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GEOLOGICAL SURVEY

APPRAISAL OF GROUND-WATER CONDITIONS IN MERCED, CALIFORNIA, AND VICINITY

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CONVERSION FACTORS

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

English	*Multiply by*	*Metric (SI)*
acres	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.234×10^{-3}	hm^3 (cubic hectometers)
ft (feet)	3.048×10^{-1}	m (meters)
gal/min (gallons per minute)	6.308×10^{-2}	L/s (liters per second)
(gal/min)/ft (gallons per minute per foot)	2.07×10^{-1}	(L/s)/m (liters per second per meter)
in (inches)	2.54×10	mm (millimeters)
mi (miles, statute)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

Degrees Fahrenheit are converted to degrees Celsius by using the formula

$$°C=5/9\ (°F-32).$$

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ABSTRACT

Merced and vicinity comprises about 112 square miles in the northeastern part of the San Joaquin Valley of California. Two physiographic units occur in the area: (1) Dissected uplands, and (2) low alluvial plains and fans.

The fresh-ground-water basin is about 1,200 feet thick. Geologic units that are important to that basin are: (1) The Mehrten Formation (Miocene and Pliocene fluviatile deposits), (2) continental deposits (Pliocene and Pleistocene?), (3) older alluvium (Pleistocene and Holocene?), (4) lacustrine and marsh deposits (Pleistocene and Holocene?) consisting of the Corcoran Clay Member of the Tulare Formation and the shallow clay bed, (5) flood-basin deposits (Holocene?), and (6) younger alluvium (Holocene). The lacustrine and marsh deposits, the flood-basin deposits, and the younger alluvium yield little water to wells. The continental deposits and the older alluvium are the main sources of ground water, but some water is derived from the Mehrten Formation.

Five aquifers are defined in the Merced area: (1) The Mehrten Formation; (2) a confined aquifer (under the Corcoran Clay Member of the Tulare Formation); (3) an intermediate aquifer (confined between the Corcoran Clay Member, where present, and a shallow clay bed); (4) a shallow unconfined aquifer on a shallow clay bed; and (5) a probable unconfined aquifer in the continental deposits in the northeastern part of the area.

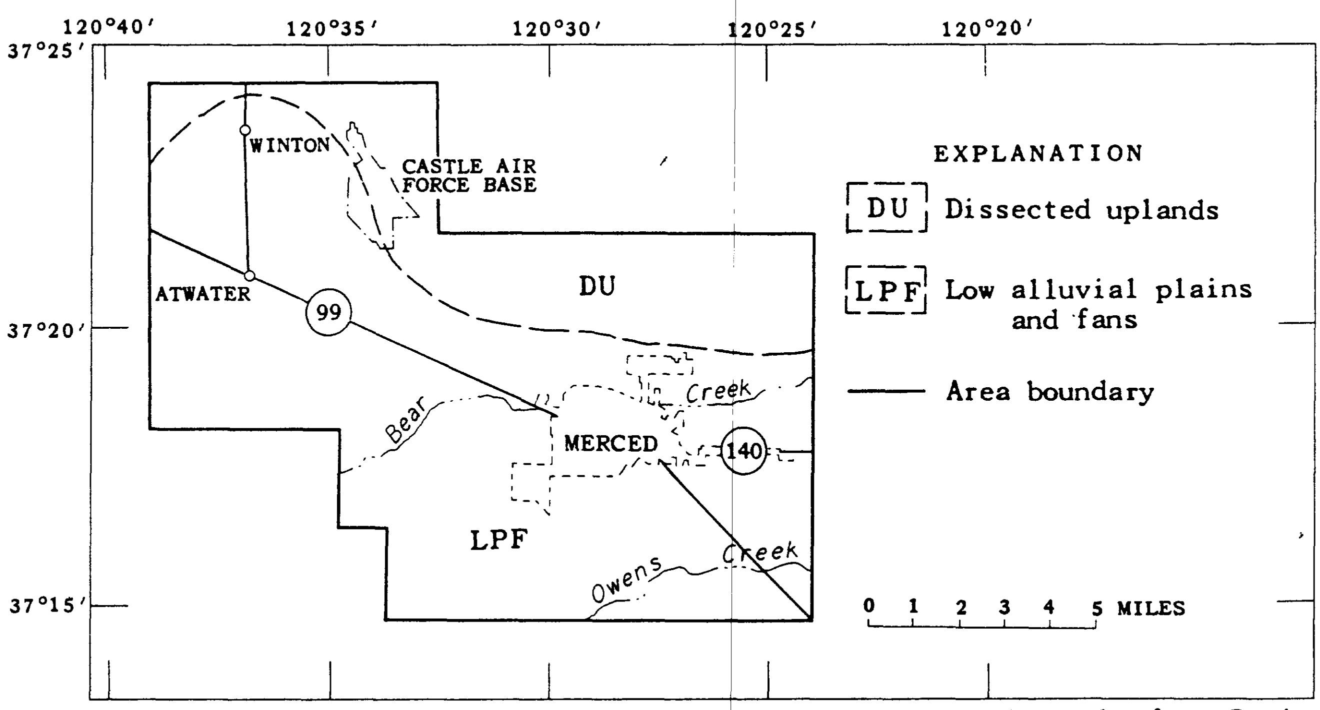
The direction of ground-water movement in the Mehrten Formation, in part of the intermediate aquifer, and in the probable unconfined aquifer is not known, but in the other aquifers water moves generally westward or southwestward. Some water moves through the lacustrine and marsh deposits.

Recharge to the aquifers is from ground-water flow, leakage from other aquifers, and irrigation water that moves downward into the shallow aquifer. Recharge from precipitation on the study area is small.

Discharge of ground water in the area is probably by seepage into streams, by evaporation, by transpiration from crops, and by pumping. Total pumpage varies considerably from year to year because agricultural pumpage is inversely proportional to available surface water; however, municipal pumpage has grown steadily through the years.

