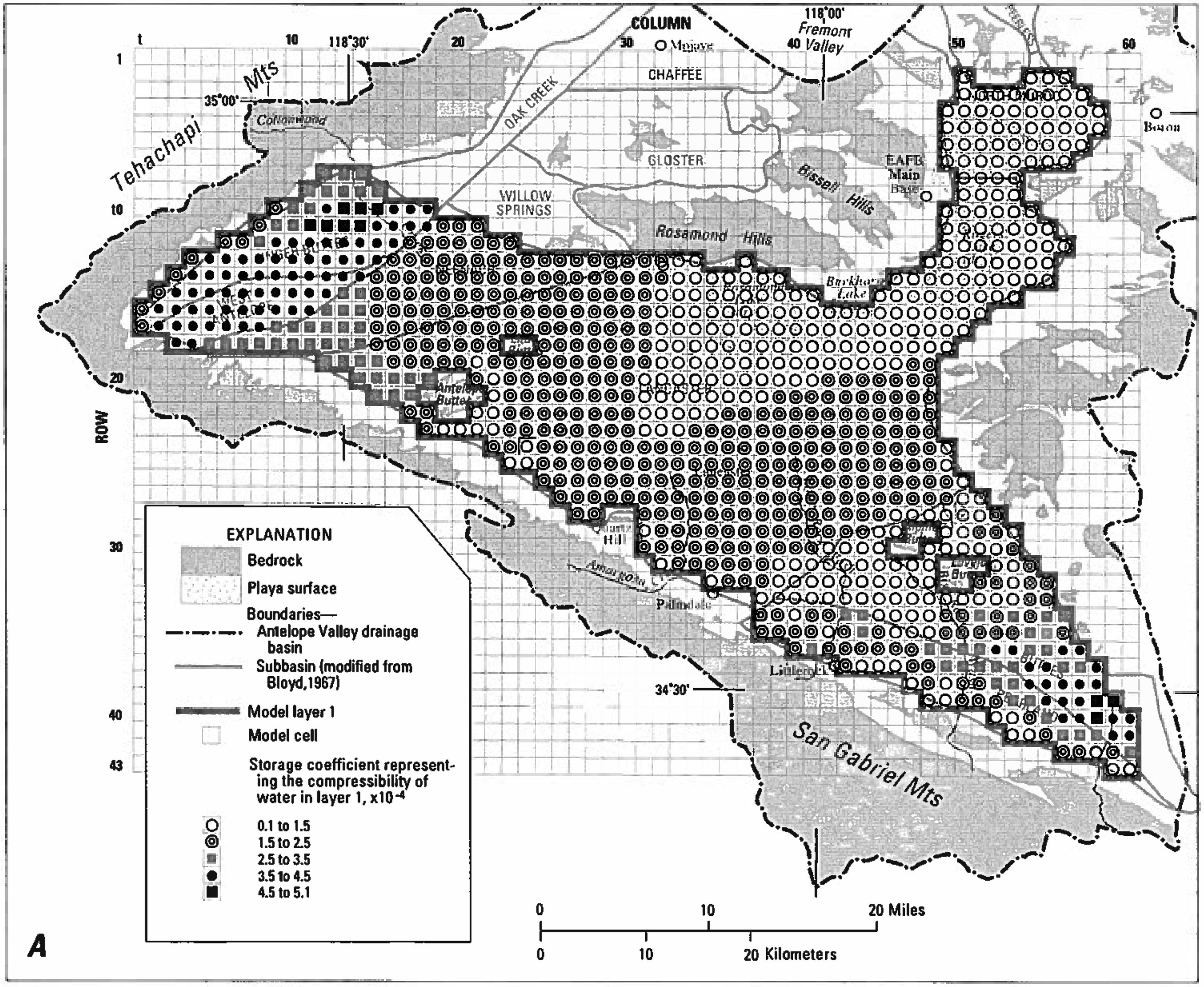


**Figure 21.** Areal distribution of the storage coefficient representing the compressibility of water for *(A)* layer 1 and *(B)* layer 2 in the ground-water flow model of the Antelope Valley ground-water basin, California.

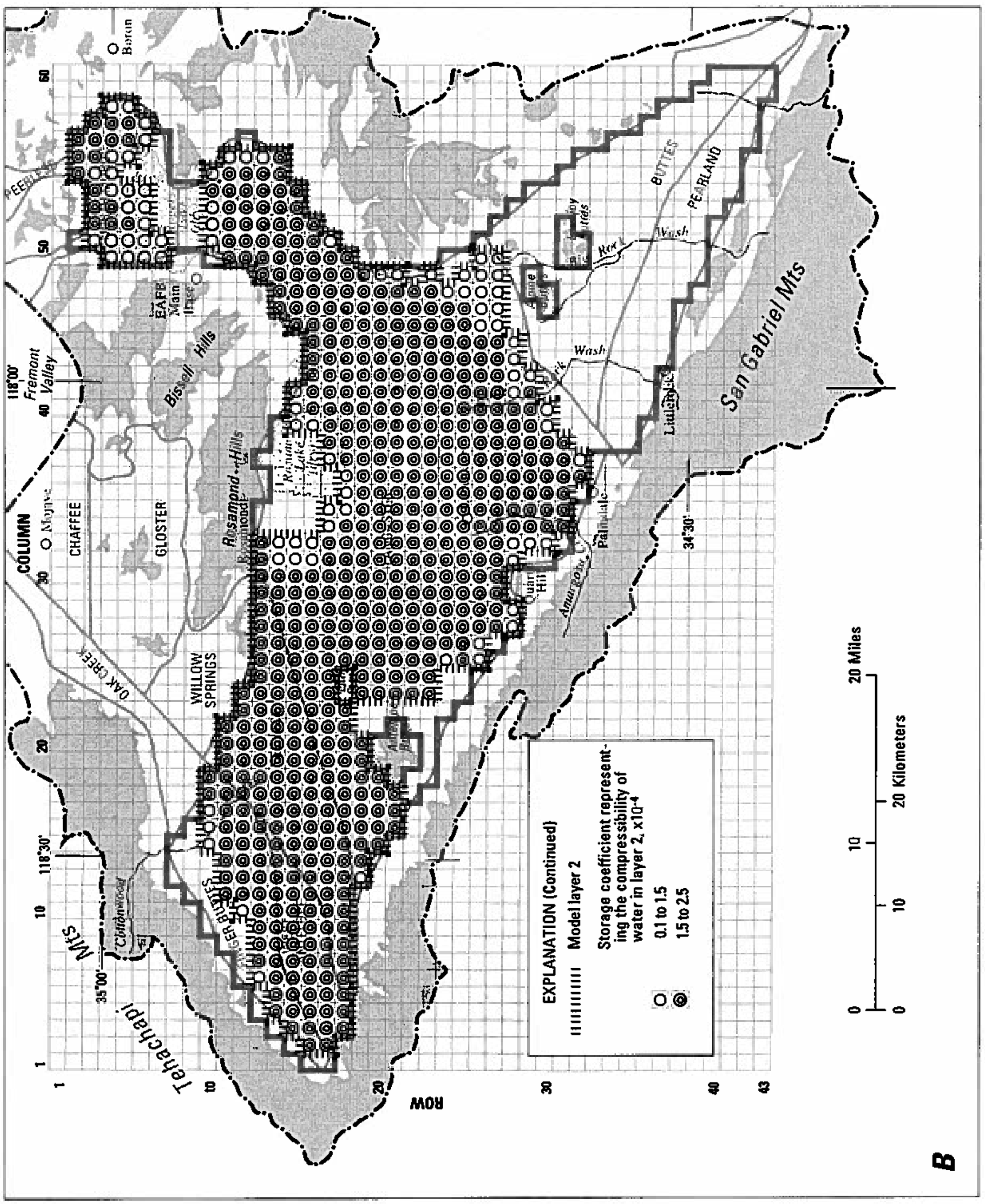


Figure 21.—Continued.

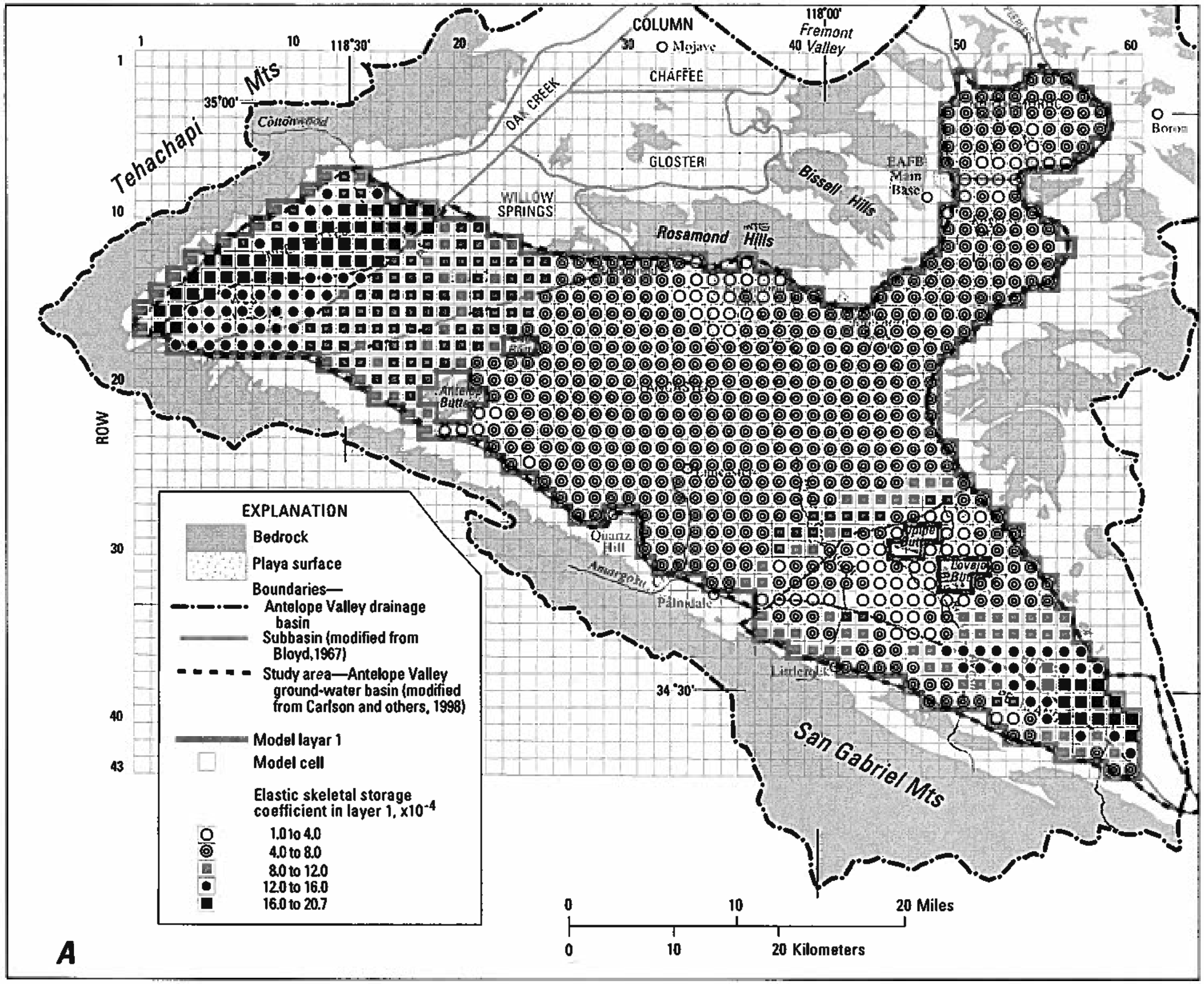


**Figure 22.** Areal distribution of the elastic skeletal storage coefficient for *(A)* layer 1 and *(B)* layer 2 in the ground-water flow model of the Antelope Valley ground-water basin, California.

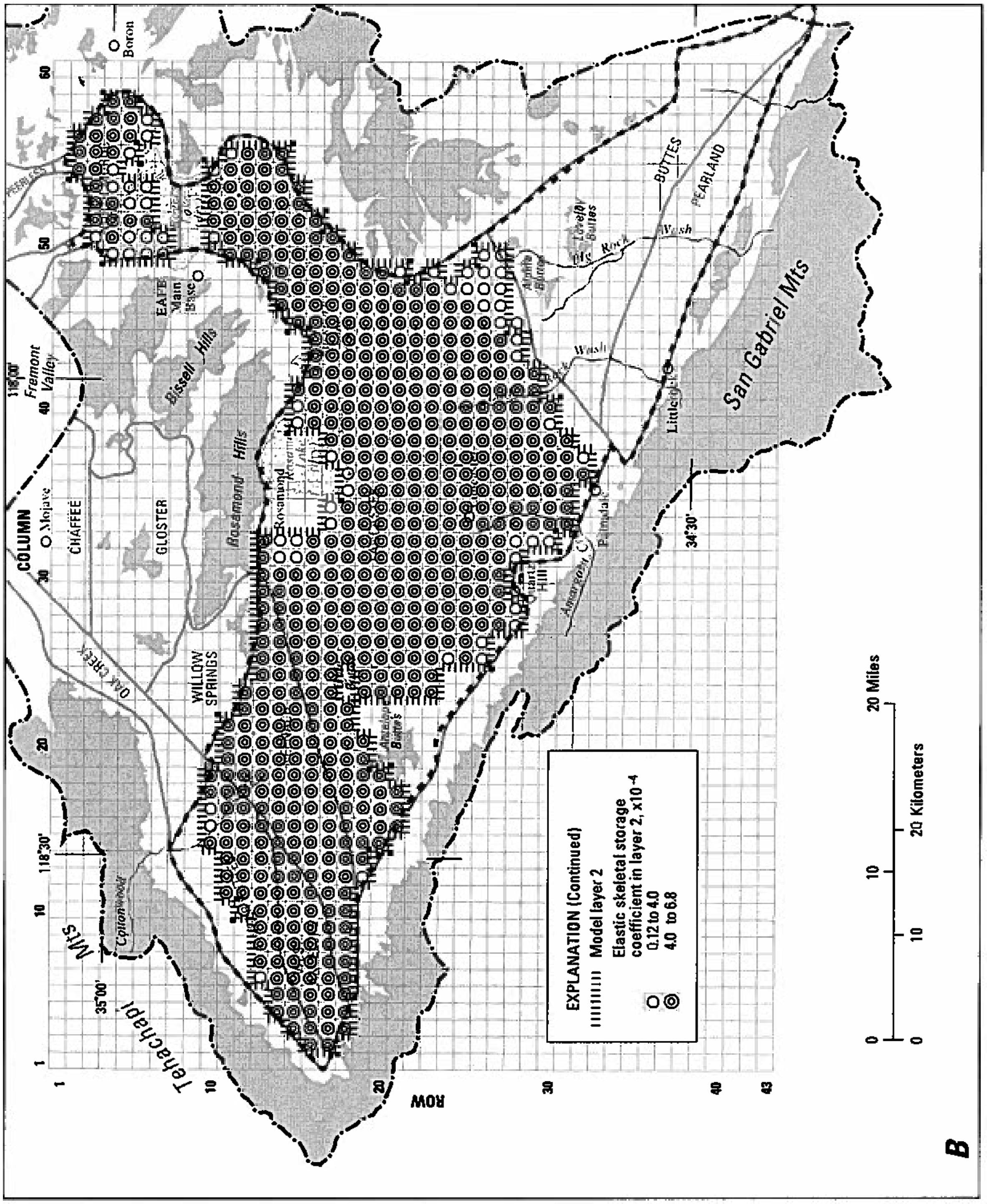


Figure 22.—Continued.

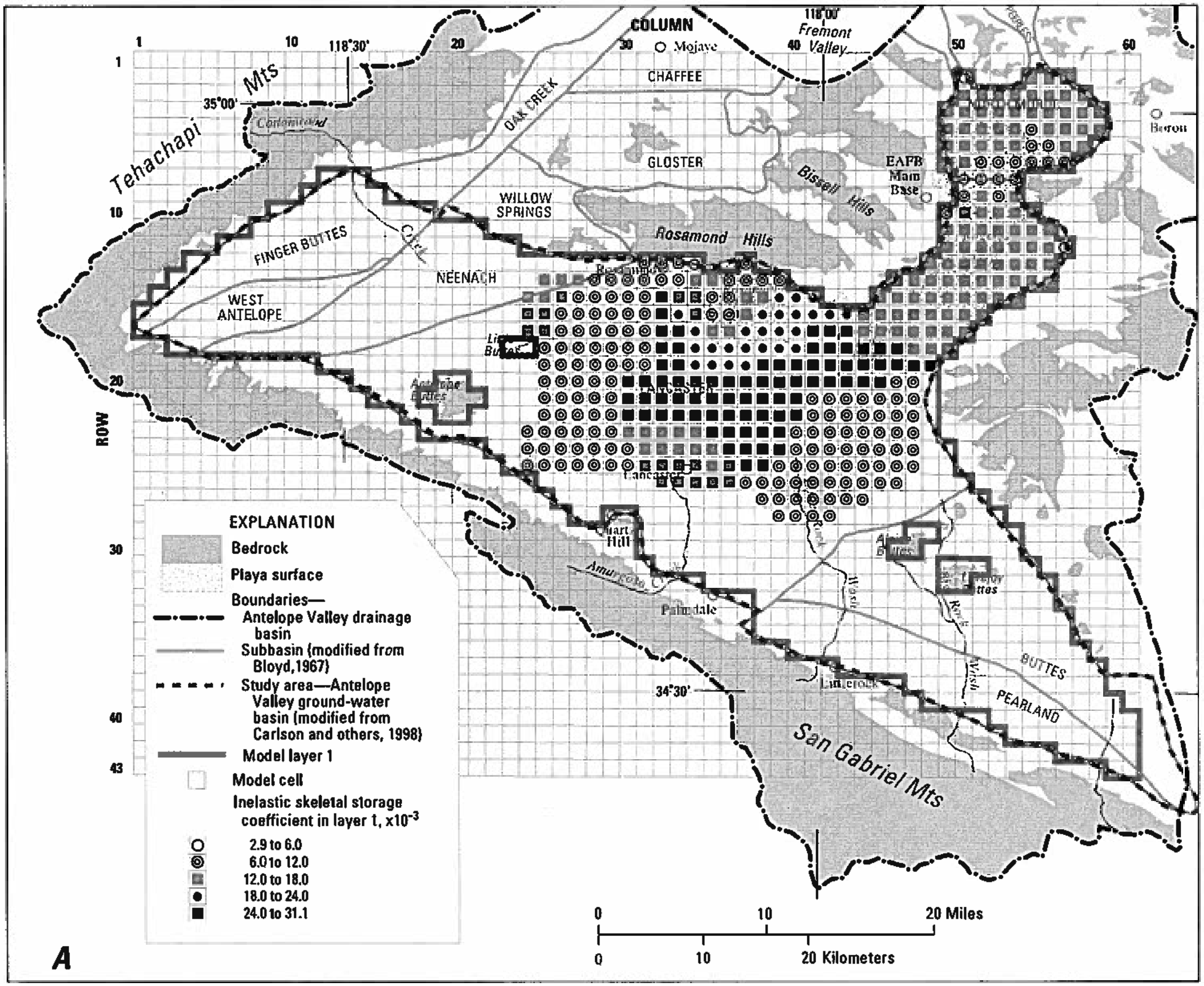


**Figure 23.** Areal distribution of the inelastic skeletal storage coefficient for *(A)* layer 1 and *(B)* layer 2 in the ground-water flow model of the Antelope Valley ground-water basin, California.

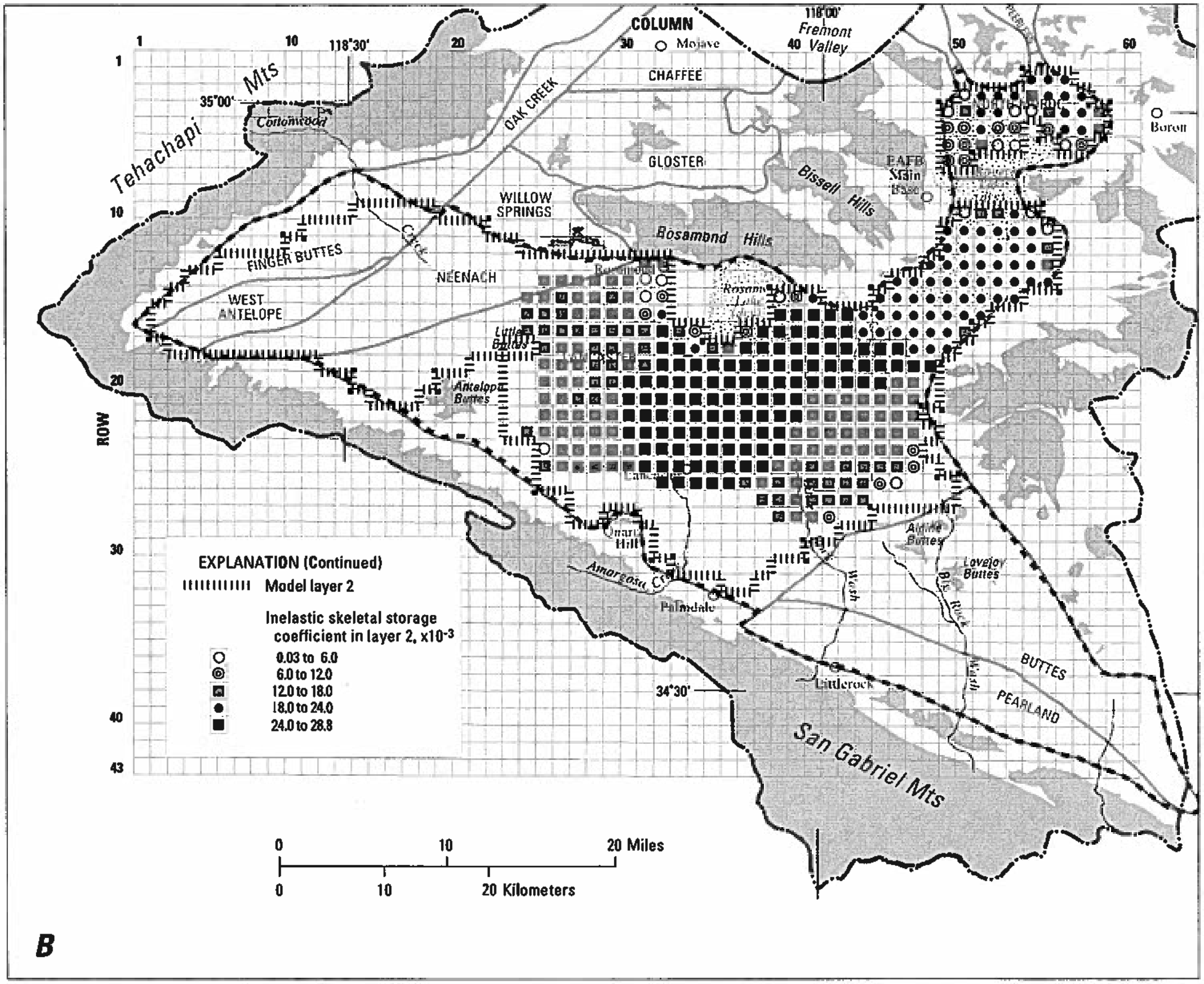


Figure 23.—Continued.

