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PWS-0197-0001

LAND USE AND WATER USE IN THE ANTELOPE VALLEY, CALIFORNIA

By WILLIAM E. TEMPLIN, STEVEN P. PHILLIPS, DANIEL E. CHERRY, MYRNA L. DeBORTOLI, *and* OTHERS

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 94-4208

Prepared in cooperation with the
ANTELOPE VALLEY WATER GROUP

Sacramento, California
1995

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND VERTICAL DATUM

Conversion Factors

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	1,234	cubic meter
acre-foot per year (acre-ft/yr)	1,234	cubic meter per year
acre-foot per acre (acre-ft/acre)	3,048	cubic meter per hectare
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
gallon per day (gal/d)	0.003785	cubic meter per day
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	259.0	hectare
	2.590	square kilometer

Temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$\text{Temp } {}^{\circ}\text{C} = 5/9\ ({}^{\circ}\text{F})\text{-}32.$$

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.

PWS-0197-0006

LAND USE AND WATER USE IN THE ANTELOPE VALLEY, CALIFORNIA

By William E. Templin, Steven P. Phillips, Daniel E. Cherry, Myrna L. DeBortoli, *and* others

Abstract

Urban land use and water use in the Antelope Valley, California, have increased significantly since development of the valley began in the late 1800's. Ground water has been a major source of water in this area because of limited local surface-water resources. Ground-water pumpage is reported to have increased from about 29,000 acre-feet in 1919 to about 400,000 acre-feet in the 1950's. Completion of the California Aqueduct to this area in the early 1970's conveyed water from the Sacramento-San Joaquin Delta, about 400 miles to the north. Declines in ground-water levels and increased costs of electrical power in the 1970's resulted in a reduction in the quantity of ground water that was pumped annually for irrigation uses. Total annual reported ground-water pumpage decreased to a low of about 53,200 acre-feet in 1983 and increased to about 91,700 acre-feet in 1991 as a result of rapid urban development and the 1987-92 drought. This increased urban development, in combination with several years of drought, renewed concern about a possible return to extensive depletion of ground-water storage and increased land subsidence.

Increased water demands are expected to continue as a result of increased urban development. Water-demand forecasts in 1980 for the Antelope Valley indicated that total annual water demand by 2020 was expected to be about 250,000 acre-feet, with agricultural demand being about 65 percent of this total. In 1990, total water demand was projected to be about 175,000 acre-feet by 2010; however, agricultural water demand was expected to account for only 37 percent of the total demand. New and existing land- and water-use data were collected and compiled during 1992-93 to identify present and historical land and water uses. In 1993, preliminary forecasts for total water demand by 2010 ranged from about 127,500 to 329,000 acre-feet. These wide-ranging estimates indicate that forecasts can change with time as factors that affect water demand change and different forecasting methods are used. The forecasts using the MWD_MAIN (Metropolitan Water District of Southern California Municipal and Industrial Needs) water-demand forecasting system yielded the largest estimates of water demand. These forecasts were based on projections of population growth and other socioeconomic variables. Initial forecasts using the MWD_MAIN forecasting system commonly are considered "interim" or preliminary. Available historical and future socioeconomic data required for the forecasting system are limited for this area. Decisions on local water-resources demand management may be made by members of the Antelope Valley Water Group and other interested parties based on this report, other studies, their best judgement, and cumulative knowledge of local conditions. Potential water-resource management actions in the Antelope Valley include (1) increasing artificial ground-water recharge when excess local runoff (or imported water supplies) are available; (2) implementing water-conservation best-management practices; and (3) optimizing ground-water pumpage throughout the basin.

INTRODUCTION

Reported water use in the part of Antelope Valley in Los Angeles County, California, peaked in 1956, when agriculture was the primary water use and ground water the primary water source. Historical pumpage data for the part of Kern

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County in Antelope Valley is severely limited, but we can assume a similar peak for the entire Antelope Valley. Rapid ground-water-level declines and associated land subsidence were consequences of extensive ground-water use. In the 1970's, increased pumping lifts because of declining ground-water levels and increased electrical costs resulted in decreases in irrigated agriculture and related agricultural water use. The decrease in irrigated agriculture and the importation of surface water to the Antelope Valley have reduced demands on local ground-water supplies to about one-third of the demand that existed 40 years ago. However, increased stress is again being placed on local ground-water resources by continued concentration of pumping in expanding urban areas and several consecutive years of drought. Information on rainfall and runoff and estimates of ground-water recharge indicate that more water continues to be pumped annually than replenishes the ground-water resource.

In 1992, the sixth year of drought, concern about the consequences of long-term declines in ground-water levels, present and future availability of surface-water, and the potential for additional land-subsidence-related damages resulted in a cooperative agreement between the U.S. Geological Survey and the newly formed Antelope Valley Water Group (AVWG) to provide information needed to manage the water resources in the area. Funds contributed by the U.S. Geological Survey's National Water Use Information Program and the Federal/State Cooperative Program were pooled with funds contributed by the following Antelope Valley Water Group members: Los Angeles County Department of Public Works; Antelope Valley-East Kern Water Agency; city of Palmdale; city of Lancaster; Palmdale Water District; Rosamond Community Services District; and Antelope Valley United Water Purveyors.

The goals of the preliminary geohydrologic study of the Antelope Valley were to (1) estimate historical water supplies and uses and future water demands, (2) determine the magnitude and extent of land subsidence, and (3) prepare detailed study plans for evaluating the hydrogeologic environment and for developing ground-water-flow and resource-optimization models for the Antelope Valley. This report addresses the first of these goals which was met in this land- and water-use study by (1) identifying and reviewing previous work, (2) compiling and creating data bases from local, regional, State, and Federal water agencies using data on ground-water withdrawals, deliveries, releases, or returns to surface- or ground-water sources, (3) determining the adequacy of the data bases, (4) addressing the inadequacies of these data bases by locating additional data and estimating other unaccounted for water uses, (5) establishing a plan for continuing to improve the data bases over time, and (6) providing forecasts of future local water demands for the area.

The objectives of this study of water-use in the Antelope Valley relate well to the goals for water-use information recognized by the Congress of the United States in 1977 when they directed the U.S. Geological Survey to establish data bases to meet this need throughout the Nation. This study represents a continuation of the national cooperative water-use studies that began in 1978, which includes the comprehensive and systematic collection, storage, analysis, and dissemination of water-use information. Statistics on water use have long been valuable for effective management, planning, and development of the Nation's water resources. These statistics provide information necessary to identify and resolve critical water problems related to the environment, resource allocations, and water quality.

Purpose and Scope

This report presents estimates of historical water supply and use and estimates of future water demands that are needed for effective management of the water resources of the Antelope Valley. The study area includes the parts of Los Angeles, Kern, and San Bernardino Counties that make up the Antelope Valley. Examples of land use are described because knowledge of current and historical land use is an integral part of understanding water use in this area. Historical, current, and future land-use trends can indicate similar water-use trends because of the close relation between these two natural-resource uses. Irrigated acreage is widely used for estimating agricultural water use.

This report includes a survey of local land use and water use for the period of record (early 1900's to 1993), options for data-base maintenance, and improvements in the historical data base. Existing information on land use, water-supply sources, water-use estimates, and water-demand forecasts for the Antelope Valley was collected and evaluated. Water-supply sources identified during this study

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are ground water, local surface water (including stormwater runoff), imported surface water, and reclaimed wastewater. Both public-supplied and self-supplied water uses were identified. The sources of this information were local water suppliers, regional and statewide data bases, and estimates made from various socioeconomic and demographic variables. The reliability of the estimates of historical, current, and future water use for Antelope Valley presented in this report was evaluated by comparing all of the above related information.

Previous Studies

One of the earliest investigations of ground-water supplies in the Antelope Valley was documented by Johnson (1911) as part of a series of reports published by the U.S. Geological Survey for Southern California areas during that period. Johnson identified 353 active wells in the valley that were completed as early as 1885, most of which were flowing wells that tapped artesian aquifers. The development of irrigation in the Antelope Valley was described by Ewing (1945).

A study by Snyder (1955, p. viii) addressed the economic and social problems arising from the dependence on ground water in the Antelope Valley. In particular, the study focused on the "mining" of ground water in the semiarid, hydrologically self-contained valley. The study called attention to the highly variable but small volume of recharge to the aquifer system and addressed economic and social forces that could affect balancing recharge and discharge before the ground-water storage was depleted. Snyder determined that there was "no simple solution" to the ground-water-management problem but suggested that the following actions could be taken: (1) education to change crop patterns and water application, (2) local zoning ordinances to limit and reduce ground-water pumpage, (3) legislation of State ground-water laws, and (4) importation of surface water.

A report by the California Department of Public Works (1955) described water conditions in the Antelope Valley on the basis of data available at that time. This report documented that the highest estimated ground-water pumpage during 1 year in the Antelope Valley was about 480,000 acre-ft and occurred in 1953. Total irrigated acreage was estimated to be 73,600 acres with alfalfa accounting for 62,100 acres.

The first phase of a study on water management by the California Department of Water Resources, local agencies, and the U.S. Geological Survey produced the first ground-water-flow model for the Antelope Valley (Durbin, 1978, p. 49). The second phase of that study used the model to evaluate the possible results of various water-management alternatives. This phase was documented in a report by the California Department of Water Resources (1980). The report included the results of a survey of water supply and demand for the Antelope Valley, which was used to develop plans for coordinated use of the various available water supplies (ground water, imported water, local surface water, and reclaimed wastewater) for 1975 to 2020. Present and historical population projections for the Antelope Valley for the year 2000 have ranged from a low of 106,000 to a high of 476,000. The population was projected to grow from 94,000 in 1975 to 320,000 by 2020 (California Department of Water Resources, 1980). Irrigated acreage also could not be projected reliably and, therefore, was held constant at the 1975 level (35,000 acres). Since 1980, additional water-supply and demand estimates for the Antelope Valley have been provided by the California Department of Water Resources (1987, 1988, 1990a, 1990b, 1991b, and 1993a).

Law Environmental (1991) presented a report on available data for the Los Angeles County part of the Antelope Valley and concluded, as did Snyder (1955), that a combination of best-management practices could improve ground-water conditions in the area.

Acknowledgments

The authors wish to acknowledge the assistance of many water district personnel in the Antelope Valley, but especially the active leaders of the water community who make up the Antelope Valley Water Group, for their foresight, cooperation, and input throughout this project. We also would like to recognize the assistance of Vern T. Knoop, David Inouye, and Glenn I. Bergquist, California Department of Water Resources; Javier Minjares, Southern California Association of Governments; and Gregory Poseley, California Department of Conservation, for supplying their land-use and water-use information for the study area and for their cooperation on comparing land-use maps from various sources with their maps and the supporting aerial photography. We also appreciate the advice and assistance of Eva Opitz, Planning Management Consultants, Ltd., and Shane Chapman, Metropolitan Water District of Southern California, in this initial application of the MWD_MAIN system for forecasting urban water demands in the Antelope Valley.

DESCRIPTION OF STUDY AREA

Antelope Valley is in the southwestern part of the Mojave Desert in southern California (fig. 1). Most of the valley is in Los Angeles County and Kern County, and a small part of the eastern valley is in San Bernardino County. The valley is triangular in shape and lies between the San Andreas Fault on the southwest and the Garlock Fault on the northwest. The study area is about 2,400 mi^2. The land-surface elevation in the study area ranges from about 2,300 to 3,500 ft above sea level. Native vegetation includes Joshua trees, saltbrush, mesquite, sagebrush, creosote bush, and other high-desert plants.

The valley is semiarid, receiving an average of less than 10 in. of precipitation annually on the valley floor and more than 12 in. of precipitation in the surrounding mountains (Rantz, 1969). Precipitation totals for 1928-91 for the Leona Valley, Palmdale, and Lancaster (fig. 2) indicate the annual variability and regional differences in the Antelope Valley. Annual and regional variations in precipitation are important to the annual variations in applied water required for crop production and

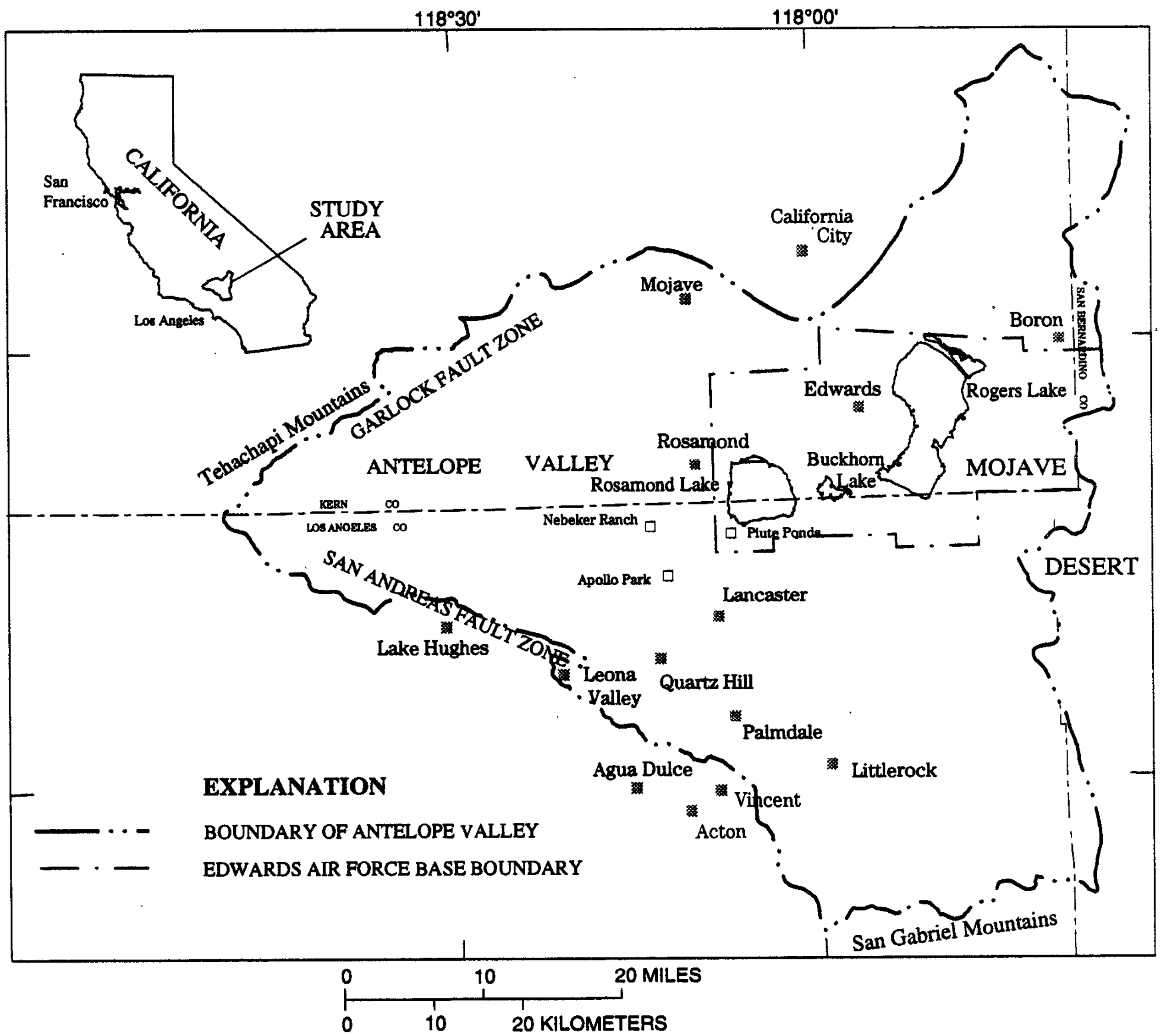

Figure 1. Location of the Antelope Valley, California.

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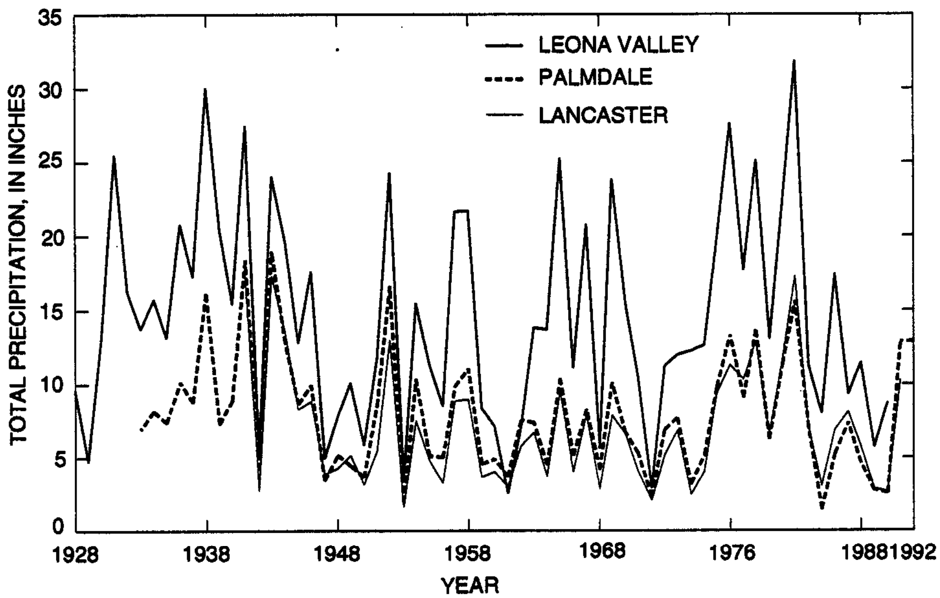

Figure 2. Annual precipitation for the Leona Valley, Palmdale, and Lancaster in the Antelope Valley (Joel Guay, U.S. Geological Survey, written commun., 1993.)

urban landscape maintenance. Rainfall records indicate that runoff sometimes may be available that could be retained and used for artificial ground-water recharge. Eighty percent of the mean annual precipitation, including some snow, falls in winter. The mean summer temperature is 78°F and mean daily summer temperatures range from 63 to 93°F. The mean winter temperature is 45°F and mean daily winter temperatures range from 34 to 57°F. The growing season is primarily from April through October (Duell, 1987).

Actual populations in 1980 and 1990 and the forecasted population for 2010 for the valley are 124,350, 260,400, and 690,000, respectively (Dolores Lykins, California Department of Finance, written commun., 1993). Actual populations in 1980 and 1990 and projected populations for 2010 for the following communities are

	1980	1990	2010
Lancaster	48,027	97,291	212,140
Palmdale	12,277	54,720	226,425
Edwards Air Force Base	8,554	7,423	7,671
Rosamond	2,869	5,467	23,372
Mojave	2,886	1,944	8,737
Boron	2,815	2,903	3,071
	77,428	169,748	481,416
	62% of 124,350	65% of 260,400	70% of 690,000

These six communities represent 62, 65, and 70 percent of the population of the Antelope Valley in 1980, 1990, and 2010, respectively. Actual and forecasted population trends and distributions between 1960 and 2010 suggest potential for increasing localized stress on the water resources from urban growth in the valley. The range in population projections (fig. 3) indicates inaccuracies that are inherent in the process of attempting to forecast future socioeconomic conditions. Population forecasts are as variable now as they were in 1976. The population forecasts for a study by the California Department of Water Resources (1980) were considered the best available at that time. Projections made in 1976 for 1990 were about 30 percent lower than actual populations. The projected population for the Antelope Valley for the year 2000 by the California Department of Finance (1993) is 25 percent higher than the population projected by Alfred Gobar and Associates (1993). Many variables presently (1994) cannot be predicted with accuracy, including national and local economics and construction of major transportation facilities (for example, a proposed international airport at Palmdale and a proposed high-speed rail line through Palmdale). Various population forecasts are presented in this report to show the range in estimates of population growth that presently (1994) exists.

California City, Acton, Agua Dulce, Vincent, and Lake Hughes are outside the boundary defined as the Antelope Valley but are within the Antelope Valley-East Kern Water Agency service area. Demand for water outside the Antelope Valley may decrease the availability of imported water for the Antelope Valley water users. Growth plans for these communities are an important consideration in terms of future availability of imported water. For example, actual populations in 1980 and 1990 and forecasted population for 2010 for California City are 7,384; 15,075; and 36,185, respectively, indicating a significant increase in future water demand.

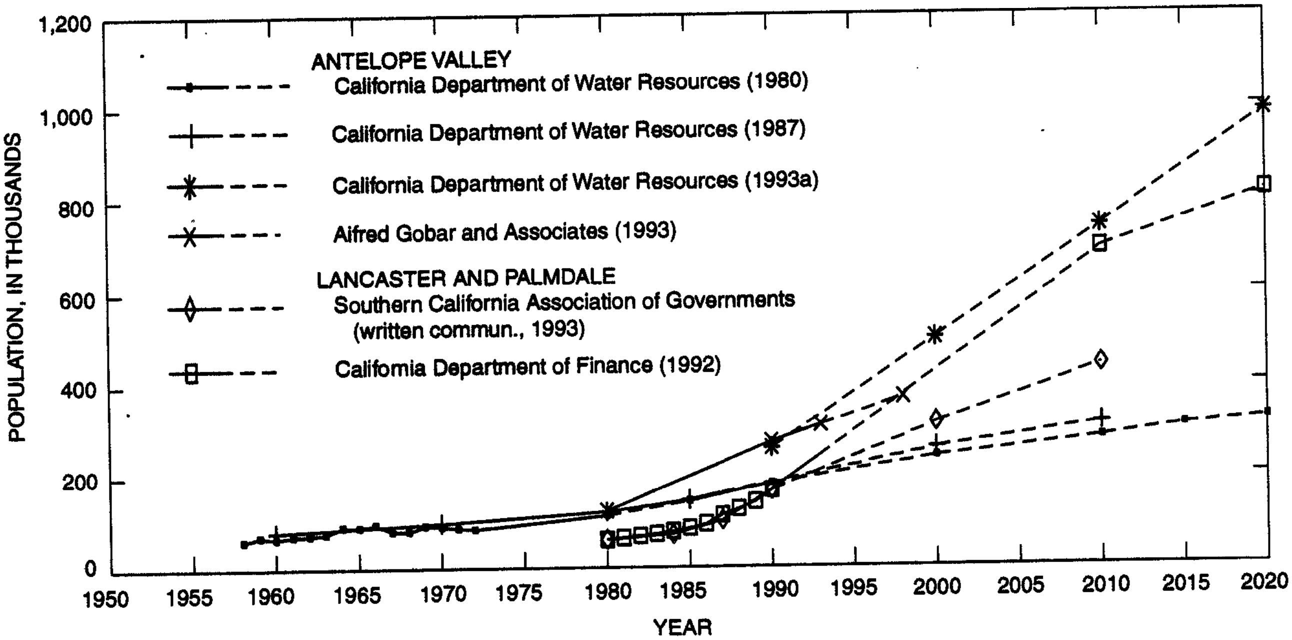

Figure 3. Population trends and projections (dashed part of lines) for the Antelope Valley, 1960-2020.