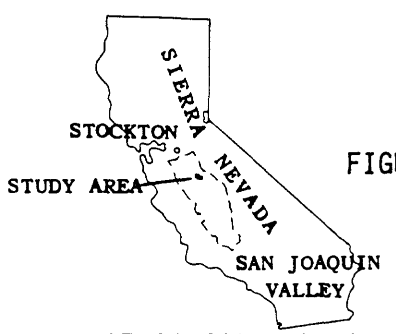
Fluctuations and long-term trends in head in the confined aquifer vary from place to place, and in some places heads have declined. Fluctuations and long-term trends in the intermediate aquifer have been similar from place to place with rises, declines, and stable periods. Fluctuations of head in the shallow aquifer generally are similar throughout the area, but long-term trends differ from place to place.

Chemical analyses indicate that ground-water quality is good and that generally it is a bicarbonate-type water.



MAP OF MERCED AREA

Physiography from Davis and others, 1959, pl. 1



MAP OF CALIFORNIA

FIGURE 1.--Location and physiography of the study area.

INTRODUCTION

The city of Merced (fig. 1) has long-range plans for all principal services except its water supply, which comes entirely from ground water. As a result of the city officials recognizing the need for long-term management of that supply, the U.S. Geological Survey made a cooperative ground-water study in the Merced area.

Purpose and Scope

The purpose of this study is to supply preliminary information that is required for the long-term management of the city of Merced water supply. Included in the purpose are (1) the identification of any zones of water of poor quality that could affect utilization of the ground-water reservoir and (2) recommendations for developing predictive tools for management of ground-water resources in the area.

The scope of this study was to appraise ground-water conditions in Merced and vicinity with regard to source, occurrence, and movement. Further, ground-water quality was investigated to determine the relationship, if any, between occurrence of water and its chemical type.

Method of Study

Planning for this study was begun in June 1975, and the fieldwork was completed in September 1975. Boundaries of the study area (fig. 1) were drawn to include the major communities in the immediate area of Merced and a sufficient number of wells and water-level data for contouring water levels around Merced.

The method of study was to collect, assemble, and evaluate data to show the source, occurrence, movement, and chemical quality of ground water in the Merced area. All available drillers' logs, chemical analyses of ground water, water data for irrigation, water-level records, and pumpage data were collected. These data were analyzed and are shown on graphs, maps, and geologic sections.

Location and General Features

Merced and vicinity, as referred to in this report, comprises about 112 mi^2 in the northeastern part of the San Joaquin Valley (fig. 1). Merced had an estimated population of 28,500 as of January 1, 1974, and is the seat of Merced County, estimated population 117,500 (written commun., May 31, 1974, Population Research Unit of Department of Finance, State of California).

The Merced area lies within the geomorphic province that Jenkins (1943, p. 83) defined as the "Great Valley of California," where alluvial plains or fans are the dominant features. Two physiographic units occur in the area: (1) Dissected uplands, and (2) low alluvial plains and fans (fig. 1). Dissected uplands consist of old alluvial fans where locally the relief is as much as 50 ft. Low alluvial plains and fans consist of coalescing alluvial fans of low relief which, except near the streams, is everywhere less than 10 ft and commonly is less than 5 ft.

Agriculture is the mainstay of the economy in the area, and as a consequence a number of businesses related to food processing and packaging are located in Merced. Other industries include the manufacturing of rugs and materials used for packaging.

Water for the city and the immediate area is supplied from 13 city wells, 2 wells of a private water company, and many privately owned domestic and industrial wells.

In the summer the climate is characterized by low relative humidity, high temperature (in summer 1975, 83 days had temperatures at or over 90°F (32°C), and a small amount of precipitation; in winter it is characterized by higher relative humidity, lower temperature, and moderate precipitation, as indicated in the following tables (U.S. Department of Commerce, 1975a, p. 18; 1975b, p. 32; 1975c, p. 18; 1975d, p. 18).

Normal[1] temperature and precipitation, Merced
[U.S. Department of Commerce, 1975e, p. 3 and 8]

Month	Temperature (degrees Fahrenheit)	Precipitation (inches)	Month	Temperature (degrees Fahrenheit)	Precipitation (inches)
Jan.	45.1	2.24	July	78.3	0.19
Feb.	49.8	1.92	Aug.	76.4	.20
Mar.	53.8	1.74	Sept.	72.3	.11
Apr.	59.7	1.41	Oct.	63.4	.55
May	66.4	.45	Nov.	52.8	1.61
June	72.5	.07	Dec.	45.8	2.09

[1]Normals are climatological normals based on the period 1941-70 (U.S. Department of Commerce, 1975e, p. 31).

Normal[1] relative humidity, Stockton

[U.S. Department of Commerce, 1975f, p. 2]

Month	Hour 0400	1000	1600	2200
January	90	80	70	86
April	78	54	40	69
July	65	41	26	50
October	74	56	38	64

[1]Normals are climatological normals based on the period 1941-70 (U.S. Department of Commerce, 1975e, p. 31).

Normal annual precipitation is 12.6 in, and most of it falls between October and May. Moreover, precipitation can vary widely from year to year in the valley and in the Sierra Nevada. For example, annual precipitation in 1972 and 1973 at Merced was 9.16 in and 18.01 in, respectively, and at Catheys Vy Bull Run Ranch, which is about 27 mi east southeast of Merced, precipitation was 14.71 in and 27.86 in, respectively (U.S. Department of Commerce, 1972, p. 472, and 1973, p. 8). These variations have a strong effect on streamflow and the amount of available water (Davis and others, 1959, pls. 17, 18, 20, and 23).

