Evaluation of Water-Level Recovery, 1996–97 to 1999–2000, and Comparison of 1999–2000 and 1972–73 Water Levels in Goleta Central Subbasin, Santa Barbara County, California

By Jill N. Densmore, Matthew C. Scrudato, *and* Ernest R. Houston

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND WELL-NUMBERING SYSTEM

CONVERSION FACTORS

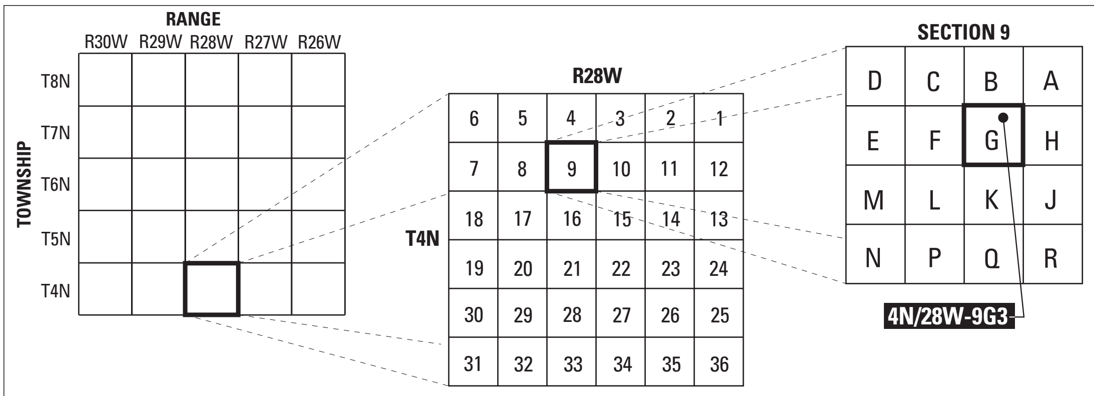
Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
foot (ft)	0.3048	meter
foot per yer (ft/yr)	0.3048	meter per year
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer

VERTICAL DATUM

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Well-Numbering System

Wells are identified and numbered according to their location in the rectangular system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section numbers. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). All wells in the study area are referenced to the San Bernardino base line and meridian (S). Well numbers consist of 15 characters and follow the format 004N028W09G003S. In this report, well numbers are abbreviated and written 4N/28W-9G3. Wells in the same township and range are further abbreviated and referred to by only their section designation, 9G3. The following diagram shows how the number for well 4N/28W-9G3 is derived.



Well-numbering diagram (Note: maps in this report use abbreviated well numbers such as **"9G3"**)

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ABSTRACT

Ground-water levels were measured during January 1999–June 2000 to evaluate the rate of water-level recovery in the Goleta Central ground-water subbasin that has resulted from injection of about 2,225 acre-feet of surplus water for storage in the ground-water basin. Injection of surplus water was tabulated and compared with water-level rises since 1996 to evaluate the effectiveness of the recharge effort. Water levels have risen about 4 to 37 feet since 1996–97. A preliminary water budget was compiled to assess recharge and discharge in the basin, and it is estimated that total inflow exceeded total outflow during 1998–99 by about 2,844 to 7,518 acre-feet. In addition, water levels for 1999–2000 were compared with water levels for 1972–73 to determine if a "drought buffer" exists. Water levels measured in two wells during January 1999–June 2000 exceeded January 1972–June 1973 levels. Water levels in the remaining wells measured during January 1999–June 2000 ranged from less than 1 foot to about 32 feet below 1972–73 water levels. In general, the largest water-level rise between 1996–97 and 1999–2000 was about 37 feet in the southeastern end of the basin; the rise was less than 4 feet in the western end of the basin and about 10 feet north of the Goleta Fault. Long-term hydrographs indicate that water levels have been recovering throughout the basin since the early 1990's.

INTRODUCTION

Until the early 1990's, the Goleta Water District (GWD) relied primarily on local water supplies to meet its water needs. Because surface-water-supply shortages are a recurring problem during droughts, GWD began pumping as much as 5,500 acre-ft/yr (acre-feet per year) of ground water from the Goleta Central ground-water subbasin between 1970 and the early 1990's to supplement its needs. This pumping caused water-level declines and overdraft conditions in the basin. Overdraft as defined by Freeze and Cherry (1979) is any withdrawal in excess of safe yield: that is, the quantity of water that can be withdrawn from a ground-water basin annually without producing an undesired result.

In 1994, a voter-adopted ordinance was passed that governs imported-water and ground-water operations until a drought buffer was established throughout the basin. The drought buffer was defined in a litigation settlement involving Goleta Water District as the 1972 water level in the Central ground-water subbasin. As a result, GWD halted ground-water production from its wells in the basin in the early 1990's to allow water-level recovery to 1972 levels and began using imported water supplied by the State Water Project. In addition, GWD has injected surplus water from the Cachuma Project when available.

The purpose of this study was to compare 1972–73 and 1999–2000 ground-water levels, and evaluate the rate of recovery that has resulted from injection of surplus water. This report also provides a tabulation of the quantity of water injected and assesses the rate of change in water levels measured in 1996–97 to water levels measured in January 1999–June 2000 at the same wells. This report updates the information published in the U.S. Geological Survey (USGS) Water-Resources Investigations Report 97-4109 (Kaehler and others, 1997).

Description of Study Area

The Goleta Central subbasin is in the Goleta ground-water basin, immediately west of the Santa Barbara ground-water basin, in the coastal part of Santa Barbara County, California. The Goleta ground-water basin is in a narrow lowland between the Santa Ynez Mountains on the north and the Pacific Ocean on the south, and it is approximately 8 mi long and 3 mi wide. The basin is subdivided into the Central, West, North, and Foothill (formerly known as East) subbasins (fig. 1). The Central subbasin is about 4 mi long and 2 mi wide.

The geohydrology of the Goleta ground-water basin, as a whole unit, has been described by previous investigators (Upson,1951; Evenson and others, 1962; Kaehler and others, 1997). The Central subbasin is bounded by Tertiary-age consolidated rocks of the Santa Ynez Mountains to the north, the Modoc Fault on the east, the More Ranch Fault near the coast on the south, and a north-south-trending hydrologic barrier, inferred from water-level and water-quality differences, on the west. The main water-bearing deposits are of Quaternary age and consist of younger alluvium of Holocene age, and terrace deposits, older alluvium, and the Santa Barbara Formation of Pleistocene age. The Santa Barbara Formation, which is the primary source of water, is composed of sand, silt, and clay.

The Central subbasin consists of an unconfined shallow aquifer and a confined deep aquifer. The shallow aquifer is fairly continuous throughout most of the basin and is composed of the upper part of the younger alluvium and the terrace deposits. The shallow aquifer receives recharge from stream seepage and infiltration of precipitation and irrigation-return flow. The deep aquifer underlies the shallow aquifer and is composed of the lower part of the younger alluvium, older alluvium, and the Santa Barbara Formation. Throughout most of the basin, the deep aquifer is virtually hydraulically separate from the shallow aquifer (Upson, 1951; pl. 5) and probably only receives recharge along the base of the Santa Ynez Mountains (fig. 1).

The Goleta area is characterized by a mediterranean-like climate of warm summers (about 70°F) and mild winters (about 50–55°F) with little frost hazard. Most of the rainfall occurs between November and March; occasional thundershowers occur during the summer in the adjacent mountains. Annual precipitation is generally more than 20 in/yr in the bordering foothills and more than 30 in/yr at the mountain crests. Mean annual precipitation in the Goleta area was 9 to 10 in. for the period December 1998–November 1999 (Ceres online, 1999).

Acknowledgments

The authors thank David Iverson, Mike Kanno, and Mike Stevens of the Goleta Water District for providing access to wells, for permitting use of GWD equipment, and for providing information on additional pumped wells. The authors also thank local farmers who provided information on their pumping practices.

GROUND-WATER RECHARGE

The injection of surplus water from the Bureau of Reclamation Cachuma Project first began in March 1978. It is unknown how much water was injected prior to 1983, but about 2,575 acre-ft was injected during 1983, about 670 acre-ft during 1984, about 448 acre-ft during 1986, about 1,770 acre-ft during 1993, and about 1,120 acre-ft during 1995. In the most recent injection period, the surplus water was injected through 18 existing production wells that had been modified to also act as injection wells (fig. 1). During February 1998–January 1999, approximately 2,225 acre-ft of surplus water was injected into the Goleta Central ground-water subbasin (fig. 2). There was also a minor injection period of 3 weeks duration in April 2000. Monthly recharge ranged from about 320 acre-ft during May 1998 to 30 acre-ft during January 1999. The amount of water injected in each well between February 1998 and January 1999 is given in table 1. During this period, about 70 percent of the injection was in the eastern half of the basin. The highest percentage of water (about 17 percent) was injected in well 4N/28W-10G7: this relatively high volume of injected water (383 acre-ft) may reflect more frequent occurrences of injection than in other wells and may indicate that the formations penetrated have a higher storativity than those penetrated by other wells.

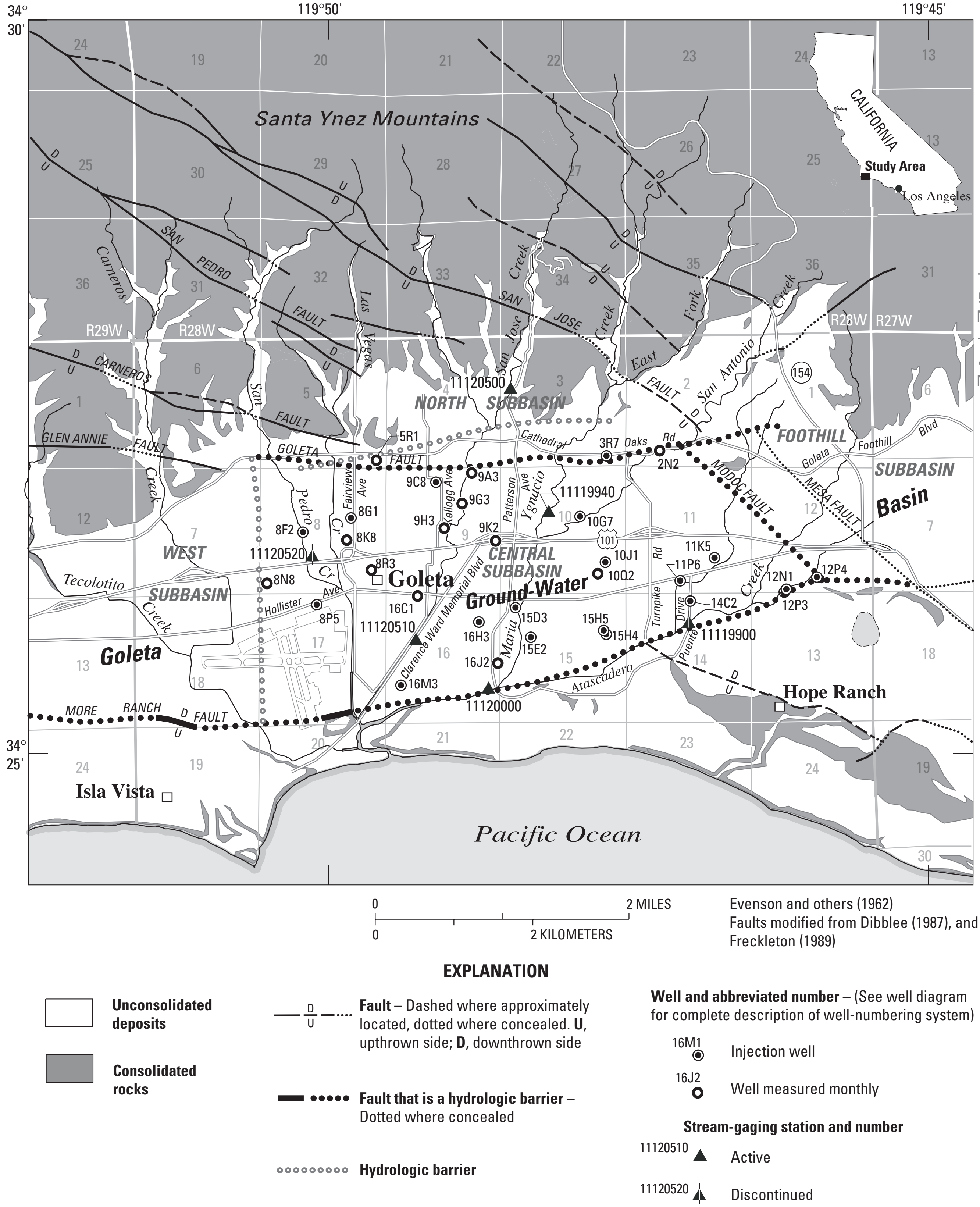


Figure 1. Location of study area showing monthly measured wells, injection wells, and stream-gaging stations in the Goleta Central ground-water subbasin, Santa Barbara County, California.