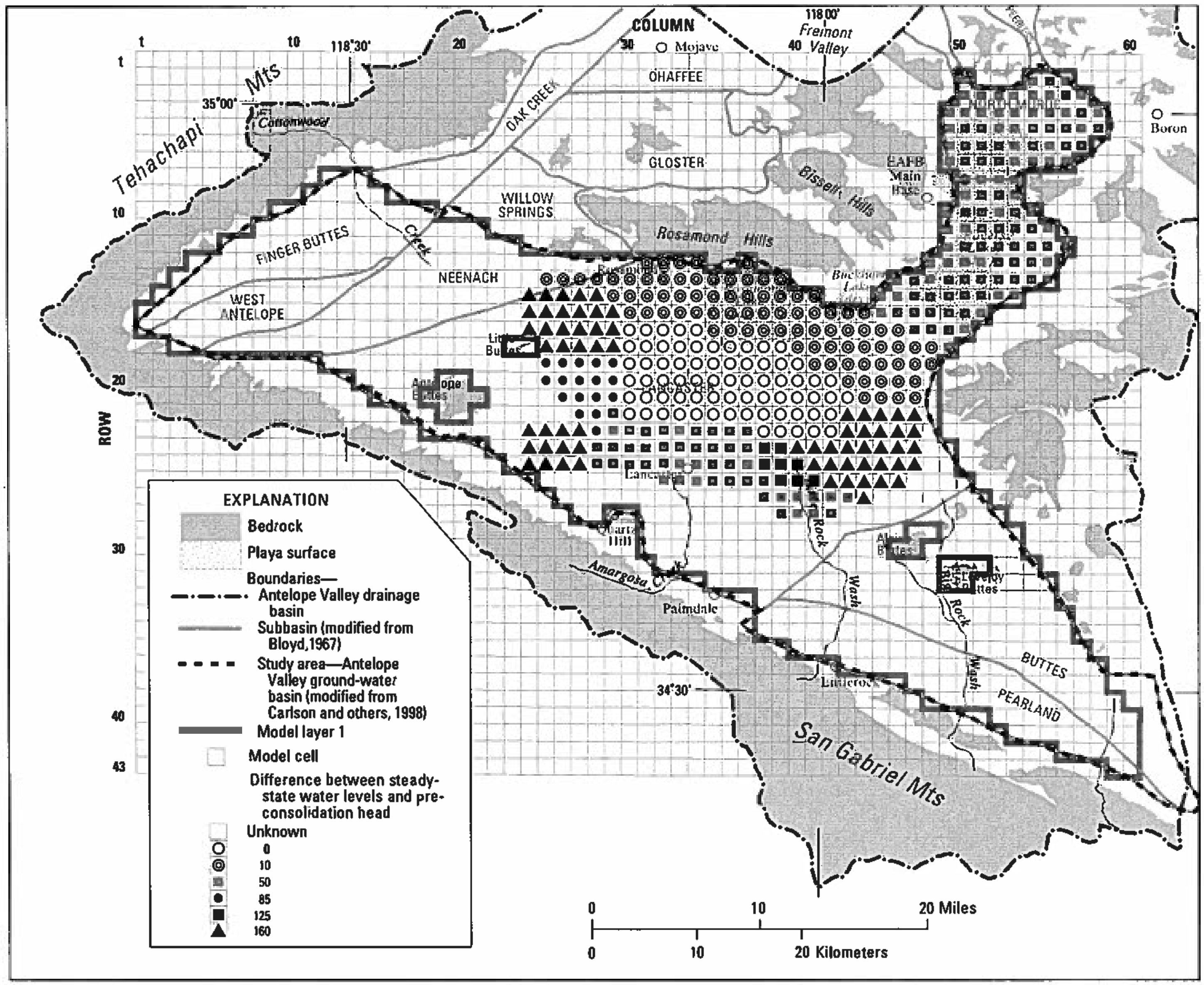


**Figure 24.** Difference between steady-state water levels and preconsolidation head in the ground-water flow model of the Antelope Valley ground-water basin, California.

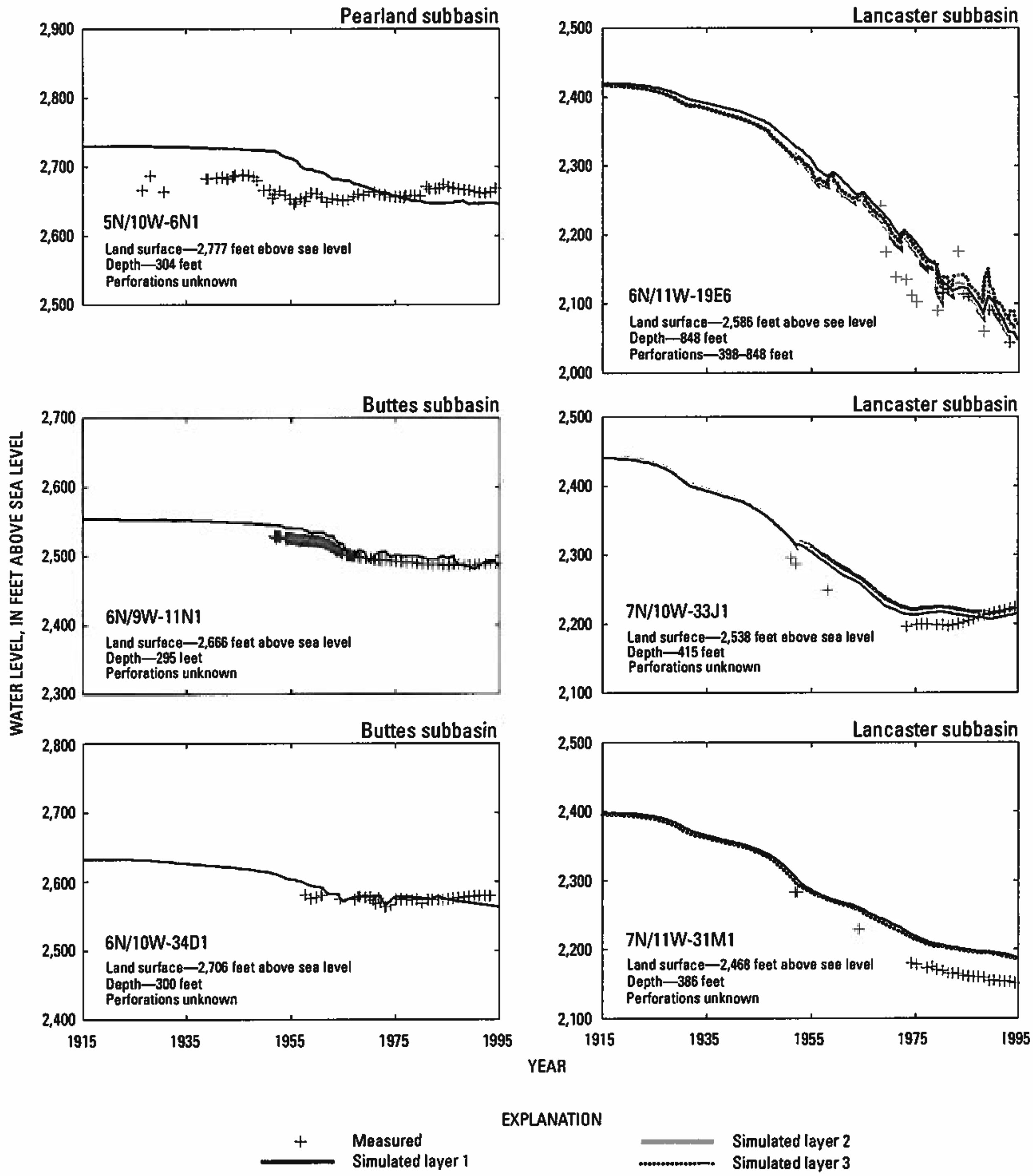


**Figure 25.** Measured and simulated water levels at selected wells in the Antelope Valley ground-water basin, California, 1915–95. (See figure 15 for location of wells.)

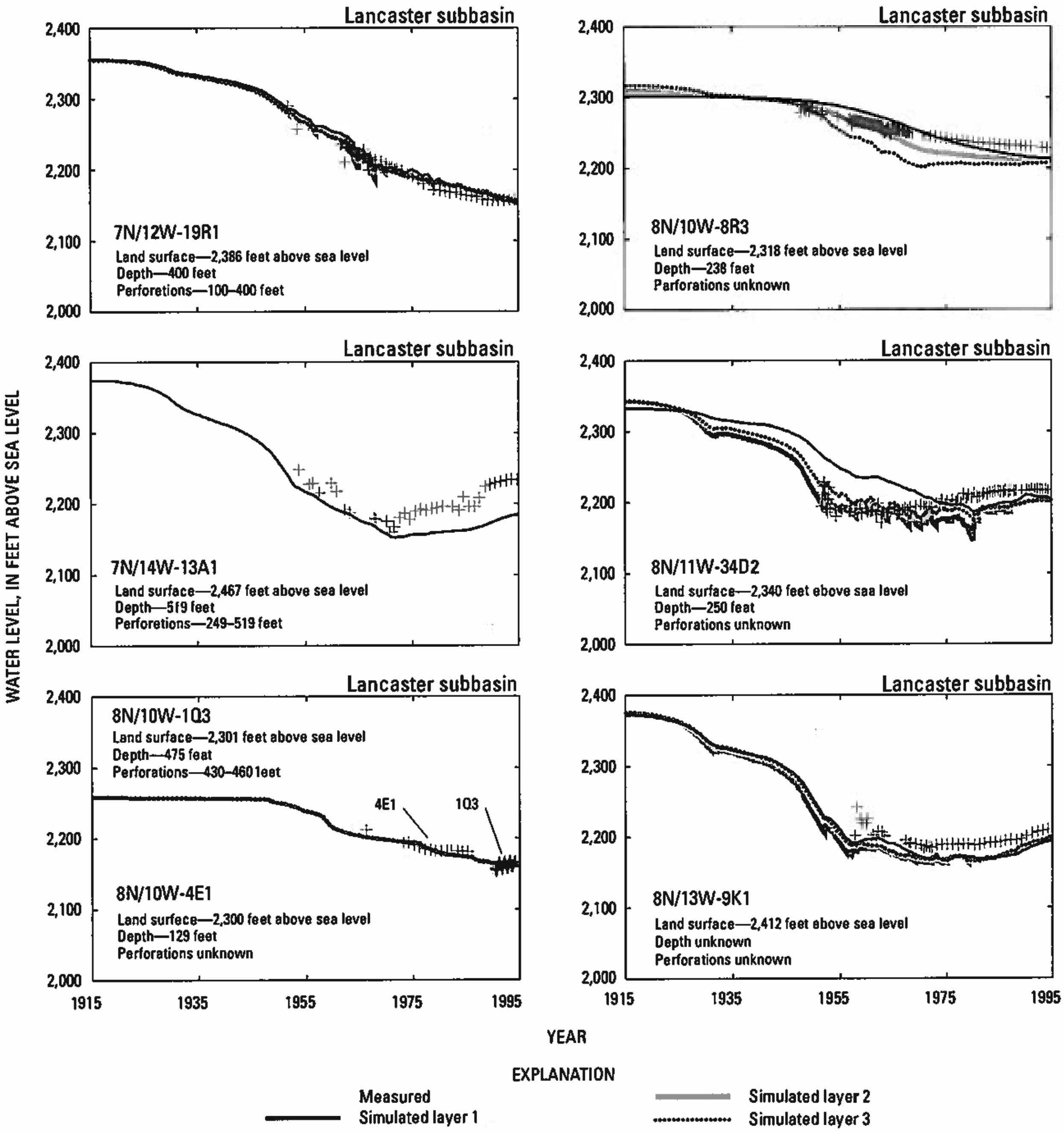


**Figure 25.**—Continued.

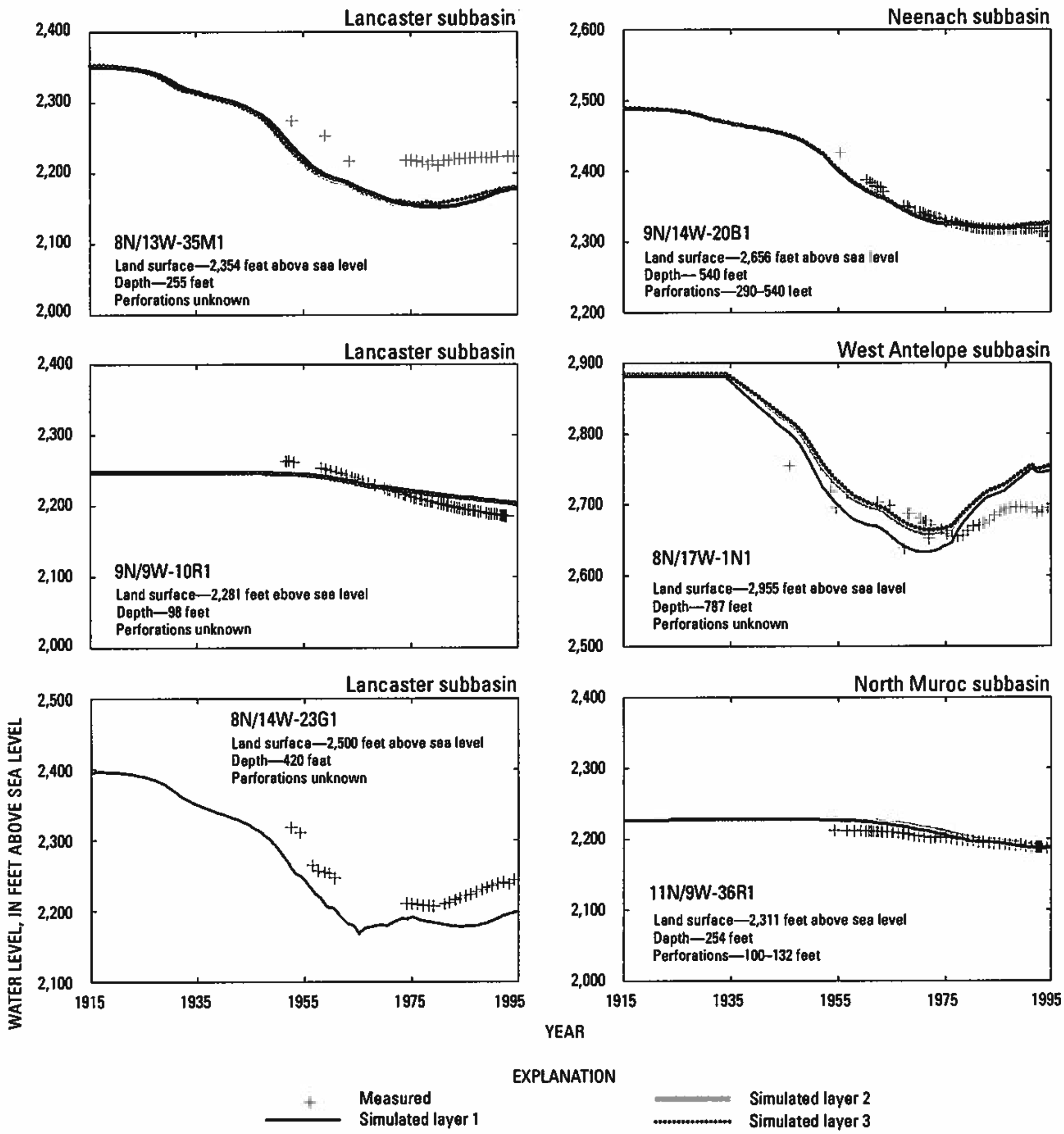


**Figure 25.**—Continued.

In the Buttes subbasin (wells 6N/9W-11N1 and 6N/10W-34D1), measured and simulated water levels matched well. In the Pearland subbasin (well 5N/10W-6N1), the simulated water levels were higher than the measured water levels prior to the 1970s and were lower than the measured water levels after the 1970s. The simulated water level was about 24 ft lower than the measured water level by the end of the simulation period. In the West Antelope subbasin (well 8N/17W-1N1), the simulated water levels matched the measured water levels well through the 1970s, but the simulated water level overestimated the measured water-level rise that occurred from the mid 1970s to 1995 by as much as 65 ft. Because there are virtually no data for this subbasin in the pumpage database, the estimated quantity and distribution of annual pumpage were based only on 1961 land-use data. In addition to the lack of pumpage data for the West Antelope subbasin, there are uncertainties in the estimates of the quantity and distribution of recharge from irrigation-return flows of water delivered by the AVEK Water Agency. It was assumed that water delivered by the AVEK Water Agency was applied to fields near the area where the water was discharged from the aqueduct. In the Neenach subbasin (well 9N/14W-20B1) and the North Muroc subbasin (well 11N/19W-36R1), the simulated and measured water levels matched well.

The simulated water-level gradient between model layers at the end of the model simulation (1995) was compared with the measured February 1996 water-level gradient at nested piezometers 7N/12W-27F5–27F7 in the southern part of the Lancaster subbasin and the measured October 1995 water-level gradient at nested piezometers 8N/10W-1Q1-3 in the northeastern part of the Lancaster subbasin (table 7). In the southern Lancaster subbasin, the measured data indicated that there was an upward water-level gradient, with the largest water-level difference (14 ft) between the middle and lower aquifers (layers 2 and 3). The lacustrine deposits separate the middle and lower aquifers in this part of the subbasin (fig. 3). The model simulated an upward water-level gradient at this site, but the simulated water-level difference between layers 2 and 3 was 11 ft, about 3 ft less than measured water-level difference. In the northeastern Lancaster subbasin, the measured data indicated that there was a small downward water-level gradient; the difference between measured water levels for wells 8N/10W-1Q1–1Q3 was 1–2 ft (table 7). Simulated water levels for the three layers were within 1 ft of each other at this site, indicating little or no vertical ground-water movement at this site. The lacustrine deposits are near land surface in this area (Londquist and others, 1993); these three wells are all perforated below the lacustrine deposits.

**Table 7.** Measured and simulated water levels at two sites with nested piezometers completed at multiple depths in the Lancaster subbasin of the Antelope Valley ground-water basin, California.

[State well No.: See well-numbering in text]

| Layer | Wells 7N/12W-27F5–7 Land surface altitude: 2,443 feet above sea level | | | | Wells 8N/10W-1Q1–3 Land surface altitude: 2,301 feet above sea level | | | |
|---|---|---|---|---|---|---|---|---|
| | State well No. of nested piezometer | Perforated interval, in feet below land surface | Measured water level, February 1996, in feet above sea level | Simulated water level, 1995, in feet above sea level | State well No. of nested piezometer | Perforated interval, in feet below land surface | Measured water level, October 1995, in feet above sea level | Simulated water level, 1995, in feet above sea level |
| 1 | [1]27F7 | 505–525 | 2,138 | 2,156 | [2]1Q3 | 430–460 | 2,154 | 2,159 |
| 2 | [1]27F6 | 705–725 | 2,139 | 2,161 | [2]1Q2 | 605–635 | 2,153 | 2,159 |
| 3 | [2]27F5 | 905–925 | 2,153 | 2,172 | [2]1Q1 | 980–1,010 | 2,152 | 2,160 |

[1] Above the lacustrine clay.
[2] Below the lacustrine clay.

Contours of simulated 1995 and measured 1996 (Carlson and others, 1998) water levels for layer 1 are shown in figure 26. The measured 1996 water-level contours were assumed to be representative of 1995 conditions and were used to qualitatively evaluate the transient-state simulation. The model does a good job of simulating the observed pumping depression near Lancaster and Palmdale, an area of recent extensive pumping for public supply. However, the simulated water levels were lower than measured water levels in the eastern and western parts of the Lancaster subbasin. These areas historically were subject to large amounts of agricultural pumping, which was not metered and therefore difficult to estimate. The simulated flat water-level gradient in the northern part of the Lancaster subbasin and the North Muroc subbasin matched the measured water-level gradient in these areas. The simulated water levels matched the measured water levels throughout most of the Neenach subbasin except in the western part of the subbasin. The simulated and measured water levels matched well in much of the Buttes and Pearland subbasins even though the hydrogeologic and agricultural pumpage data for these subbasins were limited. Because of insufficient water-level data for the Finger Buttes, West Antelope, and parts of the Buttes and Pearland subbasins, comparisons could not be made for these subbasins.

### Land Subsidence

Simulated land subsidence was compared with periodic surveyed (measured) data collected at 10 bench marks (locations shown in figure 15) since about 1930 (fig 27). Simulated land subsidence is the sum of aquifer-system compaction in layers 1 and 2. Recall, compaction was assumed to be minimal in layer 3, and was not simulated in the model. Pumping-induced subsidence is controlled by the thickness of compressible sediments, preconsolidation head, and water-level declines. Where simulated water-level declines are greater than actual water-level declines or where the aquifer contains a smaller thickness of compressible sediments than was represented in the model, simulated subsidence will be larger than measured subsidence. Simulated subsidence will be smaller than measured subsidence where simulated water-level declines are less than actual water-level declines or where the aquifer contains a larger thickness of compressible sediments than was represented in the model. The MODFLOW package, IBS1, simulates an instantaneous release of water from the compressible interbeds (aquitards) and thus subsidence—and does not account for hydrodynamic lag or residual compaction. This limitation is further discussed in the "Limitations of the Model" section of this report.

Simulated subsidence closely matched measured subsidence at all of the 10 bench marks (fig. 27). Simulated subsidence began at most locations in the 1930s, but as early as 1928 at bench mark BM 479 and as late as 1950 at bench mark BM 474. Simulated subsidence was greatest (6.3 ft) at bench mark BM 474 near Lancaster; the maximum measured subsidence also was at this bench mark (Ikehara and Phillips, 1994). Large water-level declines have occurred near bench mark BM 474, and the aquifer contains a substantial thickness of compressible sediments. Simulated subsidence was lowest at bench marks BM 2317 (2.0 ft) and BM 823 (2.17 ft). These two sites are located in areas that historically have been subjected to large amounts of pumpage, but the aquifers in the area contain fewer compressible sediments than aquifers in areas that had greater subsidence. Simulated subsidence also was small at bench mark BM 483 (2.2 ft) even though the aquifer in this area consists of a thick layer of compressible sediments. However, there has been minimal pumping and associated water-level declines in this area. The abrupt increase in simulated subsidence at bench marks BM 474, BM 2180, and BM 2317 in about 1977 corresponds to the increase in pumpage for public supply in 1977 (fig. A2) from the aquifer near these benchmarks.

Although water levels have declined more than 200 ft throughout much of the study area, subsidence greater than 1 ft has been documented only in the central part of the study area (fig. 8). In the area around Palmdale where water-level declines have been large, no measurable subsidence has occurred (Ikehara and Phillips, 1994). This lack of measurable subsidence suggests that this area may not be susceptible to subsidence even though lacustrine deposits have been mapped in this area (fig 3). However, it is possible that water levels may not yet have declined below the preconsolidation head in areas where subsidence has not occurred. Subsidence can be simulated in the model only where inelastic storage is specified; inelastic storage was specified only for areas where measurements have shown that subsidence has occurred.