Previous Reports

Reports that contain geologic and hydrologic data for Merced and vicinity include:

Balding and Page (1971), Descriptions of wells in the Merced study area;

Davis and others (1959), Ground-water storage capacity by township units, specific-yield-percentage categories for each of three depth zones by township units and by ground-water storage units, hydrographs, physiographic units, a geologic-geochemical section, water-level contour map, and depth-to-water map;

Davis and others (1964), Map showing the relative permeability of soils, and a cross section showing relatively permeable deposits and relatively impermeable deposits to depths of 200 ft; and

Page and Balding (1973), Water-bearing properties of geologic units, the relation of specific yield to lithofacies units in the area, a geologic section, a geochemical section, and maps showing ground-water chemical data, physiographic units, geology, basement complex, lithofacies, and water-level contours.

Well-Numbering System

The well-numbering system used by the Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public lands. For example, in the number 7S/14E-19B1, the part of the number preceding the slash indicates the township (T. 7S.); the number after the slash the range (R. 14E.); the digits after the hyphen the section (sec. 19); and the letter after the section number the 40-acre subdivision of the section as indicated on the diagram below. Within each 40-acre tract the wells are numbered serially as indicated by the final digit of the well number. Thus, well 7S/14E-19B1 was the first well to be listed in the NW ¼ NE ¼ sec. 19. The entire Merced study area is south and east of the Mount Diablo base line and meridian. For wells not field located but referred to in this report, the final digit has been dropped.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Table 1 shows the correlation between city of Merced well numbers and those of the Geological Survey.

Table 1.--*Correlation of Merced and Geological Survey well numbers*

City of Merced well number	Geological Survey well number	City of Merced well number	Geological Survey well number
1A	7S/14E-19B1	4	7S/14E-19J1
1B	-19B2	5	-24Q1
1C	-19B3	6	-31C1
2A	-29R1	7A	-16L1
2B	-29R2	7B	-16L2
3A	-29E2	8	-24M1
3B	-30E1		

Origin of the Data

Two major well inventories by the Geological Survey provided data for the Merced area. One inventory made in 1952-53 covered the entire San Joaquin Valley; the other, in 1970-71, covered the valley area of eastern Stanislaus and Merced Counties. The 1952-53 inventory included most of the then existing wells; the 1970-71 inventory included only those wells that could be correlated with data, such as drillers' logs and chemical analyses.

As a part of this study, Geological Survey personnel attempted to locate in the field all wells equipped with pump motors of 7½ horsepower or larger. In addition, well data were obtained from Castle Air Force Base, the city of Atwater, the city of Merced, the Merced Irrigation District, and several agricultural and industrial firms in the area. These data were extremely helpful in the interpretation of the geology and hydrology of the Merced area.

GEOLOGIC UNITS AND THEIR WATER-BEARING PROPERTIES

Geologic units that crop out in the Merced area include unconsolidated deposits consisting of (1) continental deposits of Pliocene and Pleistocene(?) age, (2) older alluvium of Pleistocene and Holocene(?) age, (3) flood-basin deposits of Holocene(?) age, and (4) younger alluvium of Holocene age (pl. 1). A consolidated unit, the Mehrten Formation of Miocene and Pliocene age, does not crop out in the area, but is reached by several water wells in the eastern and in the southern parts of the area (pl. 2). Also, the subsurface lacustrine and marsh deposits consisting of the Corcoran Clay Member of the Tulare Formation and the shallow clay bed, both of Quaternary age, are penetrated by several wells (pl. 2).

Some deposits of Tertiary and Quaternary age in the Merced area were laid down in an oxidizing environment and some in a reducing environment (pl. 2). According to Meade (1967, p. C6-C7) and Davis and others (1959, p. 58-59), oxidized deposits are red, yellow, or brown, indicating subaerial deposition; and reduced deposits are blue, green, or gray, indicating subaqueous deposition.

In terms of water use, the effective base of the ground-water basin is placed at the base of the zone in which dissolved-solids concentrations in the water are less than 2,000 mg/L (milligrams per liter). In the study area, the base of that zone is at a depth of about 1,200 ft and probably lies mostly in the basal part of the Mehrten Formation or in the top part of the underlying Valley Springs Formation of Miocene and Oligocene age (Page, 1973, and Page and Balding, 1973, fig. 6).

Mehrten Formation

The subsurface Mehrten Formation underlies the Merced area at depths ranging from 200 ft to 500 ft (pl. 2) and is probably more than 700 ft thick (Page and Balding, 1973, p. 22). It consists of fluviatile deposits of sandstone, breccia, conglomerate, tuff, siltstone, and claystone (Davis and Hall, 1959, p. 9-10; Piper and others, 1939, p. 61-67). It is distinguished in the field by the large amounts of andesite that occur in most of its beds. In the Merced area, drillers often describe the Mehrten as black packed sand, black sand and gravel, or cemented sand all mixed with red, pink, or brown sandy clay, clay, or shale,

The Mehrten Formation is an important aquifer in the Merced area, and several wells in the eastern and southern parts of the area reach it. Only one well, 7S/14E-26K1 (pl. 2), is known to yield water exclusively from the Mehrten. The yield of that well is 3,400 gal/min and the specific capacity[1] is 36 (gal/min)/ft.

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[1]The specific capacity of a well is the discharge divided by drawdown.

Continental Deposits

The continental deposits crop out in the northeastern part of the area (pl. 1). There they underlie dissected rolling hills having as much as 50 ft of relief. The deposits consist of a gently southwestward-dipping alluvium of poorly sorted gravel, sand, silt, and clay. They are generally finer grained than the overlying older alluvium (pl. 1).

The continental deposits thicken from the northeastern part of the area toward the western and southern parts and range in thickness from about 110 ft to at least 330 ft (pl. 2). From the sections shown on plate 2 it can be seen that thickness information is deficient in the southwestern half of the study area.

Well 8S/14E-4H2 yields water mostly from the continental deposits. The yield of that well is about 2,000 gal/min, and the specific capacity is 16 (gal/min)/ft. Well 8S/14E-5A2 yields water exclusively from these deposits. The yield of that well is 3,000 gal/min, and the specific capacity is 37 (gal/min)/ft.

