GROUND WATER IN THE

KOEHN LAKE AREA

KERN COUNTY, CALIFORNIA

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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ILLUSTRATIONS

CONVERSION FACTORS

For readers who prefer metric units rather than English units, conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain metric unit
acres	4.047×10^{-1}	hectares
acre-ft (acre-feet)	1.233×10^{-3}	cubic hectometers
ft (feet)	3.048×10^{-1}	meters
ft^2/d (feet squared per day)	9.290×10^{-2}	meters squared per day
gal/min (gallons per minute)	6.309×10^{-2}	liters per second
mi (miles)	1.609	kilometers
mi^2 (square miles)	2.590	square kilometers

IV

INTRODUCTION

Purpose and Scope

Residents of the Koehn Lake area (fig. 1) depend entirely on ground water for their water supply. Increased withdrawal of ground water for agricultural expansion has resulted in declining water levels in wells. The declining water levels have caused concern about the possibility of saline water from under Koehn Lake being drawn into and degrading the water supply.

The purposes of this study were (1) to define the current and historical ground-water conditions in order to describe the magnitude and distribution of the potential water-quantity and water-quality problems, and (2) to define changes and trends in the hydrologic system sufficiently that reasonable estimates of future effects can be made by local management agencies.

Data from a well inventory made in 1958 were published in California Department of Water Resources Bulletin 91-16 (Moyle, 1969). Since 1963, a monitoring program has furnished annual water-level data on 13 wells and water-quality data on 5 wells in the study area (fig. 2). These data, however, are not sufficient to determine the magnitude and areal distribution of changes in water levels and water quality caused by increased pumping.

Ground-water data obtained since 1958 by well drillers, pump companies, and other agencies were collected and correlated with wells in the field. The water level in all accessible wells was measured, and these data were used to draw a current (1976) water-level contour map. Water-level data from Moyle (1969) were used to draw a water-level contour map for 1958. These maps were compared to define the change of ground water in storage and the change in ground-water gradient resulting from increased pumpage.

Specific yield and thickness of the unconsolidated deposits were estimated from drillers' logs and were used to calculate the quantity of water in storage.

Consumptive use was calculated on the basis of types and areas of irrigated crops, taking into account the effect of local climatic conditions on applied water requirements.

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ABSTRACT

Hydrologic characteristics of the Koehn Lake area were investigated to determine the effects of external stresses on the system. Unconsolidated deposits are more than 900 feet thick in the central part of the basin. Cantil Valley fault, in the central part of the basin, acts as a barrier to the flow of ground water.

Average annual recharge to aquifers from percolation of surface water and from underflow, between 1958 and 1976, was 10,200 acre-feet. Average annual consumptive use, between 1960 and 1976, was 32,000 acre-feet, 21,800 acre-feet more than the recharge, implying that average annual withdrawal from storage is about 22,000 acre-feet. Storage depletion in 1976 was 50,000 acre-feet, considerably higher than the average. The cumulative storage depletion has caused a decline in water levels and a pumping depression about 5 miles southwest of Koehn Lake.

Ground water in storage in 1976 was about 4 million acre-feet, and ground water in storage above the 500-foot depth excluding the saline water under Koehn Lake was about 2 million acre-feet.

Water samples were collected from 24 wells for chemical analysis. Comparison of analyses made during this study with historical water-quality analyses indicated no significant change. A recent reversal in ground-water gradient southwest of Koehn Lake may allow the saline water below Koehn Lake to invade the fresh-water aquifer.
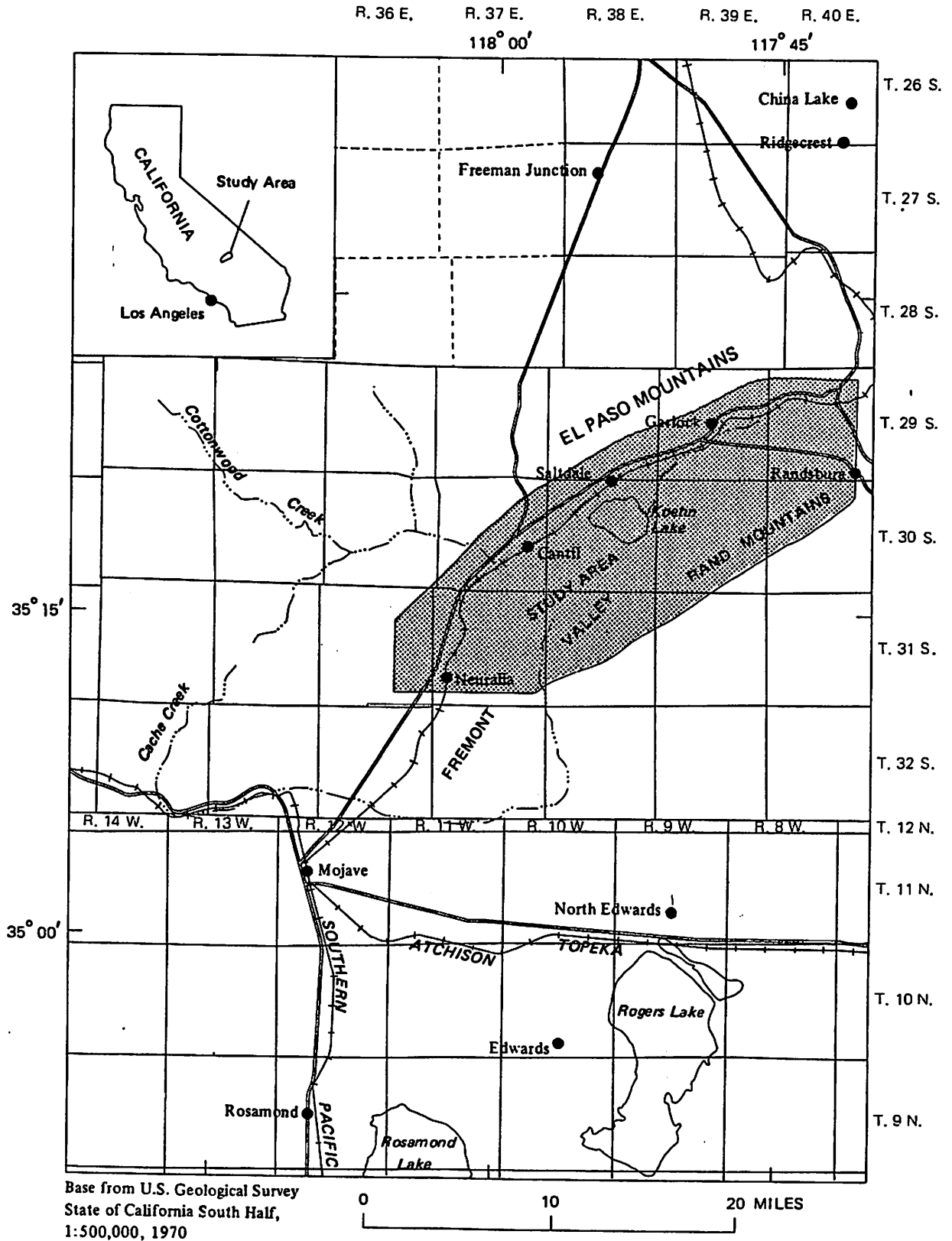
FIGURE 1.--Index map.
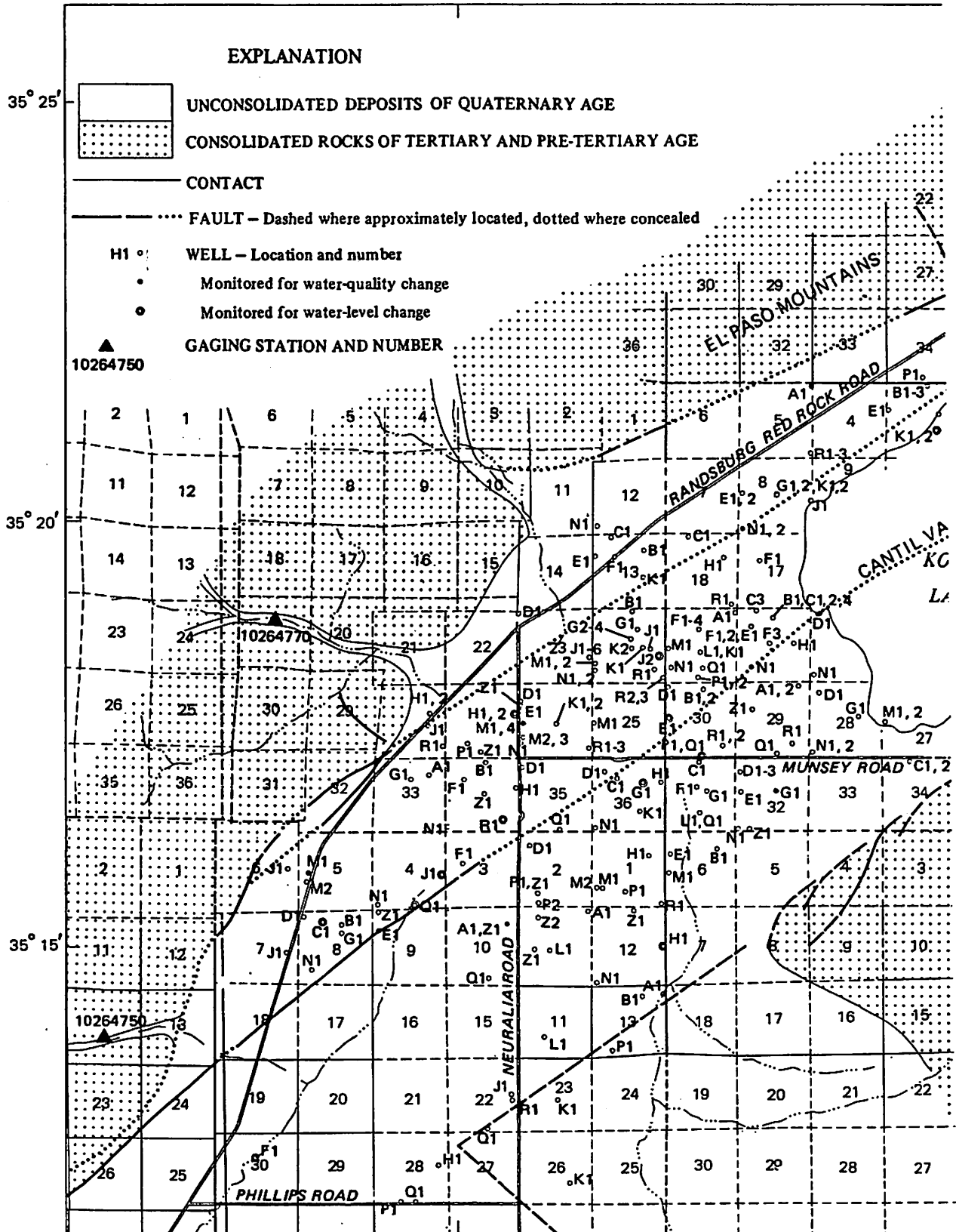
FIGURE 2.--Location of wells.