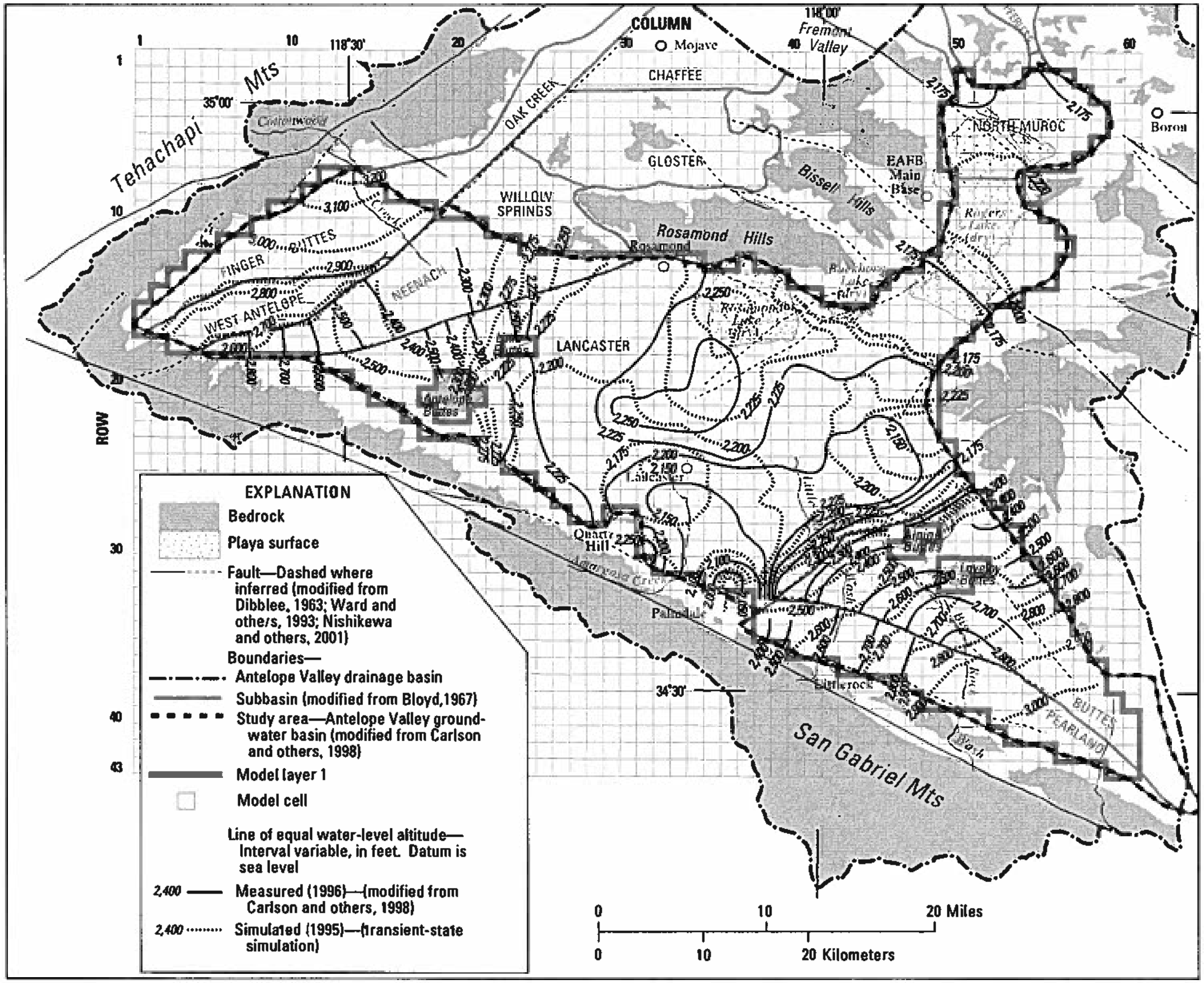


**Figure 26.** Measured (1996) and simulated (1995) water levels from the ground-water flow model of the Antelope Valley ground-water basin, California.

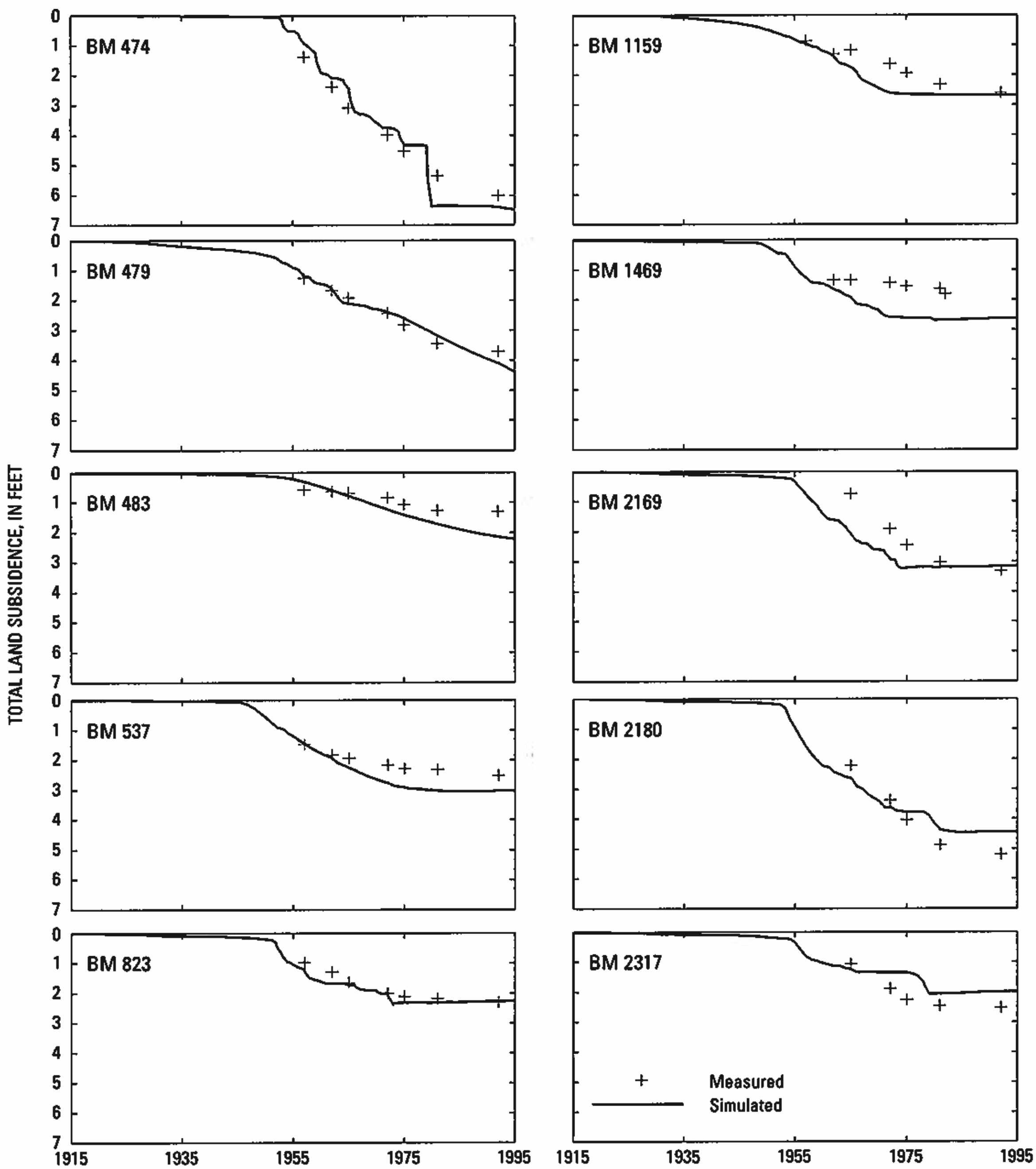


**Figure 27.** Measured and simulated total land subsidence at selected bench marks in the Antelope Valley ground-water basin, California, 1915–95. (See figure 15 for location of bench marks.)

Because of the limitations of the IBS1 Package in the simulation of subsidence, a match between simulated and measured subsidence does not necessarily indicate that the parameters controlling subsidence are accurately represented by the model. The IBS1 Package simulates subsidence instantaneously after a decline in hydraulic head below the preconsolidation head; therefore, there is no time delay in the simulated subsidence to account for the delayed equilibration of hydraulic heads in the thick aquitards. Results from the one-dimensional model developed by Sneed and Galloway (2000) and from a comparison of paired water-level and subsidence data (Ikehara and Phillips, 1994) (fig. 9) indicate that the delayed drainage of the thick aquitards is an important process in the occurrence of subsidence in Antelope Valley. Therefore, the model developed for this study may simulate subsidence before it actually occurs, owing to hydrodynamic lag and residual compaction and land subsidence. Additionally, simulated subsidence is dependent on simulated drawdown. If simulated drawdown does not match actual drawdown, then simulated subsidence would not be expected to match measured subsidence.

### Water Budget

The simulated annual volumes of recharge, discharge, and change in storage for Antelope Valley ground-water basin are shown in table 8. Graphs of the simulated recharge and discharge components are shown in figure 28 and a graph of simulated cumulative change in storage for the entire simulation period is shown in figure 29. Results of the transient-state simulation indicate that more than 8.5 million acre-ft of ground water was removed from storage during 1915–95, with most of the storage change occurring between about 1945 and 1975. Ground-water storage changed little during the final 10 years of simulation period because discharge by pumpage had declined sufficiently to be balanced by recharge (fig. 28C).

Water-budget components for the steady-state simulation and for the 1949–53 and 1991–95 periods of the transient-state simulation are shown in figure 30. The period 1949–53 was selected to represent hydrologic conditions when agricultural production and associated pumping were at a maximum. The period 1991–95 was selected to represent conditions when pumping for public supply was at a maximum and pumping for agricultural production was at a recent minimum. All components of recharge and the pumpage component of discharge were specified as model input parameters. Evapotranspiration, ground-water underflow, flow between model layers, and changes in aquifer and aquitard storage were simulated by the model.

Under steady-state conditions, recharge from natural sources was balanced by discharge as evapotranspiration and ground-water underflow from the North Muroc subbasin into Fremont Valley, and there were no changes in aquifer storage. The simulated ground-water underflow into Fremont Valley (400 acre-ft/yr) was less than half the amount estimated by Durbin (1978) (1,000 acre-ft/yr). Flow northward across the Willow Springs Fault, southeast of Rogers Lake (barrier 7, fig. 11), was equal to the ground-water underflow out of the basin. The model simulated that evapotranspiration averaged 29,900 acre-ft/yr; all of the evapotranspiration simulated by the model occurred in the area of alkali soils (fig. 4) south of barrier 7.

During the 1949–53 period, pumpage reached a maximum of 363,000 acre-ft/yr and recharge averaged 77,800 acre-ft/yr (fig. 30). Model results indicate that 79 percent of the ground-water pumpage was contributed from aquifer storage (71 percent or 265,100 acre-ft/yr) and aquitard storage (8 percent or 21,600 acre-ft/yr); of that, more than 95 percent (263,000 acre-ft/yr) came from storage in layer 1. Leakage from layer 1 into layer 2 accounted for 86 percent of the ground-water pumpage from layer 2. Recharge from irrigation-return flows was 47,500 acre-ft/yr; about 13 percent of the ground-water pumpage (fig. 30). As a result of water-level declines (fig.25), evapotranspiration was only 1,200 acre-ft/yr, about 4 percent compared to steady-state conditions.

**Table 8.** Simulated recharge, discharge, and change in storage for the Antelope Valley ground-water basin, California, 1915–95

[AVEK, Antelope Valley–East Kern Water Agency; evapotranspiration and ground-water underflow are model computed values; all other values are model inputs; units in thousand acre-feet; positive numbers represent water added to the system, and negative numbers represent water removed from the system]

| | Recharge | | | | Discharge | | | | | Total | | Change in storage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Irrigation-return flows | | | | Pumpage | | | Natural | | | | | |
| Year | Pumpage | AVEK deliveries | Natural | Waste-water | Public supply | Agriculture | Total | Evapotran-spiration | Ground-water underflow | Recharge | Discharge | Annual | Cumulative |
| 1915 | 0.0 | 0.0 | 30.3 | 0.0 | 0.0 | 0.0 | 0.0 | −30.0 | −0.4 | 30.3 | −30.4 | −0.1 | −0.1 |
| 1916 | .0 | .0 | 30.3 | .0 | .0 | −1.9 | −1.9 | −29.8 | −.4 | 30.3 | −32.1 | −1.8 | −1.9 |
| 1917 | .0 | .0 | 30.3 | .0 | .0 | −5.8 | −5.8 | −29.5 | −.4 | 30.3 | −35.7 | −5.4 | −7.3 |
| 1918 | .0 | .0 | 30.3 | .0 | .0 | −10.7 | −10.7 | −28.9 | −.4 | 30.3 | −40.0 | −9.7 | −17.0 |
| 1919 | .0 | .0 | 30.3 | .0 | .0 | −15.5 | −15.5 | −28.1 | −.4 | 30.3 | −44.0 | −13.7 | −30.7 |
| 1920 | .0 | .0 | 30.3 | .0 | .0 | −22.3 | −22.3 | −27.1 | −.4 | 30.3 | −49.8 | −19.5 | −50.2 |
| 1921 | .0 | .0 | 30.3 | .0 | .0 | −29.1 | −29.1 | −25.8 | −.4 | 30.3 | −55.3 | −25.0 | −75.2 |
| 1922 | .0 | .0 | 30.3 | .0 | .0 | −35.9 | −35.9 | −24.4 | −.4 | 30.3 | −60.7 | −30.4 | −105.6 |
| 1923 | .0 | .0 | 30.3 | .0 | .0 | −40.7 | −40.7 | −23.0 | −.4 | 30.3 | −64.1 | −33.8 | −139.4 |
| 1924 | .0 | .0 | 30.3 | .0 | .0 | −50.4 | −50.4 | −21.4 | −.4 | 30.3 | −72.2 | −41.9 | −181.3 |
| 1925 | .0 | .0 | 30.3 | .0 | .0 | −64.0 | −64.0 | −19.7 | −.4 | 30.3 | −84.1 | −53.8 | −235.1 |
| 1926 | .6 | .0 | 30.3 | .0 | .0 | −81.4 | −81.4 | −17.8 | −.4 | 30.9 | −99.6 | −68.7 | −303.8 |
| 1927 | 1.7 | .0 | 30.3 | .0 | .0 | −98.9 | −98.9 | −15.8 | −.4 | 32.0 | −115.1 | −83.1 | −386.9 |
| 1928 | 3.2 | .0 | 30.3 | .0 | .0 | −125.1 | −125.1 | −13.7 | −.4 | 33.5 | −139.2 | −105.7 | −492.6 |
| 1929 | 4.7 | .0 | 30.3 | .0 | .0 | −157.1 | −157.1 | −11.6 | −.4 | 35.0 | −169.1 | −134.1 | −626.7 |
| 1930 | 6.7 | .0 | 30.3 | .0 | .0 | −166.8 | −166.8 | −9.8 | −.4 | 37.0 | −177.0 | −140.0 | −766.7 |
| 1931 | 8.7 | .0 | 30.3 | .0 | .0 | −145.4 | −145.4 | −8.6 | −.4 | 39.0 | −154.4 | −115.4 | −882.1 |
| 1932 | 10.8 | .0 | 30.3 | .0 | .0 | −108.6 | −108.6 | −7.8 | −.4 | 41.1 | −116.8 | −75.7 | −957.8 |
| 1933 | 12.2 | .0 | 30.3 | .0 | .0 | −99.9 | −99.9 | −7.3 | −.4 | 42.5 | −107.6 | −65.1 | −1,022.9 |
| 1934 | 15.1 | .0 | 30.3 | .0 | .0 | −111.8 | −111.8 | −6.7 | −.4 | 45.4 | −118.9 | −73.5 | −1,096.4 |
| 1935 | 19.2 | .0 | 30.3 | .0 | .0 | −119.1 | −119.1 | −6.2 | −.4 | 49.5 | −125.7 | −76.2 | −1,172.6 |
| 1936 | 24.4 | .0 | 30.3 | .0 | .0 | −124.3 | −124.3 | −5.7 | −.4 | 54.7 | −130.4 | −75.7 | −1,248.3 |
| 1937 | 29.7 | .0 | 30.3 | .0 | .0 | −132.5 | −132.5 | −5.3 | −.4 | 60.0 | −138.2 | −78.2 | −1,326.5 |
| 1938 | 37.5 | .0 | 30.3 | .0 | .0 | −136.7 | −136.7 | −4.9 | −.4 | 67.8 | −142.0 | −74.2 | −1,400.7 |
| 1939 | 47.1 | .0 | 30.3 | .0 | .0 | −143.9 | −143.9 | −4.6 | −.4 | 77.4 | −148.9 | −71.5 | −1,472.2 |
| 1940 | 50.0 | .0 | 30.3 | .0 | .0 | −149.1 | −149.1 | −4.2 | −.4 | 80.3 | −153.7 | −73.4 | −1,545.6 |
| 1941 | 43.6 | .0 | 30.3 | .0 | .0 | −156.4 | −156.4 | −3.8 | −.4 | 73.9 | −160.6 | −86.7 | −1,632.3 |
| 1942 | 32.6 | .0 | 30.3 | .0 | .0 | −165.7 | −165.7 | −3.3 | −.4 | 62.9 | −169.4 | −106.5 | −1,738.8 |

**Table 8.** Simulated recharge, discharge, and change in storage for the Antelope Valley ground-water basin, California, 1915–95—Continued

| Year | Recharge | | | | Discharge | | | | | Total | | Change in storage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Irrigation-return flows | | | | Pumpage | | | Natural | | | | | |
| | Pumpage | AVEK deliveries | Natural | Waste-water | Public supply | Agriculture | Total | Evapotran-spiration | Ground-water underflow | Recharge | Discharge | Annual | Cumulative |
| 1943 | 30.0 | .0 | 30.3 | .0 | .0 | −176.0 | −176.0 | −2.9 | −.4 | 60.3 | −179.3 | −119.0 | −1,857.8 |
| 1944 | 33.5 | .0 | 30.3 | .0 | .0 | −186.4 | −186.4 | −2.6 | −.4 | 63.8 | −189.4 | −125.6 | −1,983.4 |
| 1945 | 35.7 | .0 | 30.3 | .0 | .0 | −204.0 | −204.0 | −2.4 | −.4 | 66.0 | −206.8 | −140.8 | −2,124.2 |
| 1946 | 37.3 | 0.0 | 30.3 | 0.0 | 0.0 | −226.8 | −226.8 | −2.1 | −0.4 | 67.6 | −229.3 | −161.7 | −2,285.9 |
| 1947 | 39.8 | .0 | 30.3 | .0 | −.6 | −269.6 | −270.2 | −1.9 | −.4 | 70.1 | −272.5 | −202.4 | −2,488.3 |
| 1948 | 41.0 | .0 | 30.3 | .0 | −.7 | −330.4 | −331.1 | −1.7 | −.4 | 71.3 | −333.2 | −261.9 | −2,750.2 |
| 1949 | 43.2 | .0 | 30.3 | .0 | −.6 | −357.0 | −357.6 | −1.6 | −.4 | 73.5 | −359.6 | −286.1 | −3,036.3 |
| 1950 | 44.7 | .0 | 30.3 | .0 | −.7 | −373.0 | −373.7 | −1.4 | −.4 | 75.0 | −375.5 | −300.5 | −3,336.8 |
| 1951 | 46.9 | .0 | 30.3 | .0 | −.8 | −394.6 | −395.4 | −1.2 | −.5 | 77.2 | −397.1 | −319.9 | −3,656.7 |
| 1952 | 49.7 | .0 | 30.3 | .0 | −6.7 | −333.0 | −339.7 | −1.0 | −.5 | 80.0 | −341.2 | −261.2 | −3,917.9 |
| 1953 | 52.8 | .0 | 30.3 | .0 | −9.2 | −339.0 | −348.2 | −.8 | −.5 | 83.1 | −349.5 | −266.4 | −4,184.3 |
| 1954 | 55.9 | .0 | 30.3 | .0 | −9.6 | −313.0 | −322.6 | −.6 | −.5 | 86.2 | −323.7 | −237.5 | −4,421.8 |
| 1955 | 61.2 | .0 | 30.3 | .0 | −7.0 | −324.5 | −331.5 | −.5 | −.5 | 91.5 | −332.5 | −241.0 | −4,662.8 |
| 1956 | 68.0 | .0 | 30.3 | .0 | −13.5 | −332.2 | −345.7 | −.5 | −.5 | 98.3 | −346.7 | −248.4 | −4,911.2 |
| 1957 | 80.9 | .0 | 30.3 | .0 | −13.9 | −309.4 | −323.3 | −.4 | −.5 | 111.2 | −324.2 | −213.0 | −5,124.2 |
| 1958 | 99.1 | .0 | 30.3 | .0 | −12.7 | −293.6 | −306.3 | −.3 | −.5 | 129.4 | −307.1 | −177.7 | −5,301.9 |
| 1959 | 107.1 | .0 | 30.3 | .0 | −15.6 | −301.0 | −316.6 | −.3 | −.5 | 137.4 | −317.4 | −180.0 | −5,481.9 |
| 1960 | 111.9 | .0 | 30.3 | .0 | −16.9 | −285.5 | −302.4 | −.3 | −.5 | 142.2 | −303.2 | −161.0 | −5,642.9 |
| 1961 | 118.4 | .0 | 30.3 | .0 | −23.3 | −278.5 | −301.8 | −.3 | −.5 | 148.7 | −302.6 | −153.9 | −5,796.8 |
| 1962 | 100.0 | .0 | 30.3 | .0 | −28.5 | −284.4 | −312.9 | −.2 | −.5 | 130.3 | −313.6 | −183.3 | −5,980.1 |
| 1963 | 101.7 | .0 | 30.3 | .0 | −22.5 | −317.5 | −340.0 | −.2 | −.5 | 132.0 | −340.7 | −208.7 | −6,188.8 |
| 1964 | 93.9 | .0 | 30.3 | .0 | −24.7 | −332.5 | −357.2 | −.2 | −.5 | 124.2 | −357.9 | −233.7 | −6,422.5 |
| 1965 | 97.4 | .0 | 30.3 | .0 | −26.5 | −331.3 | −357.8 | −.2 | −.4 | 127.7 | −358.4 | −230.7 | −6,653.2 |
| 1966 | 99.7 | .0 | 30.3 | .0 | −29.1 | −316.3 | −345.4 | −.1 | −.4 | 130.0 | −345.9 | −215.9 | −6,869.1 |
| 1967 | 92.8 | .0 | 30.3 | .0 | −26.0 | −297.8 | −323.8 | −.1 | −.4 | 123.1 | −324.3 | −201.2 | −7,070.3 |
| 1968 | 88.1 | .0 | 30.3 | .0 | −28.6 | −279.0 | −307.6 | −.1 | −.4 | 118.4 | −308.1 | −189.7 | −7,259.9 |
| 1969 | 90.3 | .0 | 30.3 | .0 | −35.7 | −258.3 | −294.0 | −.1 | −.4 | 120.6 | −294.5 | −173.9 | −7,433.8 |
| 1970 | 85.6 | .0 | 30.3 | .0 | −30.1 | −240.0 | −270.1 | −.1 | −.4 | 115.9 | −270.6 | −154.7 | −7,588.5 |
| 1971 | 83.5 | .0 | 30.3 | .0 | −32.3 | −217.1 | −249.4 | −.1 | −.3 | 113.8 | −249.8 | −136.0 | −7,724.6 |