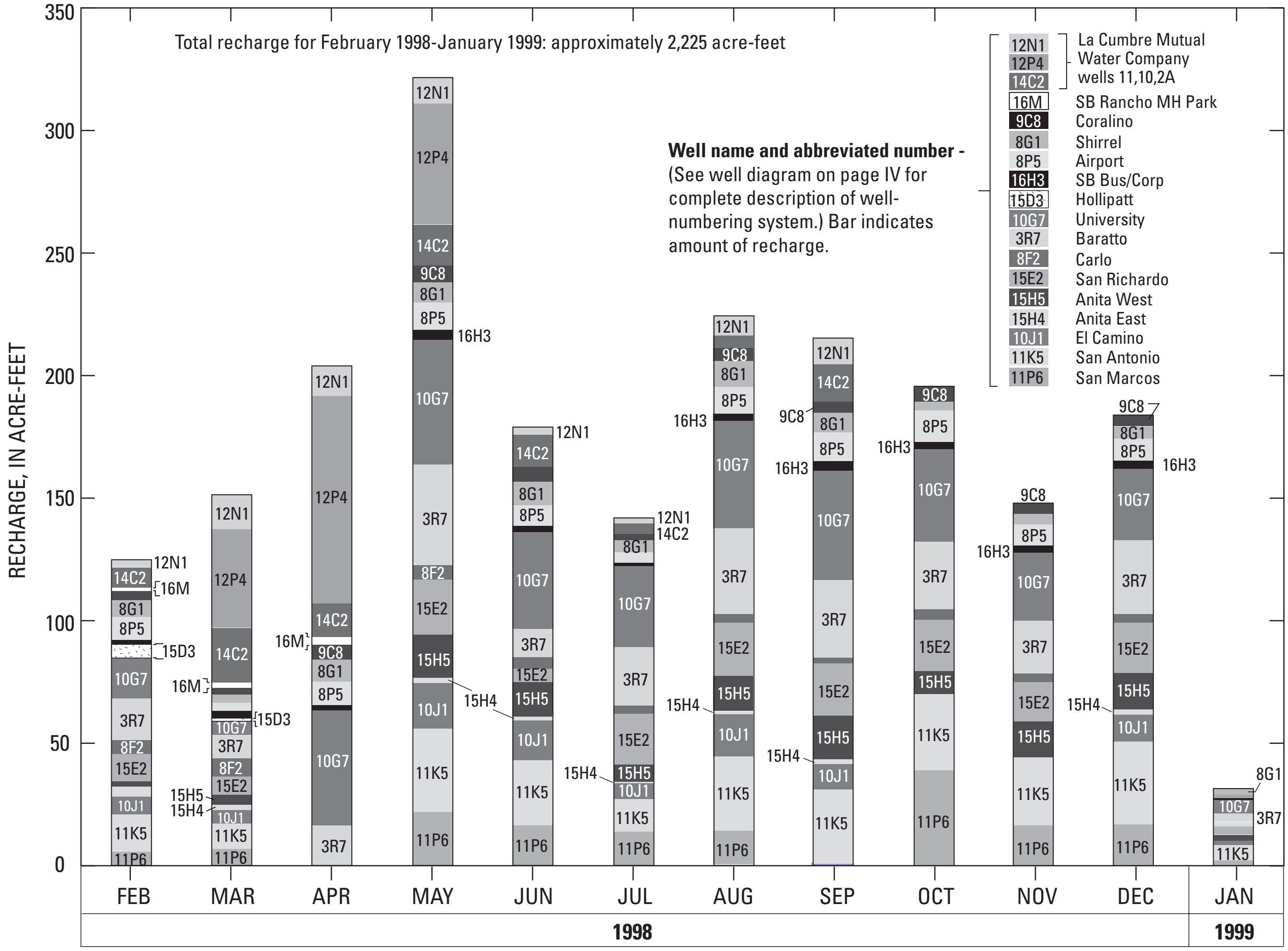


Figure 2. Monthly recharge in the Goleta Central ground-water subbasin, Santa Barbara County, California, February 1998–January 1999.

WATER BUDGET

A preliminary water budget of the entire Goleta Central subbasin was estimated by assessing the natural recharge from precipitation and runoff in creeks, artificial recharge from injection of surplus water, and pumpage from local wells (table 2). A 1996 aerial photograph was used to approximate the area of residential housing to estimate irrigation-return flow from lawn watering and to determine the current agricultural land use, which was also field checked, to estimate pumpage for agricultural fields and the resulting irrigation-return flow. Although most of the irrigation-return flow primarily recharges only the shallow aquifer, this assessment attempts to provide a preliminary budget for the entire system.

The rate of natural recharge from precipitation probably is greatest in the undeveloped areas. Most of the undeveloped area in the Goleta Central ground-water subbasin is in the northern part of the subbasin and overlies the unconfined recharge area defined by Upson (1951, pl. 5). In developed urban areas, most precipitation is captured by storm sewers, city streets, and buildings, thus preventing significant infiltration of rain. The precipitation that does infiltrate in unpaved urban areas recharges the shallow aquifer and the amount probably is minimal. Precipitation recharge was estimated by multiplying Upson's recharge area (roughly estimated at 1,220 acres) by 0.138 ft/yr as proposed by Muir (1968) for land covered with grass and weeds above an altitude of 100 ft in the Santa Barbara area. The resulting estimate for precipitation recharge

Table 1. The quantity of water injected, in acre-feet, per well during February 1998–January 1999, Goleta Central subbasin, Santa Barbara County, California

[LCMWC, La Cumbre Mutual Water Company]

State well number	Local name	Quantity injected	Percentage of total
4N/28W-3R7	Baratto	283	12.7
4N/28W-8F2	Carlo	49	2.2
4N/28W-8G1	Shirrel	73	3.3
4N/28W-8P5	Airport	97	4.4
4N/28W-9C8	Coralino	52	2.3
4N/28W-10G7	University	383	17.2
4N/28W-10J1	El Camino	121	5.4
4N/28W-11K5	San Antonio	271	12.2
4N/28W-11P6	San Marcos	182	8.2
4N/28W-12N1	LCMWC 11A	62	2.8
4N/28W-12P4	LCMWC 10	170	7.6
4N/28W-14C2	LCMWC 2A	95	4.3
4N/28W-15D3	Hollipatt	7	0.3
4N/28W-15E2	San Richardo	189	8.5
4N/28W-15H4	Anita East	20	0.9
4N/28W-15H5	Anita West	135	6.1
4N/28W-16H3	Santa Barbara Bus./Corp.	32	1.4
4N/28W-16M3	Rancho Goleta Mobile Home Park	5	0.2
Total		2,226	100.0

Table 2. Preliminary water budget for February 1998–January 1999, Goleta Central subbasin, Santa Barbara County, California

[Values are in acre-feet]

	Estimated value	Remarks
Inflow		
Natural recharge from precipitation	[1]170–[2]4,000	
Streamflow recharge	625–890	Estimated by Todd Engineers, 1985, p. 17.
Artificial recharge (injection)	2,225	
Irrigation-return flow	1,150	Assumes 70 percent irrigation efficiency.
Underflow from Santa Ynez Mountains	0–1,419	
Total inflow	4,170–9,684	
Outflow		
Agricultural pumpage	350–1,160	Low value estimated in Wright suit.[3]
Nonagricultural pumpage	130–160	
Storage, drains, underflow	846	High value estimated by Todd Engineers, 1986.
Total outflow	1,326–2,166	
Net change in storage	2,844–7,518	

[1]Based on about 1,220 acres (Upson, 1951) in recharge area.
[2]Estimated by Todd Engineers, 1984.
[3]Santa Barbara Superior Court Case No. SM57969.

in the undeveloped areas is about 170 acre-ft/yr during February 1998–January 1999 (table 2). This estimate probably represents the low end of precipitation recharge, which likely is significantly higher during years of above-average precipitation. Previous studies have estimated between 2,500 and 4,000 acre-ft for average annual precipitation recharge (Evenson and others, 1962; Todd Engineers, 1984; Kevin Walsh, Goleta Water District, oral commun., 2000).

Recharge also occurs along Atascadero, Maria Ygnacio, San Antonio, and San Jose Creeks, which flow through the Goleta Central ground-water subbasin. Flow in these streams is highly variable from year to year. For example, streamflow measured in Atascadero Creek (station 1112000) was 29,490 acre-ft during the 1998 calendar year, a relatively wet year (Agajanian and others, 1998), yet was only 1,240 acre-ft during 1999 (Ernest Houston, U.S.

Geological Survey, unpublished data,1999). August 1998–July 1999 streamflow data from the four active USGS streamflow-gaging stations are presented in table 3. Because two stations are on the upper and lower reaches of San Jose Creek (11120500 and 11120510, respectively), only data for these stations were used to compute an estimate of surface-water recharge to the ground-water system during February 1998–January 1999. The streamflow loss (the difference in flow) between the upper and lower reaches was about 380 acre-ft during this period. This streamflow loss is higher than the 120 acre-ft recharge estimated by Todd Engineers (1985) and probably represents the upper range of streamflow recharge from San Jose Creek. Multiplying the streamflow loss (380 acre-ft) by the percentage of the creek that lies within the deep aquifer recharge area (30 percent) yields an estimate of 114 acre-ft, similar to Todd Engineers estimate, for the maximum recharge to the deep aquifer from San Jose Creek. The remaining 70 percent of this stream loss recharges the shallow aquifer during periods of high flow. Little of this recharge probably reaches the deep aquifer; most drains back to the streams when high flow has receded, moves laterally to a slough in the southeast edge of the subbasin near the airport, or evaporates. A combined estimate of average recharge for the entire lengths of Atascadero, Maria Ygnacio, and San Antonio Creeks of 509 acre-ft/yr, made by Todd Engineers (1985, p. 17), is assumed to approximate current recharge from these creeks. However, this may

Table 3. Streamflow data for selected sites in the Goleta Central ground-water subbasin, Santa Barbara County, California, August 1998–July 1999

		Number of days of flow	Flow, in acre-feet	Number of days of flow	Flow, in acre-feet
		Maria Ygnacio Creek		**Atascadero Creek near Goleta**	
1998	August	31	163	31	113
	September	30	81	30	56
	October	27	34	31	16
	November	25	9.3	30	58
	December	31	14	31	75
1999	January	31	35	31	140
	February	28	54	28	124
	March	31	86	31	360
	April	30	31	30	323
	May	25	18	31	83
	June	1	0.1	30	38
	July	1	0.1	31	15
Total		291	525.5	365	1,401
		San Jose Creek near Goleta (upper reach)		**San Jose Creek at Goleta (lower reach)**	
1998	August	31	89	31	47
	September	30	56	27	5.2
	October	31	23	26	3.8
	November	30	23	30	23
	December	31	53	31	24
1999	January	31	54	31	45
	February	28	281	28	96
	March	31	290	28	156
	April	30	35	30	138
	May	31	29	31	75
	June	30	21	5	1.5
	July	31	14	3	0.06
Total		365	968	301	614.56
Streamflow loss between upper and lower reaches of San Jose Creek					353.44
Percent of creek that lies within deep aquifer recharge area as defined by Upson (1951)					30
Maximum recharge to deep aquifer (Streamflow loss × percent of creek within recharge area)					106.032

represent a high estimate because the recharge covers the entire length of the creeks and includes recharge to both the shallow and deep aquifers. Thus, total recharge from the creeks probably ranges between about 625 acre-ft/yr (which is the sum of the deep aquifer recharge estimate of 114 acre-ft and Todd Engineers' estimate of 509 acre-ft) and 890 acre-ft/yr (which is the sum of streamflow loss on San Jose Creek of 380 acre ft and Todd Engineers estimate of 509 acre-ft).

Artificial recharge into the subbasin, as discussed earlier, is surplus water injected into wells perforated primarily in the deep aquifer. About 2,225 acre-ft of surplus water was injected between February 1998 and January 1999. Because the water was delivered to the wells by pipeline, it is assumed that all of this water entered the aquifer system and none was lost by evaporation.