LAND USE

Water use in the Antelope Valley varies directly with land use. Historically, this valley was developed primarily around alfalfa farming and the aerospace industry. Water use required for production of crops is related directly to the acreage of land irrigated, crop-water requirements, irrigation methods practiced, and other factors such as effective precipitation, soil-salt leaching requirements, and soil conditions. As agricultural land use has decreased, agricultural water use similarly has decreased, and as urban land use has increased, urban water use also has increased. The net change has been a decrease in water use since the 1950's.

The change in land use from agricultural to urban is reflected in the land-use information for 1973-92 (figs. 4-7). Large cropland and pasture areas shown in the land-use map for the mid-1970's (fig. 4) represent about 35,000 acres, less than half of the 73,000 acres irrigated in the early 1950's (fig. 6, table 1). Similar reductions in water use have been observed (California Department of Public Works, 1955; California Department of Water Resources, 1980). By 1987, irrigated land had decreased from 73,000 to 15,762 (22 percent) acres and by 1992 it had decreased to 12,854 (18 percent) acres (fig. 5). Land-use maps for 1984 and 1990 (fig. 7) confirm these trends, showing a decrease in prime farmland (12 percent) and an increase in residential and other urban acreage (46 percent). Land-use planning for urban expansion is emphasized in additional mapping of future planned conditions done in 1990 by the Los Angeles County Department of Regional Planning (not available for inclusion in this report). This mapping indicates that increased urban land use is expected and that similar increases in water use can be anticipated.

Land-use mapping can be done at various levels of detail as described by Anderson and others (1976, p. 7). They defined four levels of land-use mapping on the basis of the source and resolution of remotely sensed data. Resolution is the detail that can be shown on a map and is dependent on altitude and scale. The following description of a multilevel land-use and land-cover classification system helps in understanding these variations. Level I and Level III land-use data for the Antelope Valley are presented in this report.

Classification level	Typical data characteristics
I	Satellite-imagery data
II	High-altitude data taken at altitudes greater than 40,000 ft above land surface (less than 1:80,000 scale)
III	Medium-altitude data taken at altitude between 10,000 and 40,000 ft above land surface (1:20,000 to 1:80,000 scale)
IV	Low-altitude data taken at altitude below 10,000 ft above land surface (more than 1:20,000 scale).

Table 1. Irrigated and nonirrigated land use by year and crop type

[See footnotes for sources used. Acreage by crop type may not always provide total irrigated acreage when some data were not available. --, no data available]

Year	Irrigated land use by crop type, in acres						Total, in acres	
	Alfalfa	Pasture and turf	Grain	Field crops	Truck	Deciduous trees/vines	Irrigated	Non-irrigated
Los Angeles County part of Antelope Valley[1]								
1940	26,600	--	100	--	400	2,183	29,283	49,552
1941	26,600	--	100	--	400	2,222	29,322	51,292
1942	26,600	--	100	--	400	2,239	29,339	47,109
1943	25,600	--	100	--	400	2,150	28,250	46,075
1944	26,600	--	100	--	380	2,035	29,115	45,795
1945	30,200	--	100	--	475	1,870	32,645	48,025
1946	33,100	--	100	--	1,035	1,902	36,137	48,425
1947	36,730	252	100	--	953	2,032	40,067	53,860
1948	37,320	456	100	420	1,287	2,057	41,640	54,820
1949	39,035	85	100	760	625	2,242	42,847	57,740
1950	34,125	91	100	2,720	716	2,260	40,012	55,092
1951	34,945	1,341	100	3,890	915	2,342	43,533	9,332
1952	36,550	1,380	100	4,100	585	2,224	44,939	54,074
1953	37,900	2,330	100	4,300	770	2,299	47,699	50.582
Antelope Valley, total								
1910[2]	2,500	--	--	--	--	--	--	--
1912[2]	--	--	--	--	--	--	4,629	--
1916[2]	--	--	--	--	--	--	10,000	--
1919[2]	7,155	--	--	--	--	4,655	11,810	--
1920[2]	7,400	--	--	--	--	4,900	12,300	--
1922[2]	7,000	--	--	--	--	4,700	--	--
1924[2]	12,000	--	--	--	--	4,780	16,780	--
1929[2]	25,000	--	--	--	--	--	--	--
1930[2]	22,000	--	--	--	--	--	--	--
1931[2]	21,700	--	--	--	--	--	--	--
1934[2]	15,317	--	--	--	--	--	23,800	--
1935[2]	16,000	--	--	--	--	--	--	--
1938[2]	23,000	--	--	--	--	--	--	--
1940[2]	24,202	1,113	--	--	--	1,950	--	--
1945[2]	29,600	5,850	--	--	--	1,870	37,320	--
1949[3]	62,100	100	4,200	200	100	4,500	71,200	88,470
1950[2]	38,525	13,022	--	--	--	2,375	53,922	--
1959[3]	--	--	--	--	--	--	50,000	--
1975[3]	--	--	--	--	--	--	35,000	--
1987[4]	8,810	1,050	1,330	60	2,380	2,000	15,630	--
1987[5]	8,624	1,246	1,290	15	2,511	2,076	15,762	--
1988[6]	9,000	700	400	200	3,000	2,000	15,300	--
1992[7]	6,124	955	835	32	2,645	2,263	12,854	--
Antelope Valley, projected								
2000	500	100	0	50	200	1,350	[8]2,200	--
2010	0	0	0	20	0	1,200	[8]1,220	--
2020	0	0	0	0	0	900	[8]900	--

[1]1940-53 (California Department of Public Works, 1955, p. 18).
[2]Snyder (1955, p. 161-162).
[3]1949 (California Department of Public Works, 1955, p. 16); 1959 and 1975 (California Department of Water Resources, 1980, p. 12).
[4]California Department of Water Resources (1990b, p. 39).
[5]U.S. Geological Survey data bases, May 1994. Original quadrangle data used in California Department of Water Resources (1990b) were digitized for this study.
[6]California Department of Water Resources (1990a).
[7]U.S. Geological Survey data bases, May 1994.
[8]Preliminary projected total irrigated acreages in California Department of Water Resources (1993a, v. 2, p. 261) were rounded off to 2,000 acres in the year 2000; 1,000 acres in the year 2010; and 1,000 acres in the year 2020.

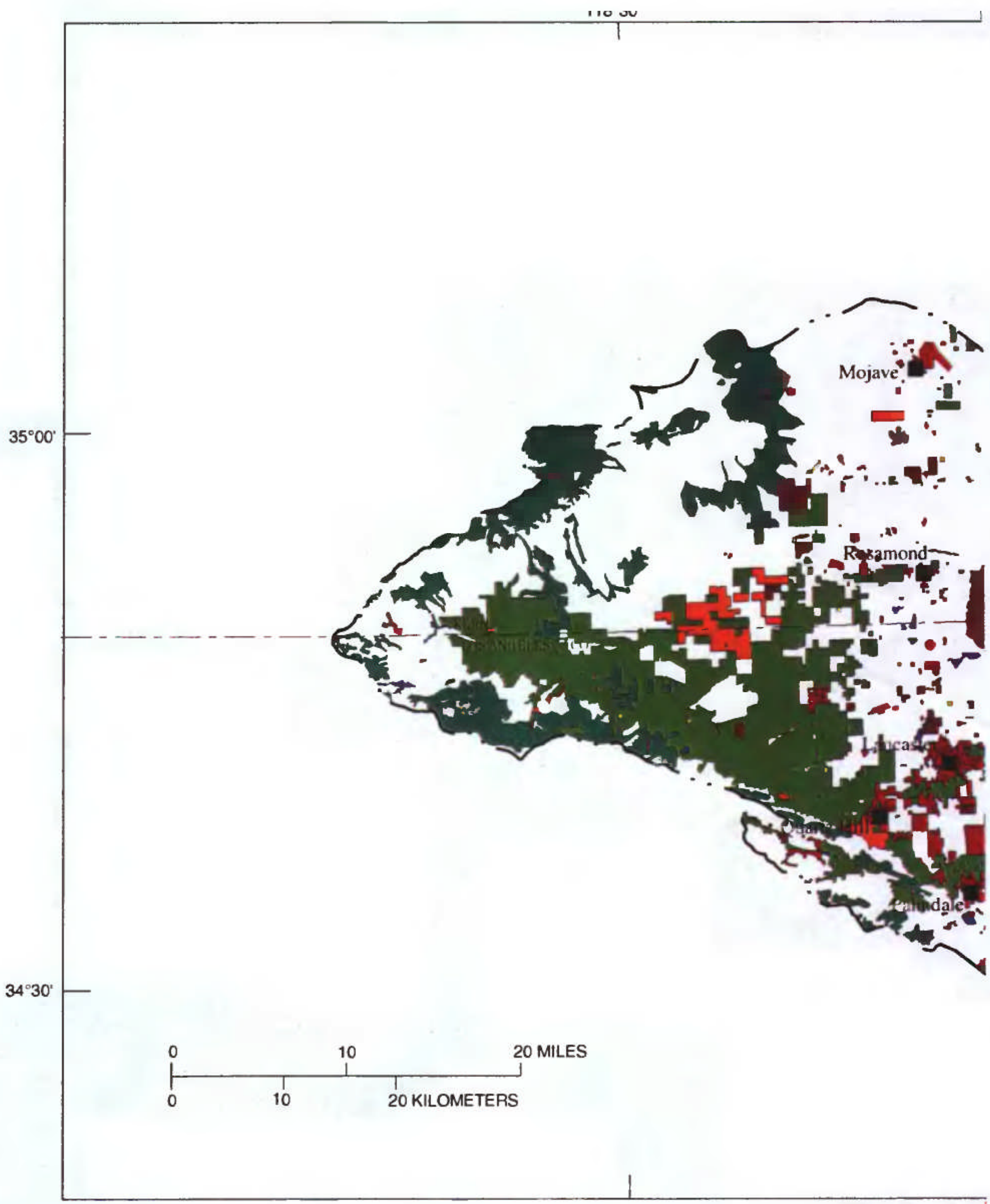

Figure 4. Land use in the Antelope Valley, 1973-77.

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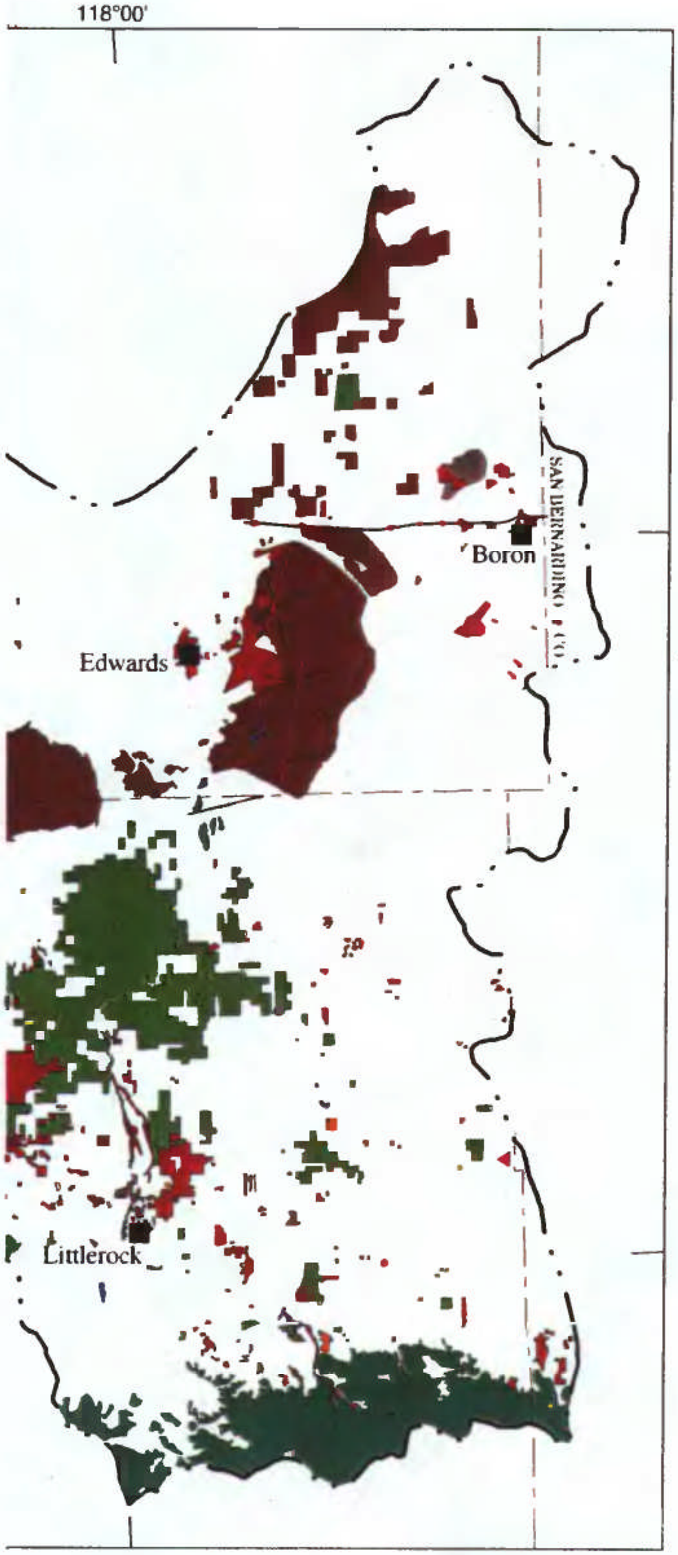

EXPLANATION

- Urban
- Cropland and pasture
- Orchards, groves, vineyards, nurseries, and ornamental horticultural areas
- Confined feeding operations and other agricultural land
- Mixed rangeland
- Mixed forest land
- Water and wetlands
- Strip mines, quarries, and gravel pits
- Sandy areas, bare exposed rock, and mixed barren land
- BOUNDARY OF ANTELOPE VALLEY

From United States Geological Survey Geographical Information Retrieval and Analysis System (GIRAS)

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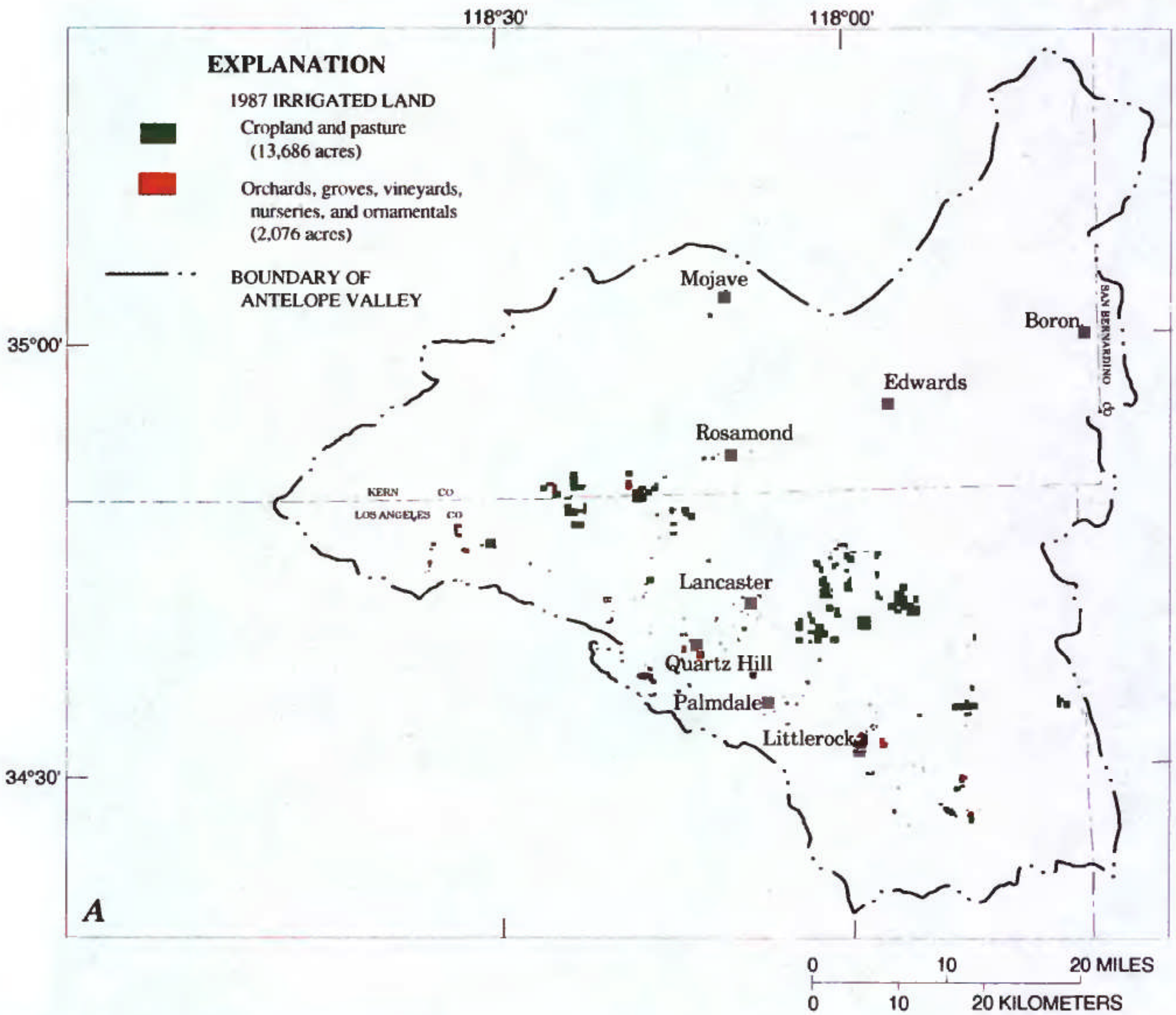

Figure 5. Land use by crop type in the Antelope Valley for ***A*** 1987 and ***B*** 1992. (Sources: California Department of Water Resources and U.S. Geological Survey data bases.)

Land-Use Classification for National Resource Appraisal, U.S. Geological Survey

Land-use mapping by the U.S. Geological Survey using the Geographic Information Retrieval and Analysis System (GIRAS) for national resource appraisal (fig. 4) is an example of Level I of the land-use classification system. Anderson and others (1976) describe this large-scale, nationwide mapping (1:100,000 or 1:250,000 scale) and the various uses of these maps. For water-use purposes, this level of mapping can indicate the types of water use in any area mapped in the nation; comparison with subsequent maps can show land-use changes—and resulting water-use changes—over time. This mapping also shows an example of what can be done with satellite imagery. Because of the relatively low resolution of the high-altitude imagery, emphasis is given to generalized land-use classifications. Irrigated land use in the Antelope Valley in 1975 (35,000 acres) was less than one-half of irrigated land use reported for the valley in 1949 (71,200 acres) (table 1). Urban land use in 1973-77 (fig. 4) is small compared with urban use in 1984 and 1990 (fig. 7).

Land-Use Classification for Statewide Planning, California Department of Water Resources

Level III of the land-use classification system is used statewide by the California Department of Water Resources to estimate water use for planning for future growth and for water management. One example of Level III land-use mapping for the Antelope Valley is the statewide mapping of urban

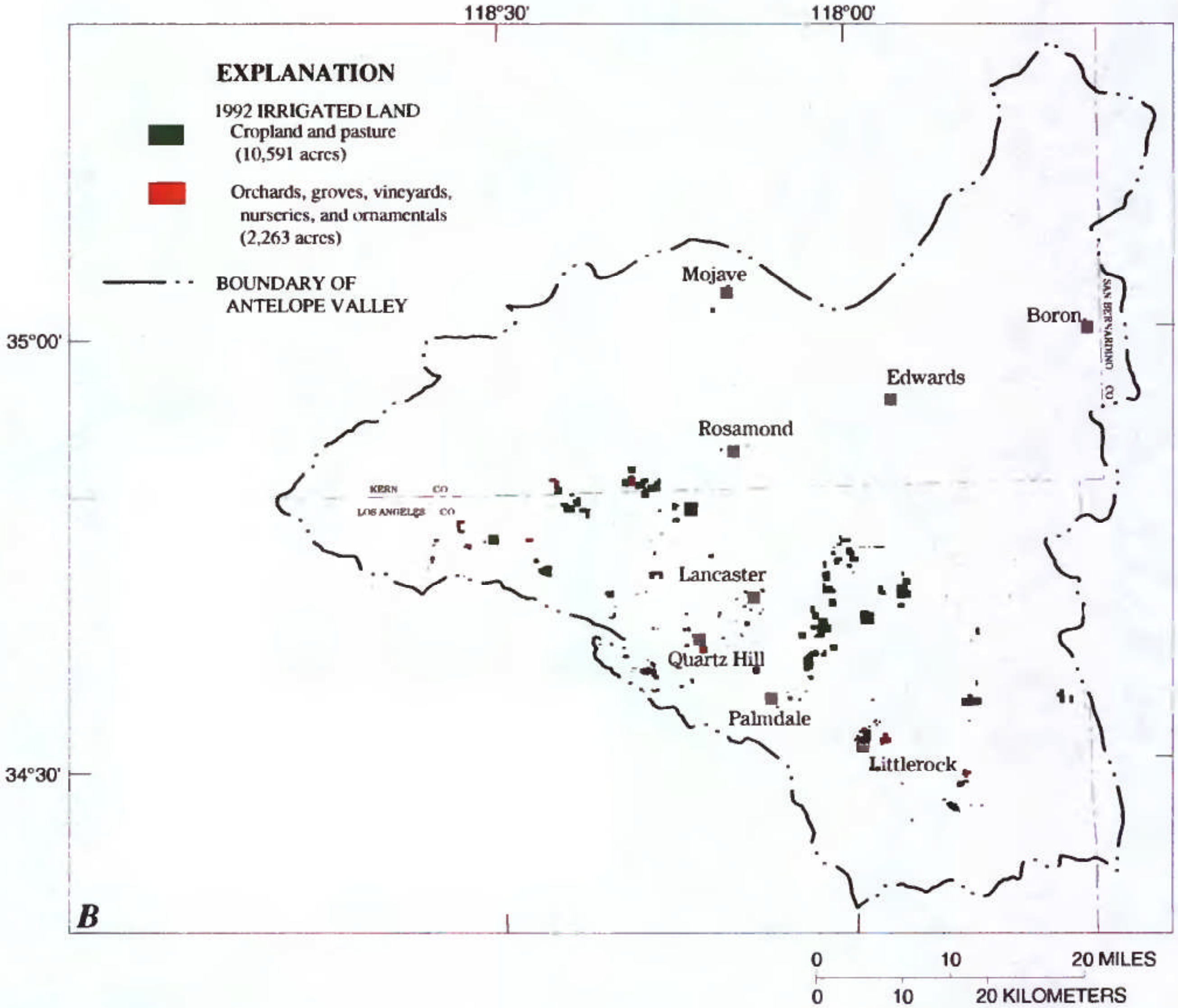

Figure 5.--*Continued*

lands, native vegetation, and irrigated and non-irrigated agricultural land done periodically by the California Department of Water Resources, Land and Water Use Sections (fig. 5). This mapping is done using aerial photography on 1:24,000 scale and 7.5-minute U.S. Geological Survey topographic quadrangle base maps and then is field verified with site visits. Emphasis is given to agricultural land use, which is required to estimate water use on the basis of acreages of irrigated crops and crop-water demands. Although the acreages and types of crops grown in the valley during the period of record have changed with time, alfalfa continues to be the primary crop (table 1). Crop diversity and total irrigated acreage has decreased greatly since the 1950's.