**Table 8.** Simulated recharge, discharge, and change in storage for the Antelope Valley ground-water basin, California, 1915–95—Continued

| | Recharge | | | | Discharge | | | | | Total | | Change in storage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Irrigation-return flows | | | | Pumpage | | | Natural | | | | | |
| Yeer | Pumpaga | AVEK deliveries | Natural | Weste-water | Public supply | Agriculture | Total | Evapotren-spiretion | Ground-water underflow | Recharge | Discharge | Annual | Cumulative |
| 1972 | 85.3 | .0 | 30.3 | .0 | –32.4 | –192.2 | –224.6 | –.1 | –.3 | 115.6 | –225.0 | –109.4 | –7,834.0 |
| 1973 | 95.3 | .0 | 30.3 | .0 | –33.8 | –178.6 | –212.4 | .0 | –.3 | 125.6 | –212.7 | –87.1 | –7,921.1 |
| 1974 | 100.8 | .0 | 30.3 | .0 | –32.2 | –164.9 | –197.1 | .0 | –.3 | 131.1 | –197.4 | –66.3 | –7,987.4 |
| 1975 | 99.4 | .0 | 30.3 | .0 | –30.3 | –161.1 | –191.4 | .0 | –.3 | 129.7 | –191.7 | –62.0 | –8,049.4 |
| 1976 | 94.9 | .0 | 30.3 | .0 | –31.7 | –138.0 | –169.7 | .0 | –.3 | 125.2 | –170.0 | –44.8 | –8,094.2 |
| 1977 | 89.3 | .0 | 30.3 | .0 | –29.0 | –166.3 | –195.3 | .0 | –.3 | 119.6 | –195.6 | –76.0 | –8,170.2 |
| 1978 | 83.7 | .0 | 30.3 | .0 | –36.4 | –155.8 | –192.2 | .0 | –.3 | 114.0 | –192.5 | –78.5 | –8,248.7 |
| 1979 | 77.5 | 0.0 | 30.3 | 0.0 | –26.0 | –135.3 | –161.3 | 0.0 | –0.3 | 107.8 | –161.6 | –53.8 | –8,302.4 |
| 1980 | 72.0 | .0 | 30.3 | .0 | –26.1 | –128.4 | –154.5 | .0 | –.3 | 102.3 | –154.8 | –52.5 | –8,354.9 |
| 1981 | 65.1 | .0 | 30.3 | .0 | –26.9 | –93.9 | –120.8 | .0 | –.3 | 95.4 | –121.1 | –25.7 | –8,380.6 |
| 1982 | 57.7 | .0 | 30.3 | .0 | –25.4 | –86.1 | –111.5 | .0 | –.3 | 88.0 | –111.8 | –23.8 | –8,404.4 |
| 1983 | 53.6 | .0 | 30.3 | .0 | –20.9 | –91.7 | –112.6 | .0 | –.3 | 83.9 | –112.9 | –29.0 | –8,433.4 |
| 1984 | 49.5 | .0 | 30.3 | .5 | –27.0 | –80.9 | –107.9 | .0 | –.2 | 80.3 | –108.1 | –27.8 | –8,461.1 |
| 1985 | 48.3 | .0 | 30.3 | 1.4 | –26.5 | –64.3 | –90.8 | .0 | –.2 | 80.0 | –91.0 | –11.0 | –8,472.1 |
| 1986 | 41.4 | 7.9 | 30.3 | 2.0 | –31.5 | –55.1 | –86.6 | .0 | –.2 | 81.6 | –86.8 | –5.2 | –8,477.3 |
| 1987 | 44.4 | 9.1 | 30.3 | 2.9 | –33.0 | –60.6 | –93.6 | .0 | –.2 | 86.7 | –93.8 | –7.1 | –8,484.4 |
| 1988 | 39.8 | 10.2 | 30.3 | 3.2 | –23.1 | –47.8 | –70.9 | .0 | –.2 | 83.5 | –71.1 | 12.4 | –8,472.0 |
| 1989 | 35.8 | 13.5 | 30.3 | 3.4 | –39.1 | –33.7 | –72.8 | .0 | –.2 | 82.9 | –73.0 | 9.9 | –8,462.0 |
| 1990 | 34.8 | 14.8 | 30.3 | 4.9 | –36.2 | –34.5 | –70.7 | .0 | –.2 | 84.8 | –70.9 | 13.9 | –8,448.2 |
| 1991 | 26.0 | 16.2 | 30.3 | 4.5 | –56.5 | –47.6 | –104.1 | .0 | –.2 | 77.0 | –104.3 | –27.3 | –8,475.5 |
| 1992 | 24.4 | 9.8 | 30.3 | 5.6 | –38.3 | –42.7 | –81.0 | .0 | –.2 | 70.1 | –81.2 | –11.1 | –8,486.6 |
| 1993 | 25.7 | 5.1 | 30.3 | 6.5 | –33.4 | –39.7 | –73.1 | .0 | –.2 | 67.6 | –73.3 | –5.7 | –8,492.3 |
| 1994 | 22.7 | 4.4 | 30.3 | 6.9 | –40.2 | –35.6 | –75.8 | .0 | –.2 | 64.3 | –76.0 | –11.7 | –8,504.0 |
| 1995 | 18.7 | 5.0 | 30.3 | 7.5 | –40.4 | –34.1 | –74.5 | .0 | –.2 | 61.5 | –74.7 | –13.2 | –8,517.1 |

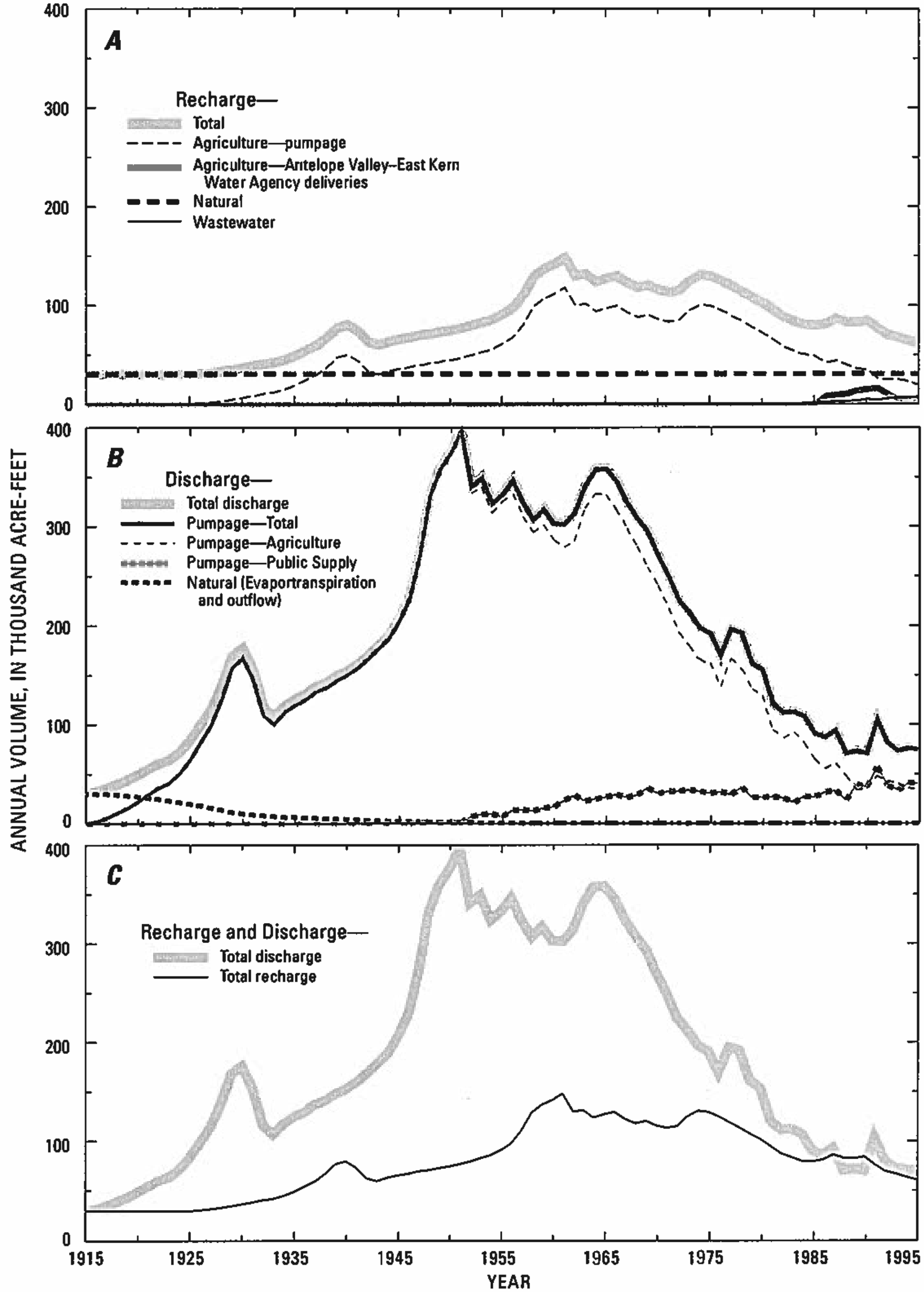


**Figure 28.** Simulated annual volumes of *(A)* recharge, *(B)* discharge, and *(C)* recharge in relation to discharge in the Antelope Valley ground-water basin, California, 1915–95.

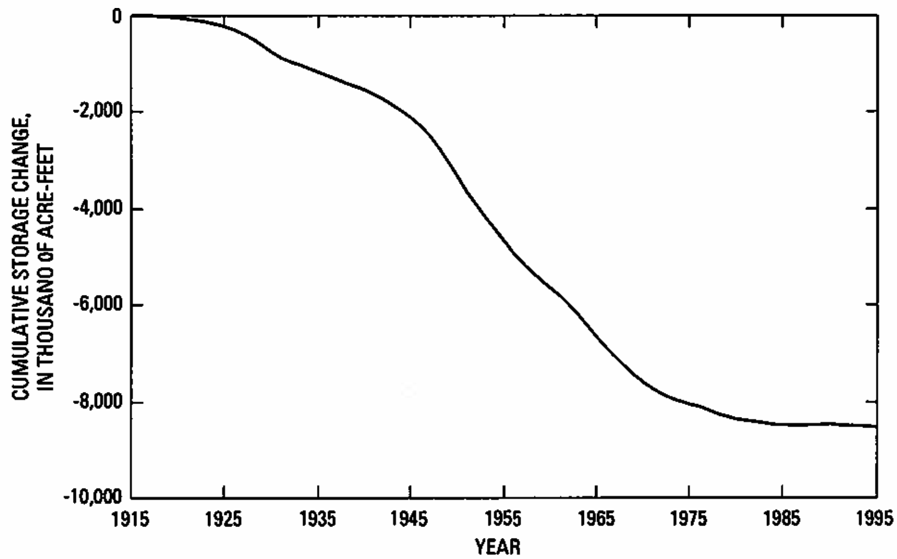


**Figure 29.** Cumulative change in simulated ground-water storage in the Antelope Valley ground-water basin, California, 1915–95.

During the1991–95 period, pumpage averaged 81,700 acre-ft/yr, which is only 23 percent of the pumpage during the 1949–53 period and total recharge averaged 68,100 acre-ft/yr, which is about 86 percent of the total recharge during the 1949-53 period. Model results indicate that about 13,700 acre-ft/yr of ground water was being removed from aquifer and aquitard storage, which is about 17 percent of the total pumpage. Compaction of the aquitards accounted for 3,800 acre-ft/yr of water being removed from storage, which is 28 percent of the change in storage. Similar to the1949–53 period, the source of nearly all the ground-water pumpage from layer 2 was leakage from layer 1. Continued water-level declines (fig. 25), resulted in the cessation of simulated evapotranspiration and a 50-percent reduction of ground-water underflow from the North Muroc subbasin compared to steady-state conditions.

## Model Sensitivity Analysis

A sensitivity analysis was done to determine the sensitivity of the model to changes in model input parameters. Sensitivity analysis can help determine which model parameters have the greatest effect on a model; results of the analysis can guide future data collection efforts that will reduce model errors. The sensitivity simulations were done by changing one input parameter at a time, while holding all others constant. A limitation of this approach is that the effects of simultaneous changes of multiple input parameters are not evaluated. The sensitivity of the model was evaluated by comparing water levels and subsidence from the sensitivity simulations with those from the calibrated transient-state model at the end of the transient period (1995). Sensitivity simulations also were done for the steady-state model; results generally were similar to the results of the transient-state model and therefore are not discussed here.

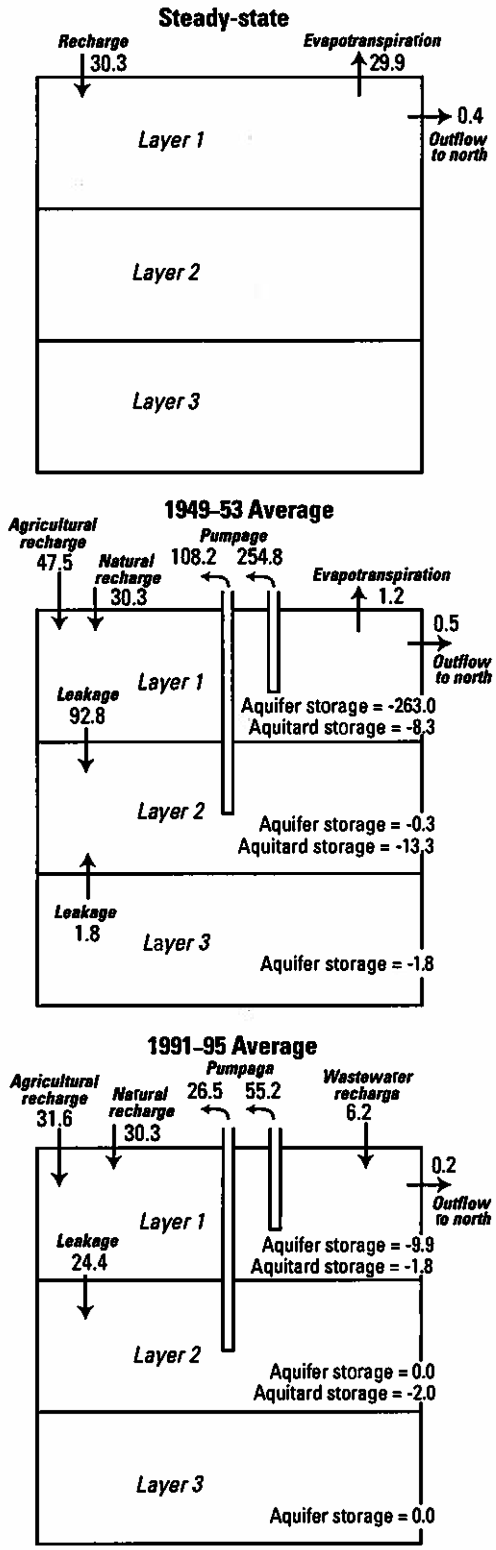


**Figure 30.** Components of the simulated water budget for selected periods from the ground-water flow model of the Antelope Valley ground-water basin, California. (Units are in thousand acre-feet.)

Model sensitivity was determined for variations in hydraulic conductivity (layer 1), transmissivity (layers 2 and 3), confined and unconfined storage coefficients, vertical leakance, pumpage, recharge, and the hydraulic-characteristic values of the flow barriers. The magnitude of these variations was somewhat subjective, but based loosely on the range of reasonable values for each parameter and on the sensitivity observed during the calibration process. Hydraulic conductivity, transmissivity, and specific yield were varied from 0.5 to 2 times calibrated values. Vertical leakance and confined storage coefficients were varied from 0.1 to 10 times calibrated values. Total pumpage, agricultural pumpage, and recharge were increased and decreased by 10 percent. The sensitivity of the model to the effects of the flow barriers was analyzed by removing the barriers (no restriction to flow) and reducing the hydraulic-characteristic values of the barriers to one-half the calibrated values (increased restriction to flow). Sensitivity-analysis results were aggregated into four subareas because the simulated water levels within each subarea showed a similar response to changes in the input parameters. These subareas are (1) the western subarea (the Finger Buttes, Neenach, and West Antelope subbasins); (2) the southeastern subarea (the Buttes and Pearland subbasins); (3) the northern subarea [the North Muroc subbasin and the part of the Lancaster subbasin north of barrier 7 (figure 11)]; and (4) the central subarea (the remainder of the Lancaster subbasin south of barrier 7).

Water-level changes resulting from the sensitivity analysis are shown in table 9. Simulated water levels were most sensitive to changes in the hydraulic characteristic of the flow barrier. The largest water-level changes resulting from changes in the hydraulic characteristic of the flow barriers occurred in the western and southeastern subareas. Water levels in the northern and central subareas were relatively insensitive to changes in the hydraulic characteristics of the flow barriers compared with water levels in the western and southeastern subareas. The western and southern subareas also were sensitive to changes in hydraulic conductivity, transmissivity of layer 2, specific yield, and natural recharge.

Water levels in the northern and central subareas were most sensitive to changes in hydraulic conductivity, specific yield, inelastic skeletal storage coefficient, and vertical leakance between layers 1 and 2. These subareas also were sensitive to the changes in total pumpage and agricultural pumpage. The insensitivity of the model to changes in transmissivity of layer 3 indicates that defining the base of the model at an altitude of 1,000 ft above sea level was reasonable.

The sensitivity of simulated land subsidence at the end of the transient period (1995) to selected model input parameters is shown in table 10. All the bench marks used for the subsidence analysis are located in the Lancaster subbasin (fig. 15), and, therefore, the results of the subsidence sensitivity analysis are for this subbasin only. Pumping-induced subsidence is controlled by the inelastic skeletal storage coefficient and the water-level drawdown below the preconsolidation head. Simulated subsidence, therefore, was most sensitive to the changes in inelastic skeletal storage and specific yield.

In summary, the results of the sensitivity analysis indicate that the model is sensitive to different parameters in different areas. In the northern and central subareas, the model is most sensitive to changes in hydraulic conductivity of layer 1, specific yield, inelastic skeletal storage coefficient, vertical leakance between layers 1 and 2, and pumpage. In the western and southeastern subbasins, the model is most sensitive to changes in hydraulic conductivity of layer 1, transmissivity of layer 2, specific yield, natural recharge, and the hydraulic-characteristic values. Because changes in one model parameter may be offset by changes in another, improving the understanding of one parameter may aid in decreasing the uncertainty of other parameters.

## Limitations of the Model

A ground-water flow model is a valuable tool for testing the conceptualization of the ground-water flow system and for predicting the response of the system to changes in aquifer stresses. However, a model is only an approximation of the actual aquifer system and, therefore, will not exactly simulate the system being modeled. The model relies on estimates of aquifer properties and stresses, which have some degree of uncertainty, and it lacks the small-scale spatial and temporal variability present in the actual system.

**Table 9.** Change in simulated water levels at the end of the transient period (1995) resulting from the sensitivity analysis of the ground-water flow model of the Antelope Valley ground-water basin, California

[Subarea: Western (Finger Buttes, Neenach, and West Antelope subbasins); Southeastern (Buttes and Pearland subbasins); Northern (North Muroc and the part of the Lancaster subbasin north of barrier 7); Central (the part of the Lancaster subbasin south of barrier 7). Order of presentation: from most sensitive (highest median water-level change) to least sensitive (lowest median water-level change)]

| | | Water-level change, in feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Western subarea | | | Southeastern subarea | | | Northern subarea | | | Central subarea | | |
| Change in parameter or stress | Layer | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median |
| Flow barriers not simulated | 1 | −611/12 | −192 | −198 | −125/73 | −44 | −48 | −25/15 | 6 | 11 | −52/29 | −2 | 0 |
| | 2 | −626/16 | −172 | −52 | | | | −26/18 | 7 | 12 | −36/27 | −2 | 0 |
| | 3 | −628/14 | −160 | −34 | | | | −24/20 | 7 | 12 | −36/25 | −2 | −1 |
| Hydraulic characteristics of flow barriers × 0.5 | 1 | 2/278 | 118 | 128 | −62/172 | 50 | 38 | −12/4 | −6 | 1 | −6/52 | 1 | 0 |
| | 2 | 4/273 | 98 | 14 | | | | −12/2 | −6 | −7 | −5/17 | 1 | 0 |
| | 3 | 4/273 | 94 | 11 | | | | −12/2 | −7 | −11 | −5/14 | 1 | 0 |
| Hydraulic conductivity of layer 1 × 0.5 | 1 | 12/245 | 104 | 105 | 27/340 | 162 | 130 | −11/12 | 5 | 6 | −29/126 | 14 | 6 |
| | 2 | 14/142 | 91 | 102 | | | | −3/9 | 4 | 6 | −15/113 | 11 | 5 |
| | 3 | 14/138 | 89 | 101 | | | | −3/9 | 3 | 2 | −11/112 | 11 | 5 |
| Specific yield of layer 1 × 0.5 | 1 | −26/−116 | −76 | −68 | −119/89 | −19 | −19 | −81/0 | −25 | −26 | −184/131 | −108 | −110 |
| | 2 | −36/−113 | −82 | −84 | | | | −86/−22 | −25 | −26 | −177/0 | −115 | −110 |
| | 3 | −36/−111 | −83 | −98 | | | | −88/−22 | −26 | −26 | −164/−62 | −115 | −111 |
| Hydraulic conductivity of layer 1 × 2 | 1 | −177/−9 | −82 | −87 | −186/−8 | −105 | −94 | −12/11 | −6 | −8 | −106/14 | −19 | −14 |
| | 2 | −108/−11 | −74 | −72 | | | | −10/0 | −6 | −8 | −101/3 | −18 | −13 |
| | 3 | −106/−11 | −72 | −84 | | | | −9/0 | −5 | −4 | −100/2 | −17 | −12 |
| Specific yield of layer 1 × 2 | 1 | 5/75 | 46 | 40 | 2/102 | 25 | 22 | 0/52 | 17 | 18 | 6/166 | 72 | 74 |
| | 2 | 10/75 | 51 | 51 | | | | 12/54 | 17 | 18 | 0/145 | 75 | 74 |
| | 3 | 12/75 | 53 | 62 | | | | 14/56 | 17 | 16 | 29/138 | 74 | 73 |
| Natural recharge × 0.9 | 1 | −56/−8 | −34 | −40 | −36/0 | −22 | −23 | −2/1 | 0 | 0 | −24/0 | −8 | −7 |
| | 2 | −51/−9 | −31 | −34 | | | | −3/1 | 0 | 0 | −23/0 | −8 | −7 |
| | 3 | −50/−9 | −31 | −29 | | | | −3/1 | 0 | 0 | −23/−2 | −8 | −7 |