Irrigation-return flow is another source of recharge, primarily to the shallow aquifer. This is water not consumptively used by the plants during irrigation of lawns in the residential areas, of agricultural fields, and of large grass fields. During 1999, the areas of residential housing (lawns), and areas of agricultural fields and large grass fields (that have existing usable wells) was estimated from a 1996 aerial photograph. These two groups were delineated separately because the water used in residential housing is provided by Goleta Water District, whereas water for field irrigation is assumed pumpage (estimated as discussed below) from the existing wells. The area of residential housing was estimated to be about 700 acres (from a 1996 aerial photograph); because houses, garages, and pavement cover much of a residential lot, the actual area of lawn irrigation may be only half of this area that was identified on the aerial photograph. Agricultural and large grass fields total about 300 acres. The consumptive use by lawns was estimated to be at most 1,890 acre-ft/yr; this estimate was derived by multiplying the area of lawns in residential housing (about 700 acres) by 2.7 acre-ft/acre/season (the consumptive use of grass; University of California Cooperative Extension, 1991). Assuming a 70 percent lawn-irrigation efficiency, about 2,700 acre-ft of water was applied (that is, 1,890 acre-ft ÷ 70 percent), and about 810 acre-ft (that is, 2,700 –1,890 acre-ft) recharged the shallow aquifer. The amount of water applied to agricultural and large grass fields was estimated to be 1,160 acre-ft (that is, 810 acre-ft ÷ 70 percent). For agricultural and grass fields, assuming a 70 percent irrigation efficiency, 30 percent of applied water was lost to the shallow water table, or about 350 acre-ft (that is, 1,160 acre-ft × 30 percent). In summary, for 1999, it is estimated that irrigation-return flow of about 1,160 acre-ft (about 810 acre-ft from lawn irrigation and 350 acre-ft from agricultural and grass-field irrigation) recharged the shallow aquifer. As noted earlier, irrigation-return flow from water applied in areas outside the recharge area defined by Upson (1951, pl. 5) undoubtedly recharges the shallow aquifer but probably does not reach the deep aquifer.

The quantity of subsurface underflow entering the Goleta Central ground-water subbasin from the Santa Ynez Mountains and across the Goleta, Modoc, and eastern More Ranch Faults is not well documented. During calibration of a ground-water-flow model for the basin, Todd Engineers (1986) estimated that underflow was as much as 1,419 acre-ft/yr, consisting of about 627 acre-ft/yr across the Goleta Fault, 217 acre-ft/yr across the Modoc Fault, and 576 acre-ft/yr across the eastern More Ranch Fault. However, Freckleton and others (1998) modeled both the Santa Ynez Mountains and Goleta Fault as no-flow boundaries in the adjacent Santa Barbara and Foothill ground-water basins. And on the basis of the large water-level rise where the two faults intersect, the Modoc and eastern More Ranch Faults seem to act as effective barriers to ground-water flow. Underflow to the basin probably is somewhere between 0 and 1,419 acre-ft/yr. This value may be better constrained by updating the ground-water-flow model using new hydrologic data—such as data from aquifer tests for wells on either side of the faults or from water-quality differences between imported water and native ground water—to quantify flow across the faults.

Although GWD ceased pumping ground water from the basin in the early 1990's, other local agricultural users continue to pump ground water for their water-supply needs. To estimate current pumpage, the acreage and type of agriculture were assessed by determining the amount of agricultural acreage from a 1996 aerial photograph of the Goleta Central ground-water subbasin (obtained from Pacific Western Aerial Surveys in 1999) and by field-checking agricultural land use during 1999 (shown in figure 3); average water use for the crops was then applied as described by University of California Cooperative Extension (1991).

From the 1996 aerial photograph, it was possible to discern between three tree types and smaller crops. After the agricultural areas identified from the 1996 photograph were field checked, the trees were divided into avocado, citrus, and Christmas trees. The small crops were divided into large areas of lawn, nurseries, and row crops such as vegetables and flowers. The total agricultural area within Goleta Central ground-water subbasin during 1999 was about 300 acres. The average water use for these crop types in Santa Barbara County was provided by University of California Cooperative Extension (1991) and was used to estimate the amount of water needed by the plants (table 4). Thus, on the basis of the acreage and crop types identified in 1999, about 810 acre-ft of irrigation water would be needed

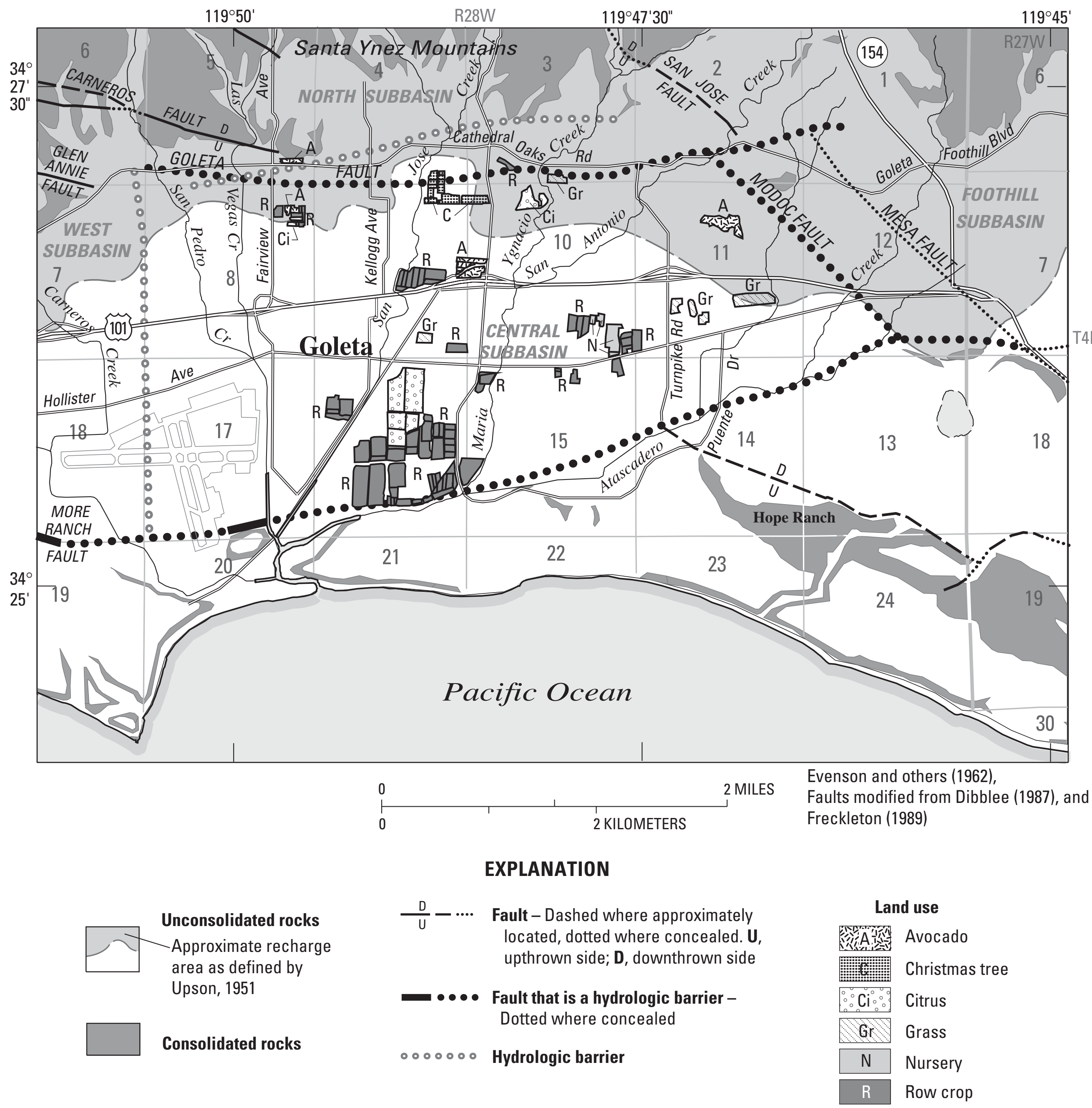


Figure 3. Agricultural land use in Goleta Central ground-water subbasin, Santa Barbara County, California, in September 1999.

Table 4. Agricultural acreage and water use by crop type in Goleta Central ground-water subbasin, Santa Barbara County, California, during 1999

[Average water-use data from University of California Cooperative Extension, 1991]

Crop type	Acres	Water use, in acre-ft/acre/season	Water needed, in acre-ft/season
Avocado	24.0	1.6	38.4
Christmas tree	16.9	1.5	25.4
Citrus	58.1	1.5	87.2
Grass	23.6	2.7	63.7
Nursery	11.1	3.0	33.3
Row crop	170.2	3.3	561.7
Total.............	303.9		809.7

to maintain these crops. If an irrigation efficiency of 70 percent is assumed (as described above), about 1,160 acre-ft (810 acre-ft ÷ 70 percent) was pumped and applied. This estimate assumes that pumped ground water is used on fields that have an existing usable well, but some of the fields may actually be using water served by the Goleta Water District; therefore, this estimate represents an upper pumpage range. The pumpage estimated for the Wright suit (Santa Barbara Superior Court Case No. SM57969) was only about 350 acre-ft.

As determined by field checks, non-agricultural pumping (not used to irrigate fields) occurs from at least 17 existing wells. Most of these wells were pumped for domestic use; of the others, three were for La Cumbre Mutual Water Company (LCMWC) production, one provides water for a manmade lake, and at least two were for industrial use. Domestic wells for which pumpage data could not be obtained were assigned (on the basis of average household use) pumpage of 200 gallons per day (Driscoll, 1986). Non-agricultural pumpage was estimated to range from about 130 to 160 acre-ft/yr.

The quantity of underflow discharging from the Goleta Central ground-water subbasin across the hydrologic barrier to the west is unknown. In a ground-water-flow model by Todd Engineers (1986), the West subbasin and Central ground-water subbasin were modeled as one basin. Although ground-water flow across this boundary was not specifically determined in the model, the underflow into the West subbasin from the Santa Ynez Mountains was estimated to be about 846 acre-ft/yr (Todd Engineers, 1986) and may approximate the upper limit of underflow at this barrier. It is also not known how much water discharges to the slough in the southern edge of the basin near the airport.

In this preliminary budget, inflow during 1998–99 was estimated to range from about 4,170 to 9,684 acre-ft and outflow was estimated to range from about 1,326 to 2,166 acre-ft. It should be noted that these numbers are only an estimated range of inflow and outflow. On the basis of these preliminary numbers, inflow appears to have exceeded outflow during 1998–99.

The accuracy of this preliminary budget could be improved by additional streamflow monitoring and comparison with climatological records. More detailed streamflow-discharge records would help better constrain yearly surface-water recharge to the ground-water system. Climatological records could be used to aid in estimating the variability in streamflow and precipitation recharge, and aquifer-test data could better define the hydraulic properties of the aquifer system that influence the effectiveness of injection and pumping in the basin. With additional hydrologic data such as these, the ground-water-flow model could be refined to better constrain these values.

WATER-LEVEL MEASUREMENTS

During January 1999–June 2000, water levels were measured in 15 wells in the Goleta Central ground-water subbasin (fig. 1). These wells formed the network used in the study by Kaehler and others (1997) in which a comparison of 1972 and 1996 water levels showed that, in all wells except 4N/28W-2N2, 1996 levels were lower than 1972 levels. Long-term hydrographs for the 15 wells measured during 1970–2000 are shown in figure 4. Water levels throughout the basin have been rising since the cessation of pumping by GWD in the early 1990's.