Lacustrine and Marsh Deposits

The subsurface lacustrine and marsh deposits consist of two beds: (1) The Corcoran Clay Member of the Pliocene and Pleistocene Tulare Formation, and (2) a shallow-clay bed of Holocene(?) age (pl. 2). The clayey and silty nature of the beds restricts the vertical movement of water, and, therefore, they function as confining beds.

The Corcoran Member of Pleistocene age is a bed of gray and blue silt, silty clay, and clay interbedded with the older alluvium, and it underlies the southwestern half of the study area. The shallow clay bed consists of brown, red, gray, and blue sandy clay and clay as well as some hardpan, and it underlies most of the area. The shallow clay bed may also extend past the edge of the area shown on plate 2, but data were lacking to define it there.

Although numerous other silt and clay beds occur in the area, they could not be correlated over large areas. Therefore, those beds are considered to be of only local importance to the confinement of ground water. Further, the beds do not yield significant quantities of water to wells.

Older Alluvium

Older alluvium crops out over a large part of the area (pl. 1). It consists of intercalated beds of gravel, sand, silt, and clay, with some hardpan. In most places the alluvium underlies slightly dissected hills or nearly flat-lying plains. The older alluvium thickens from the northeastern part of the area toward the west and south and ranges in thickness from 0 to at least 375 ft.

Yields to 18 wells and specific capacities of 12 wells that are perforated or bottomed exclusively in the older alluvium are shown in the following table.

Yields and specific capacities of wells perforated or bottomed in the older alluvium

Well number	Geologic section	Yield (gal/min)	Specific capacity [(gal/min)/ft]
6S/12E-22P1	A-A'	2,950	107
26N1	A-A'	1,500	37
27B1	A-A'	1,000	14
27E1	A-A'	4,160	73
35G1	A-A'	1,400	42
35K1	A-A'	690	172
36F1	A-A'	2,500	131
7S/12E- 1Q1	B-B'	2,000	--
14Q1	B-B'	1,000	42
22H2	B-B'	3,270	50
23D1	B-B'	2,150	--
7S/13E- 6M1	A-A', B-B'	1,700	53
6L1	A-A'	1,430	30
24Q1	C-C'	2,430	--
26R1	C-C'	1,250	54
27L1	C-C'	2,300	--
34A1	C-C'	2,500	--
34H1	C-C'	2,480	--

Flood-Basin Deposits

The flood-basin deposits crop out in the southwestern part of the study area (pl. 1). These deposits consist of intercalated lenses of bluish-gray, brown, and reddish-brown fine sand, silt, and clay. In the subsurface the deposits are interbedded with the older alluvium and overlie the shallow clay bed (pl. 2).

As indicated on drillers' logs, the flood-basin deposits range in thickness from 0 to about 30 ft. Because of their impermeable clayey nature, these deposits would yield only very small quantities of water to wells.

Younger Alluvium

The younger alluvium occurs as narrow bands along the stream channels in the area (pl. 1). It consists mostly of sand and gravel with little or no hardpan.

The younger alluvium ranges in thickness from 0 to probably not more than 30 ft. Because the alluvium is thin, and generally lies above the water table, it yields very little, if any, water to wells.

HYDROLOGY

Occurrence of Ground Water

Ground water in the Merced area occurs in (1) the Mehrten Formation, (2) a confined aquifer, (3) an intermediate aquifer, (4) a shallow aquifer (fig. 2), and (5) a probable unconfined aquifer.

Mehrten Formation

Because the depth to the base of the Mehrten Formation is not well known, the thickness of the fresh-water section in the Mehrten cannot be defined. Near well 8S/14E-4R1, however, the thickness of the fresh-water section in the Mehrten probably is at least 600 ft (Page and Balding, 1973, fig. 6).