**Table 9.** Changes in simulated water levels at the end of the transient period (1995) resulting from the sensitivity analysis of the ground-water flow model of the Antelope Valley ground-water basin, California—Continued

| Change in parameter or stress | Layer | Water-level change, in feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Western subarea | | | Southeastern subarea | | | Northern subarea | | | Central subarea | | |
| | | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median |
| Natural recharge × 1.1 | 1 | 9/54 | 34 | 40 | 0/35 | 21 | 21 | 0/2 | 0 | 0 | −26/23 | 6 | 6 |
| | 2 | 9/49 | 31 | 34 | | | | 0/2 | 0 | 0 | −19/23 | 6 | 6 |
| | 3 | 9/48 | 30 | 29 | | | | 0/2 | 0 | 0 | −1/22 | 7 | 6 |
| Inelastic skeletal storage coefficient of layer 2 × 10 | 1 | 0/27 | 4 | 1 | 0/32 | 2 | 0 | 0/59 | 12 | 7 | 0/63 | 36 | 28 |
| | 2 | 0/26 | 5 | 1 | | | | 0/65 | 16 | 8 | 0/89 | 41 | 42 |
| | 3 | 0/26 | 6 | 2 | | | | 0/62 | 20 | 25 | 0/69 | 42 | 44 |
| Inelastic skeletal storage coefficient of layer 1 × 10 | 1 | 0/27 | 4 | 1 | −1/23 | 1 | 0 | 0/56 | 12 | 6 | 0/56 | 31 | 32 |
| | 2 | 0/26 | 5 | 1 | | | | 0/50 | 13 | 7 | 0/51 | 32 | 33 |
| | 3 | 0/26 | 5 | 1 | | | | 0/49 | 17 | 21 | 2/49 | 33 | 34 |
| Transmissivity of layer 2 × 2 | 1 | −59/−1 | −29 | −30 | −24/0 | −3 | −2 | −14/3 | 0 | 0 | −55/17 | −8 | −6 |
| | 2 | −64/3 | −30 | −30 | | | | −14/7 | 0 | 0 | −61/33 | −9 | −8 |
| | 3 | −63/2 | −29 | −29 | | | | −5/4 | 1 | 1 | −59/24 | −8 | −7 |
| Transmissivity of layer 2 × 0.5 | 1 | 0/39 | 21 | 21 | 0/15 | 3 | 2 | −3/14 | 1 | 0 | −26/37 | 5 | 3 |
| | 2 | −1/41 | 21 | 21 | | | | −9/16 | 0 | 0 | −42/43 | 5 | 4 |
| | 3 | −1/41 | 21 | 21 | | | | −5/6 | 0 | 0 | −33/41 | 5 | 3 |
| Vertical leakance between layers 1 and 2 × 0.1 | 1 | 3/27 | 13 | 15 | 0/11 | 2 | 2 | −2/15 | 2 | 2 | −5/40 | 9 | 7 |
| | 2 | −36/26 | 4 | 7 | | | | −20/−1 | −10 | −7 | −64/13 | −10 | −7 |
| | 3 | −34/25 | 4 | 7 | | | | −19/−4 | −11 | −14 | −60/8 | −10 | −7 |
| Transmissivity of layer 3 × 2 | 1 | −28/0 | −12 | −11 | −3/0 | −1 | −1 | −4/1 | 0 | 0 | −22/4 | −2 | −2 |
| | 2 | −30/1 | −12 | −11 | | | | −6/1 | 0 | 0 | −23/4 | −3 | −2 |
| | 3 | −36/3 | −12 | −11 | | | | −6/2 | 0 | 0 | −28/17 | −3 | −2 |

**Table 9.** Changes in simulated water levels at the end of the transient period (1995) resulting from the sensitivity analysis of the ground-water flow model of the Antelope Valley ground-water basin, California—Continued

| Change in parameter or stress | Layer | Water-level change, in feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Western subarea | | | Southeastern subarea | | | Northern subarea | | | Central subarea | | |
| | | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median |
| Inelastic skeletal storage coefficient of layer 2 × 0.1 | 1 | –5/0 | –1 | 0 | –7/0 | 0 | 0 | –16/0 | –5 | –3 | –15/0 | –8 | –8 |
| | 2 | –4/0 | –1 | 0 | | | | –16/0 | –6 | –3 | –15/0 | –9 | –9 |
| | 3 | –4/0 | –1 | 0 | | | | –15/0 | –7 | –10 | –15/0 | –9 | –9 |
| Pumpage increased by 10 percent | 1 | –7/0 | –4 | –4 | –9/0 | –2 | –1 | –8/0 | –4 | –3 | –48/0 | –8 | –8 |
| | 2 | –7/0 | –4 | –5 | | | | –7/–2 | –4 | –4 | –39/0 | –9 | –8 |
| | 3 | –8/0 | –4 | –5 | | | | –8/–2 | –5 | –5 | –35/0 | –9 | –9 |
| Agricultural pumpage decreased by 10 percent | 1 | 0/7 | 3 | 4 | 0/3 | 1 | 1 | 0/3 | 0 | 0 | –10/11 | 5 | 6 |
| | 2 | 0/7 | 4 | 4 | | | | 0/3 | 0 | 0 | –7/10 | 5 | 6 |
| | 3 | 0/7 | 4 | 5 | | | | 0/3 | 0 | 0 | –2/9 | 6 | 6 |
| Pumpage decreased by 10 percent | 1 | 0/7 | 4 | 4 | 0/5 | 2 | 1 | 0/8 | 4 | 3 | –8/40 | 7 | 7 |
| | 2 | 0/7 | 4 | 5 | | | | 2/8 | 4 | 4 | –6/36 | 7 | 7 |
| | 3 | 0/8 | 4 | 5 | | | | 2/7 | 5 | 5 | –1/32 | 8 | 8 |
| Transmissivity of layer 3 × 0.5 | 1 | 0/16 | 7 | 7 | 0/2 | 1 | 1 | 0/5 | 0 | 0 | –3/13 | 2 | 1 |
| | 2 | 0/17 | 7 | 7 | | | | –1/6 | 0 | 0 | –5/14 | 2 | 1 |
| | 3 | –3/20 | 7 | 7 | | | | –2/7 | 0 | 0 | –11/16 | 2 | 1 |
| Agricultural pumpage increased by 10 percent | 1 | –7/0 | –4 | –4 | –7/0 | –1 | –1 | –3/0 | 0 | 0 | –12/0 | –6 | –7 |
| | 2 | –7/0 | –4 | –5 | | | | –5/0 | 0 | 0 | –11/0 | –7 | –7 |
| | 3 | –7/0 | –4 | –5 | | | | –4/0 | 0 | 0 | –9/–3 | –7 | –7 |
| Storage coefficient of layer 3 × 10 | 1 | 0/9 | 6 | 6 | –2/2 | 0 | 0 | 0/6 | 2 | 2 | –13/13 | 5 | 7 |
| | 2 | 1/9 | 6 | 7 | | | | 1/5 | 3 | 3 | –10/13 | 6 | 7 |
| | 3 | 0/10 | 6 | 7 | | | | 2/6 | 3 | 4 | –6/17 | 6 | 6 |
| Inelastic skeletal storage coefficient of layer 1 × 0.1 | 1 | –4/0 | –1 | 0 | –4/1 | 0 | 0 | –23/1 | –4 | –2 | –18/0 | –6 | –6 |
| | 2 | –4/0 | –1 | 0 | | | | –18/1 | –4 | 2 | –12/0 | –6 | –6 |
| | 3 | –4/0 | –1 | 0 | | | | –13/1 | –5 | –7 | –11/0 | –6 | –6 |

**Table 9.** Changes in simulated water levels at the end of the transient period (1995) resulting from the sensitivity analysis of the ground-water flow model of the Antelope Valley ground-water basin, California—Continued

| Change in parameter or stress | Layer | Water-level change, in feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Western subarea | | | Southeastern subarea | | | Northern subarea | | | Central subarea | | |
| | | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median | Range | Mean | Median |
| Vertical leakance between layers 1 and 2 × 10 | 1 | −12/−1 | −6 | −4 | −7/0 | −1 | 0 | −3/3 | 0 | 0 | −21/4 | −3 | −2 |
| | 2 | −18/11 | −4 | −3 | | | | −1/6 | 2 | 1 | −18/15 | −1 | 0 |
| | 3 | −17/5 | −4 | −3 | | | | −1/5 | 2 | 2 | −13/13 | −1 | 0 |
| Vertical leakance between layers 2 and 3 × 0.1 | 1 | −1/7 | 2 | 2 | 0/1 | 1 | 1 | −2/13 | −1 | −1 | −12/19 | 1 | 0 |
| | 2 | −1/7 | 2 | 2 | | | | −2/15 | 0 | −1 | −12/21 | 1 | 0 |
| | 3 | −37/9 | −1 | 1 | | | | −6/6 | 0 | −1 | −35/74 | 3 | 4 |
| Elastic storage coefficient of layer 1 × 10 | 1 | −4/5 | 2 | 2 | −2/2 | 1 | 1 | 0/3 | 1 | 2 | −17/4 | 0 | 1 |
| | 2 | −4/5 | 2 | 2 | | | | 0/3 | 1 | 2 | −15/4 | 0 | 1 |
| | 3 | −4/5 | 2 | 2 | | | | 0/2 | 1 | 2 | −8/3 | 1 | 1 |
| Elastic storage coefficient of layer 2 × 10 | 1 | −2/2 | 1 | 1 | −3/1 | 0 | 0 | 0/3 | 2 | 2 | −18/2 | 0 | 1 |
| | 2 | −3/2 | 1 | 1 | | | | −1/3 | 2 | 2 | −16/2 | −1 | 0 |
| | 3 | −3/2 | 1 | 1 | | | | −1/3 | 2 | 2 | −10/2 | 0 | 0 |
| Vertical leakance between layers 2 and 3 × 10 | 1 | −2/1 | −1 | −1 | −1/0 | 0 | 0 | −7/1 | 0 | 0 | −13/5 | 0 | 0 |
| | 2 | −3/1 | −1 | −1 | | | | −9/1 | 0 | 0 | −13/10 | −1 | 0 |
| | 3 | −6/5 | 0 | 0 | | | | −7/1 | 0 | 0 | −19/9 | −1 | 0 |
| Storage coefficient representing the compressibility of water for layer 2 × 10 | 1 | 0/2 | 1 | 1 | −4/1 | 0 | 0 | 0/2 | 0 | 0 | −18/3 | 1 | 1 |
| | 2 | 0/2 | 1 | 1 | | | | 0/2 | 1 | 1 | −15/3 | 1 | 1 |
| | 3 | 0/2 | 1 | 1 | | | | 0/2 | 1 | 1 | −9/2 | 1 | 1 |
| Storage coefficient of layer 3 × 0.1 | 1 | −1/0 | −1 | −1 | −1/1 | 0 | 0 | −1/0 | −1 | 0 | −1/0 | −1 | −1 |
| | 2 | −1/0 | −1 | −1 | | | | −1/0 | −1 | 0 | −1/0 | −1 | −t |
| | 3 | −1/0 | −1 | −1 | | | | −2/0 | −1 | 0 | −2/0 | −1 | −1 |

**Table 9.** Changes in simulated water levels at the end of the transient period (1995) resulting from the sensitivity analysis of the ground-water flow model of the Antelope Valley ground-water basin, California—Continued

| Change in parameter or stress | Layer | Water-level change, in feet: Western subarea Range | Western subarea Mean | Western subarea Median | Southeastern subarea Range | Southeastern subarea Mean | Southeastern subarea Median | Northern subarea Range | Northern subarea Mean | Northern subarea Median | Central subarea Range | Central subarea Mean | Central subarea Median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wastewater recharge × 0.5 | 1 | 0 | 0 | 0 | −3/0 | 0 | 0 | 0/1 | 0 | 0 | −28/1 | −1 | 0 |
| | 2 | 0 | 0 | 0 | | | | 0/1 | 0 | 0 | −23/0 | −1 | 0 |
| | 3 | 0 | 0 | 0 | | | | 0/1 | 0 | 0 | −7/0 | −1 | 0 |
| Wastewater recharge × 2 | 1 | 0 | 0 | 0 | 0/6 | 0 | 0 | 0/1 | 0 | 0 | 0/51 | 1 | 0 |
| | 2 | 0 | 0 | 0 | | | | 0/1 | 0 | 0 | 0/43 | 1 | 0 |
| | 3 | 0 | 0 | 0 | | | | 0/1 | 0 | 0 | 0/14 | 1 | 0 |
| Storage coefficient representing the compressibility of water for layer 1 × 0.1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | −1/0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| | 3 | 0 | 0 | 0 | | | | −1/0 | 0 | 0 | 0 | 0 | 0 |
| Storage coefficient representing the compressibility of water for layer 1 × 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0/1 | 0 | 0 | 0/1 | 0 | 0 |
| | 2 | 0 | 0 | 0 | | | | 0/1 | 0 | 0 | 0/1 | 0 | 0 |
| | 3 | 0/1 | 0 | 0 | | | | 0/1 | 0 | 0 | 0/1 | 0 | 0 |
| Storage coefficient representing the compressibility of water for layer 2 × 0.1 | 1 | −1/0 | 0 | 0 | −1/0 | 0 | 0 | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| | 2 | −1/0 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| | 3 | −1/0 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| Elastic skeletal storage coefficient of layer 1 × 0.1 | 1 | −1/1 | 0 | 0 | −1/0 | 0 | 0 | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| | 2 | −1/1 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| | 3 | −1/1 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/0 | 0 | 0 |
| Elastic skeletal storage coefficient of layer 2 × 0.1 | 1 | −1/1 | 0 | 0 | −1/0 | 0 | 0 | −1/0 | 0 | 0 | −1/1 | 0 | 0 |
| | 2 | −1/0 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/1 | 0 | 0 |
| | 3 | −1/1 | 0 | 0 | | | | −1/0 | 0 | 0 | −1/0 | 0 | 0 |

**Table 10.** Change in simulated land subsidence at the end of the transient period (1995) resulting from changes in selected model input parameters and stresses during the sensitivity analysis of the ground-water flow model of the Antelope Valley ground-water basin, California

[Order of presentation: from most sensitive (highest median subsidence change) to least sensitive (lowest median subsidence change)]

| Change in parameter or stress | Change in simulated subsidence, in feet | | |
|---|---|---|---|
| | Range | Mean | Median |
| Layer 2 inelastic skeletal storage coefficient × 10 | 1.65/14.20 | 6.08 | 5.94 |
| Layer 1 inelastic skeletal storage coefficient × 10 | 2.81/8.47 | 5.25 | 5.24 |
| Layer 1 specific yield × 0.5 | 1.90/7.98 | 4.08 | 3.40 |
| Layer 1 specific yield × 2 | –3.99/–1.37 | –2.29 | –1.93 |
| Layer 2 inelastic skeletal storage coefficient × 0.1 | –4.03/–.61 | –1.54 | –1.39 |
| Layer 1 inelastic skeletal storage coefficient × 0.1 | .21/1.53 | 1.53 | .42 |
| Pumpage increased by 10 percent | –.01/.95 | .38 | .29 |
| Agricultural pumpage increased by 10 percent | –.01/.73 | .31 | .28 |
| Layer 1 elastic skeletal storage coefficient × 10 | –.09/.73 | .31 | .23 |
| Layer 2 elastic skeletal storage coefficient × 10 | –.06/.65 | .28 | .23 |
| Layer 3 storage coefficient × 10 | –.41/–.15 | –.25 | –.20 |
| Pumpage decreased by 10 percent | –.49/–.09 | –.21 | –.20 |
| Natural recharge × 1.1 | –.41/–.05 | –.18 | –.17 |
| Natural recharge × 0.9 | .04/.46 | .18 | .16 |
| Agricultural pumpage decreased by 10 percent | –.24/–.04 | –.14 | –.15 |
| Hydraulic conductivity of layer 1 × 2 | –.32/1.05 | .33 | .14 |
| Vertical leakance between layers 1 and 2 × 0.1 | –.26/.42 | .08 | .06 |
| Hydraulic conductivity of layer 1 × 0.5 | –.56/.38 | –.08 | –.06 |
| Vertical leakance between layers 1 and 2 × 10 | –.72/.12 | –.12 | –.05 |
| Transmissivity of layer 3 × 2 | –.07/.29 | .06 | .04 |
| Layer 2 storage coefficient representing the compressibility of water ×10 | –.09/–.03 | .05 | .04 |
| Vertical leakance between layers 2 and 3 × 0.1 | –.54/.12 | –.07 | .03 |
| Layer 1 elastic skeletal storage coefficient × 0.1 | –.07/.0 | –.03 | –.02 |
| Transmissivity of layer 2 × 2 | –.33/.62 | .05 | –.02 |
| Layer 2 elastic skeletal storage coefficient × 0.1 | –.06/.0 | –.03 | –.02 |
| Layer 3 storage coefficient × 0.1 | .01/.05 | .03 | .02 |
| Vertical leakance between layers 2 and 3 × 10 | –.29/.19 | –.01 | –.02 |
| Transmissivity of layer 2 × 0.5 | –.57/.54 | –.01 | .02 |
| Layer 2 storage coefficient representing the compressibility of water × 0.1 | –.01/.0 | –.01 | –.01 |
| Hydraulic characteristics of low barriers × 0.5 | –.04/.09 | .00 | .01 |
| Wastewater recharge × 0.5 | .0/.01 | .00 | .00 |
| Wastewater recharge × 2 | –.01/.0 | .00 | .00 |
| Flow barriers not simulated | –.34/.53 | .04 | .00 |
| Transmissivity of layer 3 × 0.5 | –.30/.04 | –.05 | .00 |
| Layer 1 storage coefficient representing the compressibility of water × 0.1 | –.03/.08 | .00 | .00 |
| Layer 1 storage coefficient representing the compressibility of water × 10 | .0/.01 | .00 | .00 |

Water levels and land subsidence calculated by the model are average values for the area represented by each model cell. Simulated water levels can vary considerably from measured water levels because of well location, depth, and construction. For example, wells may be screened over a depth represented by more than one model layer, whereas, measured water levels may be a composite of the actual water levels in each layer. The size of the model cell and the length of the stress period of the model are appropriate for the resolution of available data and for simulations on a regional scale. Because model uncertainty increases significantly with the decreasing size of the area of interest, the model generally should not be used to address local-scale problems.

Little is known about the geohydrology of the Finger Buttes, West Antelope, Neenach, Pearland, and Buttes subbasins. Consequently, hydraulic properties specified in the model for these subbasins were based on limited data. Available data indicate that hydraulic conductivity of the aquifer material is lower in the upslope areas adjacent to the mountain fronts than in the downslope areas, which is contrary to what would be expected for areas with typical alluvial fan development, where coarse-grained material is deposited at the fan heads (higher hydraulic conductivity) and fine-grained material is deposited at the fan margins (lower conductivity). In these five subbasins, which have depths to water greater than the other subbasins, the water table may be below the more transmissive coarse-grained material. Tectonic processes, such as uplift and erosion, also may affect the hydrologic properties of the aquifers. The water-level data for these subbasins used to calibrate the model also were limited; consequently, the differences between the simulated and the measured water levels were greatest in these subbasins. Although the simulated water levels for Finger Buttes, West Antelope, Neenach, Pearland, and Buttes subbasins provide reasonable boundary conditions for simulating the water levels in the Lancaster subbasin for the calibration period, the high degree of uncertainty in the model input for these subbasins greatly reduces the potential for accurate predictions of ground-water conditions in these subbasins. Additional geohydrologic data would improve the accuracy of the model for these subbasins.

The model is sensitive to the location and simulated barrier effect of faults. It is likely that there are additional concealed faults crossing the study area that have not yet been identified in areas that are not currently being stressed. The barrier effect of these faults may become apparent in the future, if pumping or recharge occurs near unknown faults. If these faults significantly affect ground-water flow, the faults should be added to the model.

The quantity and distribution of agricultural pumpage is uncertain. As shown in the sensitivity analysis, the variability in estimates of pumpage can significantly affect model results. More accurate estimates of agricultural pumpage would improve the model results. Results from simulations of future conditions that include pumpage for areas where pumping had not previously occurred should be interpreted carefully because the stresses from pumping were not simulated during the calibration process of the model.

Natural and agricultural recharge are difficult to measure and, therefore, the recharge rates and temporal distribution of recharge were based on the model calibration results. The calibration process resulted in a lower rate of natural recharge than had been estimated for previous studies. Additional geohydrologic data are needed to confirm that the natural recharge rates used in the model are accurate; however, collection of additional data was beyond the scope of this study. The travel time for irrigation-return flows to reach the water table was simulated as a constant (10 years) for the entire model area. Model results probably could be improved by more accurately specifying the travel time for each area on the basis of the depth-to-water and aquifer material.

The approach taken in this study to simulate aquifer-system compaction in unconfined portions of the model layer 1 using the IBS1 package will tend to overestimate compaction in that layer, where the water table declines, and underlying mode layers. IBS1 does not account for changes in the total stress that occur when the water table rises and lowers, as it may in model layer 1. Changes in the position of the water table cause changes in the total stress exerted on the underlying sediment owing to the overlying weight of water that changes when the water table fluctuates. These effects are relatively small and the overestimated subsidence in the model simulation is expected to be in the range of 1.18 to 1.33 percent, and is primarily dependent upon the porosity of the sediments in model layer 1 in the zone of water-table fluctuation.

Although the model does a relatively good job of simulating the measured quantity of land subsidence, the IBS1 Package used to simulate aquifer compaction does not accurately simulate the delayed drainage in the thick aquitards or the timing of subsidence in areas where thick aquitards are a major contributor to subsidence. ISB1 simulates the instantaneous release of water from storage from fine-grained, compressible interbeds for a head decline in the surrounding aquifer. As such, the heads in the interbeds are assumed to equilibrate instantaneously with head changes in the aquifers. This treatment ignores the delayed equilibration of head associated with the low permeability interbeds and aquitards which is further exacerbated by their thickness—the time constants governing head equilibration in these units is proportional to their squared thickness. Additionally, the model does not simulate subsidence throughout the modeled area because values of inelastic storage only were specified in areas where subsidence previously had been measured. In areas where inelastic skeletal storage was not specified, future water-level declines below preconsolidation heads could cause subsidence where compressible sediments exist in these areas. Subsidence cannot be simulated for these areas unless inelastic skeletal storage coefficients and preconsolidation heads are specified for these areas.

Owing to uncertainty in some parameters used in the model, especially in the agricultural component of pumpage, model results from the predictive simulation should be used with caution. The model, like most models, is not ideally suited for predicting absolute changes in water levels or subsidence. The most appropriate application of the model is comparing the relative effects of different water-management scenarios on the aquifer system.

## Simulation of Aquifer-System Response to Pumping Scenarios

A calibrated flow model can be used as a tool to evaluate and compare the responses of an aquifer system to potential future stresses. Management actions involving changes in the quantity and distribution of pumpage or recharge can be simulated and the aquifer-system responses compared to evaluate the effectiveness of these actions satisfying management goals. Although water levels and subsidence simulated for a given scenario may not accurately represent the values in the real system, the relative differences in water levels and subsidence over time can be compared to provide managers with useful information for planning and decision making.

For this study, the model was used to simulate the aquifer-system response to two potential pumping scenarios for 1995–2025. For both scenarios, all model parameters were unchanged from those specified in the transient-state simulation. Natural recharge and artificial recharge from irrigation-return flows and from reclaimed wastewater were specified equal to the quantities specified for those sources for 1995. For both scenarios, recharge from irrigation-return flows was calculated as 30 percent of the water used for irrigation and was assumed to recharge the water table 10 years after the irrigation water was applied. For scenario 1, total annual pumpage for 1995–2025 was specified equal to total annual pumpage in 1995. For scenario 2, public-supply pumpage was increased 3.3 percent annually and agricultural pumpage was assumed to be 75 percent greater than agricultural pumpage in 1995 for the simulated period 1995–2025. Recharge from irrigation-return flows was correspondingly increased by 75 percent. The annual increase in public-supply pumpage was based on population growth projections for Palmdale and Lancaster from the Southern California Association of Governments (2001). The increase in agricultural pumpage was based on crop-acreage data from the Los Angeles County Agricultural Commissioner which indicated that agricultural production in the study area increased as much as 75 percent during 1995–98. The spatial distribution of pumpage for both scenarios was the same as was specified for 1995.

The simulated water-level (layer 1) and land-subsidence values for both scenarios are shown in figures 31 and 32, respectively. Recall that the simulated water-level and land-subsidence values are averages for the entire model cell and, therefore, may be different from the measurements for specific wells and bench marks.