Since 1996–97, water levels have risen in all 15 wells. The water-level rise generally ranged from about 3 ft in well 4N/28W-8N8 to about 37 ft in well 4N/28W-12P3. Well 4N/28W-8N8 is located near the western boundary of the subbasin and about 0.4 mi

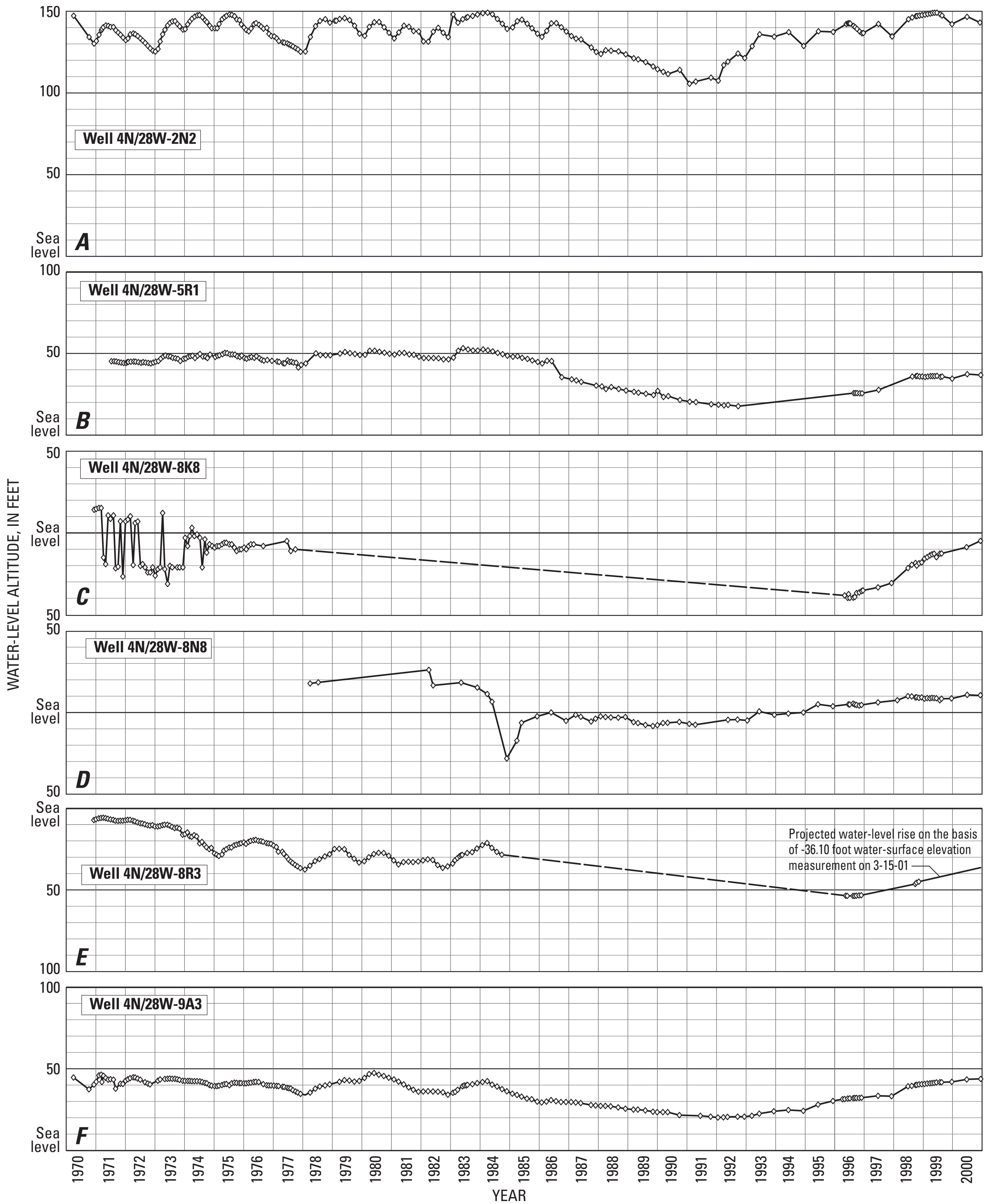


Figure 4. Water levels for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California, 1970–2000.

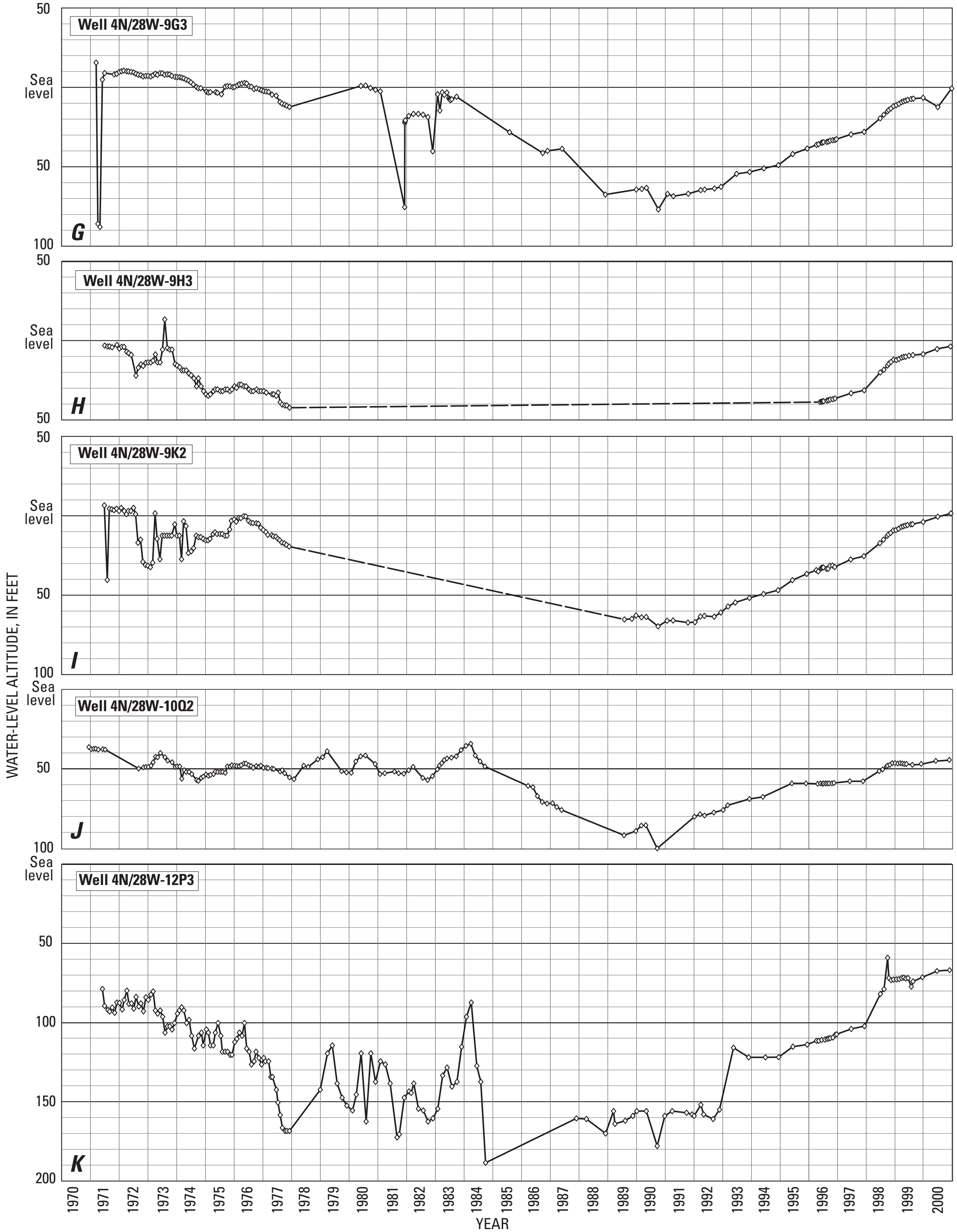


Figure 4.—Continued.

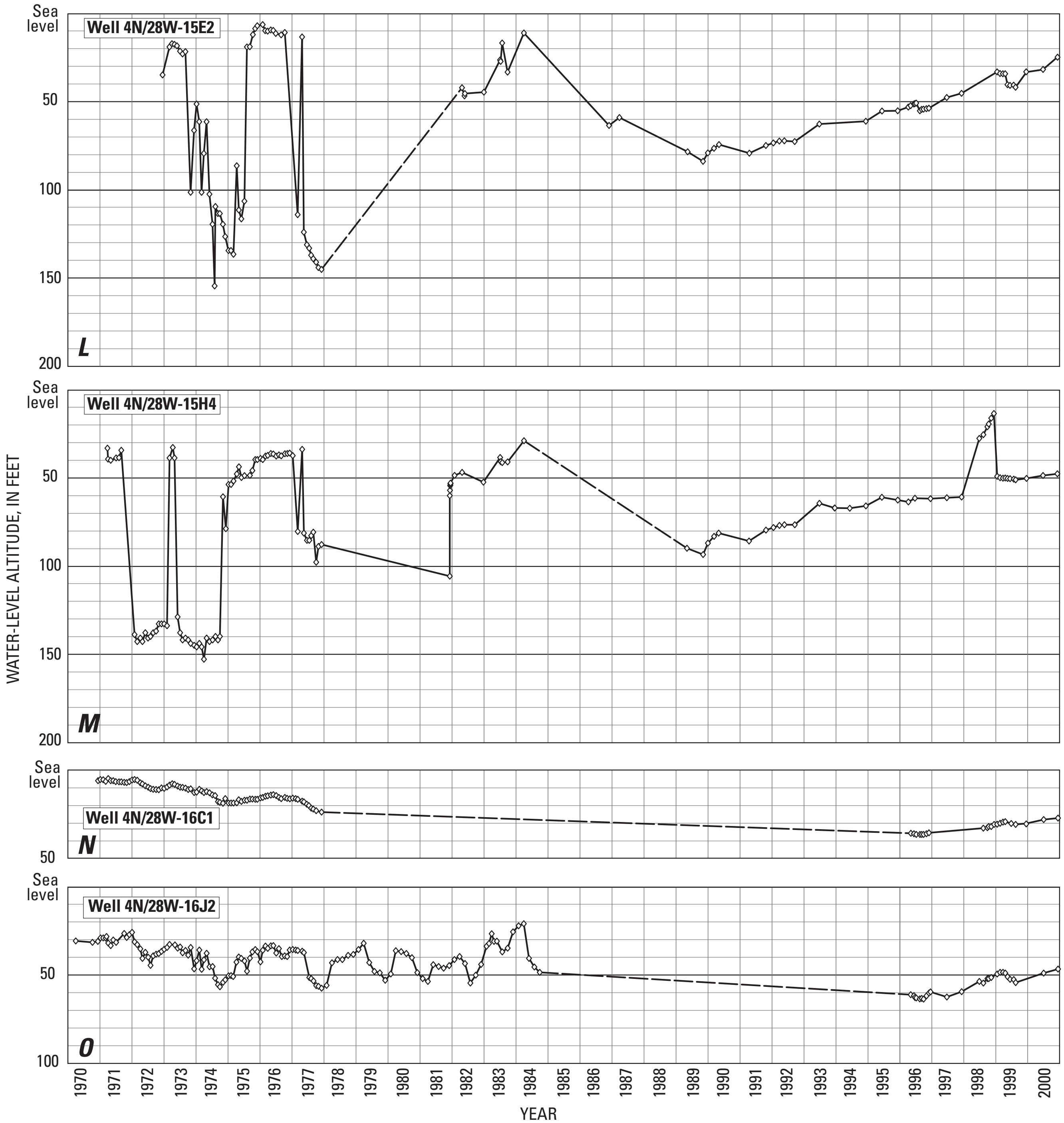


Figure 4.—Continued.

from the nearest injection well, 4N/28W-8P5 (fig. 1). Injection well 4N/28W-8P5 received only about 97 acre-ft of the 2,225 acre-ft (4.4 percent) of injected water. The small water-level rise in 4N/28W-8N8 reflects this small quantity of recharge nearby and also the fact that only about 30 percent of the injection occurs in the western half of the subbasin. Well 4N/28W-12P3, the well with the largest water-level rise, is located in the southeastern corner of the subbasin bounded by the Modoc and More Ranch Faults and is about 0.1 mi from injection well 4N/28W-12N1 and 0.26 mi from injection well 4N/28W-12P4 (fig. 1). These wells accounted for about 62 and 170 acre-ft of the 2,225 acre-ft injected (2.8 and 7.6 percent), respectively. The highest measured water level in well 4N/28W-12P3 occurred in September 1998, the month in which the largest quantity of water was injected near this well. The large water-level rise in well 4N/28W-12P3 probably was due to its proximity to two injection wells and the fact that about 75 percent of injection was in the eastern part of the basin. This large water-level rise suggests that in this area the Modoc and More Ranch Faults are effective barriers to ground-water flow across these faults.

COMPARISON OF 1999–2000 AND 1972–73 WATER LEVELS

A comparison of 1999–2000 and 1972–73 water levels in 15 wells is shown in figure 5. The 1972–73 water-level measurements for well 4N/28W-8N3, which was destroyed (Kaehler and others, 1997), were compared with 1999–2000 water-levels measurements for well 4N/28W-8N8.

Water levels in two wells (4N/28W-2N2 and -12P3) measured during January 1999–June 2000 were higher than the January 1972–June 1973 levels (figs. 5*A*, *K*). As noted by Kaehler and others (1997), 1996 water levels in well 4N/28W-2N2 had already exceeded 1972 levels. In the remaining 13 wells, the 1999–2000 change in water level ranged from less than 1 ft to as much as 32 ft below 1972–73 measurements. Water levels measured during 1999 and 2000 were only about 1 ft below January–August levels measured in 1972 and 1973 in wells 4N/28W-8N3, 8N8, -9A3, -9H3, and -9K2 but were about 32 ft below 1972–73 water levels in well 4N/28W-8R3 (table 5). It should be noted that some of the 1972–73 water-level measurements were made during pumping (wells 4N/28W-8K8, -15E2, and -15H4), which would result in lower water levels than those of static conditions and therefore bias the interpretation on the high side; that is, the 1999–2000 water levels might appear closer to 1972–73 levels than actually existed under static conditions.