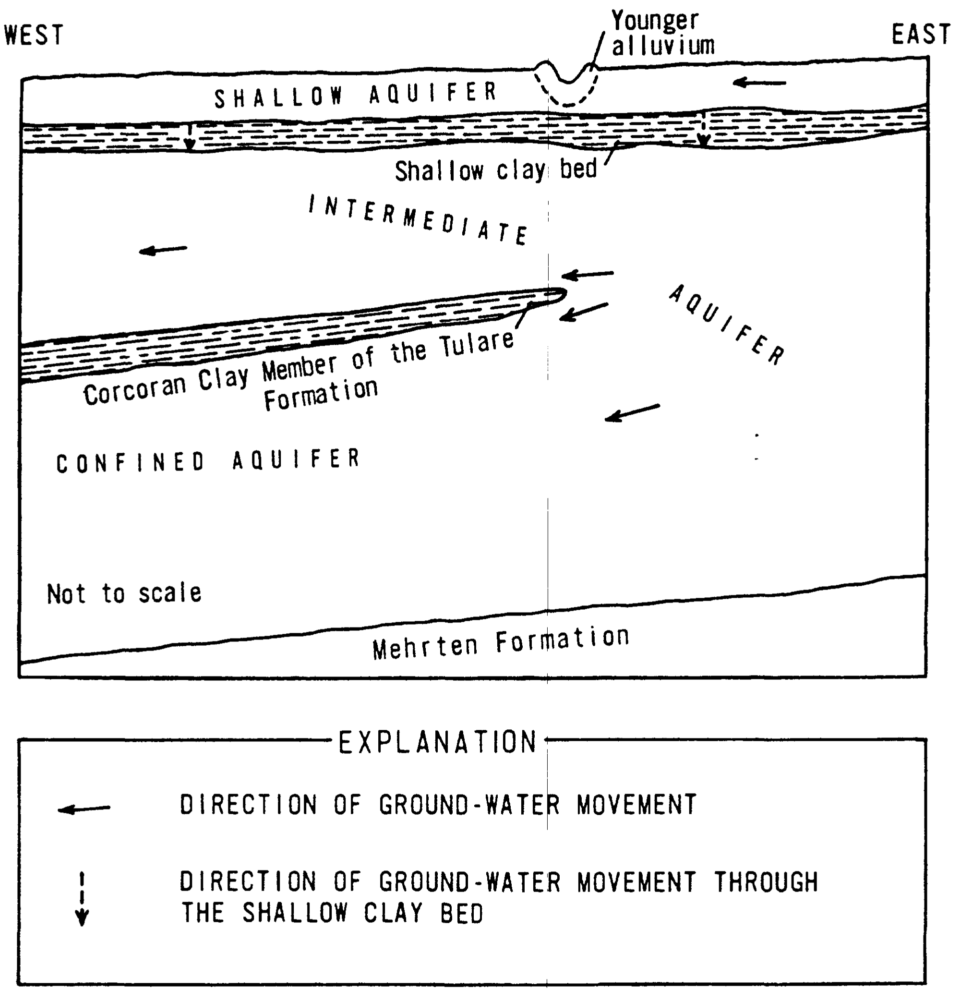


FIGURE 2.--Diagrammatic section across the central part of the Merced area, showing occurrence and movement of ground water.

The Corcoran Clay Member of the Tulare Formation is underlain by the confined aquifer; therefore, water in the Mehrten Formation is also considered to be confined where it underlies the Corcoran Member. Where the Mehrten does not underlie the Corcoran, the degree of confinement in the Mehrten is difficult to determine because most wells that reach it are perforated opposite the overlying deposits and left uncased in the Mehrten or are perforated opposite both the Mehrten and the overlying deposits (pl. 2).

Most of the wells that yield water from the Mehrten Formation are in the eastern part of the study area. Few wells yield water from the Mehrten in the western part.

Confined Aquifer

The confined aquifer occurs in the deposits that underlie the Corcoran Clay Member of the Tulare Formation (fig. 2). The base of the confined aquifer is the top of the Mehrten Formation.

In the Merced area, fresh water probably occurs throughout the full thickness of the confined aquifer, but from the sections it can be seen that chemical data for ground water are deficient in the western part of the study area (pl. 2). Nevertheless, where data are sufficient to define the fresh-water section in the confined aquifer, the section ranges in thickness from 270 ft to 410 ft.

Wherever the confined aquifer occurs in the study area, it yields water to wells (pl. 2). Thus, it is one of the more important aquifers in the area.

Intermediate Aquifer

The intermediate aquifer occurs in the deposits that underlie the shallow clay bed and that overlie or are east of the Corcoran Clay Member of the Tulare Formation. Where the Corcoran is absent, the intermediate aquifer extends to the Mehrten Formation.

Where data are sufficient to define the fresh-water section in the intermediate aquifer, the section ranges in thickness from 10 ft to at least 305 ft (pl. 2).

Water in the intermediate aquifer is at least locally confined (table 2), but the static heads (referred to in this report simply as "head," which is the height of the water level above sea level) in some wells in the intermediate aquifer were below the altitude of the shallow clay bed, as mapped (table 3). Where the head in the intermediate aquifer falls below the base of the shallow clay bed, water in the intermediate aquifer becomes unconfined and water in the overlying shallow aquifer becomes perched.

The intermediate aquifer yields water to wells mostly east of the Corcoran (pl. 2). Only well 7S/14E-14Q1 was found to yield water from the part of the intermediate aquifer between the shallow clay bed and the Corcoran Member.

Shallow Unconfined Aquifer

The shallow unconfined aquifer occurs in the deposits that overlie the shallow clay bed (pl. 2). Thickness of the shallow aquifer ranges from less than 10 ft to 35 ft (pl. 2). The saturated thickness of the aquifer has ranged from virtually 0 to the full thickness of the aquifer (figs. 3-7).

Unconfined Aquifer

An unconfined aquifer probably occurs in the area where the continental deposits crop out (pls. 1 and 2), but data are not available to determine the mode of occurrence. Because data are insufficient, the unconfined aquifer is not discussed in the following sections.

Table 2.--*Selected wells in the intermediate aquifer in which heads are above the base of the shallow clay bed*

(Datum for head is sea level)

Well number	Date	Geologic section	Head (feet)	Altitude of base of shallow clay bed (feet)
7S/13E-7H1	9-10-75	A-A'	132	114
7S/14E-9R1	1-5-77	C-C'	163	133

Table 3.--*Selected wells in the intermediate aquifer in which heads are below the base of the shallow clay bed*

(Datum for head is sea level)

Well number	Date	Geologic section	Head (feet)	Altitude of base of shallow clay bed (feet)
6S/12E-36F1	9-15-75	A-A'	122	130
7S/13E-6M1	9-8-75	A-A'	123	130
7S/14E-19B3	9-16-75	C-C'	[1]115	142

[1]Well was being pumped.

Movement of Ground Water

In developing data for this discussion, drillers' logs were used, where available, to ascertain depths and perforations for wells in the aquifers underlying the shallow aquifer. Wells used to depict the water surface of the shallow aquifer are measured monthly by personnel of the Merced Irrigation District. Those wells are about 20 ft deep, and it is unusual for such wells to be more than 25 ft deep (Mr. Reuben Schmidt, Chief Engineer, Merced Irrigation District, oral commun., 1977).

Although data are not available from which to determine ground-water movement in the Mehrten Formation, movement probably is westward and southwestward toward the valley trough. Vertical movement within the formation is not known at this time.

In 1975, ground water in the confined aquifer moved westward and southwestward (pl. 3). In addition, ground water moved toward troughs of low head in the western and central parts of the area. Preliminary examination of pumpage distributions and of lithologies in those areas did not yield a ready explanation for the troughs.