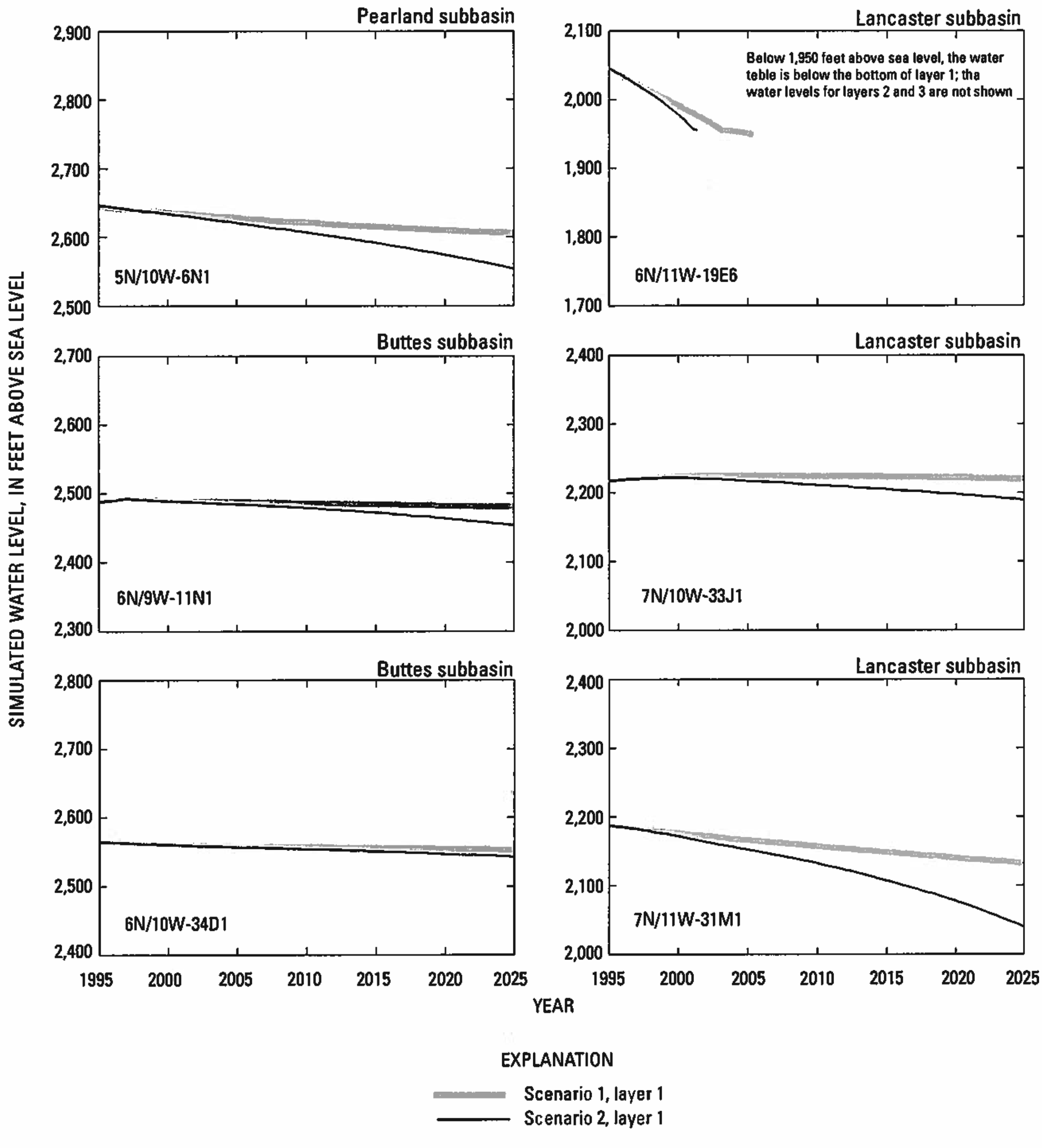


**Figure 31.** Simulated water levels for two pumping scenarios for the Antelope Valley ground-water basin, California, 1995–2025.

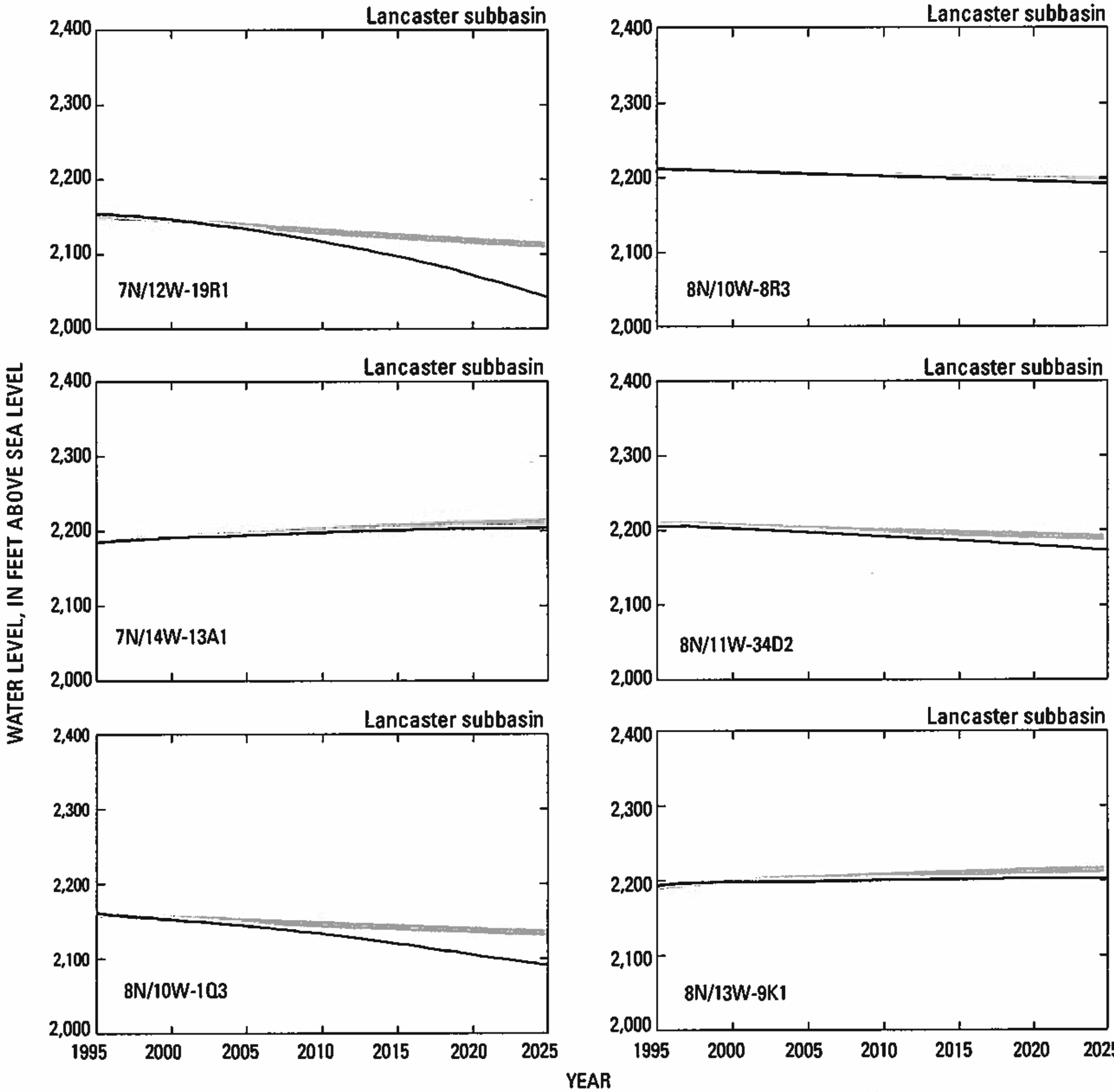


**Figure 31.**—Continued.

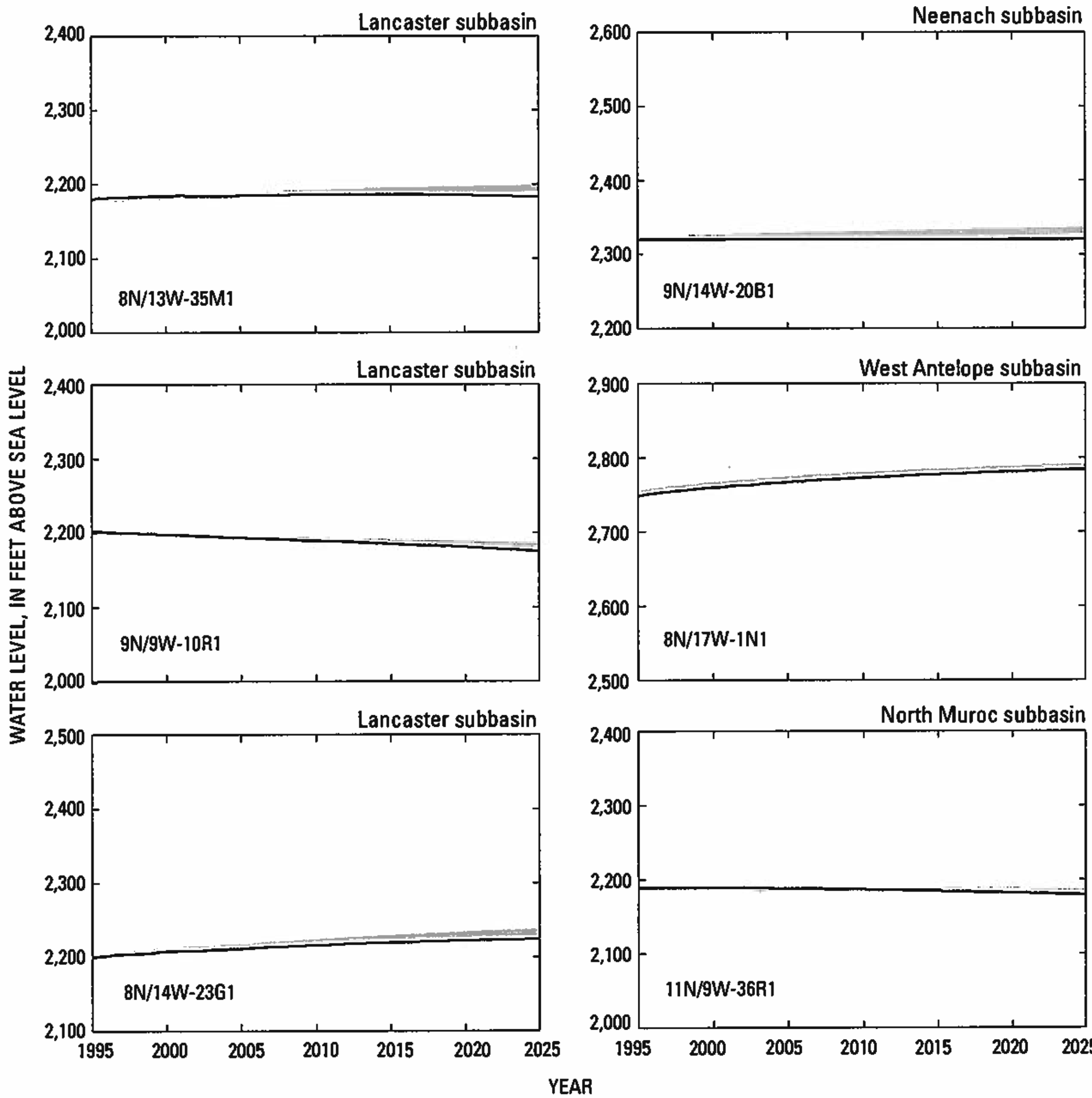


**Figure 31.**—Continued.

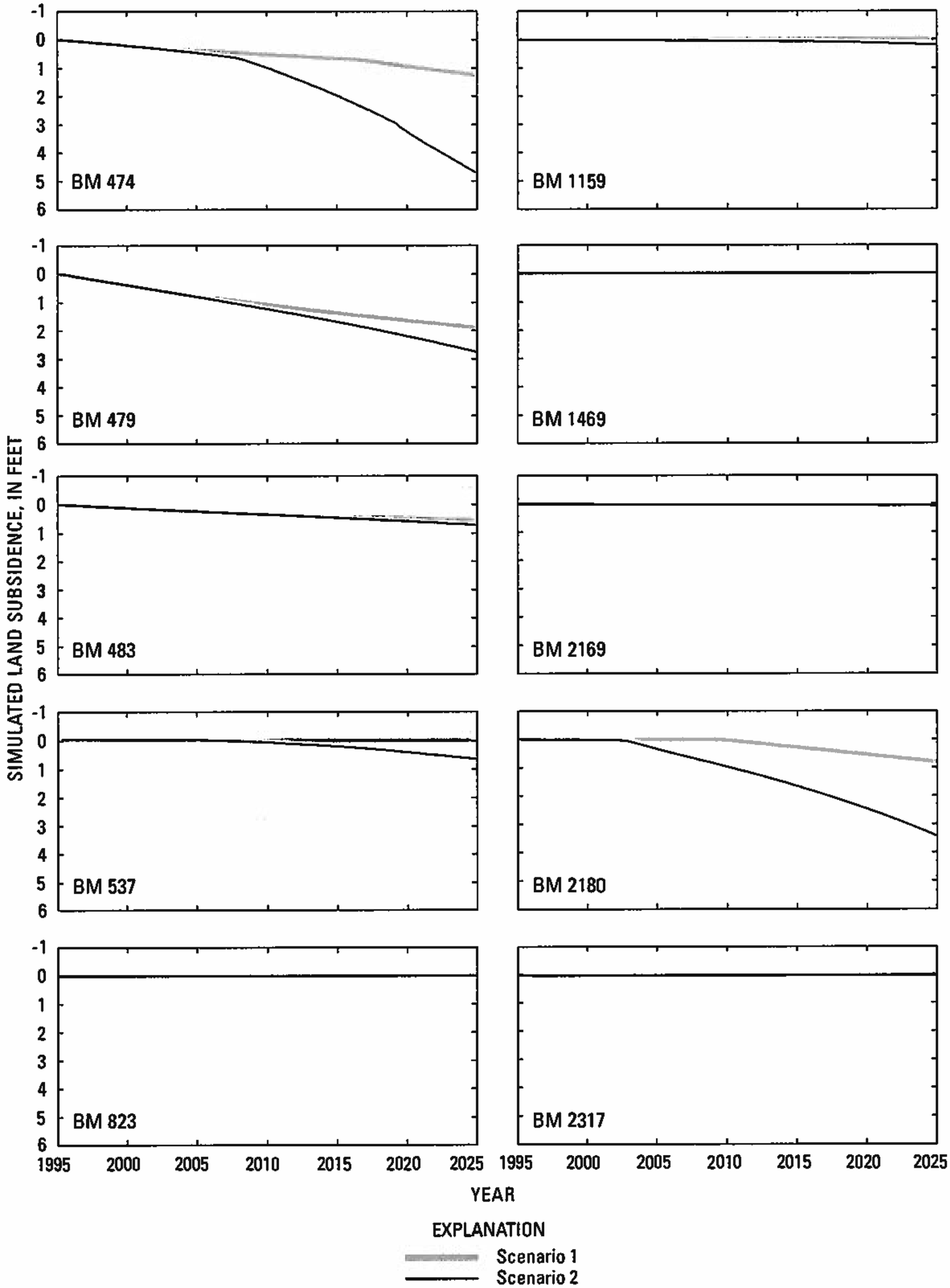


**Figure 32.** Simulated land subsidence near indicated bench marks for two pumping scenarios for the Antelope Valley ground-water basin, California, 1995–2025.

For scenario 1, water levels rose in the western Lancaster subbasin and in the Neenach and West Antelope subbasins, continuing the long-term recovery from drawdown caused by the much greater historical agricultural pumpage (Carlson and others, 1998; Carlson and Phillips, 1998). Water levels rose as much as 11 ft at well 9N/14W-20B1 in the Neenach subbasin and as much as 36 ft at well 8N/17W-1N1 in the West Antelope subbasin; however, the rate of the water-level rise declined over time (fig. 31). The decline in the rate of water-level rise was caused, in part, by the 10-year delay in recharge from irrigation-return flows. Even though the simulated annual pumpage was constant from 1995 to 2025, recharge from irrigation-return flows was based on agricultural pumpage prior to 1995, which was higher than in 1995. From 1996 to 2004, the annual quantity of recharge from irrigation-return flows gradually declined; in 2005, recharge from irrigation-return flows remained constant for the remainder of the simulation period. In the southern, eastern, and northern part of the Lancaster subbasin and in the Buttes, Pearland, and North Muroc subbasins, water levels generally declined as a result of the scenario 1 pumpage, except at well 7N/10W-33J1 in the eastern part of the Lancaster subbasin where water levels did not decline. The largest decline in the simulated water levels (more than 100 ft) was at well 6N/11W-19E6, where the water level declined below the bottom of model layer 1 into layer 2 in 2006. The water level in layer 2 continued to decline after 2006 (water levels for layer 2 are not shown in fig. 31). Simulated water-level declines were greatest at this well because most of the pumping for public supply occurs in this area. Further land subsidence was simulated in the central part of the Lancaster subbasin north and east of the city of Lancaster. The maximum simulated subsidence for scenario 1 occurred at bench mark BM 479 (1.9 ft). These model results indicate that pumpage for public supply at 1995 rates in the Lancaster and Palmdale areas will result in significant water-level declines and land subsidence, indicating that future pumpage may have to be redistributed or augmented by artificial recharge.

For scenario 2, public supply pumpage was increased 3.3 percent annually and annual agricultural pumpage and irrigation-return flows were 75 percent greater than the values simulated for scenario 1. Similar to scenario 1, water levels rose in the western Lancaster subbasin; however, the water-level rise was not as great. In the Neenach subbasin, the water levels for well 9N/14W-20B1 remained unchanged from 1995 to 2025. In the southern, eastern, and northern part of the Lancaster subbasin and in the Buttes and Pearland subbasins, water levels declined more than the water levels for scenario 1. Pumpage increases for scenario 2 resulted in significant water-level declines in the southern and northeastern part of the Lancaster subbasin (wells 6N/11W-19E6, 7N/12W-19R1, and 8N/10W-1Q3) because most pumping for public supply occurs in these areas. Water-level declines were as great as 150 ft in the south-central part of the Lancaster subbasin. Simulated subsidence at bench marks BM 474, BM 479, BM 537, and BM 2180 was greater for scenario 2 than for scenario 1, and the maximum simulated subsidence for 1995–2025 was about 5 ft at bench mark BM 474. The simulated subsidence was the greatest in the central Lancaster subbasin north and east of the city of Lancaster, near bench marks BM 474, BM 479, and BM 2180, where combined public supply and agricultural pumping are greatest. Because inelastic storage coefficients were specified only for areas where subsidence has previously been measured, neither scenario 1 nor 2 is able to predict subsidence from future water-level declines outside this area.

## SUMMARY

Ground-water pumpage has provided from 50 percent to more than 90 percent of the water supply in Antelope Valley since the early 1900s. This long-term ground-water pumpage has caused water-level declines and associated increased pumping lifts; it also has reduced well efficiencies and caused land subsidence. Urban growth and limited available surface-water supply are likely to continue to increase reliance on ground water. A numerical ground-water flow and land-subsidence model of the Antelope Valley ground-water basin was developed to improve the understanding of the ground-water flow system. The model can be used as a tool in making informed water-management decisions.

The Antelope Valley ground-water basin consists of unconsolidated alluvial and lacustrine deposits, more than 5,000 ft thick in places. The alluvium consists of poorly sorted gravels, sands, silts, and clays. Older, deep alluvial deposits are more compacted and indurated than the younger, shallow deposits. The lacustrine deposits are as much as 300 ft thick and are composed mostly of clay and silty clay with some layers of sand and silt. The lacustrine deposits are as much as 800 ft below land surface near Palmdale, become progressively shallower northward, and are exposed at the surface near the southern edge of Rogers Lake.

The study area was conceptually divided into seven ground-water subbasins on the basis of faults, bedrock outcrops, ground-water divides, and arbitrary boundaries. Some faults seem to act as barriers to ground-water flow. Geophysical logs from previous studies show that induration of the alluvial material increases with depth, which suggests a decrease in the ability to transmit and store water with depth. Data from test wells drilled in the Lancaster area and at Edwards Air Force Base indicate that there is a change in the properties of the aquifer materials at altitudes of about 1,950 ft and 1,550 ft above sea level. Unconsolidated material at altitudes of 1,950 ft above sea level and greater was designated as the upper aquifer, unconsolidated material between 1,950 and 1,550 ft above sea level was designated as the middle aquifer, and unconsolidated material below 1,550 ft above sea level was designated as the lower aquifer. The lacustrine deposits are contained within the upper aquifer in the northern part of the Lancaster subbasin and primarily within the middle aquifer in the southern part of the Lancaster subbasin. The upper aquifer is unconfined to confined and the middle and lower aquifers are confined.

Prior to ground-water development in Antelope Valley, recharge to the ground-water system was primarily from the infiltration of precipitation runoff near the valley margins. Precipitation over the valley floor generally is less than 10 in./yr and probably contributes little, if any, recharging to the aquifer system owing to the high evapotranspiration rates in the study area. In the lowland parts of the valley, discharge from the aquifer system was primarily from evapotranspiration. A small amount of ground water is discharged from the valley north into the Fremont Valley Basin.

Development of the ground-water system began around 1915 and increased rapidly into the 1950s. Ground-water pumping has caused large water-level declines in the ground-water basin; as a result, evapotranspiration has decreased to an insignificant amount. The water-level declines from pumping also have caused land subsidence owing to the compaction of compressible sediments. The major source of discharge in the valley has changed from evapotranspiration to ground-water pumping; ground water now flows from areas of recharge toward the major pumping centers rather than to natural discharge areas where evapotranspiration had occurred. Recharge from the infiltration of irrigation-return flows is a major contributor of recharge to the aquifer system.

A numerical ground-water flow model was developed and calibrated for steady-state pre-development (1915) and transient-state (1915–95) conditions. The model aggregates old and new geohydrologic information to aid in better understanding the ground-water flow system and to aid in making informed water-management decisions. The model was vertically discretized into three layers. Layer 1 (upper aquifer) extends from the water table to an altitude of 1,950 ft above sea level or to bedrock, whichever is higher; layer 2 (middle aquifer) extends from 1,950 to 1,550 ft above sea level or to bedrock, whichever is higher; layer 3 (lower aquifer) extends from 1,550 to 1,000 ft above sea level or to bedrock, whichever is higher. The bottom of layer 3 was set to an altitude of 1,000 ft because it was assumed that the alluvial material below this depth was not a significant part of the flow system owing to compaction and induration of this older material.

The model was calibrated by adjusting hydraulic conductivity, transmissivity, specific yield, natural recharge, aquitard thickness, hydraulic characteristic of flow barriers, and preconsolidation head within reasonable limits to obtain reasonable agreement between simulated and measured water levels and subsidence. The model did well in simulating water levels in the Lancaster, Neenach, Pearland, and Buttes subbasins where the geohydrology is well known. In the North Muroc Subbasin, measured and simulated horizontal and vertical water-level gradients match well; however, the simulated water levels were higher than the measured water levels. In the Finger Buttes and West Antelope subbasins, where few geohydrologic data are available, the match between the simulated and the measured water levels was not as good. Measured and simulated land subsidence data also were compared and matched well at all the bench marks used for calibration.