The average change in water levels in the 15 measured wells in the Goleta Central ground-water subbasin between 1972–73 and 1999–2000 (table 5) is shown in figure 6. Positive numbers indicate areas in which the 1999–2000 levels were above 1972 water levels; negative numbers indicate areas below 1972 levels. On the basis of measurements in the 15 wells for this study, water levels in the eastern part of the basin in 1999–2000 reached or exceeded 1972 levels. Water levels in most of the western two-thirds of the basin were below 1972 levels. Areas in which the 1999–2000 water levels were less than 10 ft below 1972 levels include a zone east of Kellog Avenue, the area north of the Goleta Fault, and a small area along the western border (fig. 6). A small area in the vicinity of well 4N/28W-9G3 along San Jose Creek and most of the remaining area of the western half of the basin have water levels between 10 and 20 ft below 1972 levels. Water levels greater than 20 feet below 1972 levels are present in a small area along Hollister Avenue that is bounded by Fairview Avenue and Clarence Ward Memorial Boulevard and extends about one-quarter mile north of Highway 101.

WATER-LEVEL RECOVERY, 1996–97 TO 1999–2000

An average water-level change was estimated by subtracting the average 1999–2000 water-level altitude from the average 1996–97 water-level altitude. The average change ranged from about 3.54 ft in well

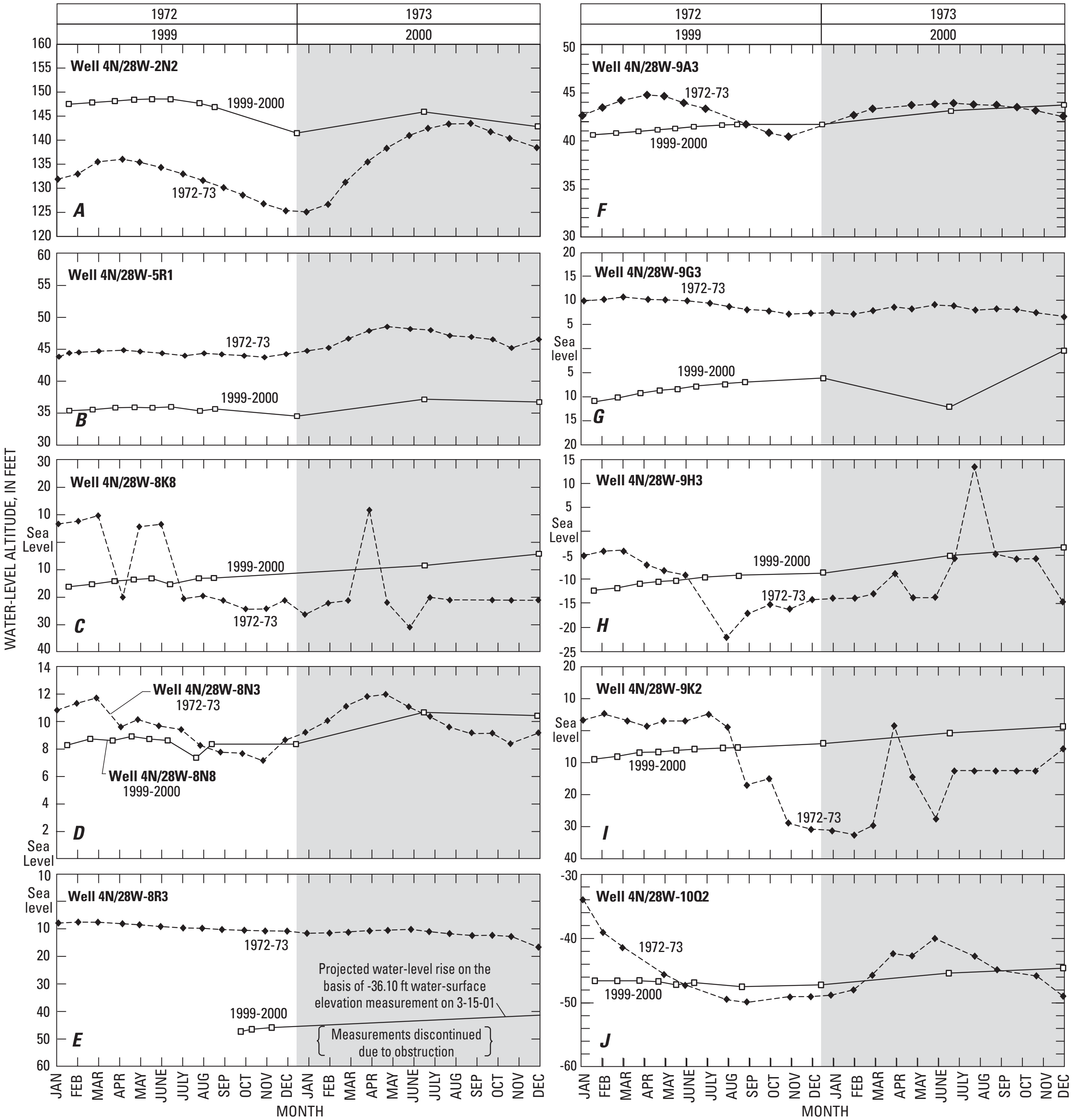


Figure 5. Water-level altitudes for 1972–73 and 1999–2000 at comparison-network wells in the Goleta Central subbasin, Santa Barbara County, California.

4N/28W-8N8 to 36.82 ft in well 4N/28W-12P3 (table 5). Well 4N/28W-8N8 is located about 0.4 mi from the nearest injection well, 4N/28W-8P5, which received about 97 acre-ft of the 2,225 acre-ft (4.4 percent) of surplus water. The lesser water-level change in well 4N/28W-8N8 suggests that recharge has not yet reached this well. As stated above, well 4N/28W-12P3 is near the Modoc and More Ranch Faults, and close to two injection wells (4N/28W-12N1 and -12P4) that received about 2.8 and 7.6 percent, respectively, of the surplus water (fig. 1).

The average water-level change for the 15 measured wells in the Goleta Central ground-water subbasin between 1996–97 and 1999–2000 is shown in figure 7. In general, the water-level change was largest (a rise of almost 37 ft) in the southeastern end of the basin near well 4N/28W-12P3, probably because about 70 percent of the injection occurs in the eastern part of the basin. The smallest rise (less than 4 ft) was in the western end of the basin where about 30 percent of the injection occurs.

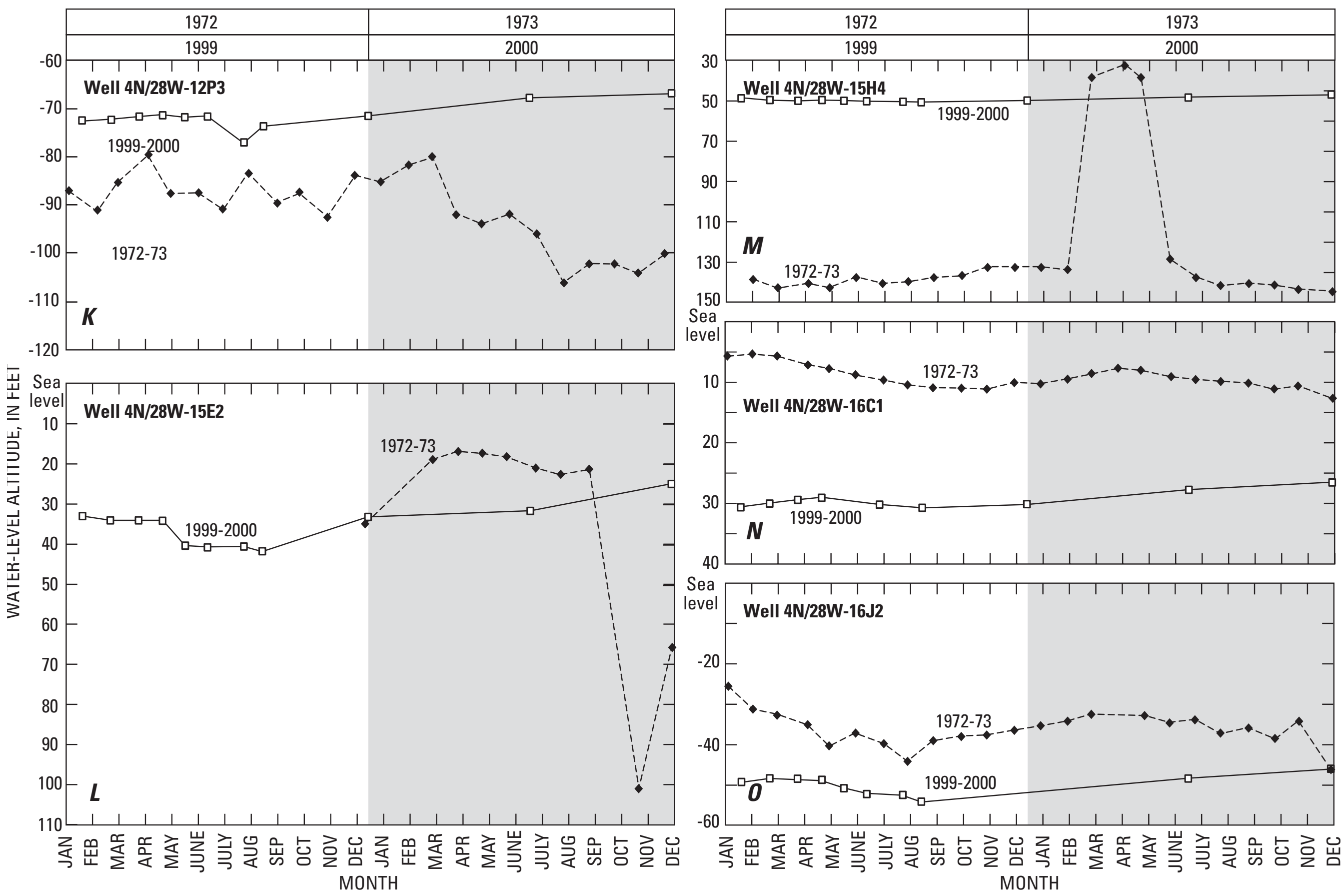


Figure 5.—Continued.

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California

[—, no data; Asterisk (*) indicates 1972–73 measurement made during pumping]

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–2N2	177.90	1/3/72	131.90	46.00				1/19/99	147.47	30.43		15.57
		2/1/72	132.99	44.91				2/22/99	147.83	30.07		14.84
		3/1/72	135.51	42.39				3/26/99	148.14	29.76		12.63
		4/6/72	136.04	41.86				4/23/99	148.45	29.45		12.41
		5/1/72	135.42	42.48	5/23/96	141.75	36.15	5/19/99	148.58	29.32	6.83	13.16
		6/1/72	134.34	43.56	6/13/96	142.14	35.76	6/15/99	148.57	29.33	6.43	14.23
		7/3/72	132.98	44.92	7/9/96	142.04	35.86	7/27/99	147.67	30.23	5.63	14.69
		8/1/72	131.63	46.27	8/20/96	140.62	37.28	8/18/99	146.89	31.01	6.27	15.26
		8/31/72	130.14	47.76	9/10/96	139.78	38.12					—
		10/2/72	128.47	49.43	10/1/96	138.81	39.09					—
		11/2/72	126.87	51.03	11/4/96	137.22	40.68					—
		12/4/72	125.45	52.45	12/2/96	136.11	41.79	12/21/99	141.50	36.40	5.39	16.05
		1/4/73	124.95	52.95								—
		2/5/73	126.52	51.38								—
		3/5/73	131.08	46.82								—
		4/5/73	135.49	42.41								—
		5/2/73	138.27	39.63								—
		6/5/73	140.84	37.06	6/23/97	141.76	36.14	6/27/00	145.90	32.00	4.14	5.06
		7/3/73	142.42	35.48								—
		8/2/73	143.40	34.50								—
		9/4/73	143.50	34.40								—
		10/4/73	141.72	36.18								—
		11/1/73	140.33	37.57								—
		12/11/73	138.39	39.51	12/8/97	134.20	43.70	12/11/00	143.02	34.88	8.82	4.63
Average change											6.22	12.59