R. 39 E.

117° 45'

R. 40 E.
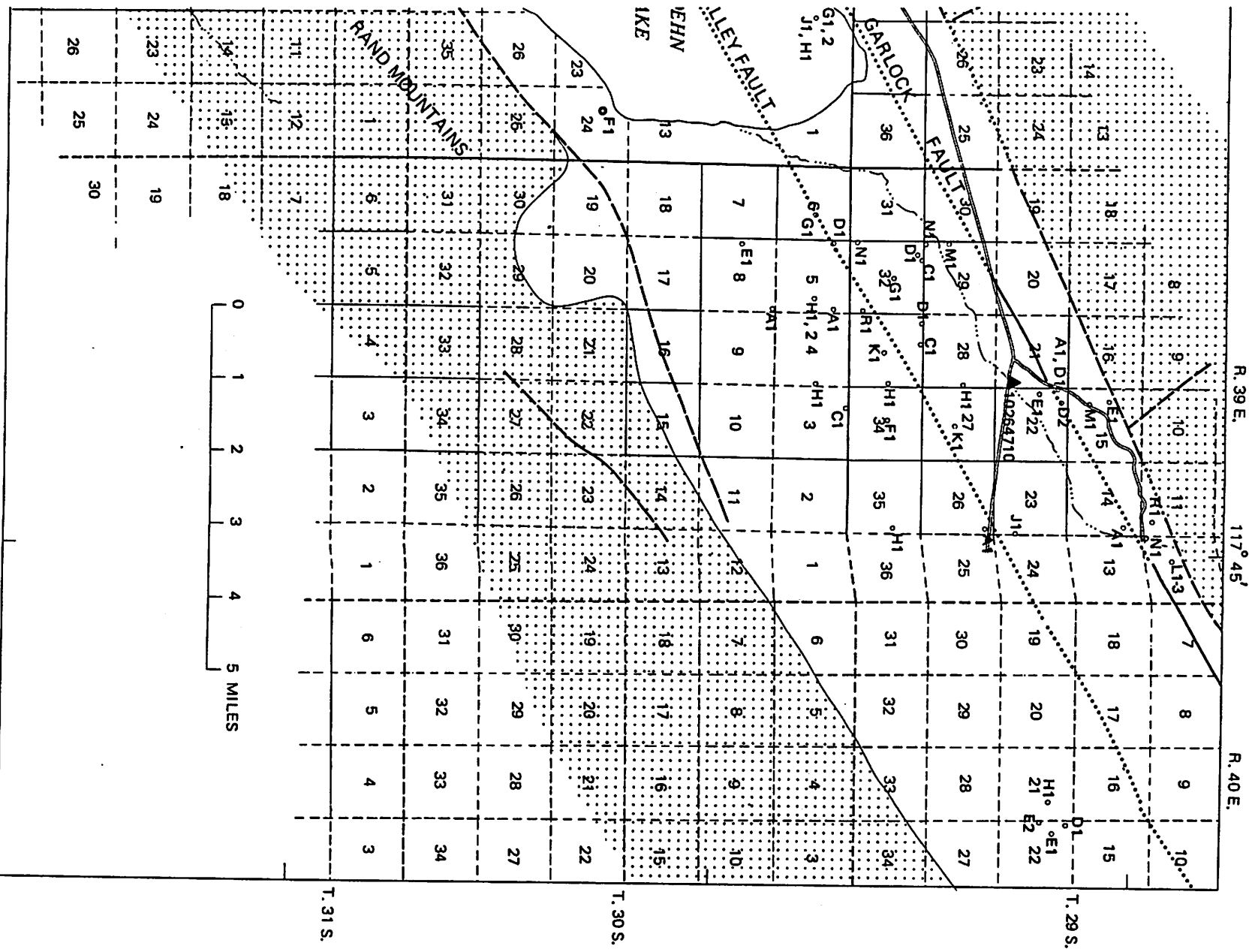
FIGURE 2.—Continued.

Geology generalized from W.R. Moyle, Jr., 1969

RAND MOUNTAINS

GARLOCK FAULT

LLEY FAULT

T. 29 S.

T. 30 S.

T. 31 S.

0 1 2 3 4 5 MILES

Water samples were collected from 24 selected wells for analysis of major chemical constituents. Four of these water samples were analyzed for trace elements. These data were compared with historical water-quality data to determine changes in water quality with time. To determine water-level and water-quality changes with depth, four test holes were augered on the southwest side of Koehn Lake.

Gamma logs were made for the test holes and for five other wells in an unsuccessful attempt to correlate lithology between wells.

Location and Physiography of Study Area

The study area of about 150 mi^2 is in Fremont Valley, about 15 mi northeast of the town of Mojave in Kern County, Calif. (fig. 1). The area extends to the town of Neuralia on the southwest, and it is bounded on the northwest by the El Paso Mountains, on the northeast by a ridge of low hills, and on the southeast by the Rand Mountains. The altitude of the valley floor ranges from about 2,300 ft on the periphery to about 1,900 ft at Koehn Lake in the central part of the study area. Infrequent storm runoff from the bordering mountains flows into Koehn Lake, which normally is dry. The valley terrain is mantled by erosional products, mostly sand with some gravel and boulders, from the surrounding mountains. Native vegetation is sagebrush and some salt-tolerant phreatophytes near Koehn Lake. The primary crop grown in the study area is alfalfa.