During model calibration, natural recharge was reduced from an initial estimate of 40,700 acre-ft/yr to 30,300 acre-ft/yr. Results of the transient-state simulation indicate that more than 8.5 million acre-ft of ground water was removed from storage during 1915–95, with most of the storage change occurring between about 1945 and 1975. Ground-water storage changed little during the final 10 years of simulation period because discharge by pumpage had declined sufficiently to be balanced by recharge. Model results show that during the period of peak pumping (1949–53) 79 percent of the ground water withdrawn from the aquifer came from storage. Water released from compaction of the aquitards accounted for about 21,600 acre-ft/yr of the ground water removed from storage. Pumpage from layer 2 induced leakage of ground water from layer 1, which accounted for about 86 percent of the total pumpage in layer 2. During the last 5 years of the simulation (1991–95), only 17 percent of pumpage came from storage.

Results of the sensitivity analysis showed that the model was most sensitive to changes in the hydraulic characteristic of flow barriers, specific yield, hydraulic conductivity of layer 1, natural recharge, inelastic skeletal storage coefficient, transmissivity of layer 2, and pumpage. The sensitivity of the model varied spatially. The model was not sensitive to the transmissivity of layer 3, which indicates that specifying the bottom of the model at 1,000 ft above sea level was a reasonable assumption.

The calibrated model was used to test the aquifer response to two future pumping scenarios for 1995 to 2025. For scenario 1, annual pumpage remained the same as pumpage specified for 1995. Water levels rose in the western Lancaster subbasin and in the Neenach and West Antelope subbasins, continuing the long-term recovery from drawdown caused by the much greater historical agricultural pumpage. In areas where pumping for public supply is concentrated, water levels continued to decline and subsidence continued in the central part of the Lancaster subbasin. Water-level declines were greatest (more than 100 ft) in the south-central part of the basin because most of the public supply pumpage occurs in this area; as much as 1.9 ft of additional subsidence was simulated in the central part of the ground-water basin for 1995 through 2025. For scenario 2, public supply pumpage was increased 3.3 percent annually compared with that specified for 1995 and agricultural pumpage was increased 75 percent. This scenario resulted in significant water-level declines in the southern and eastern part of the Lancaster subbasin because most of the public supply and agricultural pumping occurs in these areas. Results of this simulation showed that water levels declined more than 150 feet in the south-central part of the ground-water basin and that an additional 5 feet of subsidence was simulated in the central part of the basin.

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## APPENDIX: WATER USE 1992–95

Water managers and planners require comprehensive and accurate water-use data to make informed water-management decisions. Templin and others (1995) compiled available water-use data for Antelope Valley for 1919–92 (1992 data were incomplete). For the purpose of this study, annual water-use data for 1992–95 were compiled to extend the period of record reported by Templin and others (1995) for use in the ground-water flow and subsidence model developed for this study.

The methodology, sources, and areal extent [Antelope Valley drainage basin (fig. 1)] used to obtain the water-use data for 1992–95 were consistent with those used by Templin and others (1995) so that data for all years could be compared and analyzed. As a part of their work, Templin and others (1995) developed a database of ground-water pumpage for 1947–92; during this current study, pumpage data for 1992–95 were collected and added to the 1947–92 database. Some additional data for 1947–91 also were obtained and added to the database. The tables in this appendix include data only for 1992–95, but the graphs show data for the entire period of the pumpage database (1947–95) and, therefore, can show trends in water use over time.

Water supply for Antelope Valley was obtained from four sources; (1) ground-water pumping, (2) local surface-water diversions, (3) imported water, and (4) reclaimed wastewater. Each of these components and total annual water supply for 1947–95 are shown in figure A1. Total water supply increased during 1992–95 because of increases in imported surface water in 1992 and 1993, increases in ground-water pumping in 1994 and 1995, and increased use of reclaimed wastewater. Historically, ground-water pumping has been the primary source of water supply in the valley, and remained the primary source during 1992–95. Supply from local surface-water sources was small and generally remained steady during 1992–95.

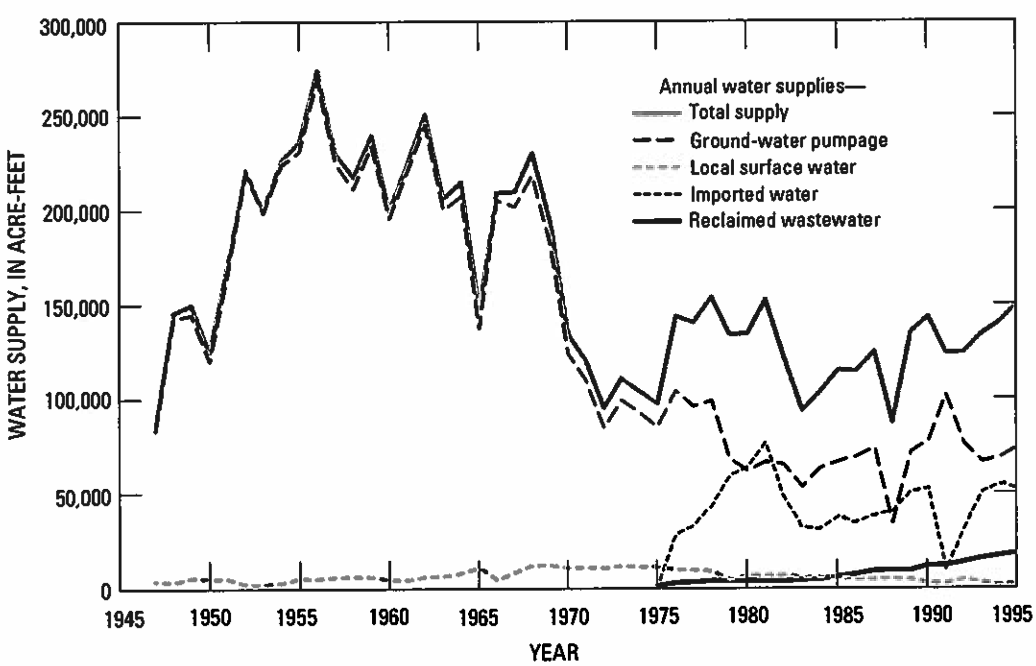


**Figure A1.** Sources of water supply in the Antelope Valley ground-water basin, California, 1947–95.

## Ground Water

Templin and others (1995) divided ground-water use into two categories, public supply and self supply. Ground-water pumpage for public supply represents ground water that is withdrawn by public or private entities for sale and delivery to customers, usually for domestic, commercial, and industrial uses. Ground-water pumpage for self supply represents ground water that is withdrawn by private entities for use by that entity. In Antelope Valley, most ground-water pumpage for self supply is used for agriculture and in this report is referred to as agricultural pumpage. Most of the ground-water-use data for public supply was obtained by contacting the suppliers directly; however, some of the data were obtained from pumpage records maintained by the California State Water Resources Control Board (SWRCB). Agricultural-pumpage data were obtained primarily from the records of the SWRCB, but these records are limited to wells in the Los Angeles County and San Bernardino County parts of Antelope Valley. Because the SWRCB does not require that agricultural pumpage in Kern County be reported, data for that part of Antelope Valley are nonexistent.

Ground-water pumpage by user is shown in tables A1 (public supply) and A2 (agricultural supply). Figure A2 shows annual ground-water pumpage for the entire period of record (1947–95) in the pumpage database. Note that the agricultural pumping presented in the data base (figure A2) is less than the agricultural pumpage estimated for this study (table 8). Templin and others (1995) noted that ground-water pumpage reported to the SWRCB may not accurately reflect actual pumpage in the valley because of evidence of underreporting and overreporting of annual pumpage, reporting of identical amounts of pumpage year after year, and inaccurate methods of estimating pumpage. Also, although agricultural-pumpage data for the Kern County part of the study areas does not exist, the data reported in table A2 are the best available data at the time of this current study. Additional work is needed to improve estimates of the quantity and spatial distribution of agricultural pumpage.

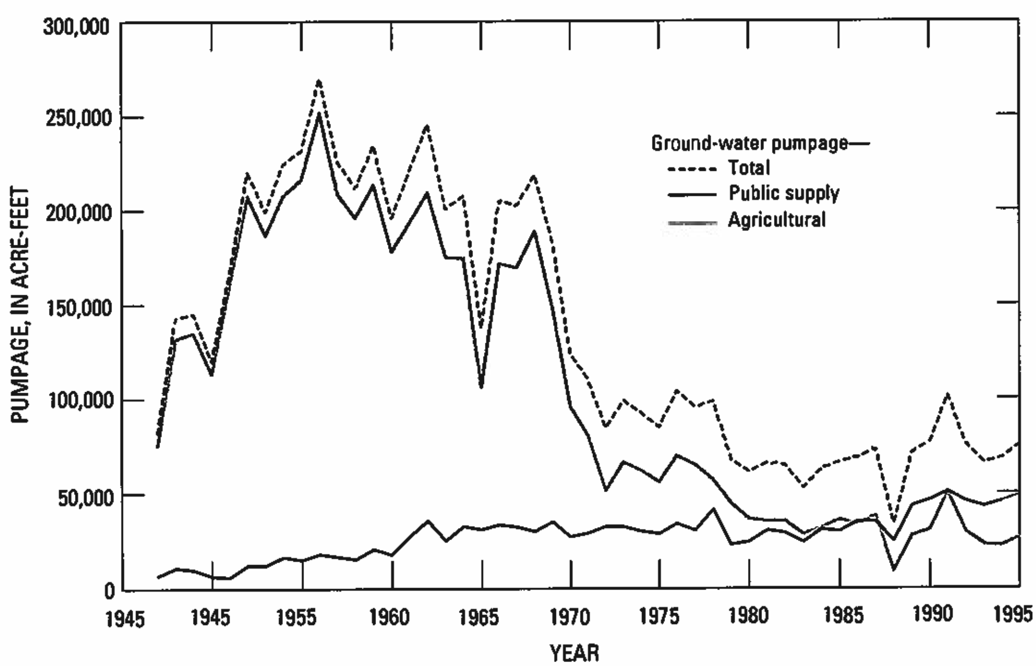


**Figure A2.** Ground-water pumpage recorded in the pumpage database for Antelope Valley, California, 1947–95.

## Surface Water

Water supply from surface water comes from local surface-water diversions and from imported water by way of the California Aqueduct. Imported water provides a much larger proportion of surface-water supply than local surface-water diversions. The availability of imported water is controlled primarily by rainfall conditions in northern California. Minimal local rainfall and limited storage facilities prevent local surface water from becoming a significant component of water supply in Antelope Valley.

### Local Surface Water

Local surface-water diversions are used for public supply and agriculture. Data on local surface-water diversions for public supply were obtained directly from the public supply entities (table A1). Palmdale Water District was the only user of local surface water for public supply for which data were available during 1992–95 (table A1).

Data on local surface-water diversions for agricultural supply (table A2) were obtained from the SWRCB, Division of Water Rights. These data and the self-supplied surface-water data reported by Templin and others (1995) indicate that, for many users, the quantity of reported local surface-water use often is constant over a period of several years. These constant values probably are due to users reporting their water-rights entitlement rather than their actual usage.

### Imported Water

Data on the annual quantity of imported water was obtained directly from the public entities that distribute the water (table A3). The annual quantity of water imported by the Antelope Valley–East Kern Water Agency (AVEK) represents only those deliveries made within the study area defined in this report. Imported water averaged about 48,900 acre-ft/yr for 1992–95 (table A3), which is less than one-third of the annual entitlement of 158,000 acre-ft reported by Templin and others (1995). Imported water is used for both public supply and agriculture.

## Reclaimed Wastewater

Data on water supply from reclaimed wastewater from the Lancaster and Palmdale Water Reclamation Plants (David Lambert, County Sanitations Districts of Los Angeles County, written commun., 1996) are shown in table A4. These two facilities are the largest treatment plants in the study area; there are about 10 additional treatment plants that treat much smaller quantities of wastewater. Templin and others (1995) reported that the Lancaster and Palmdale facilities accounted for 84 percent of the treated wastewater in Antelope Valley in 1990 (a year when data were available for all treatment plants). Discharge of treated wastewater from the Lancaster Water Reclamation Plant used for wetlands (table A4) is slightly higher than the wastewater discharge shown in table 1 because a small amount of the treated wastewater discharge from the Lancaster Water Reclamation Plant is diverted to a wildlife pond.

The quantity of reclaimed wastewater available for water supply has increased almost every year since 1975 (fig. A3) due to increases in population and in treatment capacities. In 1995, reclaimed wastewater represented about 12 percent of the total available supply in Antelope Valley. Treated wastewater disposed to land surfaces is subject to evapotranspiration and infiltration to the ground-water system. There is potential for identifying more beneficial uses for this component of reclaimed wastewater.

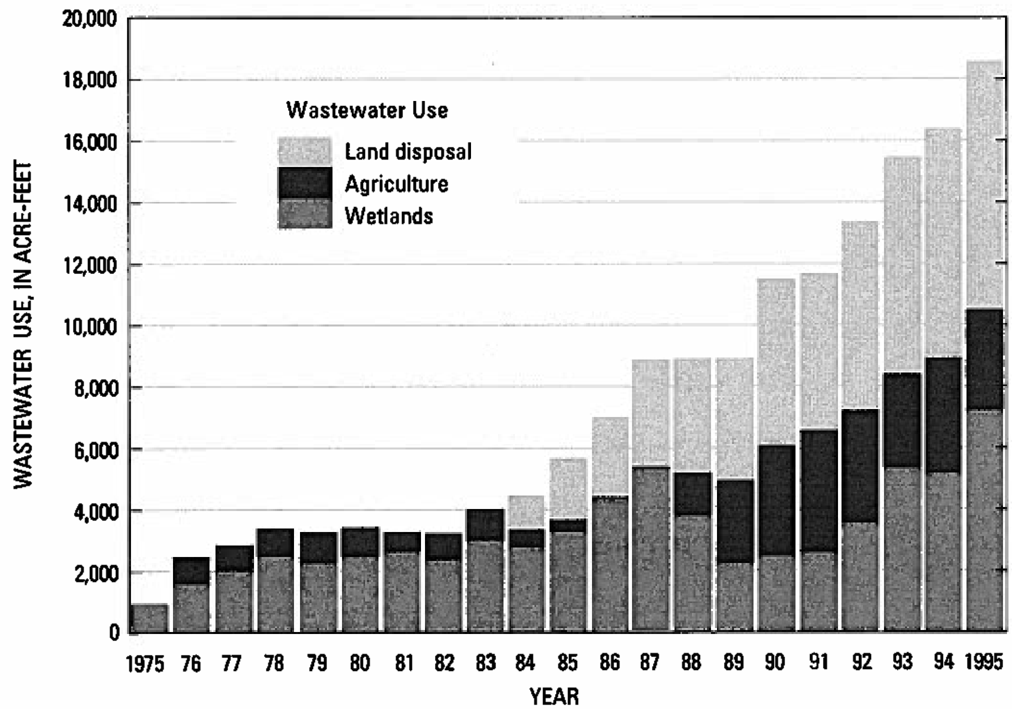


**Figure A3.** Wastewater use in Antelope Valley ground-water basin, California, 1975–95.

Owing to the depth to the water table and the existence of thin aquitards, a time delay is likely between the onset of irrigation and the recharge of this water to the regional water table. Snyder (1955) stated that agricultural recharge probably had reached the water table by the early 1950s, but Durbin (1978) assumed that no irrigation water had reached the water table by 1961. Durbin (1978) based this assumption on water-chemistry data collected from wells in agricultural areas that showed little change in dissolved solids over time. However, it is likely that water had reached the water table much sooner than estimated by Snyder (1955) or Durbin (1978). Results from a simple model of the unsaturated zone indicate that, in a silt loam, recharge will infiltrate to a depth of about 120 ft approximately 10 years after the water is applied at land surface (Alan Flint, U.S. Geological Survey, written commun., 1999).

The largest producers of reclaimed wastewater in the study area are the Palmdale Water Reclamation Plant and the Lancaster Water Reclamation Plant (Templin and others, 1995). Beginning in 1975, reclaimed wastewater has been disposed of in ponds or on spreading grounds where the water is spread over land surface to evaporate or infiltrate below land surface. A small amount of reclaimed wastewater is reused primarily for agriculture (Templin and others, 1995). The quantity of disposed wastewater to reach the regional water table as recharge was estimated by subtracting the estimated evaporation from the quantity of reclaimed water that is disposed of in the ponds or on spreading grounds. At the Palmdale Water Reclamation Plant, reclaimed wastewater is spread on approximately 60 acres of land. On the basis of a pan evaporation rate of 114 in./yr for Antelope Valley (Bloyd, 1967), it was estimated for this study that about 570 acre-ft/yr is lost to evaporation. At the Lancaster Water Reclamation Plant, wastewater is disposed of in ponds with an area of approximately 430 acres and evaporation was estimated to be about 4,080 acre-ft/yr. The estimated evaporation was subtracted from the quantity of reclaimed wastewater (David Lambert, County Sanitation Districts of Los Angeles County, written commun., 1996) to estimate the recharge to the water table at these sites (table 1) (fig. 12).

**Table A1.** Water-use information for public water suppliers in Antelope Valley, California, by water-supply sources, 1992–955

[Units are in acre-feet. USAF, United States Air Force. —, no data]

| Year | Antelope Park Mutual Water Company | Antalope Valley Indian Museum | Antelope Valley Union High School District | Antelope Valley Water Company | | | Aqua J Mutual Water Company Inc. | Averydale Mutual Water Company |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Ground water | Purchased water | Total | Ground water | Ground water |
| 1992 | 161.1 | 0.5 | — | 569.7 | 207.0 | 776.7 | 53.6 | 287.8 |
| 1993 | 149.5 | .5 | 236.0 | 616.3 | 176.0 | 792.3 | 58.2 | 296.1 |
| 1994 | 162.5 | .5 | 238.0 | — | 171.0 | 171.0 | 59.0 | 317.6 |
| 1995 | 162.0 | .5 | — | — | 171.0 | 171.0 | 64.2 | 312.2 |

| Year | Bleich Flat Mutual Water Company | Boeing (Rockwell) USAF Plant 42 | Boron Community Service District | | | California Poppy Reserve | | |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Purchased water | Total | Ground water | Purchased water | Total |
| 1992 | 17.2 | 149.6 | 253.0 | 253.0 | 506.0 | 0.5 | 16.0 | 16.5 |
| 1993 | 16.3 | 80.9 | 305.0 | 305.0 | 610.0 | .5 | .0 | .5 |
| 1994 | 16.9 | 129.3 | — | 548.0 | 548.0 | .8 | .0 | .8 |
| 1995 | 21.0 | 120.5 | — | 569.0 | 569.0 | .7 | .0 | .7 |

| Year | Desert Laka Community Services District | | | Edgemont Acres Mutual Water Compeny | Edwards Air Force Base (Mein Base) | | | Edwards Air Force Base (Rocket Site) |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Totel | Purchased water | Ground water | Purchased water | Total | Ground water |
| 1992 | 348.0 | 24.0 | 372.0 | 70.0 | 4,794.2 | 0.0 | 4,794.2 | 431.8 |
| 1993 | 353.0 | 43.0 | 396.0 | 53.0 | 3,498.8 | 1,345.0 | 4,843.8 | 415.0 |
| 1994 | — | 174.0 | 174.0 | 27.0 | 3,162.3 | 2,103.0 | 5,265.3 | 419.4 |
| 1995 | — | 314.0 | 314.0 | 45.0 | 3,803.8 | 1,171.0 | 4,974.8 | 435.1 |

| Year | El Dorado Mutual Water Company | | | Evergreen Mutual Water Company | Landale Mutual Water Company | | | Land Projects Mutual Water Company | Little Baldy Water Company |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Ground water | Purchased water | Total | Ground water | Surface water |
| 1992 | 117.4 | 186.6 | 304.0 | 80.0 | 0.0 | 1.0 | 1.0 | 795.5 | 21.7 |
| 1993 | 195.3 | 114.8 | 210.1 | 81.0 | 220.7 | 15.0 | 235.7 | 782.6 | 21.7 |
| 1994 | 39.6 | 302.0 | 341.6 | 82.0 | — | .0 | .0 | 915.4 | 21.7 |
| 1995 | 47.5 | 297.7 | 345.2 | 81.0 | — | .0 | .0 | 869.7 | — |

**Table A1.** Water-use information for public water suppliers in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | Littlerock Creek Irrigation District | | | | Lockhead Martin USAF Plant 42 | | | Los Angeles County | Los Angeles County Sheriff Mira Loma Facility |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Surface water | Purchased water | Total | Ground water | Purchased water | Total | Surface water | Ground water |
| 1992 | 1,212.0 | 1,420 | 251.0 | 2,882 | — | 12.0 | 12.0 | 8.7 | 188.7 |
| 1993 | 1,270.0 | 1,105 | 735.0 | 3,110 | 74.4 | 14.3 | 88.7 | 8.7 | .0 |
| 1994 | 1,615.0 | 1,100 | 1,100.0 | 3,815 | 9.3 | 1.2 | 10.5 | 8.7 | 81.2 |
| 1995 | 1,630.0 | 6 | 480.0 | 2,116 | 7.1 | .6 | 7.7 | 8.7 | 235.0 |

| Year | Los Angeles County Waterworks District No. 4 | | | Los Angeles County Waterworks District No. 24 | | | Los Angeles County Waterworks District No. 27 |
|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Purchased water | Total | Ground water |
| 1992 | 13,771.8 | 12,691.0 | 26,462.8 | 117.3 | 219.0 | 336.3 | 366.8 |
| 1993 | 13,368.8 | 16,765.0 | 30,133.8 | 66.3 | 513.0 | 579.3 | 196.1 |
| 1994 | 14,942.9 | 16,757.0 | 31,699.9 | 4.5 | 579.0 | 583.5 | 426.9 |
| 1995 | 17,782.6 | 13,850.0 | 31,632.6 | 42.8 | 495.0 | 537.8 | 835.6 |

| Year | Los Angeles County Waterworks District No. 33 | | | Los Angeles County Waterworks District No. 34 | | | Los Angeles County Waterworks District No. 35 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Purchased water | Total | Ground water | Purchased water | Total |
| 1992 | 0.0 | 823.0 | 823.0 | 258.5 | 2,738.0 | 2,996.5 | 86.8 | 161.7 | 248.5 |
| 1993 | .0 | 991.0 | 991.0 | 199.3 | 3,649.0 | 3,848.3 | 26.0 | 240.7 | 266.7 |
| 1994 | .0 | 1,049.0 | 1,049.0 | 224.0 | 4,035.0 | 4,259.0 | 79.0 | 217.1 | 296.1 |
| 1995 | .0 | 776.0 | 776.0 | 438.3 | 4,023.0 | 4,461.3 | 82.2 | 219.4 | 301.6 |

| Year | Los Angeles County Waterworks District No. 38 | | | Los Angeles County Waterworks District No. 39 | | | Mojave Public Utility District | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Purchased water | Total | Ground water | Purchased water | Total |
| 1992 | 200.5 | 2,068.7 | 2,269.2 | 239.0 | 0.0 | 239.0 | 0.0 | 433.0 | 433.0 |
| 1993 | 264.2 | 2,248.2 | 2,512.4 | 267.1 | .0 | 267.1 | — | 78.0 | 78.0 |
| 1994 | 1,059.5 | 1,689.0 | 2,748.5 | 228.2 | 20.5 | 248.7 | — | 380.0 | 380.0 |
| 1995 | 478.8 | 2,327.8 | 2,806.6 | 208.4 | .0 | 208.4 | — | 118.0 | 118.0 |