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–5R1	62.00	1/19/72	44.50	17.50				1/19/99	35.46	26.54		–9.04
		2/2/72	44.60	17.40				2/22/99	35.62	26.38		–8.98
		3/2/72	44.78	17.22				3/26/99	35.93	26.07		–8.85
		4/7/72	44.94	17.06				4/23/99	35.98	26.02		–8.96
		5/1/72	44.73	17.27				5/19/99	35.92	26.08		–8.81
		6/2/72	44.46	17.54				6/15/99	36.06	25.94		–8.40
		7/5/72	44.08	17.92				7/27/99	35.42	26.58		–8.66
		8/2/72	44.45	17.55	8/21/96	25.58	36.42	8/18/99	35.73	26.27	10.15	–8.72
		9/1/72	44.31	17.69	9/10/96	25.52	36.48					—
		10/4/72	44.01	17.99	10/1/96	25.53	36.47					—
		11/3/72	43.76	18.24	11/4/96	25.39	36.61					—
		12/5/72	44.30	17.70	12/2/96	25.38	36.62	12/21/99	34.62	27.38	9.24	–9.68
		1/4/73	44.72	17.28								—
		2/5/73	45.22	16.78								—
		3/6/73	46.60	15.40								—
		4/6/73	47.99	14.01								—
		5/3/73	48.58	13.42								—
		6/6/73	48.12	13.88	6/23/97	27.52	34.48	6/27/00	37.24	24.76	9.72	–10.88
		7/5/73	47.98	14.02								—
		8/3/73	47.08	14.92								—
		9/4/73	46.92	15.08								—
		10/5/73	46.51	15.49								—
		11/2/73	45.15	16.85								—
		12/12/73	46.49	15.51				12/12/00	36.73	25.27		–9.76
Average change											9.70	–9.16

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–8K8	27.00	1/4/72	6.95	20.05				1/19/99	–15.73	42.73		–22.68
		2/2/72	7.95	19.05				2/22/99	–14.83	41.83		–22.78
		3/2/72	9.95	17.05				3/26/99	–13.72	40.72		–23.67
		4/7/72	–19.55 *	46.55				4/23/99	–13.14	40.14		—
		5/1/72	5.95	21.05	5/7/96	–38.02	65.02	5/19/99	–12.74	39.74	25.28	–18.69
		6/2/72	6.84	20.16	6/13/96	–39.49	66.49	6/15/99	–14.85	41.85	24.64	–21.69
		7/5/72	–20.05 *	47.05	7/9/96	–39.50	66.50	7/27/99	–12.68	39.68	26.82	—
		8/2/72	–19.05 *	46.05	8/20/96	–39.32	66.32	8/18/99	–12.59	39.59	26.73	—
		9/1/72	–21.05 *	48.05	9/10/96	–38.91	65.91					—
		10/4/72	–24.05 *	51.05	10/1/96	–36.53	63.53					—
		11/3/72	–24.05 *	51.05	11/4/96	–36.09	63.09					—
		12/5/72	–21.05 *	48.05	12/2/96	–35.34	62.34					—
		1/4/73	–26.05 *	53.05								—
		2/5/73	–22.05 *	49.05								—
		3/6/73	–21.05 *	48.05								—
		4/6/73	11.95	15.05								—
		5/3/73	–22.05 *	49.05								—
		6/6/73	–31.05 *	58.05	6/23/97	–33.10	60.10	6/27/00	–8.50	35.50	24.60	—
		7/5/73	–20.05 *	47.05								—
		8/3/73	–21.05 *	48.05								—
		11/5/73	–21.05 *	48.05								—
		11/2/73	–21.05 *	48.05								—
		12/12/73	–21.05 *	48.05	12/8/97	–30.44	57.44	12/12/00	–4.29	31.29	26.15	—
Average change											25.70	–21.90

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
[Note: Comparison uses 1996–97 and 1999–2000 water levels for well 4N/28W–8N8 (altitude is 29.0 feet above sea level)]												
4N/28W–8N3	23.00	1/4/72	10.87	12.13				1/19/99	8.33	20.67		–2.54
		2/2/72	11.37	11.63				2/22/99	8.78	20.22		–2.59
		3/2/72	11.76	11.24				3/26/99	8.66	20.34		–3.10
		4/7/72	9.65	13.35				4/23/99	8.96	20.04		–0.69
		5/2/72	10.19	12.81				5/19/99	8.77	20.23		–1.42
		6/2/72	9.73	13.27	6/25/96	5.00	24.00	6/15/99	8.67	20.33	3.67	–1.06
		7/5/72	9.46	13.54	7/10/96	4.80	24.20	7/27/99	7.41	21.59	2.61	–2.05
		8/2/72	8.31	14.69	8/20/96	5.31	23.69	8/19/99	8.40	20.60	3.09	0.09
		9/1/72	7.83	15.17	9/10/96	4.83	24.17					—
		10/4/72	7.74	15.26	10/1/96	4.63	24.37					—
		11/3/72	7.21	15.79	11/4/96	4.23	24.77					—
		12/5/72	8.73	14.27	12/2/96	4.63	24.37	12/21/99	8.44	20.56	3.81	–0.29
		1/4/73	9.24	13.76								—
		2/6/73	10.08	12.92								—
		3/6/73	11.21	11.79								—
		4/6/73	11.88	11.12								—
		5/3/73	12.01	10.99								—
		6/6/73	11.06	11.94	6/23/97	6.18	22.82	6/28/00	10.71	18.29	4.53	–0.35
		7/5/73	10.31	12.69								—
		8/3/73	9.44	13.56								—
		9/5/73	9.05	13.95								—
		10/5/73	9.16	13.84								—
		11/2/73	8.30	14.70								—
		12/12/73	9.17	13.83				12/11/00	10.35	18.65		1.18
Average change											3.54	–1.17

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–8R3	22.00	1/4/72	–7.73	29.73								—
		2/2/72	–7.39	29.39								—
		3/2/72	–7.43	29.43								—
		4/7/72	–7.97	29.97								—
		5/2/72	–8.35	30.35	5/22/96	–54.50	76.50					—
		6/2/72	–8.98	30.98	6/12/96	–54.62	76.62					—
		7/5/72	–9.49	31.49								—
		8/2/72	–9.63	31.63	8/20/96	–54.58	76.58	8/14/98	obstructed			—
		9/1/72	–10.23	32.23	9/10/96	–54.64	76.64	9/29/98	–47.18	69.18	7.46	–36.95
		10/4/72	–10.74	32.74	10/1/96	–54.53	76.53	10/15/98	–46.38	68.38	8.15	–35.64
		11/3/72	–11.03	33.03	11/4/96	–54.40	76.40	11/13/98	–45.75	67.75	8.65	–34.72
		12/5/72	–10.77	32.77	12/2/96	–54.20	76.20					—
		1/4/73	–11.57	33.57			[Note: Measurements discontinued after 1998 because of obstruction]					—
		2/6/73	–11.46	33.46								—
		3/6/73	–11.21	33.21								—
		4/6/73	–10.67	32.67								—
		5/3/73	–10.48	32.48								—
		6/6/73	–10.41	32.41								—
		7/5/73	–10.97	32.97								—
		8/3/73	–11.72	33.72								—
		9/5/73	–12.51	34.51								—
		10/5/73	–12.29	34.29								—
		11/2/73	–12.80	34.80			[Note: Reported measurement from March 2001]					—
		12/12/73	–16.61	38.61				3/18/01	–36.10	58.10		–19.49
Average change											8.09	–31.70

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–9A3	85.09	1/3/72	42.55	42.54				1/19/99	40.59	44.50		–1.96
		2/2/72	43.41	41.68				2/22/99	40.76	44.33		–2.65
		3/1/72	44.11	40.98				3/26/99	40.94	44.15		–3.17
		4/6/72	44.66	40.43	4/11/96	31.17	53.92	4/23/99	41.11	43.98	9.94	–3.55
		5/1/72	44.54	40.55	5/8/96	31.32	53.77	5/19/99	41.25	43.84	9.93	–3.29
		6/1/72	43.79	41.30	6/13/96	31.61	53.48	6/15/99	41.43	43.66	9.82	–2.36
		7/3/72	43.22	41.87	7/9/96	31.76	53.33	7/27/99	41.60	43.49	9.84	–1.62
		8/31/72	41.62	43.47	8/20/96	31.92	53.17	8/18/99	41.60	43.44	9.68	–0.02
					9/10/96	31.99	53.10					—
		10/4/72	40.76	44.33	10/1/96	31.99	53.10					—
		11/2/72	40.35	44.74	11/4/96	32.04	53.05					—
					12/2/96	32.06	53.03	12/21/99	41.66	43.43	9.60	—
												—
		2/6/73	42.56	42.53								—
		3/6/73	43.29	41.80								—
												—
		5/2/73	43.62	41.47								—
		6/5/73	43.76	41.33	6/23/97	33.34	51.75	6/27/00	43.06	42.03	9.72	–0.70
		7/3/73	43.86	41.23								—
		8/2/73	43.78	41.31								—
		9/4/73	43.76	41.33								—
		10/4/73	43.50	41.59								—
		11/1/73	43.09	42.00								—
		12/11/73	42.53	42.56	12/8/97	33.03	52.06	12/12/00	43.73	41.36	10.70	1.20
Average change											9.90	–1.81

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–9G3	60.00	1/4/72	9.92	50.08				1/19/99	−11.10	71.10		−21.02
		2/2/72	10.15	49.85				2/22/99	−10.35	70.35		−20.50
		3/1/72	10.65	49.35				3/26/99	−9.29	69.29		−19.94
		4/6/72	10.16	49.84	4/10/96	−36.19	96.19	4/23/99	−8.74	68.74	27.45	−18.90
		5/1/72	10.09	49.91	5/7/96	−35.74	95.74	5/19/99	−8.37	68.37	27.37	−18.46
		6/2/72	9.94	50.06	6/13/96	−34.87	94.87	6/15/99	−7.79	67.79	27.08	−17.73
		7/5/72	9.42	50.58	7/9/96	−34.45	94.45	7/27/99	−7.29	67.29	27.16	−16.71
		8/2/72	8.71	51.29	8/20/96	−34.30	94.30	8/25/99	−7.02	67.02	27.28	−15.73
		9/1/72	8.03	51.97	9/10/96	−34.10	94.10					—
		10/4/72	7.73	52.27	10/1/96	−33.52	93.52					—
		11/2/72	6.96	53.04	11/4/96	−33.26	93.26					—
		12/5/72	7.32	52.68	12/2/96	−33.12	93.12	12/22/99	−6.19	66.19	26.93	−13.51
		1/4/73	7.32	52.68								—
		2/5/73	7.03	52.97								—
		3/6/73	7.83	52.17								—
		4/6/73	8.56	51.44								—
		5/2/73	7.98	52.02								—
		6/5/73	9.00	51.00	6/23/97	−29.64	89.64	6/27/00	−12.41	72.41	17.23	−21.41
		7/3/73	8.88	51.12								—
		8/3/73	7.97	52.03								—
		9/4/73	8.33	51.67								—
		10/4/73	8.18	51.82								—
		11/1/73	7.44	52.56								—
		12/12/73	6.71	53.29	12/8/97	−27.98	87.98	12/12/00	−0.36	60.36	27.62	−7.07
Average change											26.02	−17.36

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–9H3	75.00	1/4/72	–5.00	80.00				1/19/99	–12.24	87.24		–7.24
		2/2/72	–4.00	79.00				2/22/99	–11.70	86.70		–7.70
		3/2/72	–4.00	79.00				3/26/99	–10.76	85.76		–6.76
		4/6/72	–7.00	82.00				4/23/99	–10.27	85.27		–3.27
		5/1/72	–8.00	83.00	5/24/96	–38.60	113.60	5/19/99	–10.13	85.13	28.47	–2.13
		6/2/72	–9.00	84.00	6/14/96	–38.45	113.45					—
					7/9/96	–38.08	113.08	7/1/99	–9.48	84.48	28.60	—
		8/1/72	–22.00	* 97.00	8/20/96	–37.72	112.72	8/19/99	–9.14	84.14	28.58	—
		9/1/72	–17.00	92.00	9/10/96	–37.51	112.51					—
		10/4/72	–15.00	90.00	10/1/96	–37.09	112.09					—
		11/2/72	–16.00	91.00	11/4/96	–36.75	111.75					—
		12/5/72	–14.00	89.00	12/2/96	–36.36	111.36	12/22/99	–8.36	83.36	28.00	5.64
		1/5/73	–13.75	88.75								—
		2/6/73	–13.75	88.75								—
		3/6/73	–12.75	87.75								—
		4/6/73	–8.75	83.75								—
		5/3/73	–13.75	88.75								—
		6/5/73	–13.75	88.75	6/24/97	–33.14	108.14	6/27/00	–5.02	80.02	28.12	8.73
		7/5/73	–5.75	80.75								—
		8/3/73	13.25	61.75								—
		9/4/73	–4.75	79.75								—
		10/5/73	–5.75	80.75								—
		11/2/73	–5.75	80.75								—
		12/12/73	–14.75	89.75	12/8/97	–31.28	106.28	12/12/00	–3.31	78.31	27.97	11.44
Average change											28.29	–0.16