This method of land-use mapping has been used by the California Department of Water Resources to estimate water use in the Antelope Valley for more than 40 years. In 1949, 71,200 acres were reported to have been irrigated in the Antelope Valley. Irrigated acreage decreased to 35,000, 15,762, and 12,854 acres by 1975, 1987, and 1992, respectively (table 1). Land-use surveys in Antelope Valley were done in 1958, 1961, 1972, and 1987 (California Department of Water Resources, 1958; 1965; 1974; 1990b, p. 39). Some small differences in total acreages of crop types were noted during this study (table 1) when land-use maps done for 1987 by the California Department of Water Resources (1990b) were digitized for this study. These differences may be due to the accuracy limitations of the "cut and weigh" methods that historically have been used to estimate irrigated acreage or may be due to interpretations of land-use boundaries during digitizing. A survey of land use in the area done in 1992 as part of this study

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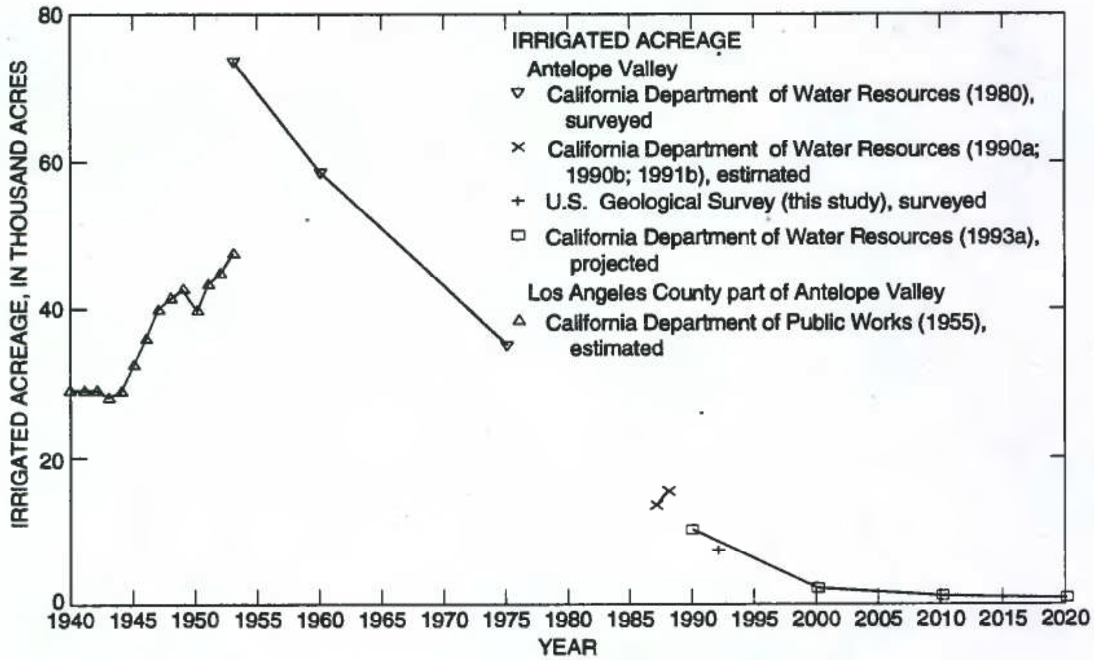

Figure 6. Surveyed, estimated, and projected land use for irrigated acreage for selected years, Antelope Valley.

indicates that cropland (primarily alfalfa) and pasture accounted for 10,591 acres of irrigated acreage (a decrease from 13,686 acres in 1987) and orchards and vineyards accounted for the remainder of the irrigated acreage, 2,263 acres (an increase from 2,076 acres in 1987). In 1987, irrigated turf areas, such as golf courses and playgrounds, accounted for 775 acres in the Antelope Valley. By 1992, irrigated turf areas increased to 895 acres and included a commercial turf farm.

Projections by the California Department of Water Resources (1993a, p. 261) for irrigated acreage in the Antelope Valley indicate a decrease in total irrigated acreage to about 2,000 acres by the year 2000; 1,000 acres by 2010; and remaining at about 1,000 acres by 2020 (table 1). These projections for irrigated acreages may be low even if we assume that no surface water or ground water will be used for irrigation by 2020. In 1990, 3,587 acre-ft of reclaimed wastewater was used for irrigation in the Antelope Valley. At 6 acre-ft/acre, almost 600 acres of alfalfa could have been irrigated. Assuming that the population increases as projected and that the present limited conservation actions continue, two or three times as much wastewater could be available for irrigation. By 2020, 1,200 to 1,800 acres could be irrigated using only reclaimed wastewater. In addition, increased use of efficient irrigation methods, such as drip irrigation, could result in increased acreage of crops that can be drip irrigated.

Land-Use Classification for Documenting Changes of Prime Farmland to Urban Use, California Department of Conservation, Farmland Mapping Program

The California Department of Conservation, Farmland Mapping Program uses Level III of the land-use classification system to document changes of prime farmland to urban use. A significant change in agricultural and urban land use occurred in the Antelope Valley between 1984 and 1990 (fig. 7). Land use for 1984 was mapped only for the Los Angeles and San Bernardino County parts of the Antelope Valley. The Kern County part of Antelope Valley was mapped for 1990. These maps show the changes in prime farmland and residential urban use. In the Los Angeles County part of the study area, urban land has expanded about 46 percent (from 26,259 to 38,422 acres) and agricultural land has decreased about 13 percent (from 55,389 to 48,933 acres) between 1984 and 1990 in the Antelope Valley, as determined from digitized maps for this study. Water use, which is related to land use, changes with changes in

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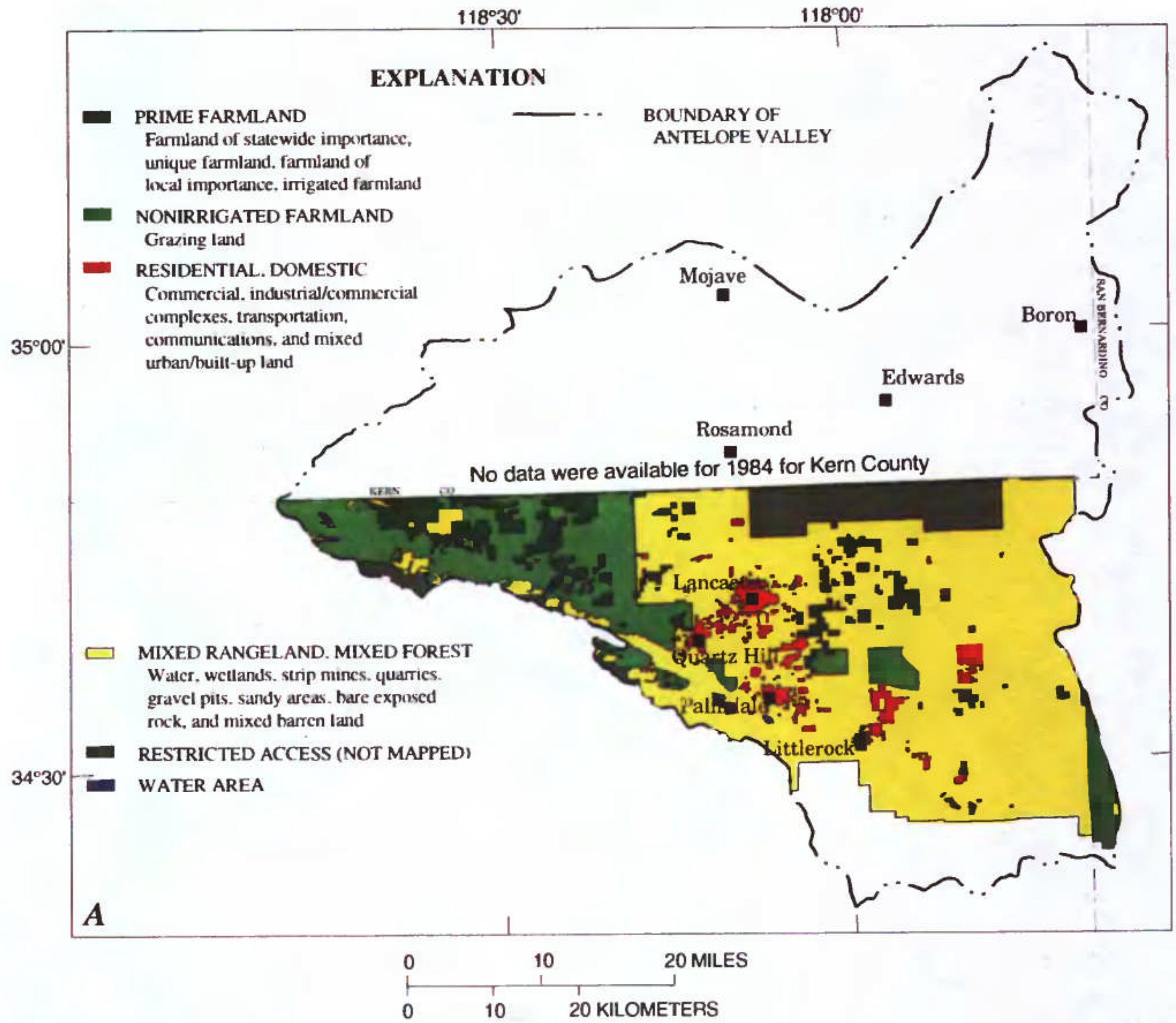

Figure 7. Land use in the Antelope Valley for ***A*** 1984 and ***B*** 1990. (Sources: California Department of Conservation, Farmland Mapping Program.)

irrigated acreage and urban land use. Therefore, changes in land use can be used to verify changes in water use for the same periods of time.

Land-Use Classification for Regional Planning, Los Angeles County Department of Regional Planning

A final example of Level III land-use mapping was done by the Los Angeles County Department of Regional Planning in cooperation with a consortium of southern California agencies for part of the Antelope Valley. In 1990, they mapped the Los Angeles County part of the study area and presently are working on an update for 1993. Aerial Information Systems (1992) modified the land-use classification system by Anderson and others (1976) to identify subgroups in greater detail. For example, the classification system by Anderson and others (1976) was further divided into classifications of single-family residential and multifamily residential with population densities also specified. These maps can be used to interpret the effects of

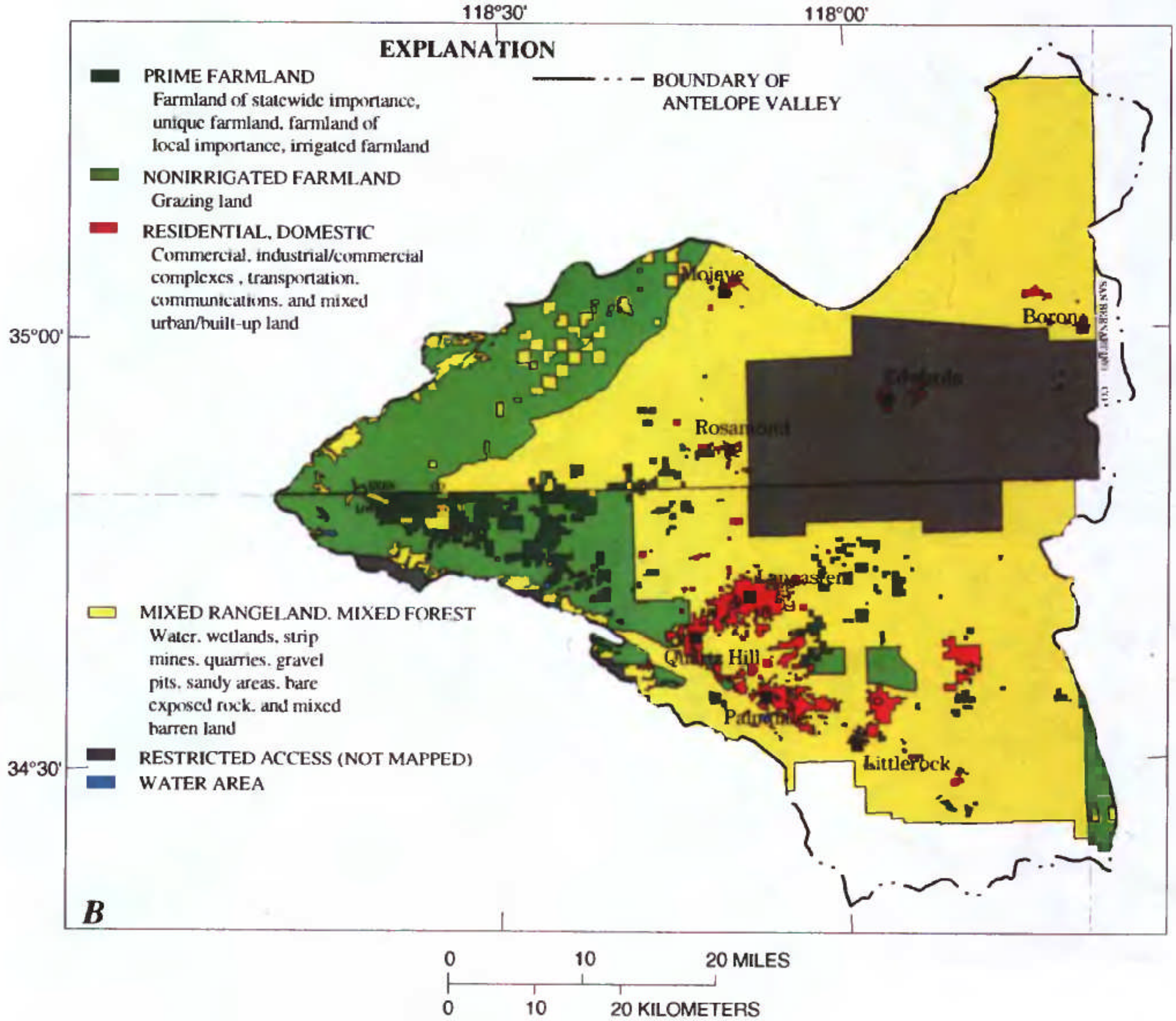

Figure 7. *Continued.*

concentrated urban growth in areas of natural ground-water recharge. For example, these maps could help future studies because the conversion of native vegetation areas to urban areas can have dramatic negative effects on recharge rates, ground-water quality, and localized stress on the aquifer. This classification system was modified by Los Angeles County Department of Regional Planning to emphasize urban land use. These maps were not available for inclusion in this report but are now available at the office of the Los Angeles County Department of Regional Planning. These maps may be available for use in digital form in the future to help anticipate and reduce effects on local ground-water levels and related land subsidence.

WATER USE

An evaluation of water use requires information related to water supply and demand. In U.S. Geological Survey reports, the meaning of the term "water use" has expanded over the years from initially meaning only supply, represented as withdrawals of water, to now include supply and demand, represented by (1) withdrawals from sources of water supplies, (2) deliveries to meet water demands by various categories of water use, (3) releases from points of use, and (4) returns to surface- and ground-water supply sources. For the purposes of this study, water supply is the water available from each water-supply source, such as

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ground water, surface water, imported water, and reclaimed wastewater, that is used to meet demands. Water demand is the volume of water required to meet the needs of irrigation, industrial, domestic, commercial and other water users. Ground-water pumpage is the quantity of water withdrawn from ground-water-supply sources to meet water demands. Data are not always available for all types of water use; thus programs need to be developed to collect these data. Presently (1994) in California, water conservation, or "demand management," also is considered a water-supply source. Water demand in the Antelope Valley historically has been discussed in two general categories, agricultural and municipal, which generally equate to self-supplied and public-supplied demands in this report.

Water demand can be estimated from land use. Changes in land use can help provide an understanding of shifts in water sources and relative locations of stress on regional ground-water resources. Such changes can provide an indication of where we can expect resultant changes in ground-water pumpage and water levels. Understanding the relation between shifting land uses and stress on local aquifers can be used to help optimize the management of ground water by distributing pumping to minimize declines in ground-water levels in any specific area.

Water Supply

In an attempt to validate previously published water-supply and demand information, a data base was created for this study using data reported by water suppliers. Historical water-supply information for the Antelope Valley was obtained by reviewing available published literature. Previous work indicates that since development of the Antelope Valley in the late 1800's ground water has been the primary water-supply source. Total water supplies for the Antelope Valley estimated by the California Department of Water Resources (1980, p. 17; 1990a; and 1991b) were about 192,600 acre-ft in 1975, 168,000 acre-ft in 1980, 152,000 acre-ft in 1985, and 118,000 acre-ft in 1988 and 1989 (table 2). Recent projections (table 2) by the California Department of Water Resources indicate that imported surface water is expected to become the primary water source for Antelope Valley by 2010.

Values in table 2 come from several different reports and were estimated in different ways. For example, estimates of "total water supply" by the California Department of Water Resources for 1975 and by the U.S. Geological Survey for 1989, 1990, and 1991 equal "total applied" demands, thus accounting for supply sources for all water demands. However, the California Department of Water Resources estimates of "total water supply" equal the "net water demands" for 1980, 1985, 1988, and 1989. The additional water supply that is required to meet "total applied demands" may be recycled water or it may be returning to the primary producing aquifers as ground-water recharge. For example, in 1988, that recharge would have been 19,000 acre-ft (137,000 acre-ft minus 118,000 acre-ft). Therefore, in 1988, total ground-water withdrawals may have been 88,000 acre-ft (69,000 acre-ft plus 19,000 acre-ft) and in 1989 total ground-water withdrawals would have been 79,000 acre-ft (53,000 acre-ft plus 26,000 acre-ft). Further descriptions of "net" water demand and "total applied" water are in the discussion of ground-water supply later in this report.

The following is an overview of water-supply data reported by water suppliers in the Antelope Valley compiled for this study (fig. 8). This study relied on available data reported by or to various public agencies. Many inherent inaccuracies in reported water use have been identified by previous studies in other states (Kenny, 1986; Holland and Baker, 1993). This study, however, serves as a first step toward improving the reliability of water-use information for the Antelope Valley by documenting the limitations of the existing data. Specific information on the sources of the data and related discussions on each data base follow this overview of water supply. Estimates of total water supply (mostly from ground water) for the Antelope Valley in 1953 were as high as 480,000 acre-ft (California Department of Public Works, 1955). Water supplies available for use in the Antelope Valley (Los Angeles County part only) reportedly peaked in 1956 at about 270,000 acre-ft and then decreased until 1972, with total reported water supplies used that year about 100,000 acre-ft (fig. 8). Annual total reported water-supply use increased to nearly 150,000 acre-ft in 1978, with increased imported water into the Antelope Valley. Between 1981-83, annual total reported use of available water supplies decreased dramatically, reaching a low of about 90,000 acre-ft/yr. An

Table 2. Water supplies and demands in the Antelope Valley, with historical and recent projections to 2020

[Imported water represents water purchased from California State Water Project contractors by water suppliers within this study-area boundary for the Antelope Valley. --, no data available]

Year	Water-supply source, in acre-feet per year					Water demands, in acre-feet per year				
	Ground water	Local surface water	Imported water	Reclaimed waste-water	Total	Agri-culture	Municipal and industrial losses	Recreation, energy, and convey-ance losses	Total applied (or gross)	Net
1949-50[1]	--	--	--	--	--	221,900	3,700	--	--	225,600
1953[1]	480,000	--	--	--	--	--	--	--	--	240,000
1975[2]	178,700	--	--	--	192,600	166,300	26,300	--	192,600	--
1980[3]	82,000	4,000	78,000	4,000	168,000	205,000	40,000	1,000	246,000	168,000
1985[3]	103,000	4,000	41,000	4,000	152,000	115,000	47,000	5,000	167,000	152,000
1988[4]	69,000	4,000	41,000	4,000	118,000	70,000	62,000	5,000	137,000	118,000
1989[5]	53,000	4,000	55,000	6,000	118,000	49,000	90,000	5,000	144,000	118,000
1989[6]	71,018	4,318	[7]50,405	[8]4,835	130,576	48,843	81,733	--	130,576	--
1990[6]	66,707	2,165	[7]53,087	[8]6,038	127,997	45,797	82,200	--	127,997	--
1991[6]	[9]91,743	1,669	[7]27,396	[8]6,553	127,361	35,279	92,082	--	127,361	--
Historical Projections										
2000[2]	--	--	--	--	--	165,000	133,400	--	299,650	--
2020[2]	--	--	--	--	--	165,000	90,000	--	255,000	--
Recent Projections by California Department of Water Resources										
2010[3]	47,000	4,000	87,000	7,000	145,000	64,000	104,000	7,000	175,000	145,000
2010[10]	12,000	5,000	108,000	2,000	127,000	4,000	115,000	8,000	185,000	127,000
2020[10]	50,000	5,000	108,000	2,000	165,000	4,000	153,000	8,000	246,000	165,000

[1]California Department of Public Works, (1955, p. 20 and 23).
[2]California Department of Water Resources (1980, p. 11 - 16).
[3]California Department of Water Resources (1988, p. 37).
[4]California Department of Water Resources (1990a, p. 21).
[5]California Department of Water Resources (1991b p. 19).
[6]U.S. Geological Survey water-use data bases, May 1994.
[7]The volumes reported for State Water Project imports include only that part of the delivery to the contractors in the Antelope Valley that was delivered to water users in the Antelope Valley defined in this study. Antelope Valley-East Kern Water Agency supplies water to water users in communities outside of the study-area boundary.
[8]This number is the sum of reclaimed wastewater that was used for agricultural irrigation, wetlands maintenence, and recreational water uses.
[9]This number is the sum of ground water pumped by public suppliers (45,208 acre-feet), self suppliers for their own use (30,877 acre-feet), and self suppliers who sold water to Antelope Valley-East Kern Water Agency to supplement State Water Project imports that were not received because of the drought (15,658 acre-feet).
[10]California Department of Water Resources (Verne Knoop, written commun., preliminary data for Bulletin 160-93, 1993). Total applied water demand for 2010 and 2020 from California Department of Water Resources (1993*a*, p. 260 and 263).

aberration during data recordation created an artificially low annual total for reported use of water supplies in 1988. Since then, annual total reported use of water supplies peaked in 1989 at 130,000 acre-ft and then declined slightly to about 128,000 in 1990 and 127,000 acre-ft in 1991 (fig. 8).