Ground water in the intermediate aquifer generally moved westward and southwestward. In the north-central part of the area, ground water moved both eastward and westward toward a trough (pl. 3). In the city of Merced, ground water, in addition to moving westward, moved northwestward and southwestward toward a small trough. The direction of ground-water movement in the intermediate aquifer above the Corcoran Member is not known.

Ground water in the shallow aquifer moved generally westward and southwestward (pl. 4). In the immediate vicinity of Merced, it moved southwestward and northwestward toward the city. In the central part of T. 7S., R. 13E., ground water moved outward from a small recharge area. Because the head in the shallow aquifer is higher than that in the underlying aquifers (pls. 3 and 4, table 4), some ground water moved slowly downward through the shallow clay bed to at least the intermediate aquifer.

Table 4.--*Comparison of heads in the shallow aquifer with heads in underlying aquifers*

[Measurements of water levels in shallow aquifer made by personnel of Merced Irrigation District; measurements in underlying aquifers made by personnel of Geological Survey]

(Datum for head is sea level)

Well number	Date of measurement	Depth (ft)	Cased (ft)	Perforations (ft)	Head (ft)	Aquifer
6S/12E-22N	9-75	[1]			136	Shallow
6S/12E-22P1	9-16-75	230	208	3-25, 103-127, 150-170	124	Intermediate and shallow[2]
6S/13E-36A		[1]			156	Shallow
6S/13E-30N1	9-16-75	No data	No data	No data	126	Probably intermediate
7S/12E-10N	9-75	[1]			123	Shallow
7S/12E-10F2	9-11-75	55	46	[3]	108	Intermediate and shallow[2]
7S/12E-14R	11-72	[1]			123	Shallow
7S/12E-14Q1	11-72	80	72	Not perforated	[4]121	Intermediate
7S/13E-19N	9-75	[1]			124	Shallow
7S/12E-24J1	9-11-75	274	232	201-210	121	Confined[5]
7S/13E-27R	9-75	[1]			146	Shallow
7S/13E-34A1	9-12-75	352	224	Not perforated	131	Confined[5]
7S/14E-27R	9-75	[1]			175	Shallow
7S/14E-27R1	9-15-75	204	188	50-54, 62-68, 80-108	162	Intermediate
7S/14E-28A	9-75	[1]			170	Shallow
7S/14E-28A2	9-18-75	145	No data	No data	165	Intermediate
7S/14E-35R	9-75	[1]			189	Shallow
7S/14E-35R1	9-15-75	200	108	60-100	167	Confined[5]
8S/14E-5A	9-75	[1]			168	Shallow
8S/14E-5A2	9-9-75	215	196	Not perforated	133	Confined[5]
8S/14E-9A	9-75	[1]			170	Shallow
8S/14E-4R1	9-9-75	587	560	220-436, 456-556	131	Confined and Mehrten Fm[5]
8S/14E-14A	9-75	[1]			185	Shallow
8S/14E-11K1	9-8-75	590	336	Not perforated	137	Confined[5]

[1]Observation wells measured by personnel of the Merced Irrigation District are about 20 ft deep; it is unusual for such wells to be 25 ft deep (Mr. Reuben Schmidt, Chief Engineer, Merced Irrigation District, oral commun., 1977).

[2]Data near well are not conclusive as to the absence or presence of the shallow aquifer.

[3]Perforated, interval not known.

[4]Measurement made by driller.

[5]Aquifer does not lie immediately below shallow aquifer.

Recharge

Recharge of water to the Mehrten Formation in the area probably is from ground-water inflow from the east. It is not known, at this time, whether or not the Mehrten is receiving recharge from the confined and the intermediate aquifers.

Recharge to the confined aquifer is from ground-water inflow from the east, and probably from downward leakage of water from at least the shallow aquifer through some wells. It is not known if recharge occurs from the intermediate aquifer to the confined aquifer because heads in the intermediate aquifer immediately above the confined aquifer generally are not known.

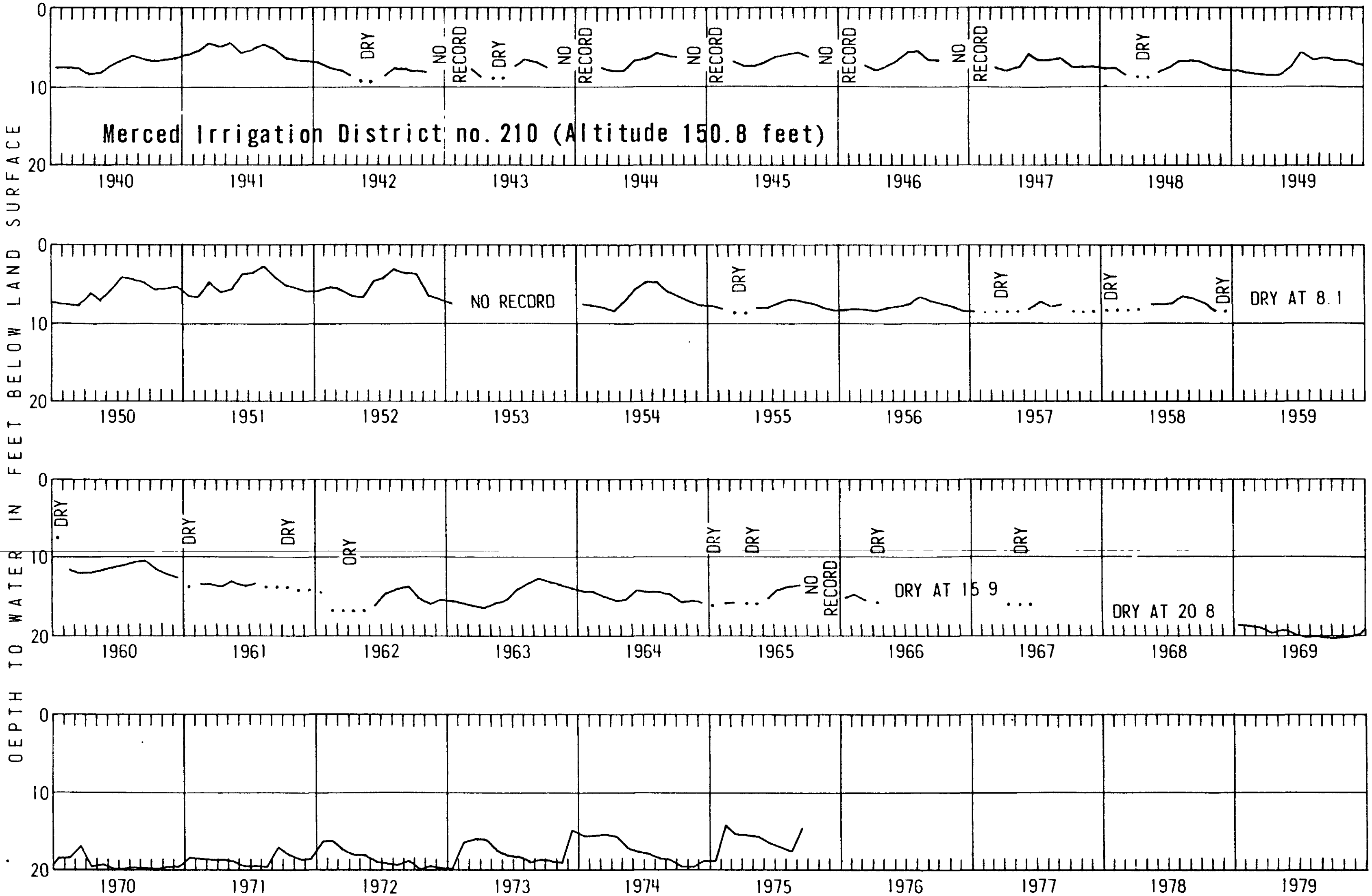
Recharge to the intermediate aquifer is from ground-water inflow from the east and from downward leakage of water through the shallow clay bed and probably through some wells (table 4).