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–9K2	58.00	1/4/72	3.00	55.00				1/19/99	–8.99	66.99		–11.99
		2/2/72	5.00	53.00				2/22/99	–8.22	66.22		–13.22
		3/9/72	3.00	55.00				3/26/99	–7.01	65.01		–10.01
		4/6/72	1.00	57.00	4/10/96	–34.30	92.33	4/23/99	–6.57	64.57	27.73	–7.57
		5/1/72	3.00	55.00	5/8/96	–35.10	93.07	5/19/99	–6.16	64.16	28.94	–9.16
		6/2/72	3.00	55.00	6/13/96	–33.00	90.97	6/15/99	–5.75	63.75	27.25	–8.75
		7/5/72	5.00	53.00	7/9/96	–32.60	90.60	7/27/99	–5.47	63.47	27.13	–10.47
		8/2/72	1.00	57.00	8/20/96	–33.50	91.51	8/18/99	–5.33	63.33	28.17	–6.33
		9/1/72	–17.00	75.00	9/10/96	–33.40	91.43					—
		10/4/72	–15.00	73.00	10/1/96	–31.50	89.54					—
		11/2/72	–29.00	87.00	11/4/96	–31.40	89.36					—
		12/5/72	–31.00	89.00	12/2/96	–32.30	90.31	12/22/99	–4.00	62.00	28.30	27.00
		1/5/73	–31.50	89.50								—
		2/6/73	–32.50	90.50								—
		3/6/73	–29.50	87.50								—
		4/6/73	1.50	56.50								—
		5/3/73	–14.50	72.50								—
		6/6/73	–27.50	85.50	6/23/97	–27.60	85.59	6/27/00	–0.87	58.87	26.73	26.63
		7/5/73	–12.50	70.50								—
		8/3/73	–12.50	70.50								—
		9/4/73	–12.50	70.50								—
		10/5/73	–12.50	70.50								—
		11/2/73	–12.50	70.50								—
		12/12/73	–5.50	63.50	12/8/97	–17.30	75.35	12/12/00	1.30	56.65	18.60	6.80
Average change											26.61	–1.55

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements: Date	1972–73: Water-surface altitude, in feet above sea level	1972–73: Depth to water, in feet below land surface	1996–97 water-level measurements: Date	1996–97: Water-surface altitude, in feet above sea level	1996–97: Depth to water, in feet below land surface	1999–2000 water-level measurements: Date	1999–2000: Water-surface altitude in feet above sea level	1999–2000: Depth to water, in feet below land surface	Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
4N/28W–10Q2	67.00	1/4/72	–34.19	101.19				1/20/99	–46.58	113.58		–12.39
		2/2/72	–38.97	105.97				2/22/99	–46.72	113.72		–7.75
		3/2/72	–41.60	108.60				3/26/99	–46.52	113.52		–4.92
								4/23/99	–46.71	113.71		—
		5/2/72	–45.68	112.68	5/8/96	–59.42	126.42	5/19/99	–47.14	114.14	12.28	–1.46
		6/2/72	–47.29	114.29	6/12/96	–59.31	126.31	6/15/99	–46.98	113.98	12.33	0.31
					7/10/96	–59.49	126.49					—
		8/2/72	–49.46	116.46	8/20/96	–59.27	126.27	8/25/99	–47.55	114.55	11.72	1.91
		9/1/72	–50.00	117.00	9/10/96	–59.21	126.21					—
					10/1/96	–59.25	126.25					—
		11/3/72	–49.11	116.11	11/4/96	–59.15	126.15					—
		12/5/72	–48.96	115.96	12/2/96	–58.97	125.97	12/20/99	–47.19	114.19	11.78	1.77
		1/4/73	–48.88	115.88								—
		2/6/73	–48.17	115.17	6/23/97	–58.03	125.03					—
		3/6/73	–45.87	112.87								—
		4/5/73	–42.44	109.44								—
		5/3/73	–42.71	109.71								—
		6/6/73	–40.06	107.06	6/23/97	–58.03	125.03	6/27/00	–45.43	112.43	12.60	–5.37
												—
		8/3/73	–42.87	109.87								—
		9/5/73	–44.84	111.84								—
												—
		11/2/73	–45.91	112.91								—
		12/12/73	–48.97	115.97	12/8/97	–57.94	124.94	12/12/00	–44.66	111.66	13.28	4.31
Average change											12.33	–2.62

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–12P3	80.00	1/4/72	–87.25	167.25				1/19/99	–72.38	152.38		14.87
		2/7/72	–91.42	171.42				2/22/99	–72.24	152.24		19.18
		3/2/72	–85.50	165.50				3/26/99	–71.57	151.57		13.93
		4/7/72	–79.50	159.50	4/9/96	–111.21	191.21	4/23/99	–71.39	151.39	39.82	8.11
		5/3/72	–87.83	167.83	5/8/96	–111.18	191.18	5/19/99	–71.84	151.84	39.34	15.99
		6/5/72	–87.60	167.60	6/13/96	–110.60	190.60	6/15/99	–71.59	151.59	39.01	16.01
		7/3/72	–90.83	170.83	7/23/96	–110.32	190.32	7/27/99	–77.03	157.03	33.29	13.80
		8/2/72	–83.50	163.50	8/20/96	–109.99	189.99	8/18/99	–73.68	153.68	36.31	9.82
		9/5/72	–89.50	169.50	9/10/96	–109.66	189.66					—
		10/1/72	–87.50	167.50	10/1/96	–109.45	189.45					—
		11/3/72	–92.50	172.50	11/4/96	–109.02	189.02					—
		12/5/72	–83.80	163.80	12/2/96	–107.40	187.40	12/20/99	–71.49	151.49	35.91	12.31
		1/5/73	–85.30	165.30								—
		2/6/73	–82.00	162.00								—
		3/7/73	–80.00	160.00								—
		4/3/73	–92.00	172.00								—
		5/3/73	–94.00	174.00								—
		6/5/73	–92.00	172.00	6/24/97	–103.68	183.68	6/27/00	–67.80	147.80	35.88	24.20
		7/5/73	–96.00	176.00								—
		8/6/73	–106.00	186.00								—
		9/5/73	–102.00	182.00								—
		105/73	–102.00	182.00								—
		11/2/73	–104.00	184.00								—
		12/3/73	–100.00	180.00	12/10/97	–101.96	181.96	12/11/00	–67.00	147.00	34.96	33.00
Average change											36.82	16.47

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–15E2	36.4							1/20/99	–32.84	69.24		—
								2/22/99	–33.77	70.17		—
								3/26/99	–33.86	70.26		—
					4/11/96	–52.72	89.12	4/23/99	–33.86	70.26	18.86	—
					5/8/96	–52.02	88.42	5/19/99	–40.12	76.52	11.90	—
					6/14/96	–51.02	87.42	6/15/99	–40.48	76.88	10.54	—
					7/10/96	–50.55	86.95	7/27/99	–40.38	76.78	10.17	—
					8/20/96	–54.82	91.22	8/18/99	–41.59	77.99	13.23	—
					9/10/96	–54.05	90.45					—
					10/1/96	–53.97	90.37					—
					11/4/96	–53.74	90.14					—
		12/17/72	–34.60	* 71.00	12/2/96	–53.38	89.78	12/20/99	–32.99	69.39		—
												—
												—
		3/6/73	–18.74	55.14								—
		4/5/73	–16.88	53.28								—
		5/3/73	–17.26	53.66								—
		6/1/73	–18.05	54.45	6/24/97	–47.37	83.77	6/28/00	–31.49	67.89	15.88	–13.44
		7/5/73	–21.18	57.58								—
		8/3/73	–22.76	59.16								—
		9/5/73	–21.38	57.78								—
												—
		11/2/73	–101.00	* 137.40								—
		12/12/73	–66.00	* 102.40	12/9/97	–44.98	81.38	12/11/00	–24.94	61.34		—
Average change											13.43	–13.44

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

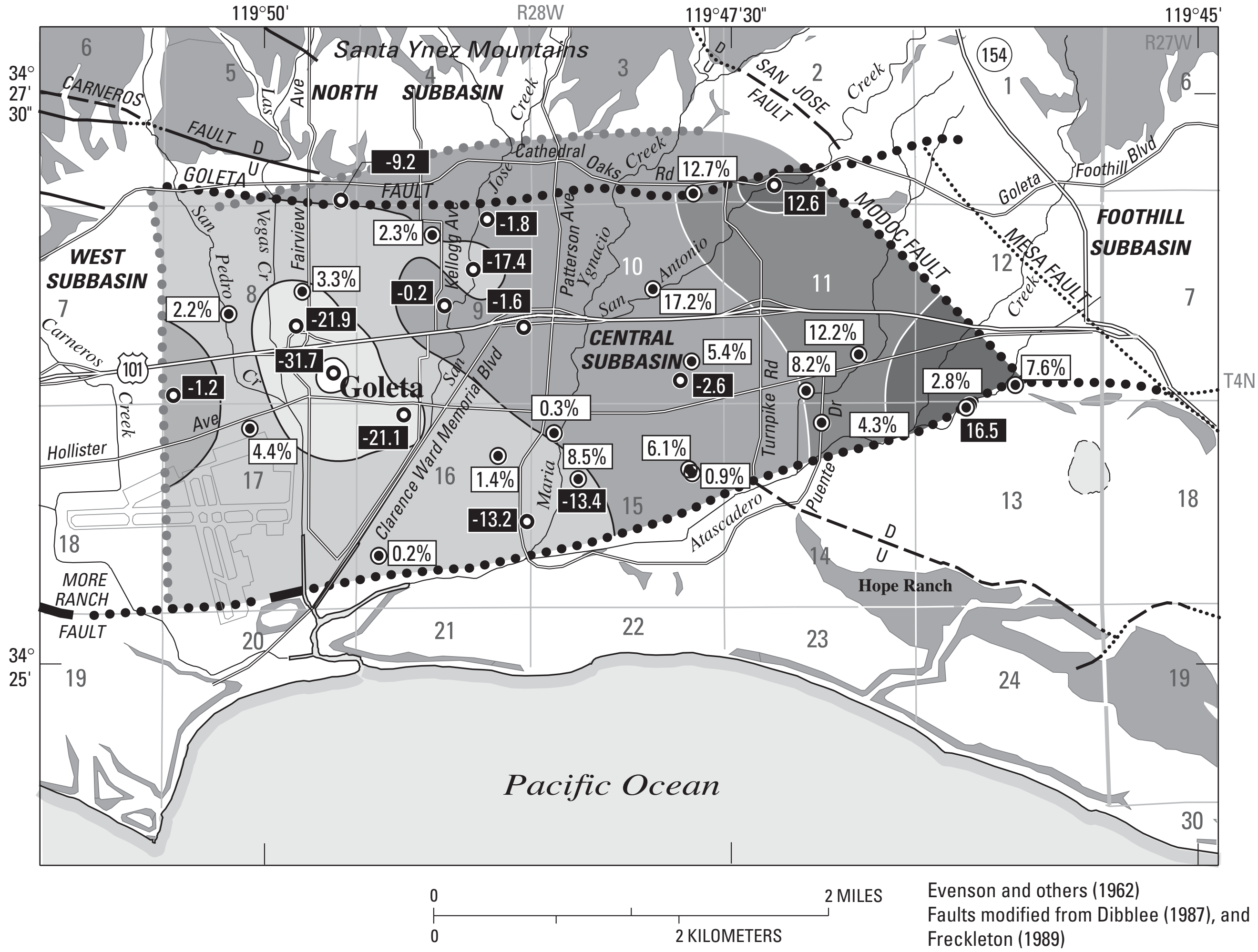
State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–15H4	40.00							1/19/99	–48.82	88.82		—
		2/2/72	–138.43 *	178.43				2/22/99	–49.58	89.58		—
		3/2/72	–142.43 *	182.43				3/26/99	–49.92	89.92		—
		4/7/72	–140.43 *	180.43	4/10/96	–63.30	103.30	4/23/99	–49.68	89.68	13.62	—
		5/2/72	–142.43 *	182.43				5/19/99	–50.00	90.00		—
		6/2/72	–137.43 *	177.43	6/25/96	–61.15	101.15	6/15/99	–50.12	90.12	11.03	—
		7/3/72	–140.43 *	180.43				7/27/99	–50.34	90.34		—
		8/2/72	–139.43 *	179.43				8/18/99	–50.72	90.72		—
		9/1/72	–137.43 *	177.43								—
		10/4/72	–136.43 *	176.43								—
		11/3/72	–132.43 *	172.43								—
		12/5/72	–132.43 *	172.43	12/19/96	–61.51	101.51	12/20/99	–49.96	89.96	11.55	—
		1/5/73	–132.43 *	172.43								—
		2/5/73	–133.43 *	173.43								—
		3/6/73	–38.43	78.43								—
		4/13/73	–32.43	72.43								—
		5/3/73	–38.43	78.43								—
		6/6/73	–128.43 *	168.43	6/24/97	–60.92	100.92	6/27/00	–48.29	88.29	12.63	—
		7/5/73	–137.43 *	177.43								—
		8/3/73	–141.43 *	181.43								—
		9/5/73	–140.43 *	180.43								—
		10/5/73	–141.43 *	181.43								—
		11/2/73	–143.43 *	183.43								—
		12/12/73	–144.43 *	184.43	12/9/97	–60.60	100.60	12/11/00	–47.32	87.32	13.28	—
Average change											12.42	—