A comparison of the data base developed for this study with published information indicates differences in total reported annual water use between 10 percent and 35 percent. For example, total reported water use from this data base for the Antelope Valley was 130,576 acre-ft in 1989 (tables 2 and 3); the California Department of Water Resources (1991, p. 19) reported that total water use was about 118,000 acre-ft (table 2). This comparison indicates a need for coordination of water-use data from individuals and agencies at all levels of government. This coordination already has begun for the Antelope Valley with the completion of this study and the development of the data base that is continuing through the efforts of the Antelope

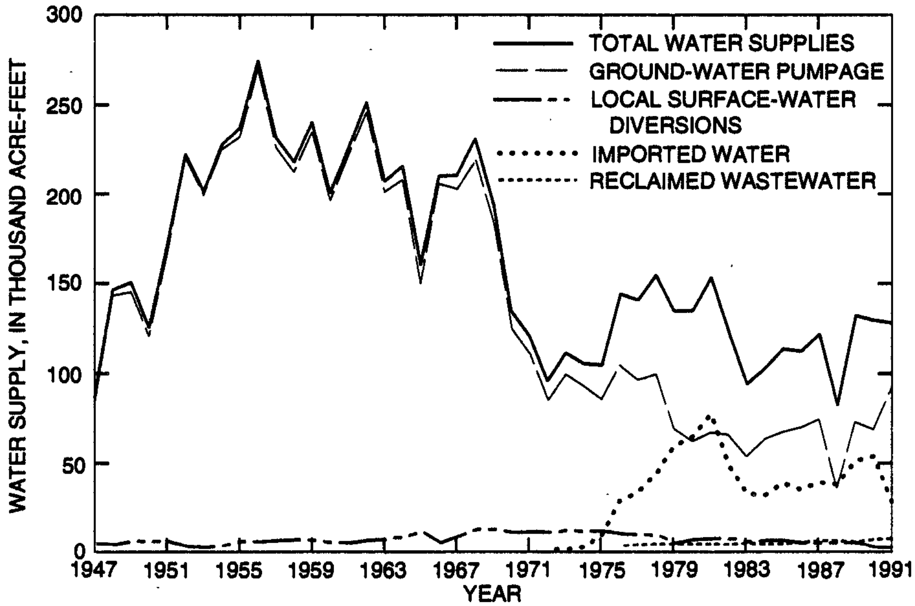

Figure 8. Total water supplies for the Antelope Valley for 1947-91 from the data base developed for this study. Historical ground-water pumpage data were available primarily for the Los Angeles County part of the valley; therefore, these estimates of total water supplies are low.

Valley Water Group. Since 1991, coordination of water-use information also has begun statewide through efforts of the U.S. Geological Survey and the California Department of Water Resources. A statewide interagency water-use coordination committee was formed. The committee has four actively working subcommittees that deal with the coordination and improvement of information on land use, ground-water use, urban water use, and agricultural water use. Similar groups could be formed in the Antelope Valley to help improve information sharing and increase information reliability and completeness.

Ground-Water Supply

Historically, the ground-water-storage capacity for the Antelope Valley was estimated to be 68 million acre-ft; in 1975, total ground water remaining in storage was estimated to be 55 million acre-ft (California Department of Water Resources, 1980, p. 25). Snyder (1955) estimated that ground water, available in storage in 1954, would last 35 to 65 years, depending on the rate of growth in the area. Useable storage was estimated to be 20 million acre-ft on the basis of 1980 data (California Department of Water Resources 1993a, table 4-2). An updated (possibly more accurate) estimate of useable ground-water-storage capacity and of remaining total ground-water storage is needed for the Antelope Valley.

Use of available ground-water supplies from aquifers typically is quantified as withdrawals from ground-water sources (also referred to as ground-water pumpage). The period of record for ground-water pumpage, compiled for this report from various published sources, starts in 1919 and continues through 1990 (fig. 9, table 4). Estimates of ground-water pumpage in 1951, which were based on records of electrical power use and consumptive use, ranged from about 400,000 acre-ft (gross) to 149,000 acre-ft (net) (Snyder, 1955, p. 64). Snyder (1955, p. 68) described net pumpage to be the consumptive-use part of the total applied water. He assumed irrigation efficiency to be about 50 percent; thus 149,000 acre-ft net is equal to 298,000 acre-ft gross. More water may actually have been consumptively used than Snyder assumed because much of the water he assumed was recharging ground water may have been retained in the unsaturated zones above the useable ground water. Ground-water-quality data (Duell, 1987) also support the idea that Snyder's consumptive-use estimate may have been low because the data do not indicate increased salinity following the peak irrigation years. Increased salinity would be expected if about 50 percent of the applied water actually were recharging the aquifer.

Ground-water pumpage values from the California State Water Resources Control Board (State Board) for the late 1940's and early 1950's are much lower than those estimated by Snyder (1955). In 1951, for example, the California State Water Resources Control Board estimated that ground-water pumpage was about 165,000 acre-ft compared with about 400,000 acre-ft estimated by Snyder (1955). This large discrepancy probably is a result of significant underreporting of water use to the State Board at that time and the fact that Kern County was not included in the State Board data base.

Table 3. Selected water-use information by water supplier and water-supply sources summarized from data bases created for Antelope Valley, 1989-91

[Imported water represents water purchased from State Water Project contractors by water suppliers within this study-area boundary for the Antelope Valley]

Water supplier	Water-supply source, in acre-feet per year				
	Ground water	Local surface water	Imported water	Reclaimed waste-water	Total water supply
1989					
Public supplied	43,098	1,191	32,609	4,835	81,733
Self supplied	27,920	3,127	17,796	0	48,843
Total	71,018	4,318	50,405	4,835	130,576
1990					
Public supplied	39,400	46	36,716	6,038	82,200
Self supplied	27,307	2,119	16,371	0	45,797
Total	66,707	2,165	53,087	6,038	127,997
1991					
Public supplied	45,208	36	[2]24,627	6,553	76,424
Self supplied	[1]46,535	1,633	2,769	0	50,937
Total	91,743	1,669	27,396	6,553	127,361

[1]In 1991, 15,658 acre-feet of ground water was pumped by private well owners included in our self-supplied data bases. This water was sold to Antelope Valley-East Kern Water Agency (see footnote 2). To avoid double accounting in this table, this volume is included in the ground-water column for "Self-supplied water" because it came from ground-water supplies. In table 8 of this report, the 15,658 acre-feet in 1991 is shown in the column for "Imported water" because that table emphasizes water use.

[2]For 1991, this number is lower by 15,658 acre-feet than is reported in table 8 because this table emphasizes water-supply sources; in table 8, emphases is on the location of the water used. In 1991, water was pumped from self-supplied wells and sold to the Antelope Valley-East Kern Water Agency to supplement shortages in deliveries to public water suppliers because of the drought.

Water supplies obtained from ground-water sources also have been estimated by the California Department of Public Works (1955, p. 20; California Department of Water Resources, 1980, p. 17; 1990a; 1991b) at about 480,000 acre-ft in 1953; 178,700 acre-ft in 1975; 58,000 acre-ft in 1980 and 1985; 69,000 acre-ft in 1988; and 53,000 acre-ft in 1989 (table 4).

Some problems were identified when we compared published estimates of ground-water pumpage from various sources with reported ground-water pumpage. These problems include (1) differences in reported volumes of pumpage; (2) variations in the interpretation of the area within the Antelope Valley boundaries; (3) periods of missing data and data that show no variation from one year to the next, and (4) comparison of water supplies for a larger area than was used for estimating water demands.

Several solutions were implemented for this study to minimize these problems. One solution was development of a common base map that delineated the most widely accepted border for the drainage basin for the Antelope Valley. This basin boundary compares well with the boundaries used by Bloyd (1967), Duell (1987), and the California Department of Water Resources. However, the boundary used by Durbin (1978) differs substantially from all other studies of the valley because it was based on the assumption (for modeling purposes) that no flow crosses a fault along the northern boundary of the study area. Totals for water supply and demand from these studies with similar boundaries should compare well with the totals in this report; totals from Durbin (1978), however, could be expected to be lower.

A second solution implemented to minimize problems with the published aggregated pumpage

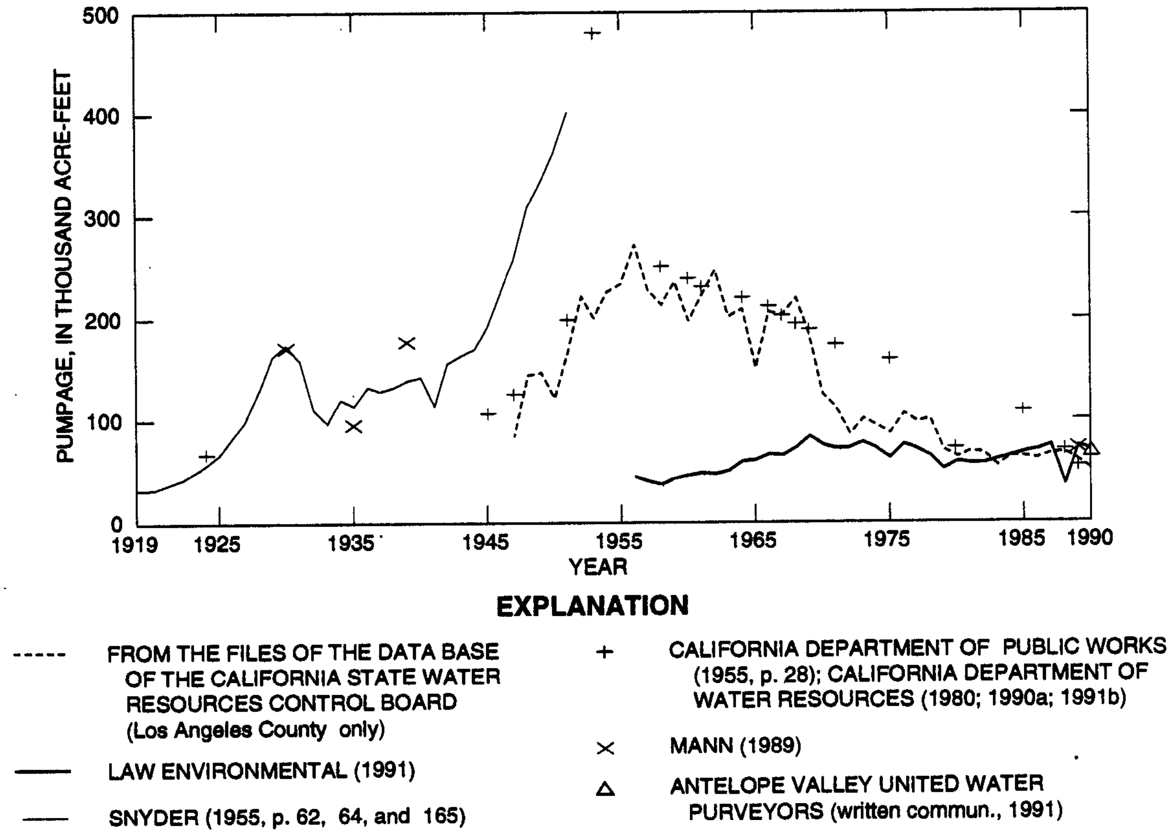

Figure 9. Historical published estimates of ground-water pumpage for the Antelope Valley.

data in the study area was to develop a computerized ground-water pumpage data base categorized by water user and by method of supply (either self supplied or public supplied). Users who supply their own water are classified as self-supplied users; users who are supplied by a government or private entity are classified as public-supplied water users. This ground-water pumpage data base includes partial data for 1946-92, but because the data are severely limited for 1946 and 1992, 1947 to 1991 was used as the period of record (fig. 10). In 1987, the quantity of water withdrawn by public suppliers exceeded the quantity withdrawn by self suppliers for the first time (fig. 10), indicating that municipal use of ground water had begun to exceed agricultural use. A summary of the data base for 1989-91 indicates ground-water pumpage accounted for 71,018; 66,707; and 91,743 acre-ft in 1989, 1990, and 1991, respectively (table 3). Although the ground-water pumpage data base from the California State Water Resources Control Board is limited to wells in the Los Angeles County and San Bernardino parts of the Antelope Valley, it is the best data available for use in developing a complete data base for ground-water pumpage from wells.

The data base used for this study was developed using the original data reported by well owners to the State Board, augmented by pumpage records of individual public water suppliers, as well as water sources and uses reported to the California Department of Water Resources. Land-use information and power-consumption data often can be used to assure the completeness of a ground-water data base. In the Antelope Valley, indications of urban and agricultural land-use information (from all sources in this report) compared favorably with our data base. Power-consumption data could not be used to estimate pumpage for comparison because the locations of the power meters were not available. Additional improvements in estimates of historical agricultural water demand may still be possible using land-use and power-consumption data. However, these improvements could require a substantial investment of time and resources.

Total reported ground-water pumpage for the Los Angeles County part of the Antelope Valley peaked in 1956 at about 270,000 acre-ft (fig. 8). This peak was followed by a gradual decrease in pumpage until 1968, with reported pumpage only

Table 4. Estimates of annual ground-water pumpage in the Antelope Valley, 1919-91

[Pumpage, in thousand acre-feet per year]

Year	California State Water Resources Control Board (Los Angles County only): Number of wells pumped	California State Water Resources Control Board (Los Angles County only): Pumpage	Law Environmental (1991)	Snyder (1955) Power method (p. 165): Total withdrawals (gross)	Snyder (1955) Power method (p. 165): Total withdrawals (net)	Snyder (1955) Consumptive-use method (p. 166 & 167): Total applied (gross)	Snyder (1955) Consumptive-use method (p. 166 & 167): Total applied (net)	Snyder (1955) Ground-water level-change method (p. 78): Total applied (gross)	California Department of Water Resources (1980, 1990a, 1991b)	Mann (1989)	Mark Johnstone (Antelope Valley United Water Purveyors, written commun., 1991)	Los Angeles County Department of Public Works (1991)
1919							29.40		31.00			
1920								30.60				
1924				54.79	27.00				66.70			
1925				64.77	32.00	90.00	45.70					
1926				81.37	41.00							
1927				97.98	49.00	115.00	63.10					
1928				128.67	64.00							
1929				161.42	81.00	152.00	77.60					
1930				172.59	86.00	140.00	68.50			170.00		
1931				157.55	79.00							
1932				109.13	55.00							
1933				95.63	48.00							
1934				119.30	60.00							
1935				112.88	56.00	100.00	48.90			95.00		
1936				131.16	66.00							
1937				127.36	64.00							
1938				130.95	65.00							
1939				137.18	69.00				176.43			
1940				141.05	82.00	155.00	82.10	25.99				
1941				113.45	58.00			31.23				
1942				155.42	79.00			96.99				
1943				162.71	82.00			62.64				
1944				169.32	86.00			27.47				
1945				192.49	98.00	210.00	103.90	119.02	106.00			
1946	3	0.83		225.65	115.00	220.00	111.60	39.47				
1947	158	82.64		258.66	123.00	235.00	121.10	157.97	125.00			
1948	265	142.39		308.57	137.00	310.00	131.90	92.24				
1949	281	144.52		333.41	142.30	335.00	133.40	120.44				
1950	218	119.67		362.52	150.50	350.00	142.10	123.65				
1951	321	165.41		400.84	168.00	370.00	149.10	142.86	198.00	Early 1950's		
1952	367	219.12								300.00 to		
1953	403	192.44							480.00	400.00		
1954	418	222.60										
1955	413	229.53				[1]440.00	[1]183.20					

See footnote at end of table.

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Table 4. Estimates of annual ground-water pumpage in the Antelope Valley, 1919-91--*Continued*

Year	California State Water Resources Control Board (Los Angles County only)		Law Environmental (1991)	Snyder (1955)					California Department of Water Resources (1980, 1990a, 1991b)	Mann (1989)	Mark Johnstone (Antelope Valley United Water Purveyors, written commun., 1991)	Los Angeles County Department of Public Works (1991)
				Power method (p. 165)		Consumptive-use method (p. 166 & 167)		Ground-water level-change method (p. 78)				
	Number of wells pumped	Pumpage		Total withdrawals (gross)	(net)	Total applied (gross)	(net)	Total applied (gross)				
1956	487	267.66	43.75									
1957	468	223.08	39.27									
1958	463	208.14	36.19									
1959	458	229.48	41.91									
1960	383	190.59	44.90				[1]228.60					
1961	422	215.25	47.29									
1962	414	239.18	46.31									
1963	399	194.31	49.02									
1964	397	199.42	58.07									
1965	267	140.67	59.57									
1966	354	197.11	65.40									
1967	335	194.17	64.51									
1968	349	216.46	71.78									
1969	315	180.16	72.40									
1970	218	121.54	73.41				280.00					
1971	204	107.50	69.76									
1972	150	81.90	70.09									
1973	189	96.19	75.91									
1974	181	89.31	70.36									
1975	167	81.49	61.45						178.70			
1976	185	94.13	74.41									
1977	186	86.07	70.47									
1978	176	88.82	64.04									
1979	38	11.04	50.80									
1980	161	58.27	57.59						58.00			
1981	158	58.12	55.90									
1982	147	57.89	55.82									
1983	122	45.48	59.51									
1984	131	55.43	63.52									
1985	166	60.14	62.38						58.00			
1986	151	61.04	60.42									
1987	157	65.34	65.14									
1988	75	25.31	66.66						69.00			
1989	145	62.10	59.07						53.00	70.85		41.42
1990	130	46.27	49.80								67.71	
1991	169	67.61										

[1]California State Water Resources Control Board, Ground Water Extractions Data Base

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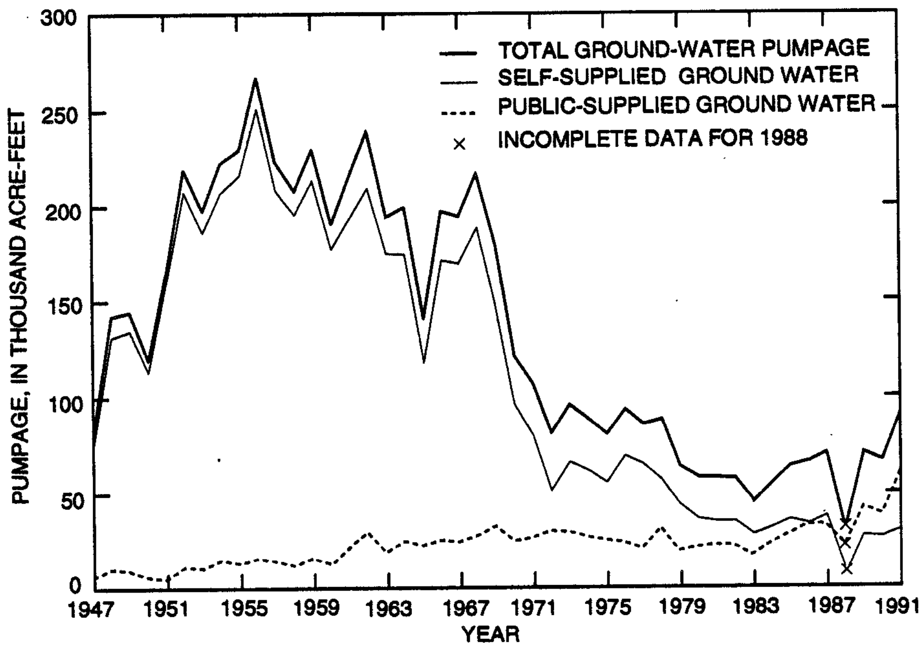

Figure 10. Ground-water pumpage from data base developed for this Antelope Valley study, 1947-91.

about 219,000 acre-ft. Between 1968-72, reported pumpage decreased dramatically, reaching a low of about 85,000 acre-ft/yr just before imported water from the State Water Project became available. The decrease in ground-water pumpage then became more gradual, reaching a low of about 53,200 acre-ft in 1983. Since 1983, reported pumpage has increased. In recent years, which were characterized by rapid urban growth and drought, between 50 and 90 percent of total annual water demands in the Antelope Valley was from ground-water pumpage. In 1991, when little imported water was available, total pumpage was about 91,743 acre-ft.

The first year for which reported ground-water pumpage data acquired for the Kern County part of this study area was 1947 for Edwards Air Force Base, 1989 for Mojave and Rosamond, and 1958 for the Boron area. The lack of reported pumpage data for Kern County represents a significant omission in estimated pumpage, particularly for the 1950's and 1960's.