Acknowledgments

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. As shown by the diagram, that part of the number preceding the slash, as in 29S/39E-14A1, indicates the township (T. 29 S.); the number following the slash indicates the range (R. 39 E.); the number following the hyphen indicates the section (sec. 14); the letter following the section number indicates the 40-acre subdivision according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision. A Z before the final digit would indicate that the well is plotted from an unverified location description; the site was visited but no evidence of a well could be found. All wells mentioned in this report are in the southeast quadrant of the Mount Diablo base line and meridian.
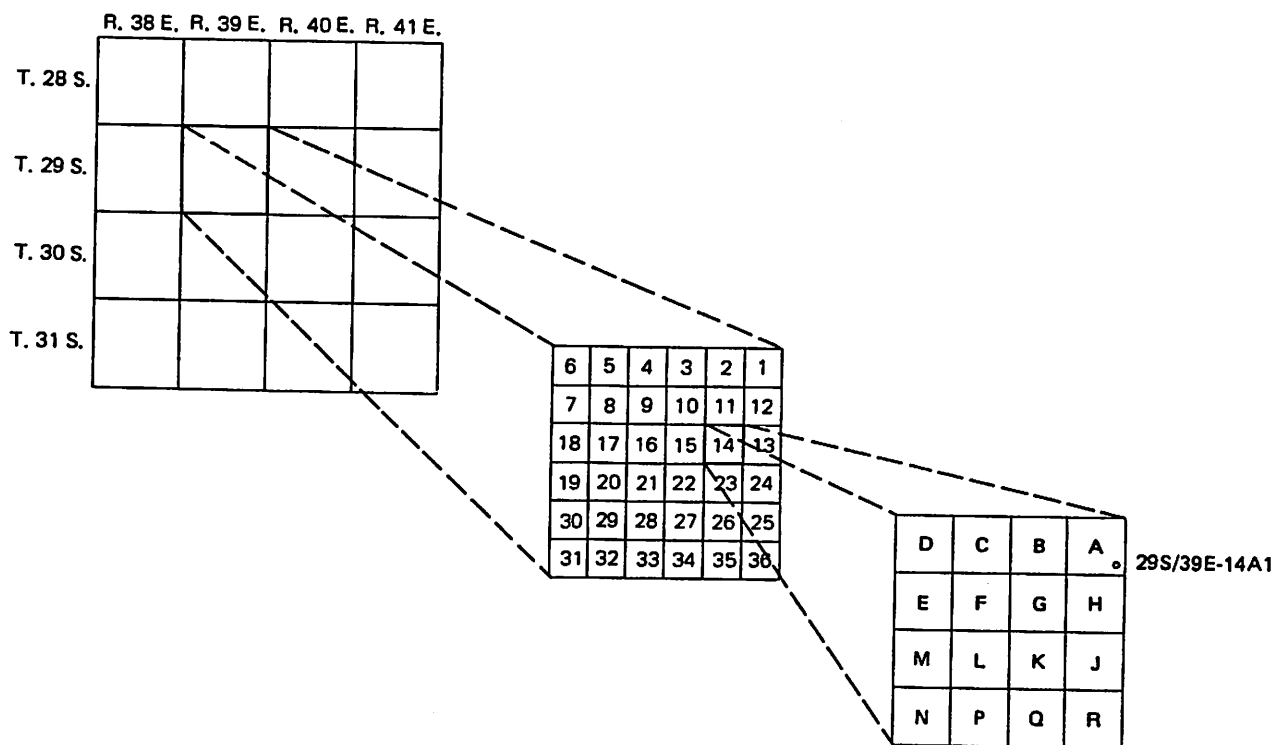
HYDROLOGY

Lithology

     The lithology of the study area, for the purpose of this report, is
divided into two units, consolidated rocks and unconsolidated deposits (fig. 2).

     Consolidated rocks consist of igneous and metamorphic rocks of
pre-Tertiary age, which make up the basement complex, and sedimentary and
volcanic rocks of Tertiary age. Sedimentary rocks are composed of conglomerate,
sandstone, and clay interbedded with lava flows and other volcanic rocks.
The thickness of the Tertiary rocks in the central part of the basin is not
known; however, an oil-test well (30S/38E-19P2) drilled to a depth of
5,065 ft did not reach the basement complex.

     Pre-Tertiary igneous and metamorphic rocks are impermeable except where
weathered or fractured, and yield only small quantities of water to wells.
Tertiary sedimentary rocks have a low permeability and yield little or no
water to wells.

     Unconsolidated deposits, of Quaternary age, are alluvial deposits
consisting of gravel, sand, silt, clay, and some boulders. These deposits
range from coarse and poorly sorted near the mountains to finer and better
sorted near the central part of the basin. Sediments of Koehn Lake bed are
mainly silt and clay.

     Thickness of the unconsolidated deposits southwest of Koehn Lake (fig. 3)
was determined by a subjective technique using data supplied from drillers'
logs. Terms such as hard, firm, rocks, or granite were presumed to be the
consolidated rocks. These data were supplemented by logs of wells that
apparently did not reach the consolidated rocks. Thickness of the
unconsolidated deposits exceeds 900 ft in the central part of the basin but
is less than 400 ft in the vicinity of sec. 11, T. 31 S., R. 37 E.

     Thickness of the unconsolidated deposits northeast of Koehn Lake could
not be contoured because data were sparse or lacking. Wells 29S/39E-32D1
and 32N1 were drilled to depths of about 800 ft below land surface and did not
encounter the consolidated rocks.

     The permeability of the unconsolidated deposits varies with the texture
of the sediments. Aquifers of well-sorted sand and gravel yield large
quantities of water to wells. Clay and mixtures of clay, sand, and gravel
yield only small quantities of water to wells. Irrigation wells drilled
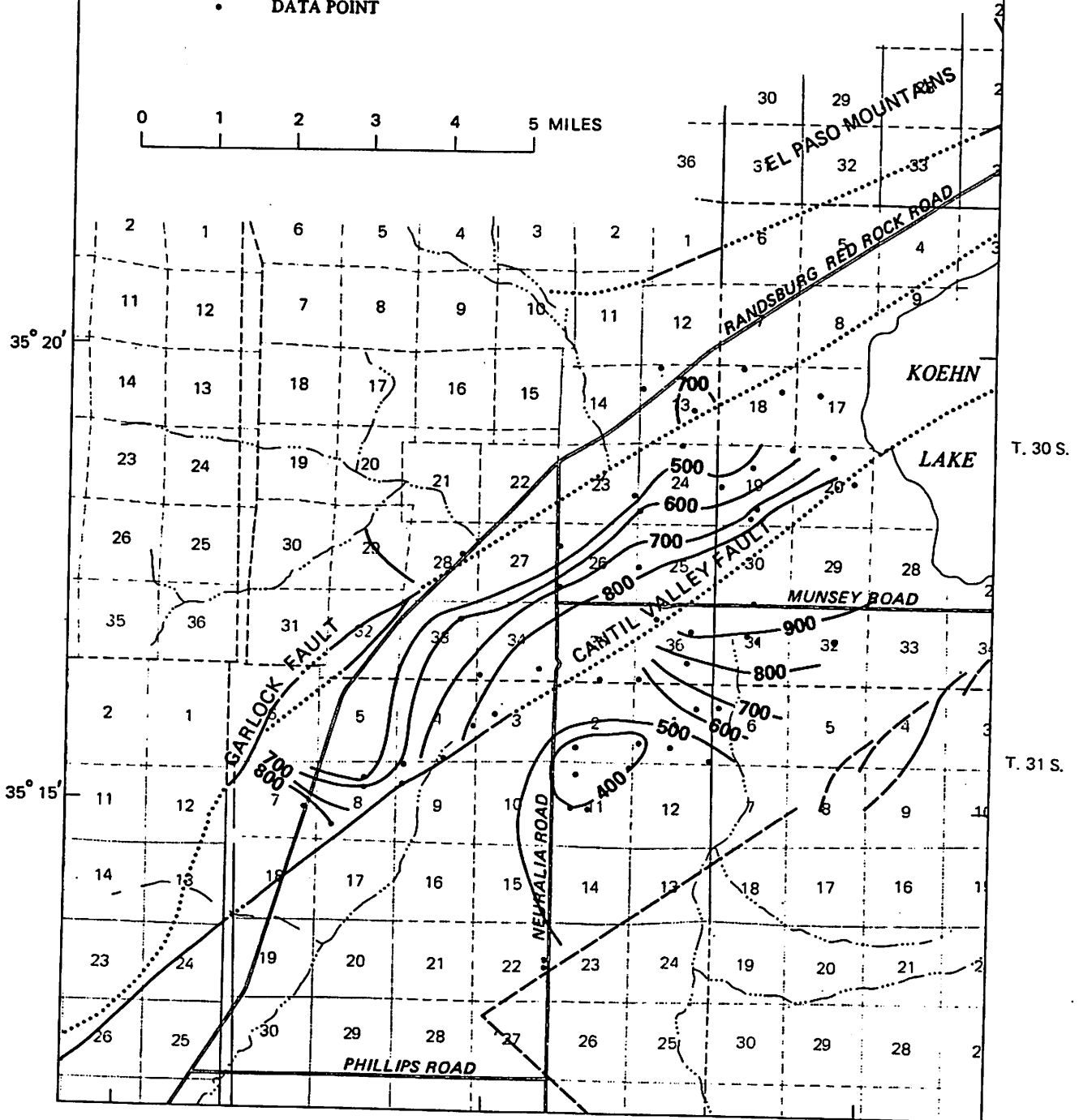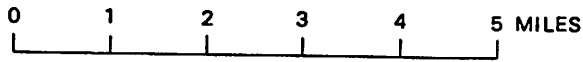in the unconsolidated deposits typically yield about 1,500 gallons of water
per minute.