Recharge to the shallow aquifer is largely from surface water applied to irrigated fields, and water levels in the shallow aquifer often show a rise during the irrigation season, generally from April through September (figs. 3-7). But deliveries of surface water vary from year to year and, consequently, so does recharge. From 1951 to 1974, for example, net surface water delivered to irrigators, as computed from records of the Merced Irrigation District, ranged from 200,000 acre-ft to 450,000 acre-ft. In 1961 the calculated consumptive use[2] by crops was larger than surface water deliveries to irrigators, so that, except for spills and an occasional large delivery of water, no recharge occurred from irrigated fields to the shallow aquifer; in 1965 the consumptive use was 360,000 acre-ft and surface water delivered to irrigators was estimated to be 460,000 acre-ft so that in the district 100,000 acre-ft of recharge occurred from irrigated fields. About 40 percent of that recharge, 40,000 acre-ft, occurred in the study area. In the city of Merced the shallow aquifer probably is recharged by water derived from watering lawns and irrigating gardens, but data indicating the amount of recharge are not available at this time.

Other sources of recharge to the shallow aquifer are ground-water inflow from the east (pl. 4) and some water from precipitation over the study area. Recharge from precipitation to the aquifer probably is small, as virtually no rise in water levels occurs in the shallow aquifer during the wet winter months (figs. 3-7).