Edwards Air Force Base, the town of Mojave, and the U.S. Borax and Chemical Corporation account for most of the ground water presently (1994) used in the Kern County part of the Antelope Valley. Reported pumpage (table 18 at back of report) at Edwards Air Force Base increased from about 600 acre-ft in 1947 to about 6,700 acre-ft in 1965 and remained at about 6,000 acre-ft/yr until 1967. Pumpage data is missing for the period 1968 through 1975 (R.F. Weston, Inc., 1986; 1988). Between 1976 and 1990, annual pumpage at Edwards Air Force Base decreased from about 6,300 acre-ft to about 5,330 acre-ft (table 18 at back of report). In 1991 and 1992, reported pumpage decreased further to 3,700 and 3,400 acre-ft/yr, respectively. Mojave accounted for about 1,200 to 1,300 acre-ft/yr of pumpage during 1989-91. Annual pumpage for U.S. Borax and Chemical Corporation peaked at about 3,000 acre-ft in 1977 and decreased to about 1,200 acre-ft by 1991, partly due to use of imported water from the State Water Project.

Comparisons between published annual historical water use for the Antelope Valley (California Department of Water Resources, 1991b) and the data base developed for this study indicate the following differences. Reported withdrawals from ground-water supplies for 1989 were 53,000 acre-ft compared with 71,018 acre-ft in our data base (tables 2 and 4). These results indicate that the total for ground-water withdrawals contained in the data base for this study are 34 percent higher than the published net for ground-water withdrawals. Data compiled for 1991 show that ground-water use increased 29 percent to 91,743 acre-ft in just 2 years, indicating that dramatic changes in water use can occur in a short period of time. There is a great potential for error if close attention is not paid to (1) annual monitoring of available water-supply information and (2) quality assurance of pumpage reported by users to the State Board.

Presently (1994), estimates of total ground-water pumpage included in the data base developed for this study are low because our data base is still incomplete for some water users and for some years throughout the period of record. Historically, not all users are included in the State Board data base for every year; as a result, totals from our data base are low. Data are severely limited for Kern County water users for much of the period of record. Data were found as part of our augmentation of the State Board's data base for some water users in the Kern County part of the Antelope Valley. Data obtained from the State Board's computer files included only reported pumpage from wells in four California counties: Los Angeles, San Bernardino, Ventura, and Riverside. However, only Los Angeles and San Bernardino County wells within the study area were retained from the original data base extracted for the Antelope Valley.

The lack of reported ground-water pumpage data for Kern County for earlier years represents significant errors or omissions in estimates of historical ground-water pumpage. To help reduce these errors, Kern County pumpage can be estimated on the basis of irrigated acreage if we assume that the water requirements of crops planted in Kern County were similar to crops planted in Los Angeles County. Using crop acreages for the parts of Kern County and Los Angeles County within our study area in 1953 (table 1) and reported self-supplied ground-water pumpage in Los Angeles County during 1953 (fig. 10), we estimated total ground-water pumpage for the entire Antelope Valley for 1953. Using this method, our estimate of total ground-water pumpage for the Antelope Valley during 1953 increased from the reported 192,000 to 308,000 acre-ft. Using this correction factor, based on the 1953 data and the peak ground-water pumpage reported for the Los Angeles County part of the Antelope Valley (267,660 acre-ft, table 4), total ground-water pumpage for the entire Antelope Valley was estimated to have been about 429,000 acre-ft in 1956. This valleywide pumpage estimate is consistent with previous estimates of 400,000 acre-ft/yr by Snyder (1955) and 480,000 acre-ft/yr by the California Department of Public Works (1955, p. 20).

Pumpage totals for wells in the Los Angeles County part of the study area do not appear to have been reported by registered well owners for every year that ground water probably was pumped. The incompleteness of the data base is caused, in part, by the State-imposed deadline of June 30 for reporting ground-water pumpage totals. Pumpage data from Recordation Notices received by the State Water Resources Control Board that were post-marked after that date were not entered for some years. Commonly, these data are kept in the State hard-copy files and we have entered them into our data base; but, for at least 1 year (1988) late reports were returned to the well owners and thus were not readily available. The effects of incomplete data can be seen on figure 10. Methods used to estimate pumpage also can influence the reliability of these estimates. For example, information pertaining to the methods that were used by each well owner to estimate their reported pumpage is noted on some of the completed Recordation Notice forms. We used this information as an indication of the accuracy of the pumpage estimates for some of the reporting water users. Some users report the methods they use to estimate their pumpage, but most users do not. For quality assurance, verification that the methods used for reported ground-water pumpage are appropriate and used accurately still needs to be done. Our observation that identical amounts of pumpage have been reported year after year by some wells owners indicates the need for closer quality assurance.

Estimates of ground-water pumpage included in the original State Board data base also may be inflated in some cases because well owners have anticipated the potential to use this data base to establish generous future water rights. In various parts of the Nation, such as Kansas (Kenny, 1986, p. 3), it is a common practice for water users to overestimate rather than underestimate their reported water use to establish future water rights. Commonly, this is done to establish a higher record of water use than actually might have occurred. However, ground-water pumpage estimates that might be represented by overreporting are not expected to approximate the ground-water pumpage that is historically absent for the Kern County area. Therefore, total ground-water pumpage in our data base is expected to be low.

The same methods used to estimate ground-water pumpage commonly are used to estimate water demand (table 4). Four methods for estimating pumpage have been used in the Antelope Valley: the power method, the consumptive-use method, the ground-water-level change method, and the flow-totalizing meter method. Pumpage between 1919-51 was estimated by Snyder (1955) using the first three methods. Snyder (1955) concluded that the power and consumptive-use methods were reliable, but results from the ground-water-level change method should be rejected because there were not enough wells in the water-level network to provide reliable results. For 1950, Snyder's (1955) estimates were about 362,000 acre-ft using the power method and about 350,000 acre-ft using the consumptive-use method. In comparison, pumpage reported to the California State Water Resources Control Board for 1950 was about

120,000 acre-ft (some of which was reported from metered municipal wells). The disparity in these numbers probably is because of extensive under-reporting at that time and the lack of recordation data for Kern County.

The strengths and weaknesses of the power, consumptive-use, and ground-water-level change methods are well documented by Snyder (1955). Although Snyder (1955) rejected the ground-water-level change method, this method may be more reliable now (1994) than it was at the time of Snyder's study because more wells are monitored for water-level changes now than were monitored during the study by Snyder. However, a detailed statistical network analysis is needed to determine the adequacy of the existing network for the objective of estimating net ground-water pumpage. Use of the power method can result in an under-estimate of ground-water pumpage if only electrical power is used because many of the wells may be powered by diesel or other fuels. Lack of available information on pump efficiencies and depths to water when wells are pumping also limits the accuracy of pumpage estimates using this method. Weakness in the consumptive-use method occurs because other uses of water, such as for weed control, leaching soil salts, frost protection and pre-irrigation to moisten dry soils, are not considered. Acreage data, irrigation efficiency, crop-water demands and applied water for each crop type usually are not available for all crops every year. When using the consumptive-use method, inaccu-racies in estimates of annual water use are generated when the data used in making these estimates are not updated annually. This method also may produce high estimates if deficit irrigation is practiced as we noticed in our land-use study in the Antelope Valley in 1992

Confusion between "applied" water and "net" water can occur when estimates of total withdrawal are made using the consumptive-use method. Typically, the difference between "applied" water and "net" water is the amount of water that is applied that exceeds the amount of water required to meet the demand of the water user at the point of use. More water must be withdrawn from whatever sources are available than is required to meet the historical demand for any specific use at the point of use because no delivery system, water-supply system, irrigation application system, toilet, or most any kind of water-use system is 100 percent efficient. "Net" water use also can be described as that part of applied water that is consumptively used (evaporated or evapotranspired) or irrecover-ably lost from the distribution system and agricul-tural return flow or treated municipal wastewater outflow (California Department of Water Resources, 1993a, p. 141).

To understand the meaning of "net" water demand, it is necessary to comprehend that not all of the water applied to a field or lawn can be used by the vegetation or absorbed by the soil. This excess water can become irrigation return flows, runoff from lawns, returns to sewers, or contri-butions to moisture-deficient soil. How much of this excess water actually goes to each of these uses is difficult to quantify. However, if the consump-tive-use method is to be used to estimate total withdrawals from available water sources (surface water, ground water, or reclaimed water), some educated guesses must be made for each of these additional uses of water. Annual and seasonal variations in irrigation efficiency, effective precip-itation, and crop-water demand because of wind and temperature variations also limit the accuracy of the consumptive-use method. Metering usually is considered the most reliable method for estimating water use (including ground-water pumpage); but, if the meters are not well maintained or installed correctly, even this method can be unreliable. One of the most effective approaches for improving estimates of water use for any area is to identify all major water users, expand the knowledge about the available methods of water-use estimation, and enhance the availability of the data needed to make the estimations.

One of the most significant limitations of this study is the lack of knowledge about the total number of wells that have pumped ground water each year in the valley. Many wells were aban-doned because of casing failure owing to land subsidence and because of the decreases in agricul-tural activity. A comparison between historical land-use maps and the distribution of wells was used to help verify the completeness of our data base for years when maps were available. Site-specific locations, which can be plotted using a computer, are not available for all wells in our pumpage data base. However, site-specific loca-tions are available for many wells included in the U.S. Geological Survey Ground Water Site Inventory data base (fig. 11). This data base indicates that there have been at least 3,723 different wells in the study area at some point in time; however, the number of wells that were active in any given year is not known. Annual land-use

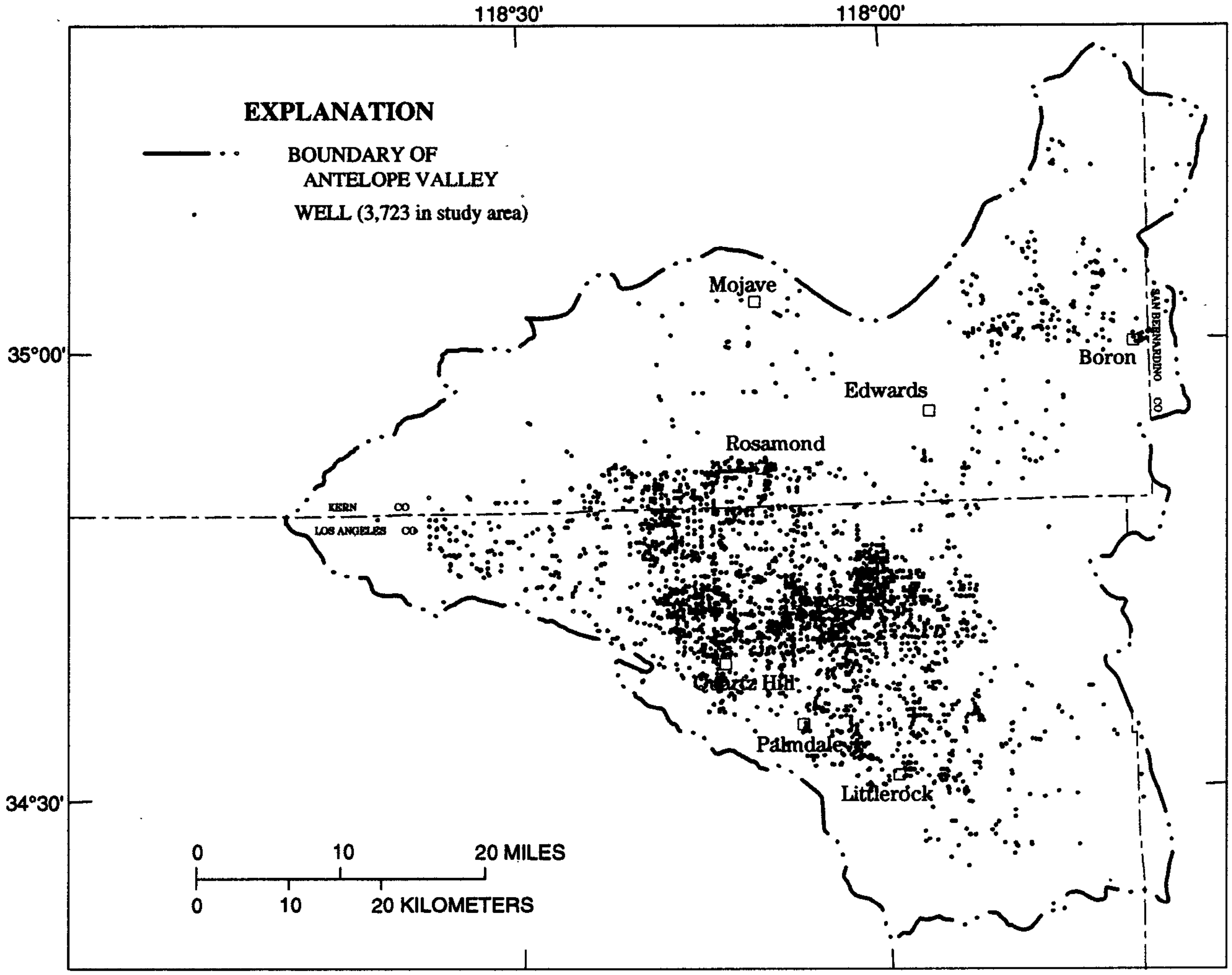

Figure 11. Locations of wells in the Antelope Valley. (Source: U.S. Geological Survey, Ground Water Site Inventory Data Base in WATSTORE.)

maps (or remotely sensed images), a detailed canvas of wells, and historical records of power use (if such information exists) could be valuable in determining the number of wells that were actively pumping each year.

Annual ground-water pumpage has been reported to the California State Water Resources Control Board for only 906 individual wells from 1947 through 1991. The highest total annual pumpage was about 268,000 acre-ft in 1956 for 487 wells—the most wells reported for any single year (table 4, fig. 9). All 487 wells were in the Los Angeles County part of the Antelope Valley. Owners of wells in Kern County are not required to report pumpage to the California State Water Resources Control Board. A complete data base of all active wells, with site-specific locations and metered monthly pumpage, is needed.

Since 1980, annual pumpage for about 100 to 200 wells has been reported to the California State Water Resources Control Board. On the basis of the U.S. Geological Survey Ground Water Site Inventory data base (fig. 11), there were many more wells that could have been active in the Antelope Valley than the 906 wells for which some of the annual pumpage was reported to the California State Water Resources Control Board for 1946-91.

Comparison between water-district boundaries (fig. 12) and recent land-use information (fig. 5*B*) indicates that self-supplied water use in 1992 may be minimal in the Kern County part of the Antelope Valley. Therefore, the self-supplied water users whose water came from wells in 1992 in the Kern County part of the study area may not account for much water use.

EXPLANATION FOR FIGURE 12

ANTELOPE VALLEY WATER DISTRICT LOCATIONS

MAP NUMBER	WATER DISTRICT
1	16th Street West Tract
2	Antelope Park Mutual Water Company
3	Antelope Valley Water Company, Lancaster District
4	Antelope Valley Water Company, Leona Valley District
5	Averydale Mutual Water Company
6	Baxter Mutual Water Company
7	Boron Community Services District
8	Brierwood Mobile Home Estates
9	Edwards Air Force Base Water Service Area
10	El Dorado Mutual Water Company
11	Evergreen Water Company
12	Hidden Valley Mntual
13	Los Angeles County Waterworks District, Number 4
14	Los Angeles County Waterworks District, Number 24
15	Los Angeles County Waterworks District, Number 27
16	Los Angeles County Waterworks District, Number 33
17	Los Angeles County Waterworks District, Number 34
18	Los Angeles County Waterworks District, Number 35
19	Los Angeles County Waterworks District, Number 38 Lake Los Angeles
20	Los Angeles County Waterworks District, Number 20
21	Lancaster Water Company
22	Land Projects Mutual Water Company
23	Lansdale Farms Mutual
24	Littlerock Creek Irrigation District
25	Mojave Public Utilities District
26	Palm Ranch Irrigation District
27	Palmdale Water District
28	Piute Mutual Water Company
29	Quartz Hill Water District
30	Rosamond Community Services District
31	Shadow Acres Mutual Water Company
32	Sunnyside Farms Water Company
33	Tierra Bonita Water Company
34	West Valley County Water District
35	West Side Park Water Company
36	White Fence Farms Mutual, Number 1
37	Wilsona Garden Mutual

——— CALIFORNIA AQUEDUCT

– – – – – ANTELOPE VALLEY-EAST KERN DELIVERY SYSTEM

▬▬ • • BOUNDARY OF ANTELOPE VALLEY

Surface-Water Supply

Local Surface-Water Resources

The close association between rainfall and runoff allows the use of rainfall to help review runoff conditions that have been experienced locally. Flow in the streams that enter the Antelope Valley are heavily influenced by rainfall and other related precipitation (such as snowfall in the higher elevations). The following discussion of local precipitation characteristics provides clues that are useful in understanding natural runoff that is available locally.

Mean annual precipitation in the valley was calculated using rainfall records available at the time of the study by Rantz (1969). These records indicate that precipitation rates are more than 12 in/yr in the surrounding mountains along the southern boundary of the study area and as low as about 5 in/yr along the northern boundary. Precipitation maps vary significantly in appearance depending on the period of record and the number of rainfall gages used, as well as the variation in rainfall distribution (Templin and Schluter, 1990, p. 34). A more recent report on mean annual precipitation (Blodgett and Nasseri, 1993, p. 11) confirms these areas with similar high and low precipitation rates, but indicates that mean annual precipitation ranges from 24 in. (in the mountains in the southeastern part of the study area) to less than 5 in. (near the northeastern border of the valley). Precipitation often is concentrated in localized areas (Blodgett and Nasseri, 1993, p. 11). Knowledge of these localized precipitation patterns can be used to enhance the capture and use of local runoff. Improvement in the collection of data for localized precipitation trends, and the associated runoff in streams, can provide local water-resource managers the information needed to make decisions. These decisions include design of drainage facilities and improvements in diversion and impoundment facilities in this moisture-deficient area.

Historically, surface-water sources have contributed only a small part of the water supplies used in the Antelope Valley. Reported diversions from surface-water sources peaked in 1968 and totaled almost 12,000 acre-ft but have since decreased to about 2,165 acre-ft in 1990, probably because of drought (fig. 13). Surface-water diversions can be expected to follow rainfall trends. Records of annual total diversions from surface-water sources

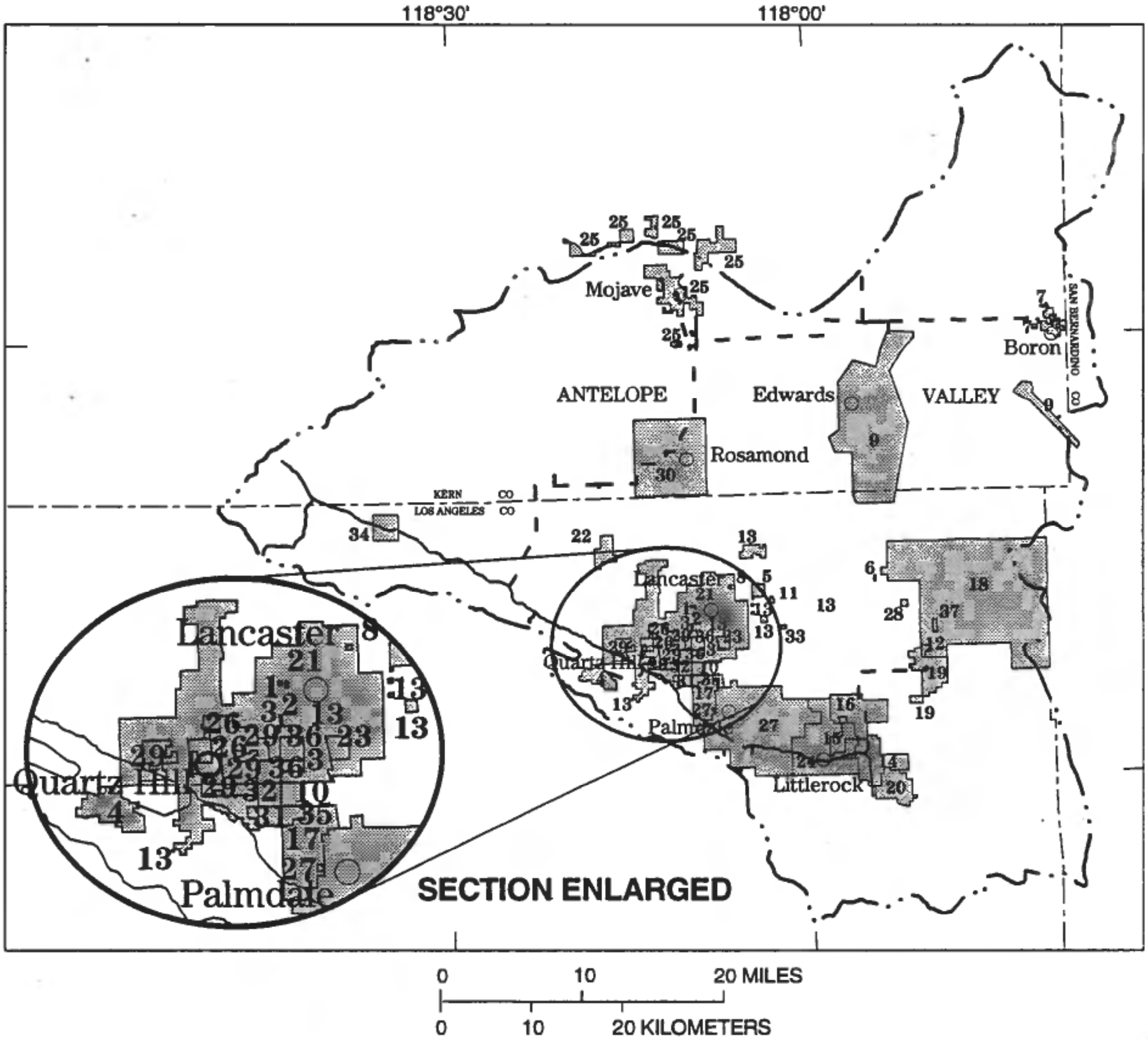

Figure 12. Water-district boundaries in the Antelope Valley.

reported to the California State Water Resources Control Board, Division of Water Rights, indicate that self-supplied water users withdraw about twice as much water as public suppliers (fig. 13). Comparisons between surface-water diversions over time and precipitation records for various gages in the area (fig. 2) can help assure that the records of reported surface-water diversions are reasonable. Surface-water diversions need to be accounted for when estimating ground-water recharge using stream-discharge data.