FIGURE 3.--Thickness of unconsolidated deposits.

Faults and Ground-Water Barriers

Four major faults traverse the project area in a northeast-trending direction (fig. 2): An unnamed fault near the base of the El Paso Mountains, the Garlock fault on the northwest side of the basin, the Cantil Valley fault near the center of the basin, and an unnamed fault near the base of the Rand Mountains. Cantil Valley fault is hydrologically the most significant because it acts as a barrier to ground-water movement. The barrier effect is most obvious southwest of Koehn Lake where there is a marked difference in water levels on opposite sides of the fault (figs. 4 and 5). The thickness of the unconsolidated deposits is less on the southeast side of the fault (fig. 3), which limits the transmitting capacity and quantity of water in storage in that part of the basin.

Occurrence and Movement of Ground Water

The water level in all accessible wells was measured in 1958 and 1976. These data were used to draw water-level contour maps for 1958 (fig. 4) and 1976 (fig. 5). In areas where differences in water levels existed because of well depth, the deeper water level was used for contouring.

The gap in water-level contours between the northeast and southwest sides of Koehn Lake on the 1958 map (fig. 4) is due to a lack of water-level data in that area. In 1958 ground water moved from all directions toward Koehn Lake. A small pumping depression developed about 5 mi southwest of Koehn Lake because of withdrawals for irrigation. Between the pumping depression and Koehn Lake a residual ground-water mound maintained a gradient toward Koehn Lake. Northeast of this residual mound water moved toward Koehn Lake.

Water-level contours for 1976 (fig. 5) show a much steeper gradient toward the pumping depression. Also it is larger and deeper, and the residual ground-water mound between the pumping depression and Koehn Lake is gone. Because the ground-water gradient is from Koehn Lake toward the pumping depression, saline water under Koehn Lake poses a potential threat to the fresh-water supply.

Figure 6 shows the net water-level decline between 1958 and 1976. A maximum decline of about 240 ft occurred in the pumping depression on the southeast side of Cantil Valley fault. Figure 7 contains hydrographs of selected wells showing the rate of water-level decline. The hydrograph of well 30S/37E-36G1 shows less water-level decline in the past 18 years than is indicated for the general area on the water-level decline map (fig. 6). This is probably because well 36G1 is shallower and not in hydraulic contact with the same aquifer as well 30S/37E-36H1 which was used for drawing the water-level decline map.

A multiple-aquifer system is indicated by differences in the water level in neighboring wells. For example, the water-level altitude in wells 30S/38E-30Q1, 78 ft deep, 30P1, 330 ft deep, and 31C1, depth unknown, is 1,900, 1,851, and 1,830 ft, respectively. These wells are within 200 ft of each other. The water-level altitude in wells 30S/37E-36G1 and 36H1, about 1,000 ft apart, is 1,877 and 1,780 ft, respectively. The areal extent of the multiple-aquifer system is not known. Available water-level data suggest that the multiple-aquifer system may be limited to a small area southwest of Koehn Lake. Many multiple-piezometer test wells would be required to define the system accurately.

Recharge

Recharge to the aquifer has two sources, percolation of runoff from the mountains and underflow from the southwest.

Slightly more than 200 acre-ft per year of runoff has been monitored at three gaging stations (fig. 2) in the study area.

Station name and number	Location (township, range, and section)	Years monitored	Drainage area (mi^2)	Average annual runoff (acre-ft)
Goler Gulch near Randsburg, Calif. 10264710	29S/39E-21	1966-72	41.3	14
Pine Tree Creek near Mojave, Calif. 10264750	31S/36E-14	1958- continuing	33.5	152
Cottonwood Creek near Cantil, Calif. 10264770	30S/37E-19	1966-72	163	46
Total			237.8	212