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–16C1	30.00	1/4/72	–5.58	35.58				1/19/99	–30.68	60.68		–25.10
		2/2/72	–5.33	35.33				2/22/99	–30.05	60.05		–24.72
		3/2/72	–5.69	35.69				3/26/99	–29.46	59.46		–23.77
		4/7/72	–7.20	37.20				4/23/99	–29.12	59.12		–21.92
		5/2/72	–7.77	37.77	5/9/96	–35.79	65.79					—
		6/2/72	–8.83	38.83	6/14/96	–36.08	66.08	6/30/99	–30.24	60.24	5.84	–21.41
		7/5/72	–9.65	39.65	7/10/96	–36.38	66.38					—
		8/2/72	–10.44	40.44	8/20/96	–36.41	66.41	8/19/99	–30.74	60.74	5.67	–20.30
		9/1/72	–10.90	40.90	9/10/96	–36.47	66.47					—
		10/4/72	–11.04	41.04	10/1/96	–36.41	66.41					—
		11/3/72	–11.13	41.13	11/4/96	–36.05	66.05					—
		12/5/72	–10.03	40.03	12/2/96	–35.52	65.52	12/20/99	–30.11	60.11	5.41	–20.08
		1/5/73	–10.28	40.28								—
		2/6/73	–9.48	39.48								—
		3/6/73	–8.54	38.54								—
		4/6/73	–7.66	37.66								—
		5/3/73	–8.02	38.02								—
		6/6/73	–9.05	39.05				6/28/00	–27.78	57.78		–18.73
		7/5/73	–9.62	39.62								—
		8/3/73	–9.81	39.81								—
		9/5/73	–10.14	40.14								—
		10/5/73	–11.01	41.01								—
		11/2/73	–10.53	40.53								—
		12/12/73	–12.67	42.67				12/11/00	–26.56	56.56		–13.89
Average change											5.64	–21.10

Table 5. Comparison of 1972–73, 1996–97, and 1999–2000 water-level data for selected wells in the Goleta Central ground-water subbasin, Santa Barbara County, California—Continued

State well number	Altitude, in feet above sea level	1972–73 water-level measurements			1996–97 water-level measurements			1999–2000 water-level measurements			Change in water-surface altitude, 1996–97 to 1999–2000, in feet	Change in water-surface altitude, 1972–73 to 1999–2000, in feet
		Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude, in feet above sea level	Depth to water, in feet below land surface	Date	Water-surface altitude in feet above sea level	Depth to water, in feet below land surface		
4N/28W–16J2	26.00	1/4/72	–25.57	51.57				1/20/99	–49.22	75.22		–23.65
		2/2/72	–31.07	57.07				2/22/99	–48.28	74.28		–17.21
		3/2/72	–32.60	58.60				3/26/99	–48.31	74.31		–15.71
		4/7/72	–35.01	61.01				4/23/99	–48.68	74.68		–13.67
		5/2/72	–40.31	66.31	5/8/96	–60.98	86.98	5/19/99	–50.77	76.77	10.21	–10.46
		6/2/72	–37.00	63.00	6/13/96	–61.43	87.43	6/15/99	–52.21	78.21	9.22	–15.21
		7/5/72	–39.68	65.68	7/10/96	–62.76	88.76	7/27/99	–52.42	78.42	10.34	–12.74
		8/2/72	–44.29	70.29	8/19/96	–63.26	89.26	8/18/99	–54.06	80.06	9.20	–9.77
		9/1/72	–38.97	64.97	9/10/96	–63.03	89.03					—
		10/4/72	–37.98	63.98	10/1/96	–63.38	89.38					—
		11/3/72	–37.57	63.57	11/4/96	–61.63	87.63					—
		12/5/72	–36.42	62.42	12/2/96	–60.03	86.03					—
		1/5/73	–35.26	61.26								—
		2/6/73	–34.14	60.14								—
		3/6/73	–32.42	58.42								—
												—
		5/8/73	–32.72	58.72								—
		6/6/73	–34.57	60.57	6/24/97	–62.26	88.26	6/27/00	–48.32	74.32	13.94	–13.75
		7/5/73	–33.92	59.92								—
		8/3/73	–37.19	63.19								—
		9/5/73	–35.93	61.93								—
		10/5/73	–38.52	64.52								—
		11/2/73	–34.22	60.22								—
		12/12/73	–46.28	72.28	12/9/97	–59.16	85.16	12/11/00	–45.99	71.99	13.17	0.29
Average change											11.01	–13.19



EXPLANATION

- Unconsolidated rocks
- Consolidated rocks
- **Fault** – Dashed where approximately located, dotted where concealed. **U**, upthrown side; **D**, downthrown side
- **Fault that is a hydrologic barrier** – Dotted where concealed
- **Hydrologic barrier**

Well

- Injection well
- Well measured monthly

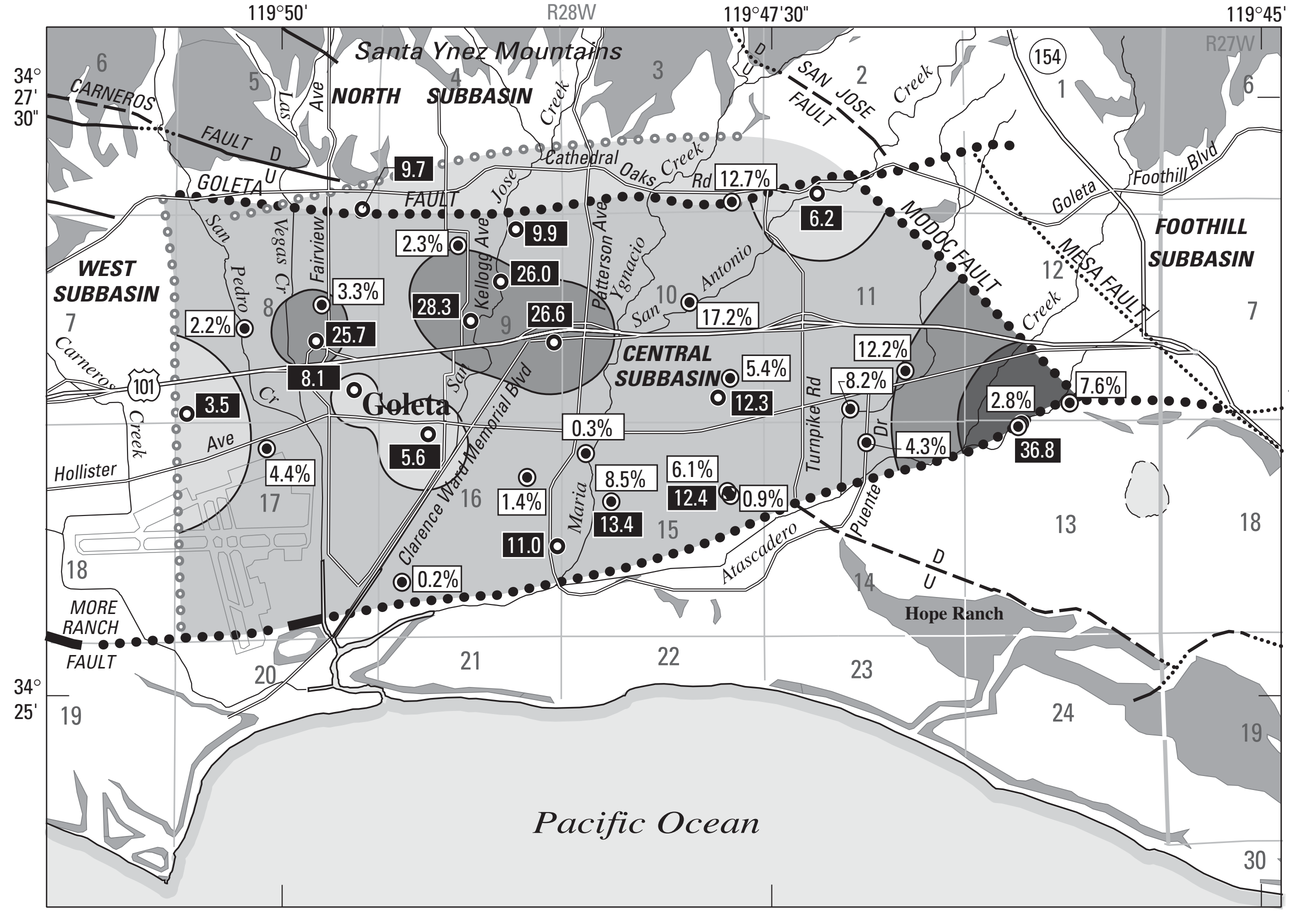
Average change in water-surface altitude, 1972-73 to 1999-2000 – In feet

Decline	Rise
-30 to -40	0 to 10
-20 to -30	10 to 20
-10 to -20	
0 to -10	No data

16.5 **Change in water-surface altitude at well**

0.2% Percentage of total quantity of imported water injected

Figure 6. Change in average water-surface altitude between 1972–73 and 1999–2000 in the Goleta Central ground-water subbasin, Santa Barbara County, California.



0 2 MILES

0 2 KILOMETERS

Evenson and others (1962),
Faults modified from Dibblee (1987), and
Freckleton (1989)

EXPLANATION

Unconsolidated rocks

Consolidated rocks

Fault – Dashed where approximately located, dotted where concealed. **U**, upthrown side; **D**, downthrown side

Fault that is a hydrologic barrier – Dotted where concealed

Hydrologic barrier

Well

Injection well

Well measured monthly

Average change in water-surface altitude, 1996-97 to 1999-2000 – In feet

0-10

10-20

20-30

30-40

No data

13.4 **Change in water-surface altitude at well**

1.4% Percentage of total quantity of imported water injected

Figure 7. Change in average water-surface altitude between 1996–97 and 1999–2000 in the Goleta Central ground-water subbasin, Santa Barbara County, California.

SUMMARY AND CONCLUSIONS

During February 1998–January 1999, approximately 2,225 acre-ft of surplus water was recharged into the Goleta Central ground-water subbasin. Monthly recharge ranged from a high of about 320 acre-ft during May 1998 to a low of 30 acre-ft during January 1999. During this period, the highest percentage of water (about 17 percent, 383 acre-ft) was injected in well 4N/28W-10G7.

A preliminary water budget suggests that the inflow into the system, which ranged from about 4,170 to about 9,684 acre-ft, exceeded the outflow, which ranged from about 1,326 to 2,166 acre-ft. This resulted in a net change in storage of about 2,844 to 7,518 acre-ft in the aquifer system during 1998–99. Because of scant streamflow and pumpage data, all recharge and discharge values in this budget were estimated from available information and various assumptions. Assuming that the preliminary estimates of natural recharge to and discharge from the basin are somewhat reasonable, the 2,225 acre-ft of injected water is about one-half to one-fourth of the recharge. A ground-water-flow model could test and refine estimated recharge and discharge from the Goleta Central ground-water subbasin and, once calibrated, it could be used to predict the effects of different pumping scenarios.

Since 1996–97, water levels in the basin have risen about 4 to 37 ft in 15 wells measured during 1999–2000 for this study. Water levels in 1999–2000 in 2 of 15 wells exceeded 1972–73 levels, whereas water levels in the remaining 13 wells were about 1 to 32 ft below 1972–73 water levels.

Solely on the basis of measured water levels, injection has had a greater effect in the eastern part of the basin than near the airport and north of the Goleta Fault. More than 50 percent of the injection is within a mile of the eastern part of the basin, whereas about 10 percent of the injection is near the airport. On the basis of a comparison of water levels measured in the 15 wells during 1972–73 and 1999–2000, water levels in the eastern part of the basin in 1999–2000 have reached or exceeded 1972 water levels. Water levels in most of the western half of the basin are below 1972 levels.

Long-term hydrographs indicate that water levels throughout the basin have been rising since the cessation of pumpage by GWD in the early 1990's. The average water-level change between 1996–97 and 1999–2000 conditions is a rise that ranged from about 4 to 37 ft in the basin. The largest water-level change is in the southeastern end of the basin near the intersection of two faults and probably is due to both the proximity of the well to the faults, which appear to act as ground-water barriers, and the relatively large amount of injection from two nearby injection wells. The smallest water-level change is in the western end of the basin and north of the Goleta Fault and suggests that the injection water has not yet affected this area.

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