In the Antelope Valley, only a few surface-water storage facilities (table 5, fig. 14) retain local runoff for later use. This marginal amount of storage capacity can accommodate only a limited amount of water. Storage of local runoff or imported water could be increased if more facilities were available or if existing facilities had greater storage capacities. These storage facilities could act as additional recharge facilities or as temporary storage for nearby artificial recharge operations to enhance management of water resources in the Antelope Valley. Other surface-water bodies are shown on figure 14 and on the land-use map for 1973-76 (fig. 4) that might have been used for storage of runoff.

Stormwater runoff is a resource that has potential for greater use in the Antelope Valley. Stormwater drains from the surrounding hillsides onto the alluvial fans and flashes down washes until it reaches the valley floor where it ponds on relatively impervious clayey materials until it evaporates. This runoff from intense, short-duration storms represents a resource that is not highly utilized and is difficult to control, as evidenced by

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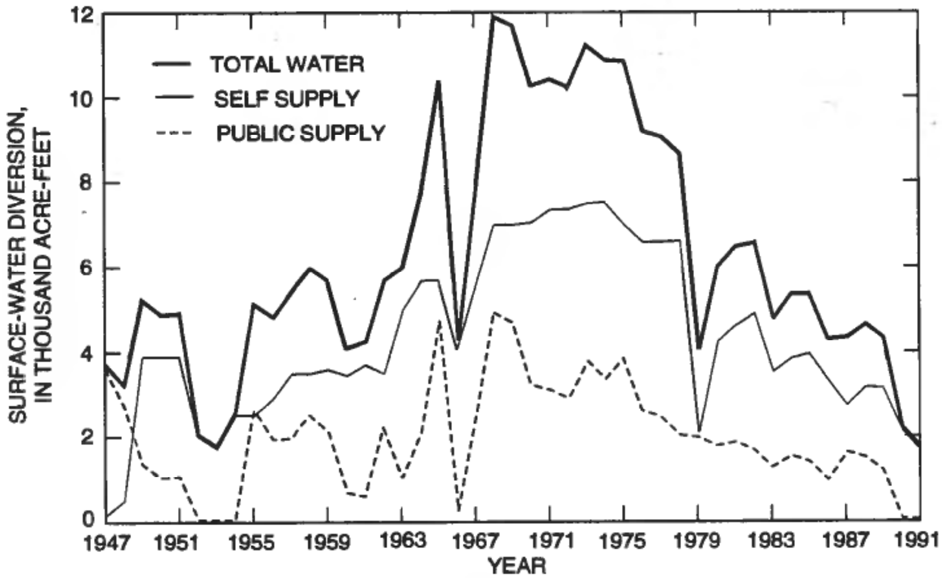

Figure 13. Surface-water diversions in Antelope Valley reported to the California State Water Resources Control Board, Division of Water Rights, 1947-91.

the resulting washes that frequently erode roads in the valley. Some runoff is captured in storm retention reservoirs or withdrawn from streams and from wells adjacent to coarse streambeds. Additional retention facilities could be designed to detain storm runoff to enhance aquifer recharge. Some recharge may be entering the aquifer, but much of it seems to evaporate without providing its maximum potential use.

Preservation of natural recharge areas (such as stream channels and permeable alluvial fans) is an important consideration in the Antelope Valley. Durbin (1978) estimated that 80 percent of total recharge in the valley could be attributed to runoff from the San Gabriel Mountains, primarily from Big Rock and Little Rock Creeks. The upper parts of the alluvial fans associated with these creeks are the primary recharge zones in the valley. Urban encroachment on areas of natural recharge may decrease recharge to the aquifer as pervious areas decrease and natural channels are altered for flood protection.

Imported Surface-Water Supplies

Imported surface water arrived in the Antelope Valley in 1972, when water was first delivered from the Sacramento-San Joaquin Delta, about 400 mi to the north, through the California Aqueduct to the Littlerock Creek Irrigation District and the Antelope Valley-East Kern Water Agency. Imported water supplies peaked in 1981 at about 77,000 acre-ft (table 6). Since then, imported supplies typically have averaged about 37,000 acre-ft/yr, consistently much less than the planned entitlements from the State Water Project. Palmdale Water District first received imported water in 1985. Deliveries of imported water generally have resulted in reduced stress on the ground-water system and have supplemented local water resources for about 20 years. During the 20-year record of imported deliveries, the water delivered to these water agencies seldom has approached the planned entitlement. Part of this difference is due to local water agencies requesting less than their annual entitlement. On the basis of this record and the likelihood of further reductions in exports from the Sacramento-San Joaquin Delta because of the recent endangered species legislation, reliability of water deliveries from the State Water Project is suspect. In addition, part of the imported water received by the Antelope Valley-East Kern Water Agency is delivered to users outside the Antelope Valley. These demands for water from communities outside the valley, such as California City, are expected to increase because of plans for substantial growth. These increasing demands (from outside communities) on the limited supplies imported into the Antelope Valley are equivalent to reducing imported water available for use within the valley.

Discrepancies between entitlements from the State Water Project and actual deliveries (fig. 15) indicate that imported water is not always available when it is needed in the Antelope Valley. A comparison of deliveries projected in 1977 and in 1991 (fig. 15*B*) indicates a delay of more than 20 years to reach planned entitlements. This delay probably is due to delays in the planned completion of additional reservoirs as part of the State Water Project.

Actual deliveries for 1977-92 (California Department of Water Resources, 1991a) typically

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Table 5. Capacities and locations of surface-water reservoirs in the Antelope Valley

[Reservoir capacity, in acre-feet]

Reservoir			Location			Location No. (fig. 14)
Capacity	Name	Owner	Township/ range	Section	Latitude/ longitude	
Kern County						
4,375	Boron Tails Pond 5	U.S. Borax and Chemical Corporation	11N/8W-	15	35°03'18"/ 117°42'36"	1
1,480	Boron Tails Pond	U.S. Borax and Chemical Corporation	11N/8W-	15	35°02'36"/ 117°43'12"	2
2,235	Boron Tails Pond 6	U.S. Borax and Chemical Corporation	11N/8W-	21	35°03'00"/ 117°42'36"	3
242	Borax Solar evaporation pond	U.S. Borax and Chemical Corporation	11N/8W-	21	35°02'18"/ 117°44'06"	4
17	Edwards Air Force Base recreation dam	U.S. Air Force, Edwards Air Force Base	9N/7W-	24	34°56'24"/ 117°40'59"	10
8,349	(Subtotal)					
Los Angeles County						
0 ([1]7,507)	Fairmont	City of Los Angeles	7N/15W-	12	34°41'12"/ 118°25'37"	5
4,200	Lake Palmdale	Palmdale Water District	5N/12W-	3	34°31'36"/ 118°06'54"	6
900 ([2]2,700)	Littlerock	Littlerock Creek Irrigation District and Palmdale Water District	5N/11W-	27	34°29'06"/ 118°01'19"	7
493	Fairmont No. 2	City of Los Angeles	7N/15W-	11	34°42'18"/ 118°26'06"	8
106	Pearblossom Spill basin	California Department of Water Resources	5N/10W-	15	34°31'12"/ 117°55'12'	9
5,699	Subtotal (of the original 15,006)					
14,048	Total (of the original 23,355)					

[1]Fairmont and Fairmont No. 2 Reservoirs are located along the Los Angeles Aqueduct in the Price Canyon drainage basin. Fairmont Reservoir was completed in 1912 but was taken out of operation in 1982 because of a fault running through the main dam. Fairmont No. 2 replaced Fairmont Reservoir but stores only a fraction of its the original capacity.

[2]Reservoir capacity for Littlerock Reservoir is 2,700 acre-feet which is the design capacity. Actual storage capacity was reduced legislatively by the California Department of Water Resources, Division of Dam Safety, to about 900 acre-feet. Construction plans indicate that completion of a new reservoir in 1994 will increase the useable capacity of Littlerock Reservoir to 3,472 acre-feet.

were from 25 to 50 percent of the deliveries projected by the California Department of Water Resources (1977) (fig. 15). The California Department of Water Resources (Paul Dabbs, California Department of Water Resources, written commun., August 1993) analyzed the reliability of imported water supplies for various scenarios that might influence the availability of water for export from the Sacramento-San Joaquin Delta area. On the basis of assumptions made for the various scenarios, results of these analyses indicate a 20- to 60-percent likelihood that deliveries will be at or above projected deliveries.

During wet years, even with the present facilities of the State Water Project, more water may be available to water contractors, such as Antelope Valley-East Kern Water Agency, Palmdale Water District, and Littlerock Creek Irrigation District, than is contracted to be delivered. The differences

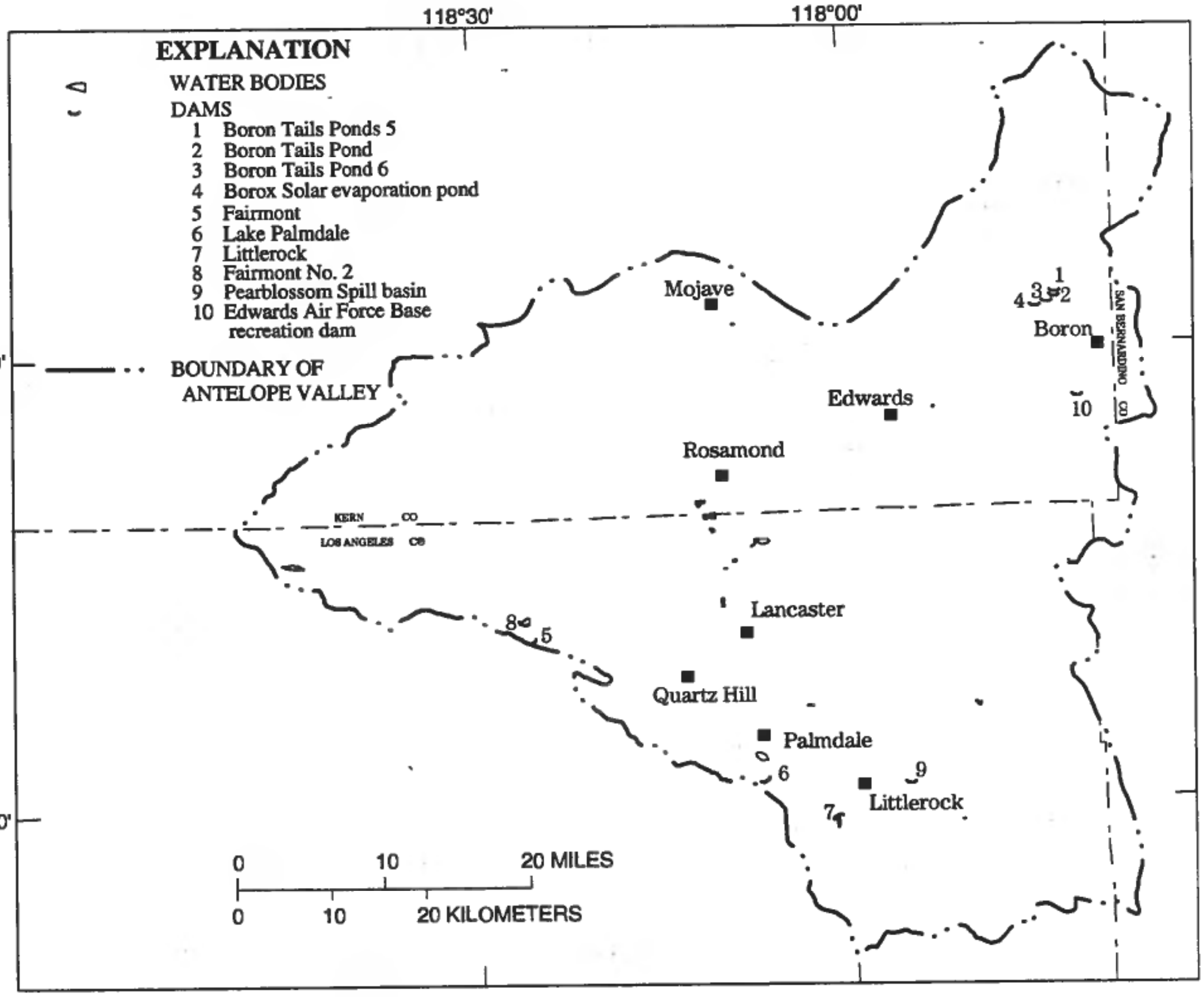

Figure 14. Locations of surface-water reservoirs and other selected water bodies in the Antelope Valley.

between entitlements and deliveries then can be narrowed if more water is requested by these local agencies and placed in storage through artificial recharge.

Reclaimed Wastewater Supply

Reclaimed wastewater is becoming an important source of water in Antelope Valley. Reclaimed wastewater supplies have increased dramatically as the population and treatment capacities have grown (fig. 16*A*). In 1985, influents to wastewater treatment facilities from the cities of Lancaster and Palmdale and for Edwards Air Force Base were 6,161, and 3,394, and 1,457 acre-ft, respectively, for a combined total of about 11,000 acre-ft, or about 90 percent of total treated sewage (12,229 acre-ft; fig. 16*B*) for all wastewater facilities in the valley. By 1990, the total influent treated by these same three communities had increased to 19,123 acre-ft, which was 92 percent of the total wastewater influent to all Antelope Valley facilities (20,873 acre-ft; table 7). In 1990, only about 55 percent (11,483 acre-ft) of the influent was accounted for by various uses (table 7). If all meters on the influents to wastewater facilities were operating properly, the balance probably evaporated from wastewater-treatment ponds or could be accounted for in sewage sludge solids (fig. 16*B*). In 1990, the Lancaster and Palmdale facilities accounted for 84 percent of the total influent to wastewater-treatment plants in the Antelope Valley. Our data base (fig. 16*B*) is limited to data from these two plants for all years except 1985 and 1990, which is why total influent is higher in 1985 and 1990.

In 1990, most reclaimed wastewater was disposed of to land surfaces (5,445 acre-ft). Volumes disposed to land surfaces primarily evaporate, but

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Table 6. Entitlements and actual deliveries of water imported to the Antelope Valley from the California Aqueduct

[Entitlement and delivery in acre-feet]

Year	Antelope Valley-East Kern Water Agency: Entitlement (a)	Antelope Valley-East Kern Water Agency: Delivery (b)	Antelope Valley-East Kern Water Agency: Antelope Valley deliveries (c)	Littlerock Creek Irrigation District: Entitlement (d)	Littlerock Creek Irrigation District: Delivery (e)	Palmdale Water District: Entitlement (f)	Palmdale Water District: Delivery (g)	Total[1] deliveries Antelope Valley agencies (h=b+e+g)	Total deliveries Antelope Valley (defined in this study) (i=c+e+g)
1972	20,000	53	0	170	338	1,620	0	391	338
1973	25,000	20	0	290	290	2,940	0	310	290
1974	30,000	1,259	1,259	400	400	4,260	0	1,659	1,659
1975	35,000	8,068	8,068	520	520	5,580	0	8,588	8,588
1976	44,000	27,782	27,295	640	589	6,900	0	28,371	27,884
1977	50,000	11,202	32,147	730	111	8,220	0	11,313	32,258
1978	57,000	44,137	42,997	920	208	9,340	0	44,345	43,205
1979	63,000	60,493	58,701	1,040	133	10,260	0	60,626	58,834
1980	69,200	72,407	66,522	1,150	191	11,180	0	72,598	66,713
1981	75,000	79,375	75,480	1,270	1,270	11,700	0	80,645	76,750
1982	81,300	50,291	47,789	1,380	0	12,320	0	50,291	47,789
1983	87,700	32,961	31,878	1,500	38	12,940	0	32,999	31,916
1984	[2]35,000	32,662	31,727	1,610	1	13,560	0	32,663	31,728
1985	[2]40,000	37,064	36,111	1,730	0	14,180	1,558	38,622	37,669
1986	[2]42,000	32,449	30,946	1,840	163	14,800	3,096	35,708	34,205
1987	[2]44,000	34,094	31,782	1,960	1,080	15,420	5,379	40,553	38,241
1988	[2]46,000	34,079	34,828	2,070	419	16,040	1,770	36,268	37,017
1989	125,700	45,280	40,428	2,190	971	16,660	9,009	55,260	50,408
1990	132,100	47,209	43,164	2,300	1,747	17,300	8,608	57,564	53,519
1991	138,400	22,992	4,355	2,300	858	17,300	[1]6,525	30,375	11,738
1992	138,400	31,937	28,607	2,300	0	17,300	4,007	35,944	32,614
1993	138,400			2,300		17,300			
2020	138,400			2,300		17,300			
2025	138,400			2,300		17,300			

[1]Sources: California Department of Water Resources (1991a, p. 268 and 280) and written communications from Antelope Valley-East Kern Water Agency, Littlerock Creek Irrigation District, and Palmdale Water District. The entitlements and deliveries shown in this table are from California Department of Water Resources (1991a). Discrepancies exist between deliveries reported by California Department of Water Resources and the individual agencies for the same years. For example, in 1991, Antelope Valley-East Kern Water Agency indicates their deliveries from the State Water Project totaled 7,263 acre-feet, and Palmdale Water District reported 3,925 acre-feet. The most striking discrepancy is shown in 1977 where (b) 11,202 acre-feet was reported by the California Department of Water Resources and (c) 32,147 acre-feet was reported by Antelope Valley-East Kern Water Agency.

[2]Entitlements for 1984-88 from California Department of Water Resources Bulletin 132-85 (1985) were modified from what had been reported in Bulletin 132-81. The numbers shown in this table are from Bulletin 132-91, which have been unchanged since Bulletin 132-85. Bulletin 132-81 showed 1984, 1985, 1986, 1987, and 1988 entitlements for Antelope Valley-East Kern Water Agency to be 94,000; 100,400; 106,700; 113,000; and 119,400 acre-feet, respectively.

also may recharge ground water, evapotranspire through native vegetation, and may compact moisture-deficient soils. Additional monitoring of ground-water levels and quality in the vicinity of this disposal area would be helpful in determining how much ground-water recharge is actually occurring. Wastewater also was used for agricultural irrigation (3,587 acre-ft) and wetlands (2,451 acre-ft) (table 7; fig. 16*B*). Nearly 100 percent of the reclaimed wastewater for agricultural irrigation in 1990 was used at the Nebeker Ranch to grow alfalfa and sudan grass. In 1990, 2,451 acre-ft of

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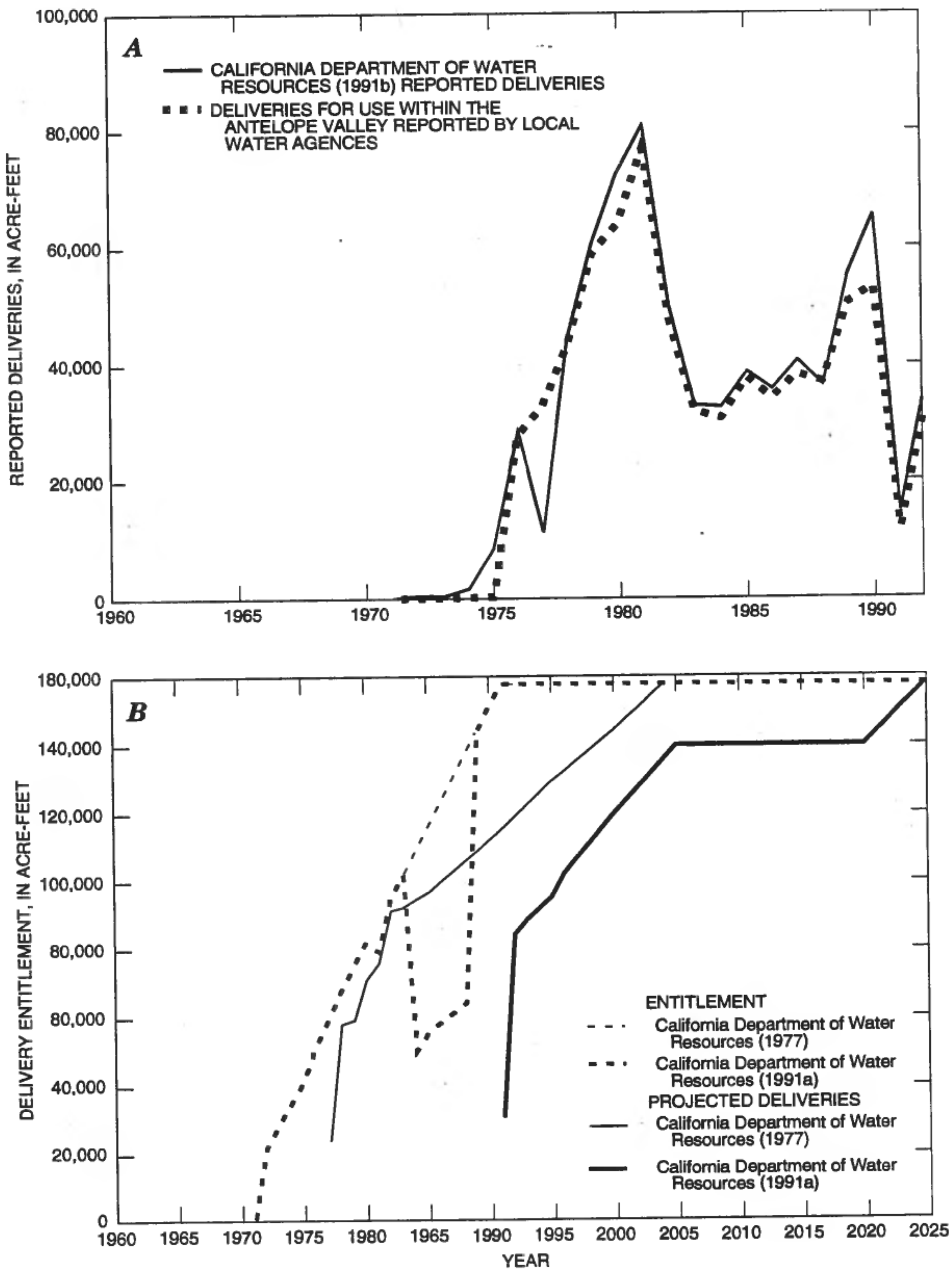

Figure 15. Imported water supplies for the Antelope Valley. ***A,*** Reported deliveries. ***B,*** Entitlements and deliveries projected in 1977 and 1991.