By extrapolating for the remaining drainage area (about 200 mi^2), an additional unmonitored 200 acre-ft per year of runoff is estimated to flow into the study area. Most of the runoff is caused by infrequent summer thunderstorms in the El Paso Mountains. As the runoff migrates over the alluvial fans and valley floor, losses occur by evaporation, transpiration by vegetation, retention as soil moisture, and percolation to the water table. When runoff is intense, some of the water reaches Koehn Lake. Because the bed of Koehn Lake is nearly impermeable, most of that water is ponded and then lost by evaporation. It is estimated that of the total runoff only half, or about 200 acre-ft per year, is recharge to the ground water.
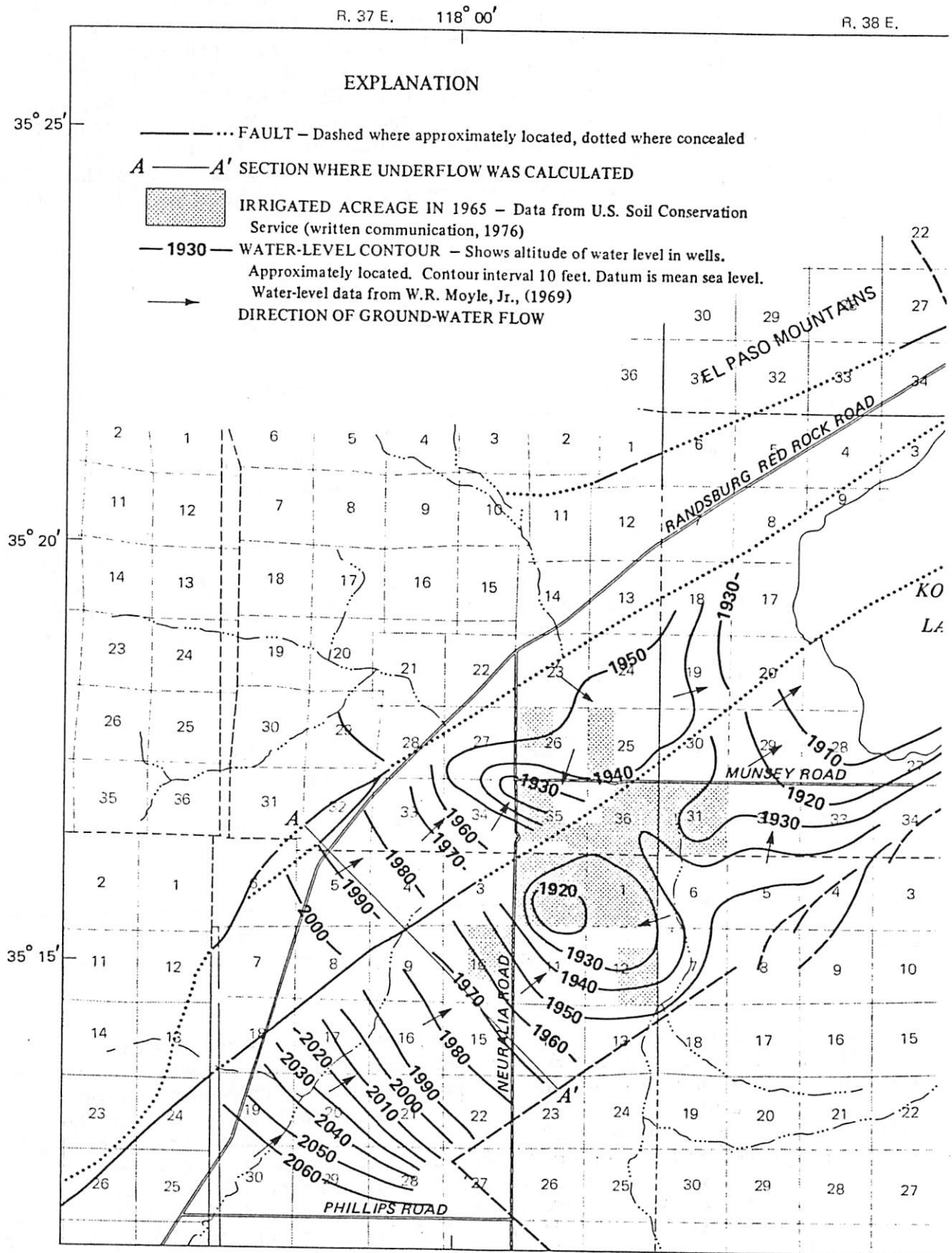
FIGURE 4.--Water-level contours for 1958.
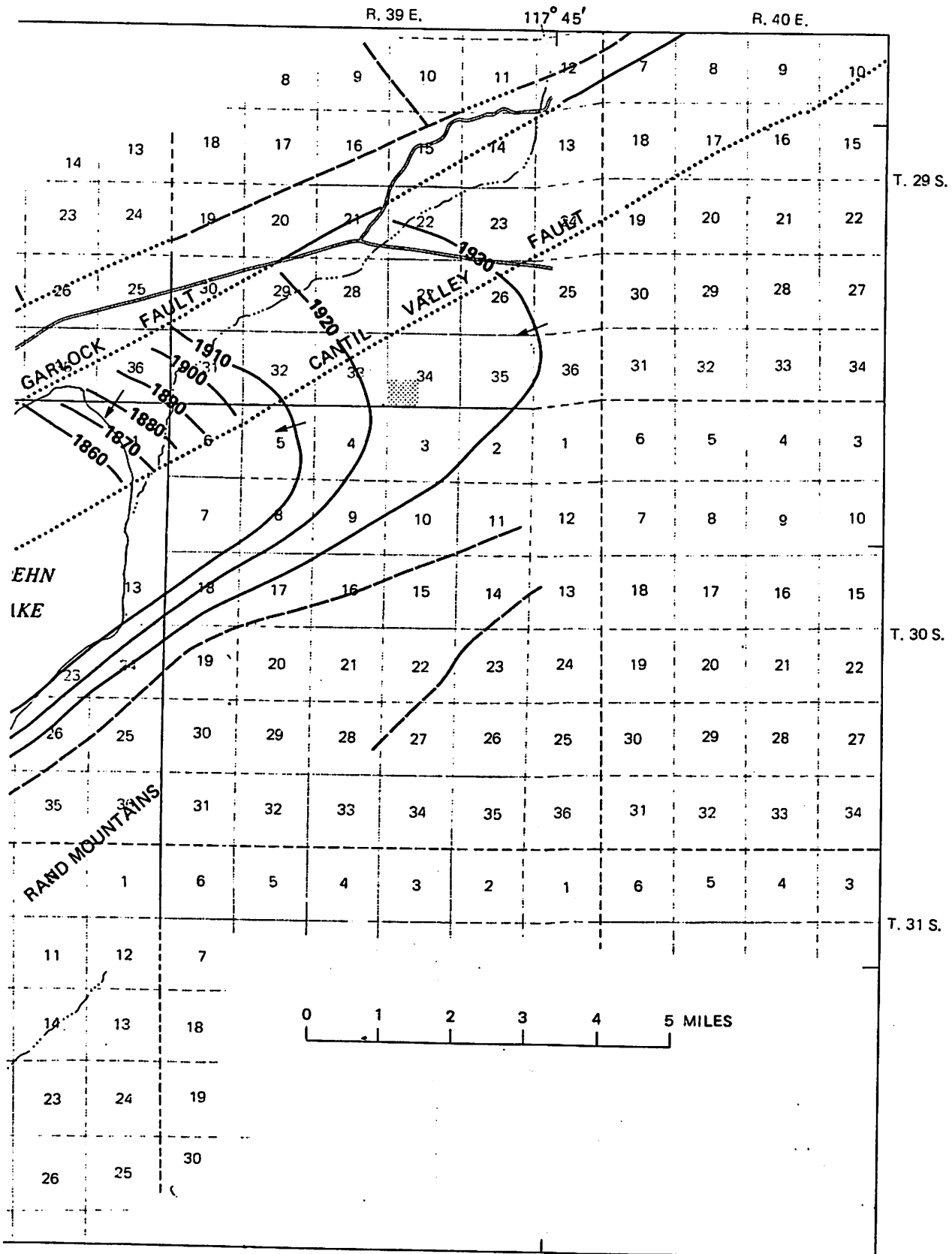
FIGURE 4.--Continued.
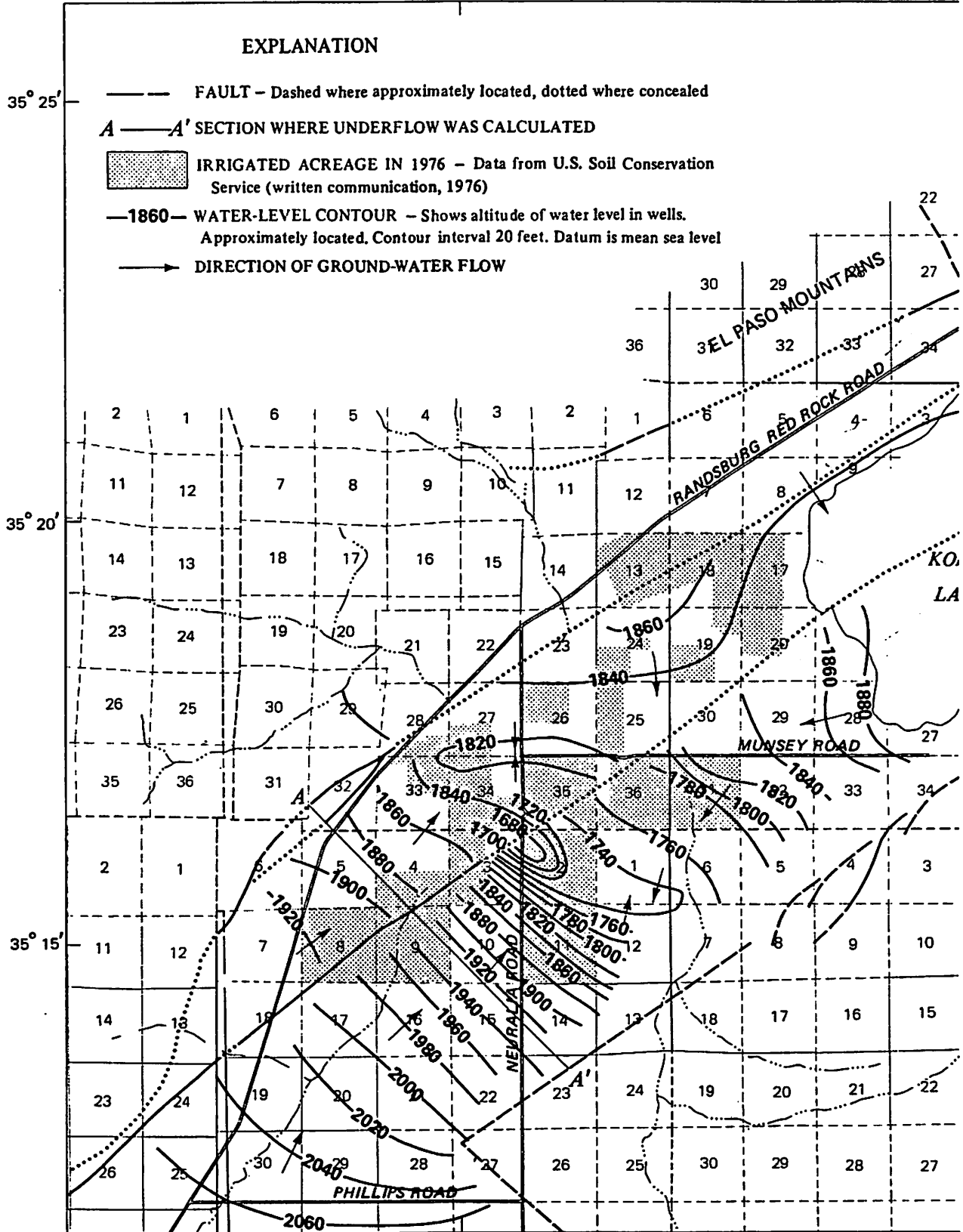
FIGURE 5.--Water-level contours for 1976.

FIGURE 5.--Continued.

HYDROLOGY 15

0 1 2 3 4 5 MILES

T. 31 S.

T. 30 S.

T. 29 S.

R. 39 E.

R. 40 E.

117°45'