**Table A1.** Water-use information for public water suppliers in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | North Edwards Water District | Northrop Corporation B-2 Division | Oak Springs Valley Water Company | Palmdale Water District | | | |
|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Ground water | Surface water | Purchased water | Total |
| 1992 | 0.0 | 138.6 | 0.0 | 10,295.0 | 3,449.0 | 3,845.0 | 17,589.0 |
| 1993 | — | 136.9 | — | 8,209.0 | 2,538.0 | 10,136.0 | 20,883.0 |
| 1994 | — | 128.2 | — | 11,458.0 | 1,123.0 | 8,037.0 | 20,618.0 |
| 1995 | — | 117.8 | — | 11,277.0 | 3,771.0 | 6,613.0 | 21,661.0 |

| Year | Palm Ranch Irrigation District | | | Quartz Hill Water District | | | Rosamond Community Service District | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Purchased water | Total | Ground water | Purchased water | Total |
| 1992 | 682.0 | 679.0 | 1,361.0 | 1,028.0 | 1,646.0 | 2,674.0 | 1,090.0 | 877.7 | 1,967.7 |
| 1993 | 1,151.0 | 175.0 | 1,326.0 | 811.8 | 1,833.0 | 2,644.8 | 1,025.0 | 1,295.1 | 2,320.1 |
| 1994 | 962.0 | 515.0 | 1,477.0 | 1,044.6 | 2,485.0 | 3,529.6 | 1,025.0 | 1,457.7 | 2,482.7 |
| 1995 | 758.0 | 736.0 | 1,494.0 | — | 2,098.0 | 2,098.0 | 826.0 | 1,632.6 | 2,458.6 |

| Year | Saddleback Butte State Park | Saint Andrews Priory | San Bernardino County Service Area No. 70L | | | Shadow Acres Mutual Water Company | | |
|---|---|---|---|---|---|---|---|---|
| | Purchased water | Ground water | Ground water | Surface water | Total | Ground water | Purchased water | Total |
| 1992 | 0.9 | — | 874.3 | 0.0 | 874.3 | 3.7 | 133.0 | 136.7 |
| 1993 | .9 | — | 934.9 | .0 | 934.9 | 4.0 | 160.0 | 164.0 |
| 1994 | .9 | — | 678.2 | .0 | 678.2 | 4.3 | 154.0 | 158.3 |
| 1995 | .9 | 321.0 | 906.8 | .0 | 906.8 | 4.6 | 163.0 | 167.6 |

| Year | Sunnyside Farms Mutual Water Company | | | Tierra Bonita Mutual Water Company | U.S. Borax and Chemical Corporation | | |
|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Ground water | Purchased water | Total |
| 1992 | 4.6 | 226.0 | 230.6 | 16.9 | 1,436.3 | 595.4 | 2,031.7 |
| 1993 | 4.6 | 219.0 | 223.6 | 16.9 | 1,289.0 | 705.9 | 1,994.9 |
| 1994 | 4.6 | 236.0 | 240.6 | 16.9 | 386.7 | 1,556.0 | 1,942.7 |
| 1995 | 4.6 | 242.0 | 246.6 | 16.9 | 21.5 | 2,538.1 | 2,559.6 |

**Table A1.** Water-use information for public water suppliers in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | West Side Park Mutual Water Company | | | West Valley County Water District | White Fence Farms Mutual Water Company 2 | | | White Fence Farms Mutual Water Compeny 3 |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Ground water | Ground weter | Purchased water | Total | Purchesed water |
| 1992 | 230.0 | 0.0 | 230.0 | 141.2 | 590.4 | 21.8 | 612.2 | 391.0 |
| 1993 | 176.0 | 47.0 | 223.0 | 141.2 | 257.5 | 398.2 | 655.7 | 382.0 |
| 1994 | 96.7 | 131.2 | 227.9 | 165.7 | 304.9 | 319.6 | 624.5 | 425.0 |
| 1995 | 238.0 | 24.0 | 262.0 | 153.4 | 583.5 | 119.7 | 703.2 | 414.0 |

| Year | Total | | | Grand total |
|---|---|---|---|---|
| | Ground water | Purchased water | Surface water | |
| 1992 | 46,129.8 | 3,575.0 | 28,319.8 | 78,024.6 |
| 1993 | 43,571.7 | 2,664.0 | 41,903.1 | 88,138.8 |
| 1994 | 46,212.6 | 1,249.0 | 43,370.1 | 90,831.6 |
| 1995 | 49,333.1 | 3,897.0 | 38,958.8 | 92,188.8 |

**Table A2.** Water-use information for self-supplied water users in Antelope Valley, California, by water-supply sources, 1992–95

[Units are in acre-feet. —, no data

| Year | No owner recorded | Alesso Farms | Almondale Farms | Antelope Valley Country Club | | | Association of Irrigation Water Users | Baicy, John (Rumar) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Purchased water | Ground water | Purchased water | Total | Purchased water | Ground water | Purchased water | Total |
| 1992 | 84.0 | 0.0 | 725.0 | 208.0 | 277.0 | 485.0 | 27.0 | 488.0 | -488.0 | 0.0 |
| 1993 | 160.0 | — | 1,102.0 | 14.6 | 402.0 | 416.6 | 31.0 | .0 | .0 | .0 |
| 1994 | 62.6 | — | 1,156.0 | .0 | 473.0 | 473.0 | 27.0 | .0 | .0 | .0 |
| 1995 | .0 | — | 925.0 | .0 | 417.0 | 417.0 | 31.0 | .0 | 333.0 | 333.0 |

| Year | Ball, William and Mildred | Beery Ranch | | | Bell, Louis and Sandra | Bio Gro Systems, Inc. | Biscaichipy Ranch | Blalock-Eddy Ranch Co. | Blua, Andrew |
|---|---|---|---|---|---|---|---|---|---|
| | Surface water | Ground water | Purchased water | Total | Surface water | Purchased water | Purchased water | Surface water | Ground water |
| 1992 | 22.4 | — | 0.0 | 0.0 | 63.9 | 0.0 | 253.0 | 312 | 0.0 |
| 1993 | 22.4 | — | 845.0 | 845.0 | 63.9 | .0 | 431.0 | 368 | — |
| 1994 | 22.4 | — | 509.0 | 509.0 | 63.9 | 1,112.0 | 930.0 | 578 | — |
| 1995 | 22.4 | — | 509.0 | 509.0 | 63.9 | 854.0 | 947.0 | 916 | — |

| Year | Bonnie AC Ranch | | | Bozigian Ranch | | | Bryden, Lloyd W. | Bushnell, David P. | Buchanan, Virginia | Calandri Ranch | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Surface water | Total | Ground water | Purchased water | Total | Ground water | Ground water | Surface water | Ground water | Purchased water | Total |
| 1992 | 0.0 | — | 0.0 | 90.0 | -90.0 | 0.0 | 0.0 | 0.0 | 14.5 | — | 0.0 | 0.0 |
| 1993 | — | — | — | — | .0 | .0 | — | — | — | — | .0 | .0 |
| 1994 | — | — | — | — | .0 | .0 | — | — | — | — | .0 | .0 |
| 1995 | — | — | — | — | 972.0 | 972.0 | — | — | — | — | .0 | .0 |

| Year | California Portland Cement Company | | | California Resources Enterprises, Inc. | Calmat Co. | Cameo Ranching Co. | Carter, Maurice R. | Castronova, Daniel | Caton, Robert and Richard |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Surface water | Total | Ground water | Ground water | Ground water | Ground water | Purchased water | Ground water |
| 1992 | 0.0 | — | 0.0 | 0.0 | 389.5 | 870.3 | 0.0 | 7.0 | 0.0 |
| 1993 | — | 166.4 | 166.4 | — | 258.9 | 1,233.9 | — | 9.0 | — |
| 1994 | — | 155.6 | 155.6 | — | .0 | 877.5 | — | 6.0 | — |
| 1995 | — | 159.0 | 159.0 | — | 310.3 | 1,175.9 | — | 7.0 | — |

**Table A2.** Water-use information for self-supplied water users in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | Christoff, Chris A. | Church of Latter Day Saints | Circle JM Ranch | City Ranch | Clark, Dick | Clayton, Richard, M. | Cole, J.G., and Sons | Coor-Pender, R.L. and Ruth B. | Compton, Alan and Carol (previously Jerome Thompson) |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Purchased water | Purchased water | Ground water | Ground water | Ground water | Surface water |
| 1992 | 128.0 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 | 3.1 |
| 1993 | 110.0 | — | — | .0 | 6.0 | — | — | — | 3.1 |
| 1994 | 129.0 | — | — | .0 | 6.0 | — | — | — | 3.1 |
| 1995 | 129.0 | — | — | .0 | 6.0 | — | — | — | 3.1 |

| Year | Corpus Cenon, and Regina | Davis, Shelton | Delia, Joseph, E. | Derosier, Lionel P. and Particia | Derrick, Olin E. | Dustin, Doug | DVM | EPIC/Smith Development Company | Fabe |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Ground water | Ground water | Ground water | Ground water | Ground water | Purchased water |
| 1992 | 0.0 | 0.0 | 34.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | — | — | 45.5 | — | — | — | — | — | .0 |
| 1994 | — | — | 65.0 | — | — | — | — | — | .0 |
| 1995 | — | — | 45.5 | — | — | — | — | — | .0 |

| Year | Freund, Jerry | Frisella, Josef | Fuson | Gagik Galstian, Trustee | Gallin, Leo and Ruth Morton | Gonzales, Avelino and Hazel | Graham, John and others | Grainger, Donald L. | Greco, Connie Marie |
|---|---|---|---|---|---|---|---|---|---|
| | Purchased water | Ground water | Purchased water | Ground water | Ground water | Surface water | Surface water | Ground water | Surface water |
| 1992 | 1.0 | 0.0 | –230.0 | 0.0 | 0.0 | 0.3 | 1.1 | 0.0 | 0.8 |
| 1993 | .0 | — | .0 | — | — | .3 | 1.1 | — | .8 |
| 1994 | 5.0 | — | .0 | — | — | .3 | 1.1 | — | .8 |
| 1995 | 6.0 | — | .0 | — | — | .4 | 1.1 | — | .8 |

| Year | Griffen, Laura | Groven, Dennis L. | Harter, Leo A. | Hathaway Ranch | Healy Enterprises Inc. | Hecht, Nathaniel | Hee, Thornton, and Patti | Heiner, David R. |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Ground water | Ground water | Surface water | Ground water | Ground water |
| 1992 | 0.0 | 600.0 | 0.0 | 0.0 | 0.0 | — | 0.0 | 0.0 |
| 1993 | — | 600.0 | — | — | — | — | — | — |
| 1994 | — | 600.0 | — | — | — | — | — | — |
| 1995 | — | 360.0 | — | — | — | 0.8 | — | — |

**Table A2.** Water-use information for self-supplied water users in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | Hicks, Lucius B. | Hines, Robert G. | Hughes | Hughes Development Corporation | Hughes, Rodger | Iarussi, Armando | Johnson, Malachi S. | Johnston, Arch D. | Kadivar, Steve |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Purchased water | Purchased water | Purchased water | Purchased water | Ground water | Ground water | Ground water |
| 1992 | 0.0 | 0.0 | -99.0 | 0.0 | 7.0 | 2.0 | 0.0 | 84.9 | 0.0 |
| 1993 | .0 | — | .0 | .0 | 21.0 | 7.0 | — | 84.9 | — |
| 1994 | .0 | — | .0 | .0 | 23.0 | 9.0 | — | 84.9 | — |
| 1995 | 20.0 | — | .0 | .0 | 17.0 | 57.0 | — | 94.9 | — |

| Year | Kaufman and Broad Land Company | | | Kellerman, Pat | Kelly Ranch | Kindig, George B. | Kindig, Paul S. | Kirby, James and Robert | Kleksted Tree Farm |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Total | Purchased water | Purchased water | Ground water | Ground water | Surface water | Purchased water |
| 1992 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 | 2.9 | 0.0 |
| 1993 | — | .0 | .0 | 6.0 | .0 | .0 | .0 | 2.9 | .0 |
| 1994 | — | .0 | .0 | 6.0 | .0 | .0 | .0 | 1.0 | .0 |
| 1995 | — | 16.0 | 16.0 | 7.0 | 525.0 | .0 | .0 | 1.0 | .0 |

| Year | Kuete, Les | Kungl, Karl | Kyle, J.W. and G.W. | Lade R.M./Hartford Management Co. | Lake, Twyla and Larry | Lane, Frank A. | | | Larsen Brothers | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Purchased water | Ground water | Ground water | Ground water | Ground water | Ground water | Purchased water | Total | Ground water | Purchased water | Total |
| 1992 | 6.0 | 15.0 | 6,639.0 | 0.0 | 12.0 | 397.0 | 31.0 | 428.0 | 0.0 | 0.0 | 0.0 |
| 1993 | 6.0 | 15.0 | 6,359.8 | — | 686.0 | 397.0 | 43.0 | 440.0 | — | .0 | .0 |
| 1994 | 6.0 | .0 | 5,343.0 | — | 15.0 | 300.0 | 58.0 | 358.0 | — | .0 | .0 |
| 1995 | 6.0 | .1 | 7,108.0 | — | 2,744.0 | 300.0 | 39.0 | 339.0 | — | .0 | .0 |

| Year | Leona Valley Estates Ltd. | Leviste Management Systems | Littlerock Aggregate Company | Llarena, Albert | Los Angeles Department of Airports | Los Angeles Firemen's Relief Assoc. | Lowe, John and Becky | Margaretten, Joel | Montemayer, Abel and others |
|---|---|---|---|---|---|---|---|---|---|
| | Purchased water | Ground water | Ground water | Ground water | Ground water | Ground water | Surface water | Surface water | Surface water |
| 1992 | 4.0 | 0.0 | 305.0 | 0.0 | 5,097.5 | 0.0 | 2.2 | 19.7 | 5.1 |
| 1993 | .0 | .0 | 305.0 | .0 | 6,376.0 | — | 2.2 | 19.7 | 5.1 |
| 1994 | .0 | .0 | 270.0 | .0 | 5,723.0 | 3,295.0 | 2.2 | 19.7 | 5.1 |
| 1995 | .0 | .0 | 270.0 | .0 | 6,445.0 | — | 2.2 | 19.7 | 5.1 |

**Table A2.** Water-use information for self-supplied water users in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | McCormick, Raymond W. | Mescal Creek Water, Inc. | Miccolis, F.P. Adele Bruno | Milford, Terry | Miller, Keith | Mitchel and Gunning | Monsello, Andrew | Morgan, Carlos, Estate of | Morris, Wayne F. and Annette L. |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Surface water | Ground water | Purchased water | Purchased water | Purchased water | Ground water | Ground water | Surface water |
| 1992 | 0.0 | 915.8 | 0.0 | 6.0 | 11.0 | 46.0 | 0.0 | 5.0 | 1.6 |
| 1993 | — | 915.8 | — | 6.0 | 10.0 | 482.0 | — | 2.0 | — |
| 1994 | — | 1,220.7 | — | 6.0 | 11.0 | 826.0 | — | .0 | — |
| 1995 | — | 1,220.7 | — | 6.0 | 9.0 | 851.0 | — | .0 | — |

| Year | Mountain Glen Ranch | Mountain High—Holiday Hill Company | Nakasone Development Company | Nebeker Ranch | | | Nishimoto, Jimmie M. | Nishimoto, Roy | Oakwood Enterprises | Ordway, Ben |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Ground water | Ground water | Ground water | Reclaimed water | Total | Ground water | Ground water | Surface water | Surface water |
| 1992 | 0.0 | 0.0 | 0.0 | 323.0 | 3,640.0 | 3,963.0 | 0.0 | 0.0 | 6.1 | 29.0 |
| 1993 | — | 0.0 | — | 259.0 | 2,997.0 | 3,256.0 | — | — | 6.1 | 29.0 |
| 1994 | — | 0.0 | — | 286.0 | 3,711.0 | 3,997.0 | — | — | 6.1 | 29.0 |
| 1995 | — | 0.0 | — | 240.0 | 3,226.0 | 3,466.0 | — | — | 6.1 | 29.0 |

| Year | Pablo, Mr. and Mrs. Pastor | Peachland Farms | Piani, Gino | Poncedeleon, Modesto | Portanova | Pratt, Dr. W.H. | Proctor, Carl | Pulsipher Enterprises |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased water | Ground water | Purchased water | Purchased water | Ground water | Ground water | Purchased water |
| 1992 | 0.0 | 288.0 | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 | 8.0 |
| 1993 | — | 264.0 | — | 6.0 | .0 | — | .0 | 9.0 |
| 1994 | — | 436.0 | — | 7.0 | 0 | — | .0 | 12.0 |
| 1995 | — | 339.0 | — | 9.0 | .0 | — | .0 | 11.0 |

| Year | Punchbowl Canyon Water Association | R and M Ranch, Inc. | RR Ranch | Rabinov, David MD | Rancho Corona Del Valle Corporation | Rancho Vista Development | Reca, Dominique | Retlaw Enterprises Incorporated |
|---|---|---|---|---|---|---|---|---|
| | Surface water | Ground water | Purchased water | Ground water | Surface water | Purchased water | Ground water | Ground water |
| 1992 | 27.5 | 3,950.0 | 479.0 | 0.0 | 31.5 | 0.0 | 0.0 | 6,914.0 |
| 1993 | 27.5 | 3,567.0 | 1,194.0 | — | 31.5 | .0 | — | 1,500.0 |
| 1994 | 27.5 | 2,837.0 | 1,357.0 | — | 31.5 | .0 | — | 2,250.0 |
| 1995 | 27.5 | 3,674.0 | 919.0 | — | 31.5 | .0 | — | 1,800.0 |

**Table A2.** Water-use information for self-supplied water users in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | Ritter and Godde | | | Robbins, David | Robinson, F. Willard and others | Rosen, Sandee | S&D | Sasland Farms Spivak-Brown |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchesed water | Total | Purchased water | Surface water | Purchased water | Purchased water | Ground water |
| 1992 | 2,275.1 | 1,124.0 | 3,399.1 | 8.0 | — | 6.0 | 0.0 | 0.0 |
| 1993 | 1,139.3 | 2,316.0 | 3,455.3 | 7.0 | — | 6.0 | .0 | — |
| 1994 | 415.6 | 2,841.0 | 3,256.6 | 6.0 | — | 1.0 | .0 | — |
| 1995 | 1,993.0 | 2,611.0 | 4,604.0 | 8.0 | — | 4.0 | .0 | — |

| Year | Schnaidt, Harold | | | Searcy, Travis | Seiki Investment Corporation | Silva, Don | Simi, Roy | Southern Californie Edison Company |
|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased weter | Total | Purchased water | Ground water | Purchased water | Purchased water | Gro weter |
| 1992 | — | 65.0 | 65.0 | 6.0 | 0.0 | 10.0 | 0.0 | 10.1 |
| 1993 | — | 56.0 | 56.0 | 7.0 | — | 11.0 | .0 | 11.2 |
| 1994 | — | 81.0 | 81.0 | 13.0 | — | 11.0 | .0 | 12.7 |
| 1995 | — | 68.0 | 68.0 | 8.0 | — | 10.0 | .0 | .0 |

| Year | Stevens, William E. | Stoner | Sundown Ranch Company | Tapia Brothers | Taunton, Windsor P. | Tejon Ranch | | | Traweek, S.V. |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Purchased weter | Ground water | Purchesed water | Ground weter | Ground weter | Purchased water | Total | Ground water |
| 1992 | 0.0 | 0.0 | 0.0 | 402.0 | 0.0 | 1,006.0 | –230.0 | 776.0 | 0.0 |
| 1993 | — | .0 | — | 238.0 | — | — | .0 | .0 | — |
| 1994 | — | .0 | — | 205.0 | — | — | .0 | .0 | — |
| 1995 | — | .0 | — | 795.0 | — | — | .0 | .0 | — |

| Year | U.S. Forest Service, Angeles National Forest | | | Union Wilshire Incorporated | Unnamed spring group | Vandereyk | Vaught, Amelia | Wade, Thomas H. | Ward, J.W./Lyman Champlain |
|---|---|---|---|---|---|---|---|---|---|
| | Ground water | Surface water | Total | Ground water | Surface water | Purchesed water | Purchased water | Ground water | Ground water |
| 1992 | 0.0 | 24 | 24 | 0.0 | 18.1 | 0.0 | 6.0 | 0.0 | 0.0 |
| 1993 | — | 24 | 24 | — | 18.1 | .0 | 6.0 | .0 | — |
| 1994 | — | 24 | 24 | — | 18.1 | .0 | 7.0 | .0 | — |
| 1995 | — | 2.5 | 2.5 | — | 18.1 | .0 | 6.0 | 3.3 | — |

**Table A2.** Water-use information for self-supplied water users in Antelope Valley, California, by water-supply sources, 1992–95—Continued

| Year | Weaver | White, J.F. Jr., H.B., and D.B. | White, James B. or Dee Ann | White, Michael G. | White, Richard A. | Williams, Claude | Wilmar Farms | Zamrzla, Johnny |
|---|---|---|---|---|---|---|---|---|
| | Purchased water | Surface water | Ground water | Ground water | Ground water | Ground water | Purchased water | Ground water |
| 1992 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | .0 | — | .0 | — | .0 | — | 1,157.6 | — |
| 1994 | .0 | — | .0 | — | .0 | — | 2,139.0 | — |
| 1995 | .0 | — | 24.0 | — | 5.7 | — | 2,119.0 | — |

| Year | Total | | | Grand total |
|---|---|---|---|---|
| | Ground water | Surface water | Purchased water | |
| 1992 | 29,925.7 | 888.5 | 2,692.0 | 33,506.2 |
| 1993 | 23,015.1 | .0 | 8,690.6 | 31,705.7 |
| 1994 | 22,437.3 | .0 | 12,833.0 | 35,270.3 |
| 1995 | 26,613.7 | .0 | 13,447.0 | 40,060.7 |

**Table A3.** Deliveries of imported water to Antelope Valley from the California Aqueduct, 1992–95

[Units are in acre-feet per year]

| Year | Antelope Valley–East Kern Water Agency[1] | Littlerock Creek Irrigation District[2] | Palmdale Water District[3] | Total |
|---|---|---|---|---|
| 1992 | 27,663 | 251 | 3,845 | 31,759 |
| 1993 | 40,928 | 735 | 10,136 | 51,799 |
| 1994 | 49,536 | 1,100 | 8,037 | 58,673 |
| 1995 | 46,091 | 480 | 6,613 | 53,184 |

[1]Russell Fuller, Antelope Valley–East Kern Water Agency, written commun., 1998.
[2]Brad Jones, Littlerock Creek Irrigation District, written commun., 1996.
[3]Matt Knudson, Palmdale Water District, written commun., 1996.

**Table A4.** Use of reclaimed wastewater in Antelope Valley, California, 1992–95

[Units are in acre-feet. Data from David Lambert (County Sanitation Districts of Los Angeles County, written commun., 1996)]

| Year | Lancaster Water Reclamation Plant | | | Palmdale Water Reclamation Plant | | |
|---|---|---|---|---|---|---|
| | Wetlands | Irrigation | Total | Land disposal | Irrigation | Total |
| 1992 | 3,520 | 3,640 | 7,160 | 6,150 | 21 | 6,170 |
| 1993 | 5,280 | 3,000 | 8,280 | 7,080 | 42 | 7,120 |
| 1994 | 5,110 | 3,700 | 8,810 | 7,480 | 51 | 7,530 |
| 1995 | 7,140 | 3,225 | 10,360 | 8,070 | 67 | 8,140 |