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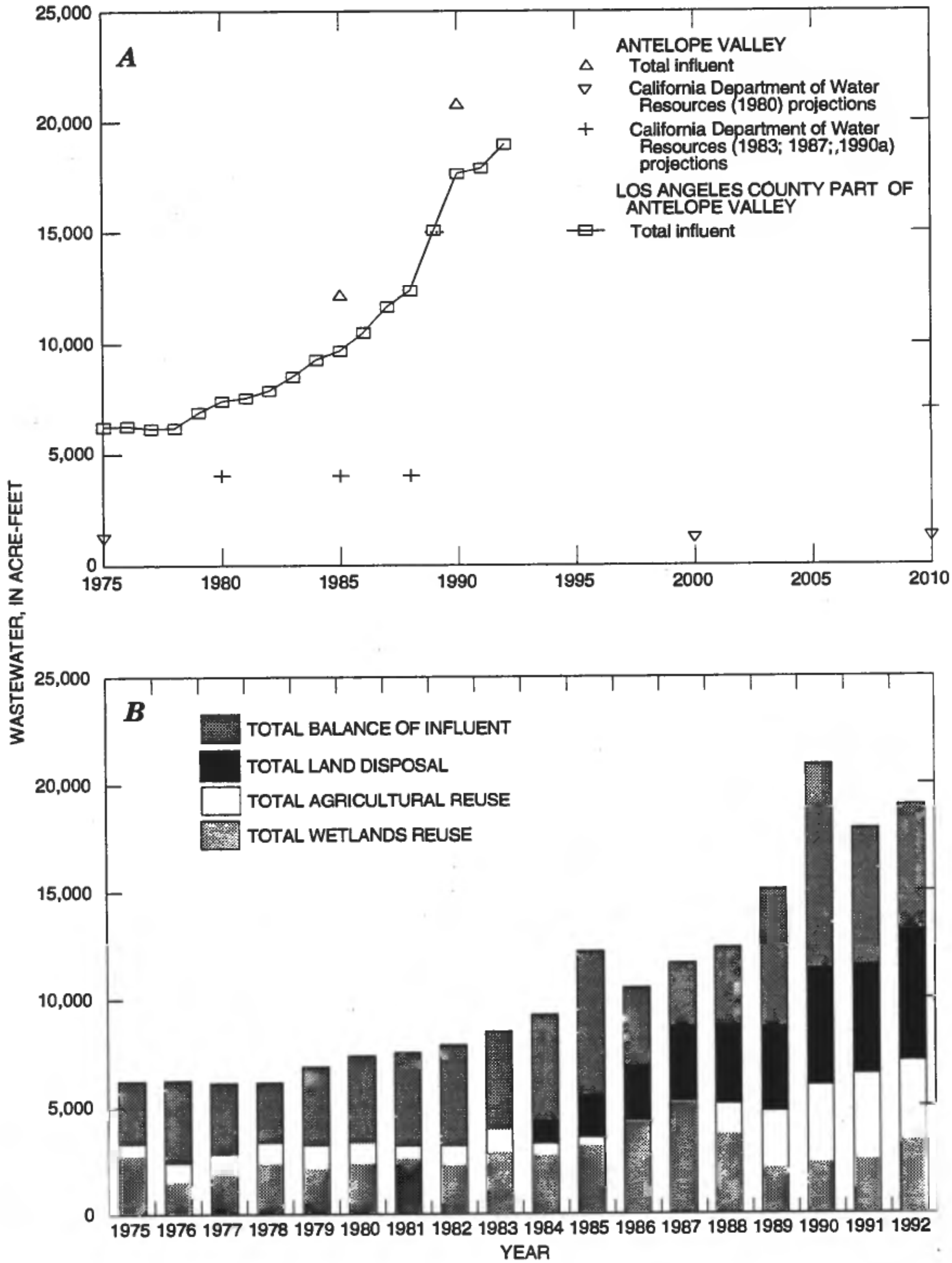

Figure 16. Wastewater ***A*** influent and ***B*** reuse in the Antelope Valley. (Sources: David Lambert, Los Angeles County Sanitation Districts, written commun., 1993, and U.S. Geological Survey data base, October 15, 1993.)

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Table 7. Wastewater influents and reclaimed wastewater use, 1989-91

[Influent and reclaimed wastewater, in acre-feet per year]

Facility name	Influent	Reclaimed wastewater use			Balance of influent
		Agricultural irrigation	Wetlands	Land disposal	
1989					
Edwards Air Force Base Wastewater Treatment Facility	0	0	0	0	0
Rosamond Wastewater Treatment Facility	0	0	0	0	0
Mojave Wastewater Treatment Facility	0	0	0	0	0
Mojave Airport Facility	0	0	0	0	0
Boron Wastewater Treatment Facility	0	0	0	0	0
Desert Lake Community Services District Wastewater Treatment Facility	0	0	0	0	0
Edwards Air Force Base Missile Test Site Wastewater Treatment Facility	0	0	0	0	0
Edwards Air Force Base North Base Research Wastewater Treatment Facility	0	0	0	0	0
Lancaster Wastewater Treatment Facility	8,625	2,671	2,135	0	3,819
Palmdale Water Reclamation Plant	6,475	29	0	3,965	2,481
Air Force Plant 42 Wastewater Treatment Facility	0	0	0	0	0
Boron Federal Prison Wastewater Treatment Facility	0	0	0	0	0
Total	15,100	2,700	2,135	3,965	6,300
1990					
Edwards Air Force Base Wastewater Treatment Facility	1,670	0	0	0	1,670
Rosamond Wastewater Treatment Facility	762	0	0	0	762
Mojave Wastewater Treatment Facility	381	0	0	0	381
Mojave Airport Facility	99	0	0	0	99
Boron Wastewater Treatment Facility	90	0	0	0	90
Desert Lake Community Services District Wastewater Treatment Facility	86	0	0	0	86
Edwards Air Force Base Missile Test Site Wastewater Treatment Facility	45	0	0	0	45
Edwards Air Force Base North Base Research Wastewater Treatment Facility	7	0	0	0	7
Lancaster Wastewater Treatment Facility	9,298	3,572	2,451	0	3,275
Palmdale Water Reclamation Plant	8,155	15	0	5,445	2,695
Air Force Plant 42 Wastewater Treatment Facility	213	0	0	0	213
Boron Federal Prison Wastewater Treatment Facility	67	0	0	0	67
Total	20,873	3,587	2,451	5,445	9,390
1991					
Edwards Air Force Base Wastewater Treatment Facility	0	0	0	0	0
Rosamond Wastewater Treatment Facility	0	0	0	0	0
Mojave Wastewater Treatment Facility	0	0	0	0	0
Mojave Airport Facility	0	0	0	0	0
Boron Wastewater Treatment Facility	0	0	0	0	0
Desert Lake Community Service District Wastewater Treatment Facility	0	0	0	0	0
Edwards Air Force Base Missile Test Site Wastewater Treatment Facility	0	0	0	0	0
Edwards Air Force Base North Base Research Wastewater Treatment Facility	0	0	0	0	0
Lancaster Wastewater Treatment Facility	9,073	3,894	2,568	0	2,611
Palmdale Water Reclamation Plant	8,827	91	0	5,110	3,626
Air Force Plant 42 Wastewater Treatment Facility	0	0	0	0	0
Boron Federal Prison Wastewater Treatment Facility	0	0	0	0	0
Total	17,900	3,985	2,568	5,110	6,237

reclaimed wastewater was used for the wetlands, of which about 2,266 acre-ft was delivered to Piute Pond (a manmade wetland) and about 185 acre-ft was delivered to a pond at Apollo Park. The reclaimed wastewater that went to Nebeker Ranch and the Piute Pond had undergone secondary treatment processes. The wastewater for the Apollo Park pond underwent a third level of treatment with an alum mixture to remove suspended particles.

Water Demand

From the 1950's to the late 1980's, water demands consistently decreased with decreasing irrigated acreage. Irrigation water demands in 1975 totaled 166,300 acre-ft in the Antelope Valley, whereas municipal water demands totaled only 26,300 acre-ft (table 2) for a population of about 95,000 (California Department of Water Resources, 1980, p. 11-16). In 1984, rapid growth in population resulted in a rapid increase in urban water demands. By 1990, the population of the Antelope Valley had increased to 260,400 and continues to grow, but at a decreasing rate compared with the previous 5 years. Most reported urban water demands presently (1994) are met by public suppliers. Unreported self-supplied water also could be contributing to urban water demands and creating a significant stress on local ground-water resources. Public-supplied water accounted for 59 percent (39,400 acre-ft) of reported demands (66,707 acre-ft) on ground-water supplies and 64 percent (82,200 acre-ft) of total reported water demands (127,997 acre-ft) in 1990 (table 8). Of the top 10 water suppliers in the Antelope Valley in 1990, 6 were public water suppliers and 4 were self-supplied agricultural water users (table 8).

Public Supplied

For purposes of this report, public-supplied water use is representative of municipal uses for the Antelope Valley. In 1990, public-supplied water was about 82,200 acre-ft compared with about 81,773 acre-ft in 1989 and 92,082 acre-ft (76,173 acre-ft plus the 15,658 acre-ft supplied by Antelope Valley-East Kern Water Agency from self-supplied ground-water pumpage) in 1991 (tables 2 and 8). In 1991, for the first time in local history, self-supplied water users pumped about 15,658 acre-ft of ground water and sold it to the Antelope Valley-East Kern Water Agency to help meet the municipal needs of public water suppliers. This 15,658 acre-ft of ground water was used to replace reductions of imported water caused by the drought. Only since 1986 have total reported public-supplied water demands exceeded self-supplied water demands in the Antelope Valley (tables 18 and 19 at back of report). This trend is attributed to the growth in urban land use and the decrease in irrigated agriculture. The top five public suppliers accounted for 82 percent, 84 percent, and 68 percent of the total public water supplied in 1989, 1990, and 1991, respectively (table 8).

The total estimated population served by public suppliers in 1990 in the Antelope Valley was 212,142 based on data compiled for this study. The total population of the valley in 1990 from U.S. Bureau of the Census records was 260,400 (Vern T. Knoop, California Department of Water Resources, written commun., 1993). The population not served by public suppliers was assumed to be self supplied or supplied by small public water companies for which estimates of the population served were not available. Of the 119 licensed public water suppliers in the Antelope Valley (Gary Silverman, U.S. Environmental Protection Agency, written commun., 1991), the top 10 public suppliers accounted for 86 percent of the total water supplied and 88 percent of the total ground water pumped by public suppliers during 1989-91 (table 8).

Water deliveries from public suppliers are voluntarily reported annually to the California Department of Water Resources by most water agencies statewide. However, in 1990, only 26 of the 119 licensed public water suppliers in the Antelope Valley responded to the State's annual "Water Utility Statistics" survey; some of the largest water suppliers were not represented. Responses to the Water Utility Statistics survey for 1990 indicated that the primary use of public-supplied water in Antelope Valley was for domestic purposes, with relatively small amounts used for industrial purposes. Responses also indicated that public-supplied irrigation water generally was applied to landscaping, golf courses, and other publicly owned areas but not to irrigated crops. Other reported public-supplied water included water unaccounted for as losses between production and delivery. Typically, losses include water lost when flushing fire hydrants and fighting fires, system leaks, and irrigation of some public parks and other facilities where water use is not metered.

Many public water suppliers in the Los Angeles County part of the Antelope Valley report their ground-water pumpage and surface-water diversions to the California State Water Resources Control Board. Several water agencies provided additional water-use records for the Antelope Valley. The

Table 8. Public-supplied and self-supplied water demands in Antelope Valley by water supplier and source, 1989-91

[Imported water represents water purchased from State Water Project contractors by water suppliers within the study area boundary for the Antelope Valley]

Water supplier	Water-supply source, in acre-foot per year				
	Ground water	Local surface water	Imported water	Reclaimed wastewater	Total water demand
1989					
Public supplied:					
Los Angeles County Water Works Districts	16,619	0	17,626	0	34,245
Palmdale Water District	10,002	0	9,009	0	19,011
Edwards Air Force Base	5,096	0	0	0	5,096
Lancaster Wastewater Treatment Facility.	0	0	0	4,806	4,806
Littlerock Creek Irrigation District	1,593	1,145	971	0	3,709
Quartz Hill Water District	1,661	0	1,369	0	3,030
Mojave	1,322	0	401	0	1,723
White Fence Farms	368	0	891	0	1,259
Rosamond Community Services District	775	0	159	0	934
Palmdale Wastewater Treatment Facility	0	0	0	29	29
All others	5,662	46	2,183	0	7,891
Total public-supplied water demand	43,098	1,191	32,609	4,835	81,733
Self supplied:					
Kyle, J.W. and G.W.	7,179	0	0	0	7,179
Retlaw Enterprises, Inc.	6,914	0	0	0	6,914
Ritter and Godde	3,888	0	2,911	0	6,799
R and M Ranch, Inc.	2,670	0	0	0	2,670
Beery, Ray	0	0	2,189	0	2,189
Kelly Ranch	0	0	2,166	0	2,166
Biscaichipy Ranch	0	0	2,104	0	2,104
Lake, Twyla and Larry	2,058	0	0	0	2,058
Tapia Brothers	0	0	1,707	0	1,707
Cameo Ranching Co.	0	0	0	0	0
Other suppliers	5,211	3,127	6,719	0	15,057
Total self-supplied water demand	27,920	3,127	17,796	0	48,843
Total water supplies	71,018	4,318	50,405	4,835	130,576
1990					
Public supplied:					
Los Angeles County Water Works Districts	14,052	0	20,917	0	34,969
Palmdale Water District	10,209	0	8,608	0	18,817
Edwards Air Force Base	5,690	0	0	0	5,690
Lancaster Wastewater Treatment Facility	0	0	0	6,023	6,023
Littlerock Creek Irrigation District	1,526	0	1,747	0	3,273
Quartz Hill Water District	1,190	0	1,950	0	3,140
Mojave	1,286	0	288	0	1,574
White Fence Farms	788	0	775	0	1,563
Rosamond Community Services District	780	0	498	0	1,278
Palmdale Wastewater Treatment Facility	0	0	0	15	15
All others	3,879	46	1,933	0	5,858
Total public-supplied water demand	39,400	46	36,716	6,038	82,200

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Table 8. Public-supplied and self-supplied water demands in Antelope Valley by water supplier and source, 1989-91--*Continued*

Water supplier	Water-supply source, in acre-foot per year				Total water demand
	Ground water	Local surface water	Imported water	Reclaimed wastewater	
1990--*Continued*					
Self supplied:					
Kyle, J.W. and G.W.	6,928	0	0	0	6,928
Retlaw Enterprises, Inc.	6,904	0	0	0	6,904
Ritter and Godde	3,162	0	3,843	0	7,005
R and M Ranch, Inc.	2,785	0	0	0	2,785
Beery, Ranch	0	0	2,099	0	2,099
Kelly Ranch	0	0	1,708	0	2,052
Biscaichipy Ranch	0	0	2,437	0	2,437
Lake, Twyla and Larry	2,052	0	0	0	1,708
Tapia Brothers	0	0	1,294	0	1,294
Cameo Ranching Co.	1,365	0	0	0	1,365
Other suppliers	4,111	2,119	4,990	0	11,220
Total self-supplied water demand	27,307	2,119	16,371	0	45,797
Total water supplies	66,707	2,165	53,087	6,038	127,997
1991					
Public supplied:					
Los Angeles County Water Works Districts	17,093	0	12,940	0	30,033
Palmdale Water District	12,720	0	6,525	0	19,245
Edwards Air Force Base	3,920	0	0	0	3,920
Lancaster Wastewater Treatment Facility	0	0	0	6,462	6,462
Littlerock Creek Irrigation District	1,991	0	858	0	2,849
Quartz Hill Water District	1,311	0	1,543	0	2,854
Mojave	1,214	0	468	0	1,682
White Fence Farms	456	0	482	0	938
Rosamond Community Services District	1,235	0	535	0	1,770
Palmdale Wastewater Treatment Facility	0	0	0	91	91
All others	5,269	36	16,934	0	22,239
Total public-supplied water demand	45,208	36	[1]40,285	6,553	92,082
Self supplied:					
Kyle, J.W. and G.W.	7,294	0	0	0	7,294
Retlaw Enterprises, Inc.	6,914	0	0	0	6,914
Ritter and Godde	6,083	0	0	0	6,083
R and M Ranch, Inc.	2,780	0	0	0	2,780
Beery Ranch	0	0	0	0	0
Kelly Ranch	0	0	0	0	0
Biscaichipy Ranch	0	0	0	0	0
Lake, Twyla and Larry	12	0	0	0	12
Tapia Brothers	0	0	0	0	0
Cameo Ranching Co.	1,248	0	0	0	1,248
Other suppliers	6,546	1,633	2,769	0	10,948
Total self-supplied water demand	[1]30,877	1,633	2,769	0	35,279
Total water supplies	[1]76,085	1,669	[1]43,054	6,553	127,361

[1]The volume of imported water use in 1991 is 15,658 acre-feet higher than the volume of imported water shown in table 4; the volume of ground-water use is 15,658 acre-feet lower than the volume of ground-water use shown in table 4. If this water had been used by the owners of these privately owned wells, it would have been considered a self-supplied use. However, in 1991, 15,658 acre-feet of ground water was transferred from self-suppliers to a wholesale water supplier (Antelope Valley-East Kern Water Agency), who in turn sold the water to public suppliers, who delivered the water to their urban water-use customers. This water use is accounted for under imported water for public-supplied users because the ground water was combined with imported water by Antelope Valley-East Kern Water Agency; it was not determined how much ground water and how much imported water went to each public water supplier. Total ground-water pumpage in 1991 sold to Antelope Valley-East Kern Water Agency for deliveries by public suppliers was 91,284 acre-feet; 44,749 acre-feet public supplied; 30,877 acre-feet self supplied; and 15,658 acre-feet self supplied.

Palmdale Water District maintains computerized data bases of water supplies and deliveries. Annual and seasonal deliveries of public-supplied water in the Antelope Valley have increased dramatically as shown in the data base for Palmdale Water District (fig. 17).

Self Supplied

Self-supplied water use represents primarily agricultural uses for the Antelope Valley because other reported self-supplied demands are small. Total reported self-supplied water (table 8) was 48,843 acre-ft in 1989, 45,797 acre-ft in 1990, and 35,279 acre-ft in 1991. The top 10 self-supplied water users accounted for 71 percent of the reported total self-supplied water demands and 82 percent of the ground water pumped by self-suppliers in 1989-91. In 1991, for the first time in local history, self-supplied water users pumped about 15,658 acre-ft of ground water and sold it to the Antelope Valley-East Kern Water Agency to help meet the municipal needs of public water suppliers. This 15,658 acre-ft of ground water was used to replace reductions of imported water that were a result of the drought.

The completeness of our self-supplied data base was checked by comparing 1987 and 1992 irrigated acreages with site-specific locations for water delivery identified by the Antelope Valley-East Kern Water Agency. This comparison indicated that most of the land irrigated in the Kern County area probably used water received from the Antelope Valley-East Kern Water Agency, so self-supplied water use in Kern County might have been minimal.

Our estimate of the annual total water demand for self-supplied domestic water users from all water sources was about 20,000 acre-ft for 1990. This estimate was based on a unit-use coefficient of 400 gal per capita per day, similar to the unit-use coefficient for local public-supplied per capita use rates reported to the California Department of Water Resources 1990 Urban Water Status Survey. The population estimate for self-supplied domestic water users was 48,258 for 1990. This population estimate was determined using the difference between population from the 1990 census (California Department of Water Resources, 1993b) for Antelope Valley and the population served by public water suppliers (for which estimates of the population served were available). Part of this water demand probably was accounted for in the reports of water-rights licensees for surface-water and ground-water pumpage for the Los Angeles County part of the study area as reported to the State Water Resources Control Board. To avoid double accounting, this estimate of domestic self-supplied water demand was not added to the total reported in table 8, which could mean that a small amount of self-supplied water use may not be accounted for in our data base. If the per capita use rate for self-supplied domestic water users is actually about 200 gal/d or even the 55 to 75 gal/d used by the California State Water Resources Control Board (1977, p. 22) in establishing water rights, the unaccounted for water use would be even less. A complete survey of all active wells and mandatory reporting of all ground-water pumpage would improve estimates of self-supplied water use.

Estimates of self-supplied industrial water use can be made using "unit-use coefficients" for the number of employees reported by local Boards of Trade or Chambers of Commerce for the area within each Standard Industrial Classification code grouping. However, because of potential inaccuracies associated with the "unit-use coefficient" method for estimating industrial water-use, only reported data were used. Unreported use was assumed to be minimal. Some self-supplied water-use information for the Antelope Valley came from industries that responded to questionnaires sent out as part of a statewide industrial survey done in cooperation with the California Department of Water Resources in 1992. Additional information on self-supplied industrial water use came from industrial well owners in the Los Angeles County part of the study area who report their pumpage to the California State Water Resources Control Board as part of their ground-water extraction ordinance.

Many well owners in the Los Angeles County part of the Antelope Valley, who report their pumpage to the California State Water Resources Control Board as part of the ground-water extraction ordinance, are self-supplied irrigation water users. Irrigation was the most frequently cited water use by those who reported self-supplied pumpage in 1990. Land-use information was used to check the completeness of the reported irrigation information.