RAND MOUNTAINS

GARLOCK FAULT

CANTIL VALLEY FAULT 30

1900

1860
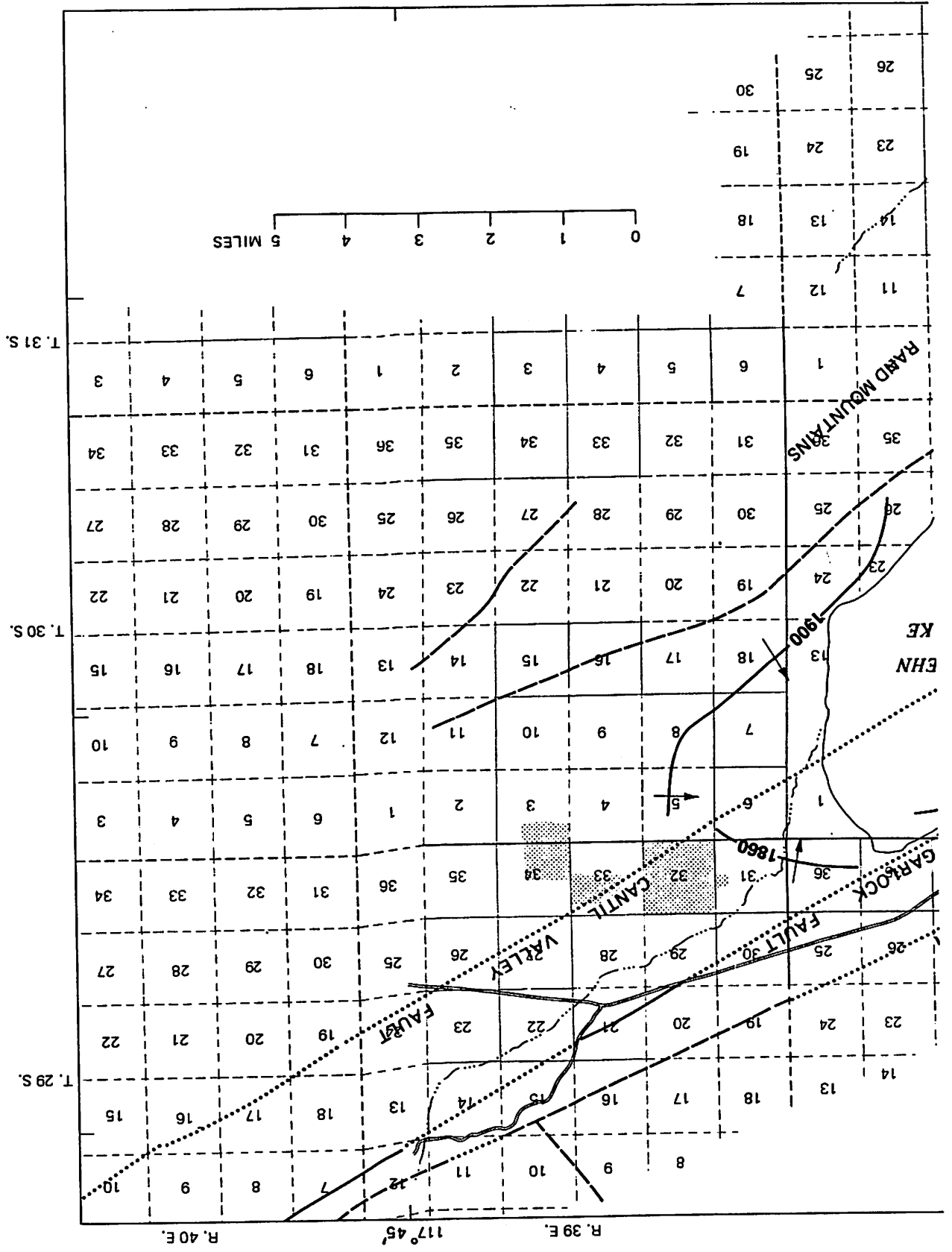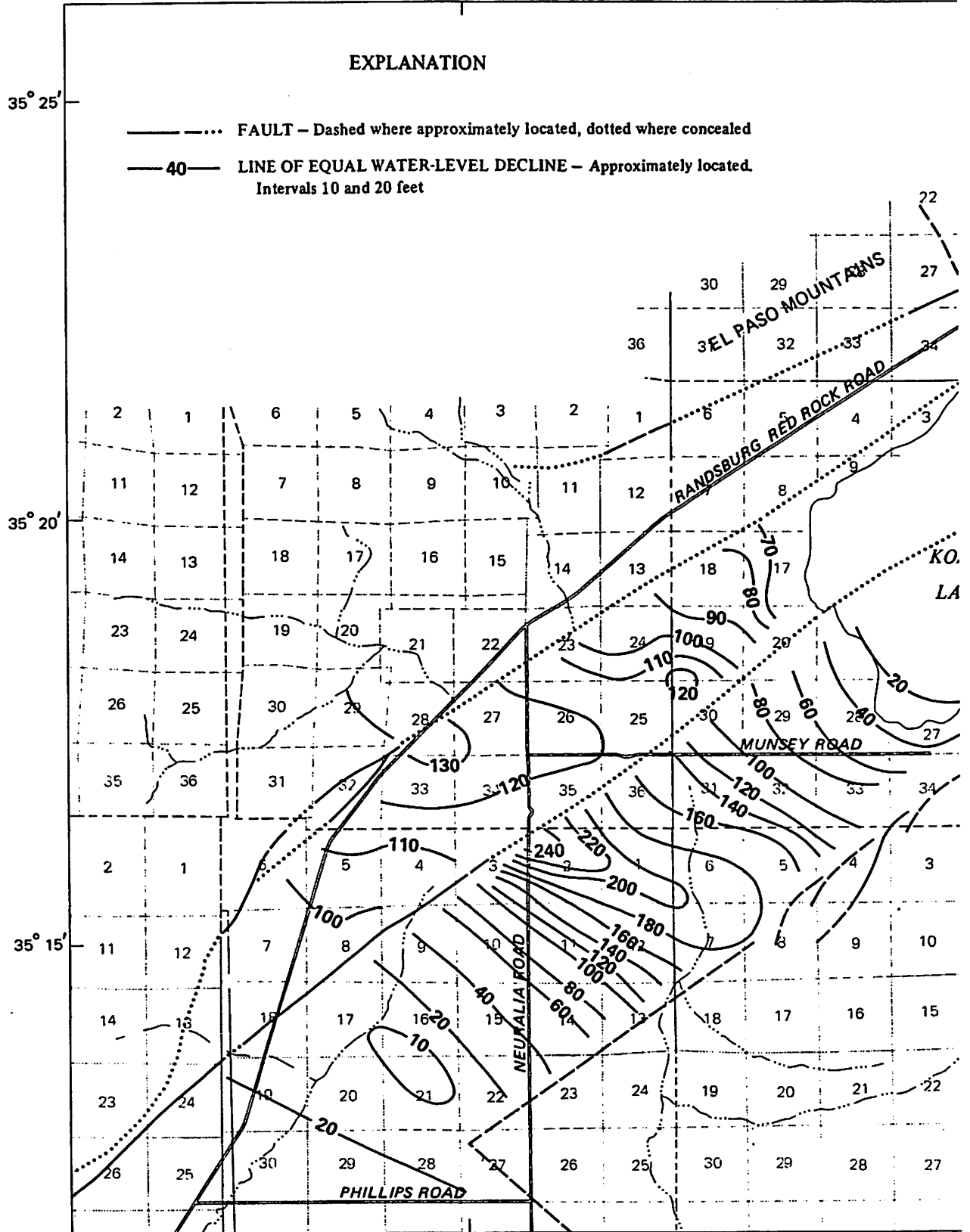
FIGURE 6.--Water-level decline between 1958 and 1976.
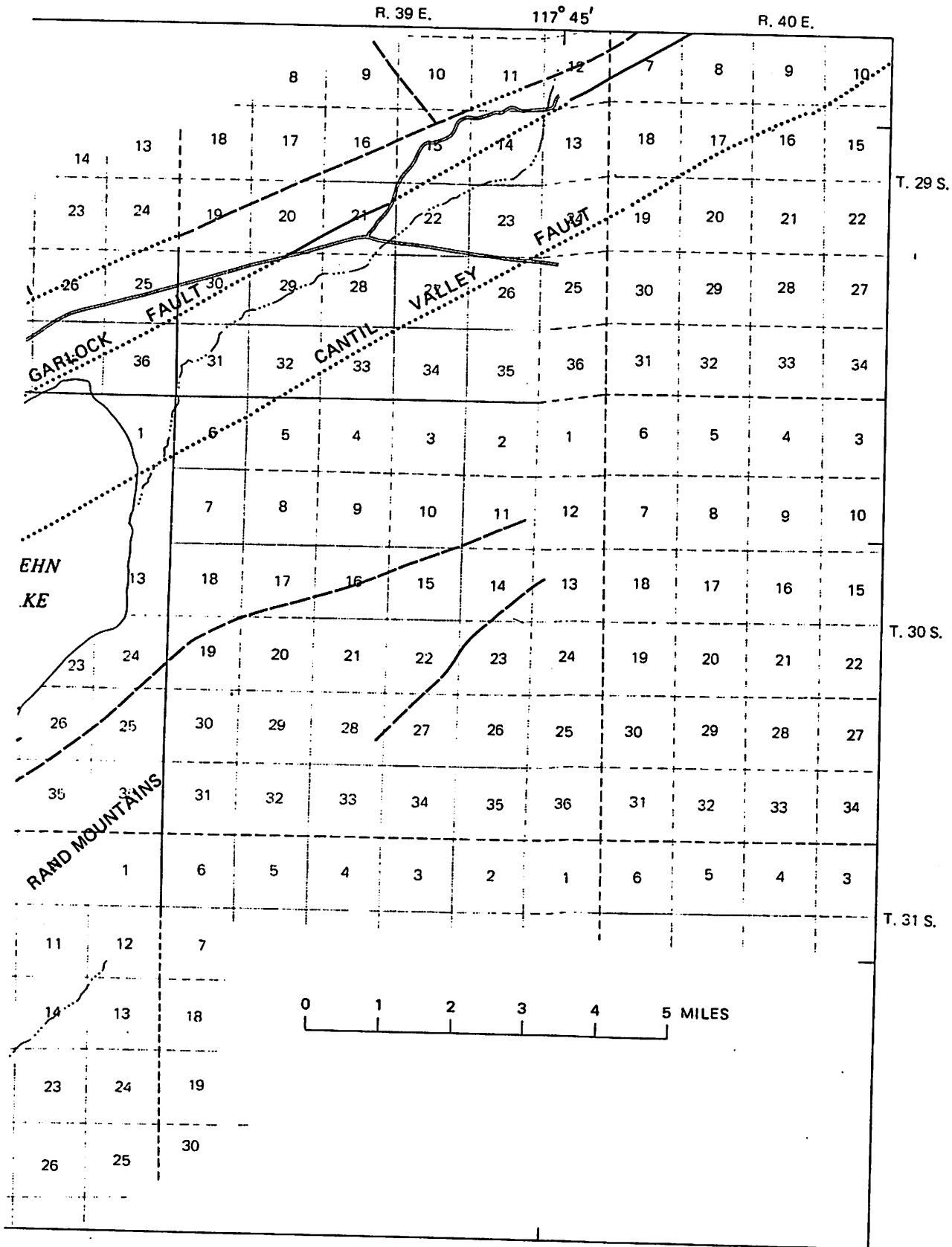
FIGURE 6.--Continued.