Total agricultural water use in the Antelope Valley has been estimated using the "consumptive-use method" on the basis of irrigated acreage, evapotranspiration of applied water, and irrigation

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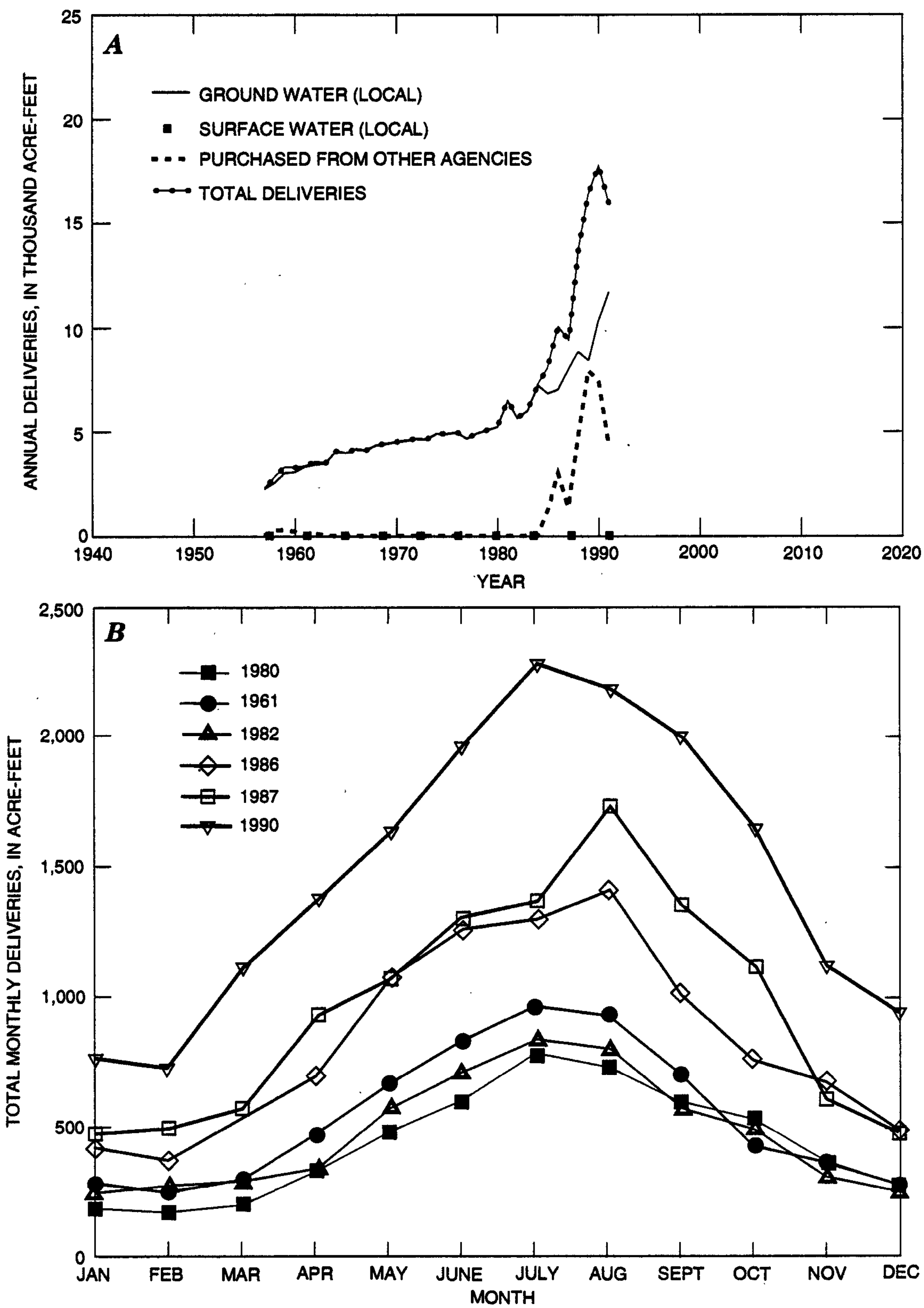

Figure 17. Annual withdrawals by ***A***, source and ***B***, seasonal water deliveries, by month, to meet demands for the Palmdale Water District.

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Table 9. Irrigation water use and irrigated acreage in the Antelope Valley, 1989

[Source: Verne Knoop, California Department of Water Resources (written commun., 1991). Units: applied water and evapotranspiration of applied water are in acre-feet per year; unit evapotranspiration and unit applied water are in acre-feet per acre; irrigation efficiencies are decimal fractions used to estimate applied water following the formula (acres × unit) evapotranspiration of applied water divided by irrigation efficiency. acre-ft/acre, acre-feet per acre; acre-ft, acre-feet]

Crop	Irrigated acreage	Unit evapotranspiration of applied water (acre-ft/acre)	Evapotranspiration of applied water (acre-ft)	Unit applied water (acre-ft/acre)	Irrigation efficiency	Applied water (acre-ft)
Alfalfa	9,050	4.3	38,915	5.5	0.78	49,891
Pasture	660	4.3	2,838	5.5	.78	3,638
Grain	420	.2	84	1.0	.20	420
Corn	50	1.7	85	2.7	.62	137
Other field	150	2.2	330	3.5	.62	532
Other truck	3,040	1.5	4,560	2.5	.61	7,475
Deciduous	1,970	2.6	5,122	3.8	.68	7,532
Vineyard	30	2.5	75	3.3	.75	100
Total	15,370		52,009			69,725

efficiency for several years (table 2). An example of this method is provided to show how an estimate was made for 1989 irrigation water use in Antelope Valley (table 9). The preliminary estimate of 1989 irrigation water use shown (table 9) indicates 52,000 acre-ft of water would have been demanded by the 15,370 acres of crops estimated to have been grown in the valley. The final estimate of 49,000 acre-ft of agricultural demand (table 2) for 1989 means that some changes were made in the data presented in table 9. This variation in estimates can provide an indication of the range in reliability that we might expect from the consumptive-use estimate. For comparison, our data base for all self-supplied water users in the Antelope Valley in 1989 (mainly agricultural irrigation water users) has a reported 48,843 acre-ft of water used (table 3). This comparison of estimated uses with reported uses indicates that our data base probably accounts for most of the irrigation water use that occurred in 1989. However, the only way to be certain that all water use is accounted for each year would be to establish routine data collection, monitoring, and analysis. There could be substantial error when comparing estimates based on "consumptive" or "net" water use with a combination of reported uses from various sources that represents "gross" water use, or total withdrawals. This error could be as large as 25 percent, the difference between the applied water estimate, 69,725 acre-ft, and the evapotranspiration of applied water, 52,009 acre-ft (table 9).

Water used for mining is commonly self supplied. Some local mining companies in the Antelope Valley voluntarily provided data on their water use for this study. However, the volumes they reported are insignificant when compared with irrigation water use in the area, accounting for only about 2 percent of the total self-supplied water use. Total annual water use for mining reported in 1990 for the Antelope Valley was 1,150 acre-ft, which includes both public-supplied and self-supplied water. For 1990, the largest reported user of water for mining was the U.S. Borax and Chemical Corporation at 178 acre-ft (146.5 acre-ft of ground water and 31.4 acre-ft of imported surface water purchased from Antelope Valley-East Kern Water Agency). For all uses (domestic, commercial, industrial, and mining) in 1990, the U.S. Borax and Chemical Corporation reported a total use of 1,682 acre-ft of ground water and 865 acre-ft of imported surface water from Antelope Valley-East Kern Water Agency (table 18 at back of report).

Water-Demand Forecasts

The difficulty of making valid predictions, projections, or forecasts is readily evident. For example, the unpredictable nature of weather often is apparent in our daily lives, especially when forecasts are made for more than a few days into the future. Water managers, however, need to anticipate water needs for years and even decades

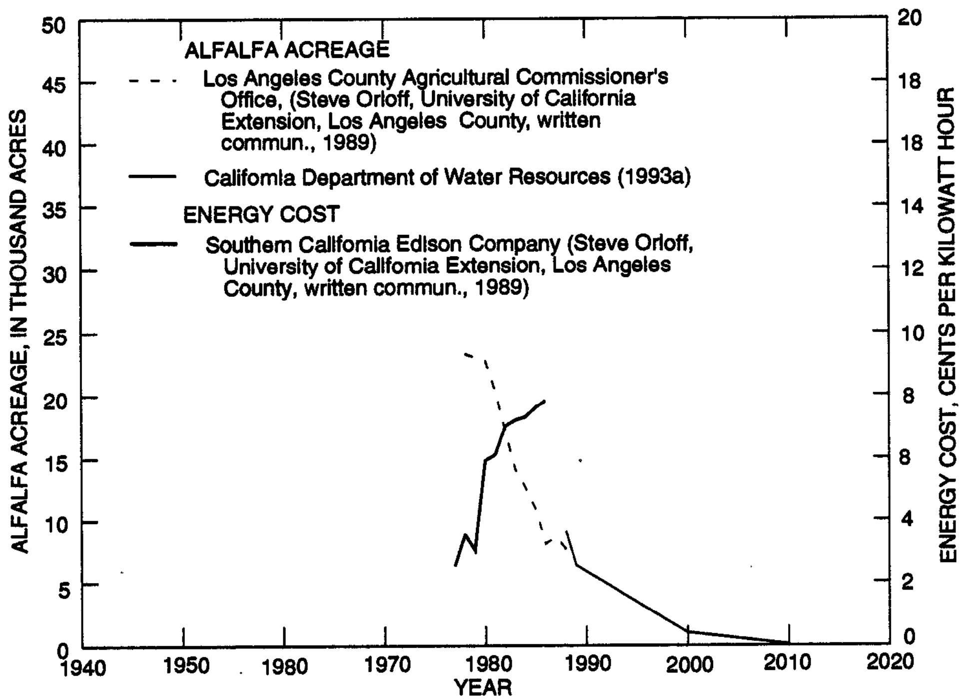

Figure 18. Historical and predicted alfalfa acreages and historical electrical costs in the Antelope Valley.

into the future. To help plan for these future needs, they look to various tools and approaches to provide some information. An essential component of water-resources planning is the water-use forecast, an estimate of the amount of water that will be used at future points in time. Although water-use forecasts help structure debate over water-policy issues, they generally are inaccurate (U.S. Geological Survey, 1990, p. 7) because underlying factors that determine future water use are likely to change in unpredictable ways. Despite the likelihood that long-term projections will prove inaccurate, forecasts still are integral to the process of water-resource planning.

Methods of water-demand forecasting commonly used in the study area, as well as in other areas within and outside of the State of California, are reviewed in this report. The first water-demand forecast specifically for the Antelope Valley was made by the California Department of Water Resources (1980, p. 11) on the basis of information available in 1975. The forecasters recognized that many factors probably would make the accuracy of their estimate short lived. In 1975, several projections for irrigated land use for the Antelope Valley were made by various agencies with each projection being significantly different. Because of the uncertainty in the projection of irrigated land use, the 1975 acreage was kept constant through the year 2020. Agricultural land use decreased steadily from the mid-1950's to the early 1970's as a result of urban encroachment, increasing water costs, and rising land values (California Department of Water Resources, 1980, p. 11). By 1972, agricultural land use had increased slightly as a result of increasing crop prices and deliveries of imported water for agricultural users by the Antelope Valley-East Kern Water Agency. However, the availability of imported water for agricultural users was expected to decrease sharply in 1983 [which it did (table 6)] when renewal of the State Water Project energy contracts would increase the cost of the imported water. The California Department of Water Resources (1980, p. 14) projected a constant agricultural water demand of about 166,250 acre-ft/yr (table 2).

Instead of remaining constant, agricultural water demand has decreased to about 35,279 acre-ft as of 1991 (tables 2 and 8). Because of the decreasing trend in irrigated acreage during the past few years, a simple projection approach can indicate future agricultural water demands on the basis of historical information of increasing electrical costs and decreasing alfalfa acreages (fig. 18). Unless changes in the value of alfalfa or the cost of electricity occur, this method indicates that less ground water will be pumped for alfalfa irrigation. Reclaimed wastewater, however, may continue to be

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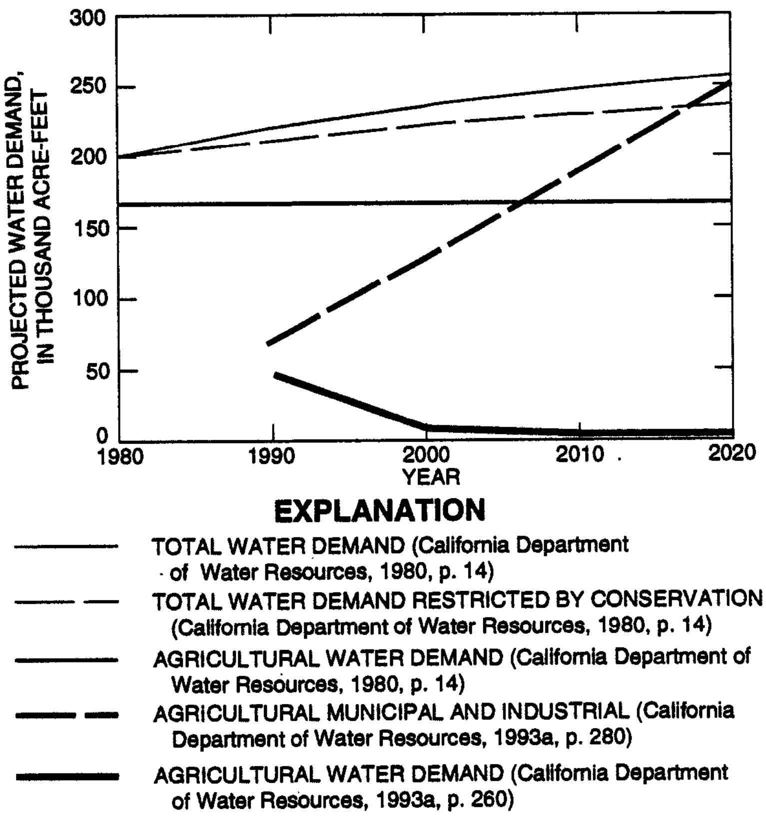

Figure 19. Water-demand projections for the Antelope Valley made in 1980 and 1990 to the year 2020. Total water demands projected in 1980 by the Dapartment of Water Resources included agricultural, municipal, and industrial demands.

a source of water supply for alfalfa in the study area and probably will increase in the future.

Statewide forecasts, or projections, for water supplies and water demands have been made for sources of water supply and types of water use by the California Department of Water Resources since 1966. These forecasts were updated in 1970, 1974, 1983, 1987, and 1993 at a statewide level (California Department of Water Resources, 1983, p. 19; 1987, p. 18, 1993, v. 2, p. 260). Earlier forecasts (1966, 1970, and 1974) as well as the most recent forecast (1993) were made to the year 2020. The 1983 and 1987 updates were extended only to the year 2010 because of increased concern about the uncertain future of the agricultural economy and the population growth. Since 1983, these forecasts have been made for regions termed "planning subareas." The Antelope Valley is considered a "planning subarea." Basinwide forecasts made in 1980 and 1993 are available for this study area (fig. 19). The most recent projections for urban water demand for the Antelope Valley are 122,000 to 126,000 acre-ft for 2000; 180,000 to 186,000 acre-ft for 2010; and 243,000 to 250,000 acre-ft for 2020 (California Department of Water Resources, 1993a, p. 260).

According to Cameron and others (1993, p. 1), the methods used by the California Department of Water Resources to make basinwide forecasts for water demand have been "based entirely upon non-stochastic point estimates of base unit use for each category of water use, fractional reduction in unit use in that category, and the population affected by each conservation measure." Deficiencies in this method have been recognized that can create misleading implications of a much greater degree of accuracy than the available information allows (Cameron and others, 1993, p. 1). These deficiencies include the lack of validation-verification procedures and confidence limits. Beginning with the 1998 forecasts, a simulation approach is planned to "succinctly convey the consequences of the stochastic nature of all of the ingredients." The many vagaries of demographics, weather, technology, and economics make forecasts so uncertain that this uncertainty needs to be understood. Further, there are wide bands of error on each side of any forecast, and these bands increase as forecasts reach farther into the future.

Water demands are expected to increase with continued urban development in the valley. Forecasting, or predicting future water demands, is of interest to those who are responsible for ensuring that sufficient water is available for the area. Forecasts can be based on projections of population growth, increases in numbers of water meters being installed, changes in acreages of land use, and through the use of many other socioeconomic variables.

Forecasts by Other Agencies

Planning forecasts for Los Angeles County Water Works Districts in the Antelope Valley were identified during our study (Henry Roedeger, Los Angeles County Department of Public Works, Lancaster, written commun., 1992). These forecasts used growth projections of 5 to 6 percent per year (obtained from planning departments of local

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communities) and annual increases in the number of meters in each of their districts to estimate the total number of meters projected to be in use by 1998. This method of forecasting is less complex than the methods used by the California Department of Water Resources and the Metropolitan Water District of Southern California, but doesn't really estimate water demand. These predictions also are for a relatively short period—about 5 years—compared with projections by the California Department of Water Resources, which are for about 30 or 40 years.

Water-demand forecasts for Littlerock Creek Irrigation District were included in a report by Suzuki (1987, p. 4-14a and 4-14b). These forecasts indicated water demand was expected to follow population growth (about 4 percent per year). By 2010, population was projected to be about 5,000 and water demand was forecasted to be about 2,000 acre-ft/yr (1.6 acre-ft/yr for a family of four), with water demand doubling between 1990 and 2010. By the year 2040, population was forecasted to be about 15,000 and water demand about 4,500 acre-ft/yr (1.2 acre-ft/yr for a family of four), indicating a decreased rate of use per person. No explanation was provided to describe the method used or the reasons behind these expectations for water-demand reductions for a family of four, but it may be assumed to be a result of conservation and reductions of irrigated orchard acreage within the district.

MAIN System Forecasts

The most sophisticated method identified in this study for forecasting urban water demands is the MAIN system. The IWR_MAIN Water Use Forecasting System is a computerized planning tool for estimating present and future water demands (Davis and others, 1991, p. I-1). The system is a collection of data intensive, econometric regression models that can be used to make detailed forecasts of water demand. The IWR_MAIN system was developed by Planning and Management Consultants, Ltd., under contract to the U.S. Army Corps of Engineers and has been modified specifically for the Metropolitan Water District of Southern California (MWD_MAIN). MAIN is an acronym for Municipal And Industrial Needs; IWR is an acronym for the Institute of Water Resources of the U.S. Army Corps of Engineers (located at Ft. Belvoir, Virginia), and MWD is for the Metropolitan Water District of Southern California. These systems are intended for use in estimating and forecasting public-supplied water demands for municipal and industrial needs but not for irrigation or self-supplied municipal and industrial needs.

One of the most challenging problems to users of this system occurs when trying to convert available census data into the data required by the MAIN model (Thompson and others, 1993, p. 425). Many assumptions and adjustments can be required that may be highly speculative or inaccurate. The MAIN model can be used with varying amounts of input data for a base year (1980 in this case), but has a minimum requirement of four variables: population, employment (by Standard Industrial Code-SIC), income, and total number of housing units for each of two housing categories (single family and multifamily; table 10). Forecasts and projections can be made with a relatively small amount of information using the "internal" growth models contained within the MAIN systems (table 11). A coefficient library, internal to the MWD_MAIN system, contains default information that can be combined with baseline information to make forecasts. The advantages of using the defaults are that the system requires a relatively small amount of information, scenarios can be changed, and the user can make "what if" comparisons with relative ease. The primary disadvantage of relying on these default coefficients is that the results may not be an accurate representation of the modeled area.

Projections can be modified to produce an "external forecast" using data outside the MWD_MAIN system, which is provided by the user. This method can produce greater accuracy for a given area or water district. The primary advantage of external forecasting is that customized study-area forecasts can be developed that are potentially very accurate when good data are available. The MAIN systems also are valuable for their use in analyzing various future scenarios. The primary disadvantages of external forecasting are (1) the system is data intensive and (2) good data can be expensive and time consuming to obtain.

The MAIN system of models, though complex, provides the user with a wide variety of capabilities. Data-manipulation capabilities are numerous, with many options for disaggregating or aggregating data into sectors of water use. Water-pricing, income, and population data are taken into account, as well as seasonal climatic changes. Once a basic model is developed, the MAIN system can simulate

Table 10. Data requirements for the MWD_MAIN base year 1980

[Explanation of Symbols: CCI, Composite Construction Index; SIC, Standard Industrial Code; $/Kgal, dollar per thousand gallons; gal/d, gallon per day; gal/d/unit, gallon per day per unit; --, no data available]

Sources of data:

Population:
Lancaster and Palmdale: City of Lancaster (1993); Southern California Association of Governments (1993).
Antelope Valley: California Department of Water Resources (1980, 1993b).

Income:
Lancaster and Palmdale: Southern California Association of Governments (1993).
Antelope Valley: Alfred Gobar and Associates (1993). All income estimates for 2000 and 2010 derived from a 6-percent increase every 10 years based on Planning and Management Consultants, Ltd., income projections for Los Angeles County. All income values reported in 1980 dollars.

Employment:
Lancaster: U.S. Department of Commerce (1980).
Palmdale: Pete Eskis, California Employment Development Department (written commun., 1993).
Lancaster and Palmdale: Southern California Association of Governments (1993).
Antelope Valley: Sum of employment totals for Lancaster, Palmdale, and Kern County for 1975; sum of Los Angeles and Kern County employment totals from Southern California Association of Governments (1993) and Kern County Council of Governments (1990).

Temperature and Rainfall: National Oceanic and Atmospheric Administration (1991).

Composite Construction Index: Eva Opitz, Planning and Management Consultants, Ltd. (oral commun., 1993).

Housing, total number of housing units:
Lancaster and Palmdale (single family and multifamily): Southern California Association of Governments (1993).
Antelope Valley: Alfred Gobar and Associates (1993).
Distribution of housing throughout the value ranges for single-family and multifamily housing: U.S. Department of Commerce (1980).

Number of persons per household:
Lancaster and Palmdale: U.S. Department of Commerce (1970, 1980, 1990).
Antelope Valley: Alfred Gobar and Associates (1993).

Water rates:
Lancaster and Antelope Valley: Ramon Gonzales, Los Angeles County Department of Public Works (written commun., 1993).
Palmdale and Antelope Valley: Tammy Lucas, Palmdale Water District (oral commun., 1993).

Data requirements	1975	1980	1984	1987	1990	2000	2010
LANCASTER							
Required data							
Municipal							
Base year	--	1980	--	--	--	--	--
Total population	--	48,103	53,827	68,063	97,291	152,279	212,140
Median income	--	24,499	25,013	20,943	25,046	26,549	28,142
Total employment	15,516	14,808	15,195	23,240	42,039	63,217	83,320
CCI or alternate CCI	--	143.3	--	--	--	--	--
Rainfall, in inches	--	5.7	--	--	--	--	--
Maximum summer temperature	--	107	--	--	--	--	--
Cooling degree days	--	1,635	--	--	--	--	--
Residential							
Multifamily, housing by value range	--	([1])	--	--	--	--	--
Multifamily, persons per unit	--	4.1	--	--	--	--	--
Multifamily, winter rate ($/Kgal)	--	.44	--	--	--	--	--
Multifamily, summer rate ($/Kgal)	--	.44	--	--	--	--	
Single family, housing by range	--	([1])	--	--	--	--	--
Single family, persons per unit	--	2.4	--	--	--	--	--
Single family, winter rate ($/Kgal)	--	.56	--	--	--	--	--
Single family, summer rate ($/Kgal)	--	.56	--	--	--	--	--

See footnotes at end of table.

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