FIGURE 7.--Hydrographs of selected wells.

Underflow into the study area from the southwest was calculated using the following equation:

$$Q = 0.00838 \; TIW$$

where Q = underflow, in acre-feet per year

     0.00838 = constant factor to convert cubic feet per day to acre-feet per year

     T = transmissivity, in feet squared per day

     I = ground-water gradient, in feet per mile

     W = width of aquifer, in miles.

Section A-A' (fig. 4) was chosen for the calculation of underflow because the water-level gradient is uniform and the flow of ground water is nearly parallel to the basin boundaries. The value for T was estimated using the relation: T = 270 times the average specific capacity of wells in the area. Specific capacity is the discharge of a well, in gallons per minute, divided by the drawdown in feet. Because of the different hydraulic characteristics on the two sides of Cantil Valley fault, the basin was divided into two parts. The value of T was estimated to be 20,000 ft^2/d on the northwest side of the fault and 8,000 ft^2/d on the southeast side of the fault. The difference in values of T is larg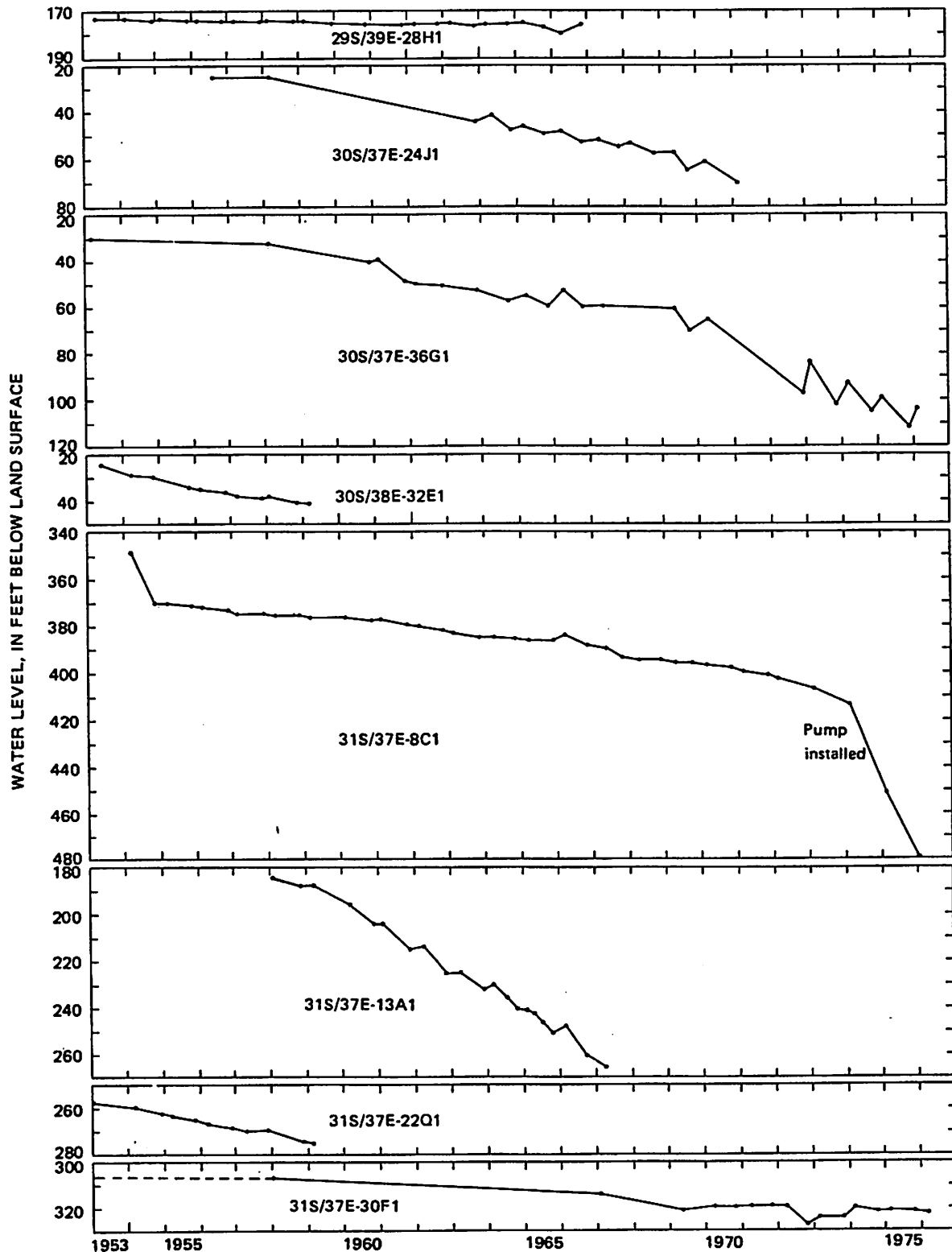ely because of the different thickness of alluvium in the basin on opposite sides of the fault (fig. 3). The annual underflow was calculated to be at least 9,500 acre-ft under steady-state conditions.

Recharge occurs from underflow in the creek channels that emanate from the Rand Mountains. Permeability of the channel deposits, cross-sectional area, and ground-water gradient were estimated, and it was calculated that 500 acre-ft per year of recharge occurs in this manner.

The area northeast of Koehn Lake does not receive any recharge from underflow and receives only a very small quantity from stream runoff; therefore, nearly all the recharge is confined to the area southwest of Koehn Lake.

Total annual recharge to the basin is the sum of the infiltration from surface runoff (200 acre-ft), underflow at section A-A' (9,500 acre-ft), and underflow from the stream channels (500 acre-ft), or 10,200 acre-ft.

Discharge

Ground water in the study area is discharged naturally by evapotranspiration only. Evapotranspiration is equivalent to consumptive use and is defined as the conversion of water into vapor by transpiration and evaporation from vegetation and by direct evaporation from the soil or water surface.

Figures 4 and 5 show the location of irrigated acreage in 1965 and 1976, respectively. Irrigated acreage increased from 4,100 acres in 1965 to 9,900 acres in 1976. During this period, crop type shifted from a diversity of crops to alfalfa almost exclusively.

Consumptive use by irrigated crops was calculated from crop-type and acreage data obtained from the U.S. Soil Conservation Service (T. D. Cattron, written commun., 1976). Alfalfa, the principal crop in the study area, uses about 6.2 acre-ft of water per acre per year (T. D. Cattron, U.S. Soil Conservation Service, oral commun., October 1976). Annual consumptive use by other crops was computed using the following values: Cotton, 3.4 acre-ft; barley, 2.1 acre-ft; wheat, 1.9 acre-ft; and other, 2.5 acre-ft. Figure 8 shows the annual consumptive use from 1960 to 1976, with the exception of 1967 for which no acreage data are available. The average annual consumptive use by native vegetation, residents, livestock, and industry is estimated to be 500 acre-ft. Total consumptive use ranged from 18,500 acre-ft in 1960 to 60,000 acre-ft in 1976, an average of about 32,000 acre-ft per year. Average annual consumptive use exceeds recharge by 21,800 acre-ft; this water comes from storage.

Storage

As previously discussed, average ground-water discharge for the period 1960-76 exceeded recharge; the difference of 21,800 acre-ft per year came from storage.

As a check on the figures used for recharge and discharge, the storage depletion was calculated by a second method. This method is based on the assumption that the multiple-aquifer system is not extensive and that the decline in water level represents dewatered sediments.

The volume of dewatered sediments was multiplied by the specific yield of the sediments. The total volume of sediments dewatered southwest of Koehn Lake was estimated by the change in water level between 1958 and 1976 (fig. 6). The volume of sediments dewatered northeast of Koehn Lake was estimated based on the extrapolation of water-level change in four wells between 1958 and 1976.

Specific yield is defined as the percentage, by volume, of drainable pore spaces in the sediments. An average value for specific yield was estimated by the method described by Davis, Green, Olmsted, and Brown (1959). Eleven drillers' logs were selected on the basis of well location and succinctness of lithologic terms. Each lithologic unit was assigned a value for specific yield. The average specific yield is about 11 percent.

The total water taken from storage between 1958 and 1976 is about
365,000 acre-ft or about 20,000 acre-ft per year. This figure compares
well with the previously computed average storage depletion of 21,800 acre-ft
per year determined from consumptive-use data. If consumptive-use data are
extrapolated to span the same time period (1958-76), then the average storage
depletion would be about 20,000 acre-ft per year. The long-term averages
do not reflect the recent increases in storage depletion. In 1976 the storage
depletion was about 50,000 acre-ft; the increase is approximately proportional
to the consumptive use.

Most of the storage depletion has occurred in the area of large
water-level declines southwest of Koehn Lake (fig. 6). Northeast of Koehn
Lake, irrigated acreage increased from 40 acres in 1965 to 360 acres in 1975
and to 1,000 acres in 1976. Nearly all the acreage is in alfalfa; therefore,
about 6,000 acre-ft of water was consumptively used in 1976. Because there
is little recharge to this part of the basin, nearly all the water comes from
storage. Consequently, as agricultural development expands, the rate of
water-level decline, per unit of consumptive use, will be greater than that
for the area southwest of Koehn Lake.

The total volume of water in storage in the study area was estimated by
assuming that the basin northeast of Koehn Lake is symmetrical. To
determine total water in storage between the water table and the consolidated
rocks, the volume of saturated sediments was multiplied by the specific yield
of the sediments. Total ground water in storage in 1976 was 4.1 million acre-ft.
Pumping water for agricultural use from a depth of more than 500 ft below land
surface is generally considered uneconomical. Total water in storage above
the 500-ft depth is 2.5 million acre-ft. About 0.4 million acre-ft of this
is in storage below Koehn Lake. If we presume that this water is too high in
dissolved solids for agricultural uses, then about 2 million acre-ft of
usable water is in storage above the 500-ft depth.

CHEMICAL QUALITY OF GROUND WATER

Water samples were collected from 24 wells in 1976 for analysis of major
chemical constituents. Trace elements were determined on four of the samples.
Of the 24 wells sampled, 6 had been sampled in 1953 or 1965. A comparison
of chemical constituents indicated no significant change in water quality.

The dissolved-solids concentration of the water from wells used for
irrigating crops ranged from about 500 to 800 mg/L (milligrams per liter). Of
the wells sampled, well 30S/38E-3B3, 200 ft deep, on the northwest side of
Koehn Lake had the highest dissolved-solids concentration, 68,800 mg/L. A
sample collected from well 30S/38E-3B1, 99 ft deep, in 1962 contained a
dissolved-solids concentration of 101,000 mg/L (Moyle, 1969). Water from
several wells in sec. 3 is pumped into evaporation ponds for the
commercial production of sodium chloride (table salt).
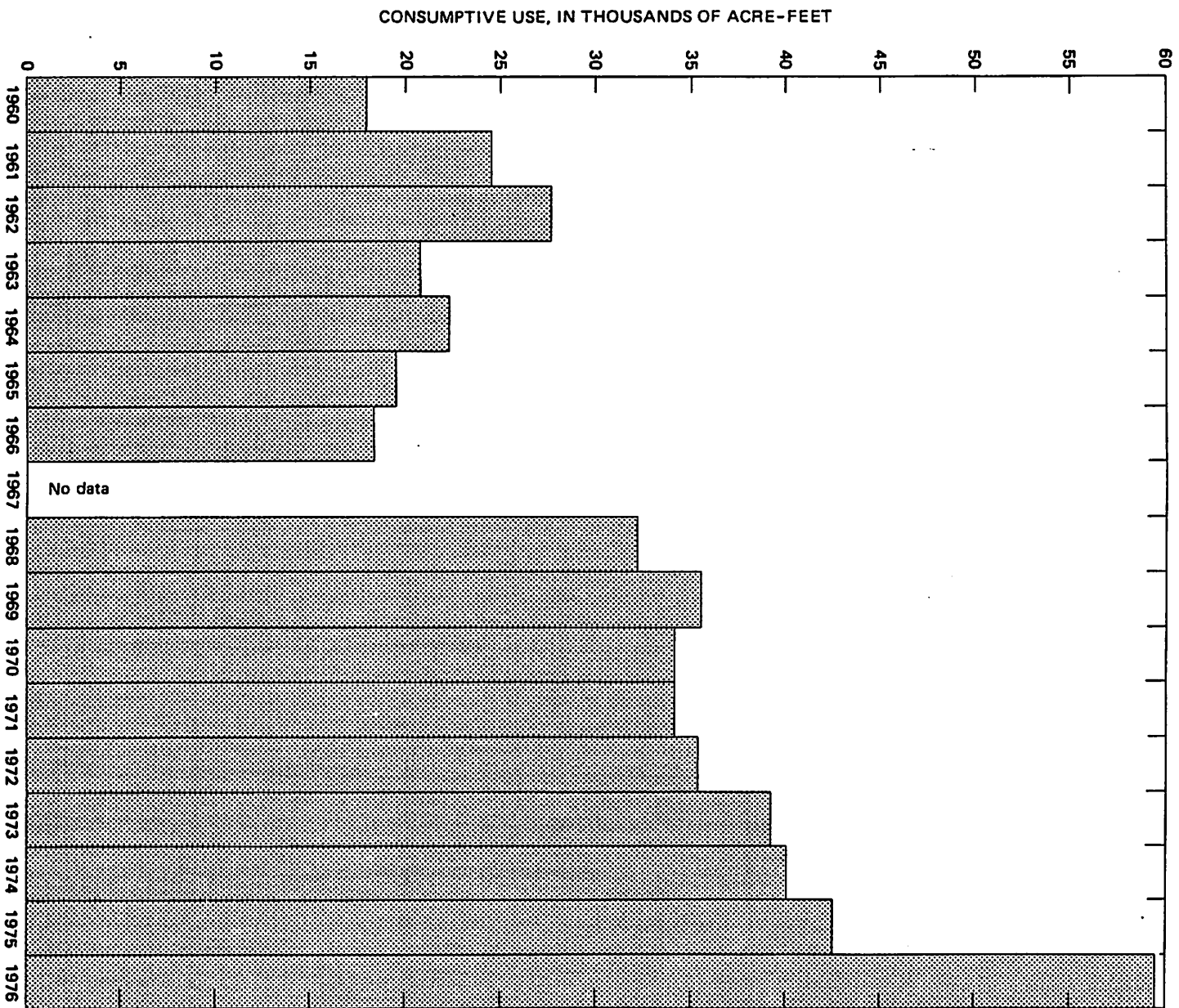
CONSUMPTIVE USE, IN THOUSANDS OF ACRE-FEET

FIGURE 8.--Consumptive use by irrigated crops.

As agriculture development continues on the northeast side of Koehn Lake, the water levels will decline at a greater rate, per unit of consumptive use, than they have southwest of the lake. Pumping depressions will probably develop, and saline water from under Koehn Lake may move in the direction of the depressions.

In order to more accurately assess the changing ground-water conditions, especially in the pumping depression and around Koehn Lake, the current monitoring program should be expanded to include about 25 wells for water-level monitoring and about 15 wells for water-quality monitoring. Two test wells, one northeast and one southwest of Koehn Lake, would help define the vertical and lateral extent of the saline water. Several aquifer tests would help in assessing the potential movement of the saline water.

REFERENCES CITED

Davis, G. H., Green, J. H., Olmsted, F. H., and Brown, D. W., 1959, Ground-water conditions and storage capacity in the San Joaquin Valley, California: U.S. Geol. Survey Water-Supply Paper 1469, 287 p.

Moyle, W. R., Jr., 1969, Water wells and springs in the Fremont Valley area, Kern County, California: California Dept. Water Resources Bull. 91-16, 157 p.