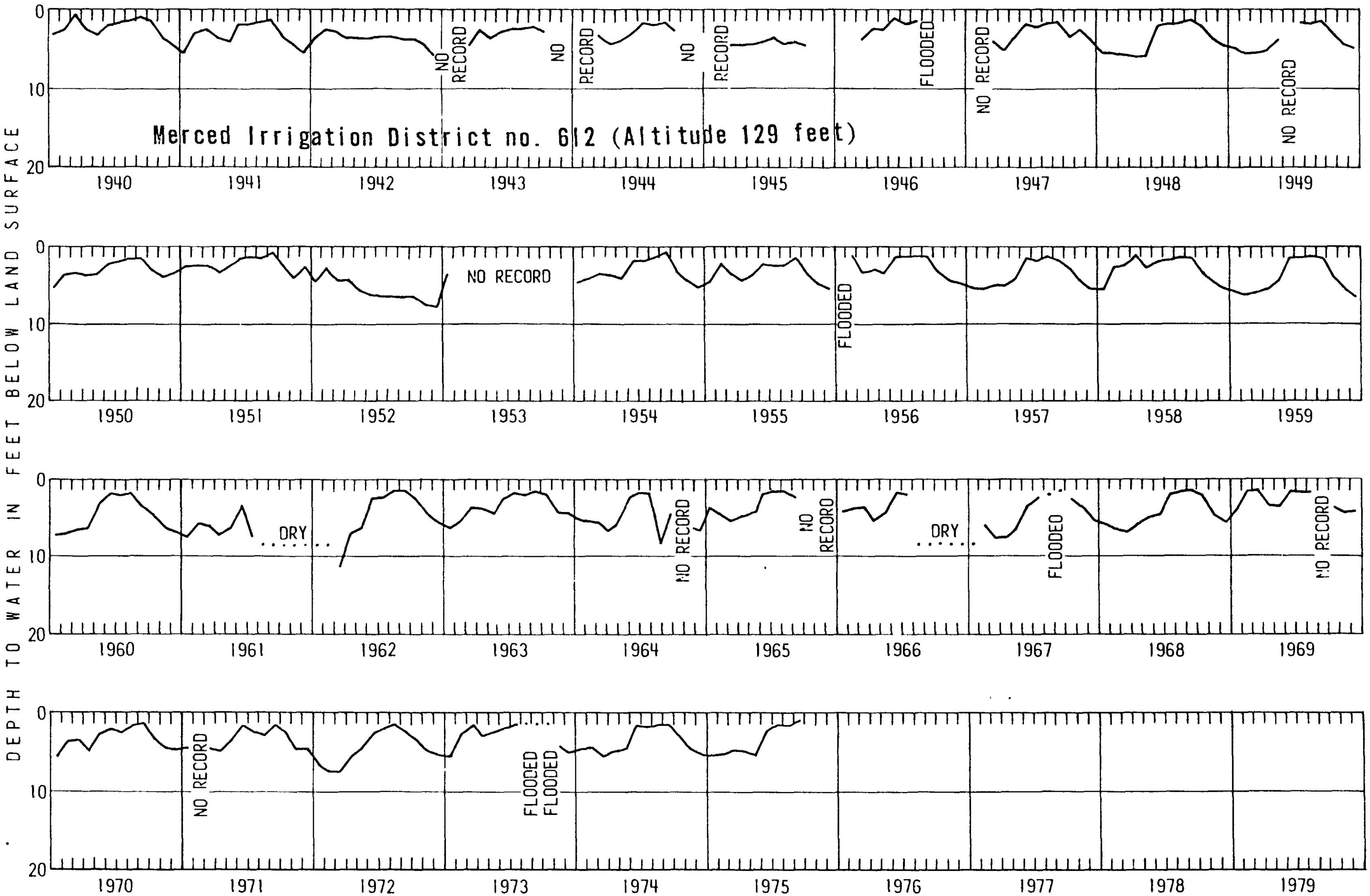
---

[2]The irrigated acreage for each crop was determined from records of the Merced Irrigation District. Crops having similar water-use characteristics were grouped, and the sum of the products of unit-consumptive use for each group (California State Water Resources Board, 1955, p. 170) and acreage of each group gave the total consumptive use for each crop group. Those values were added together to give total consumptive use for the Merced Irrigation District.



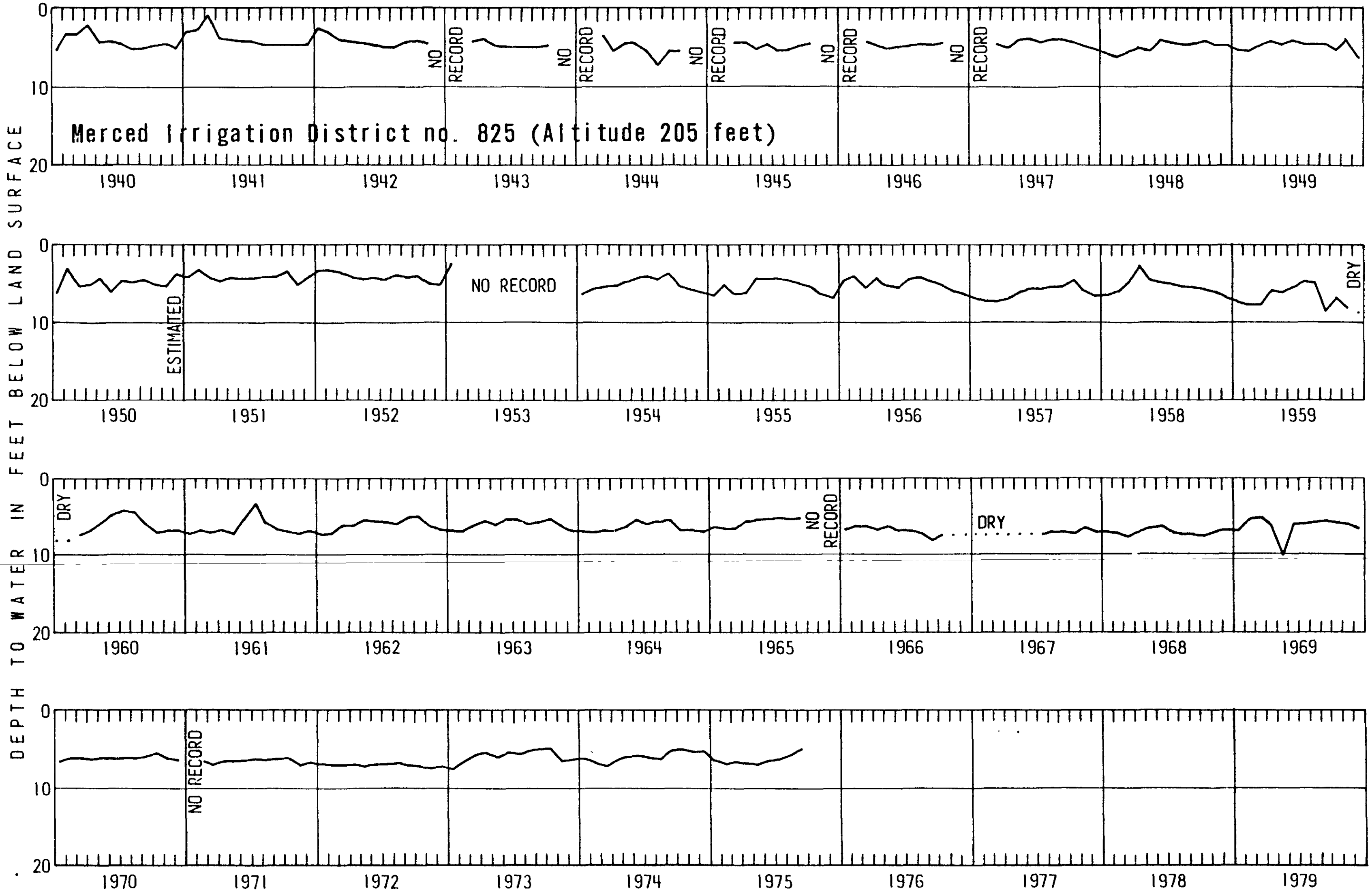
Hydrograph by R.W. Page, 1976
Data from Merced Irrigation District

FIGURE 3.--Water-level fluctuations in the shallow aquifer: Well 6S/12E-22N.



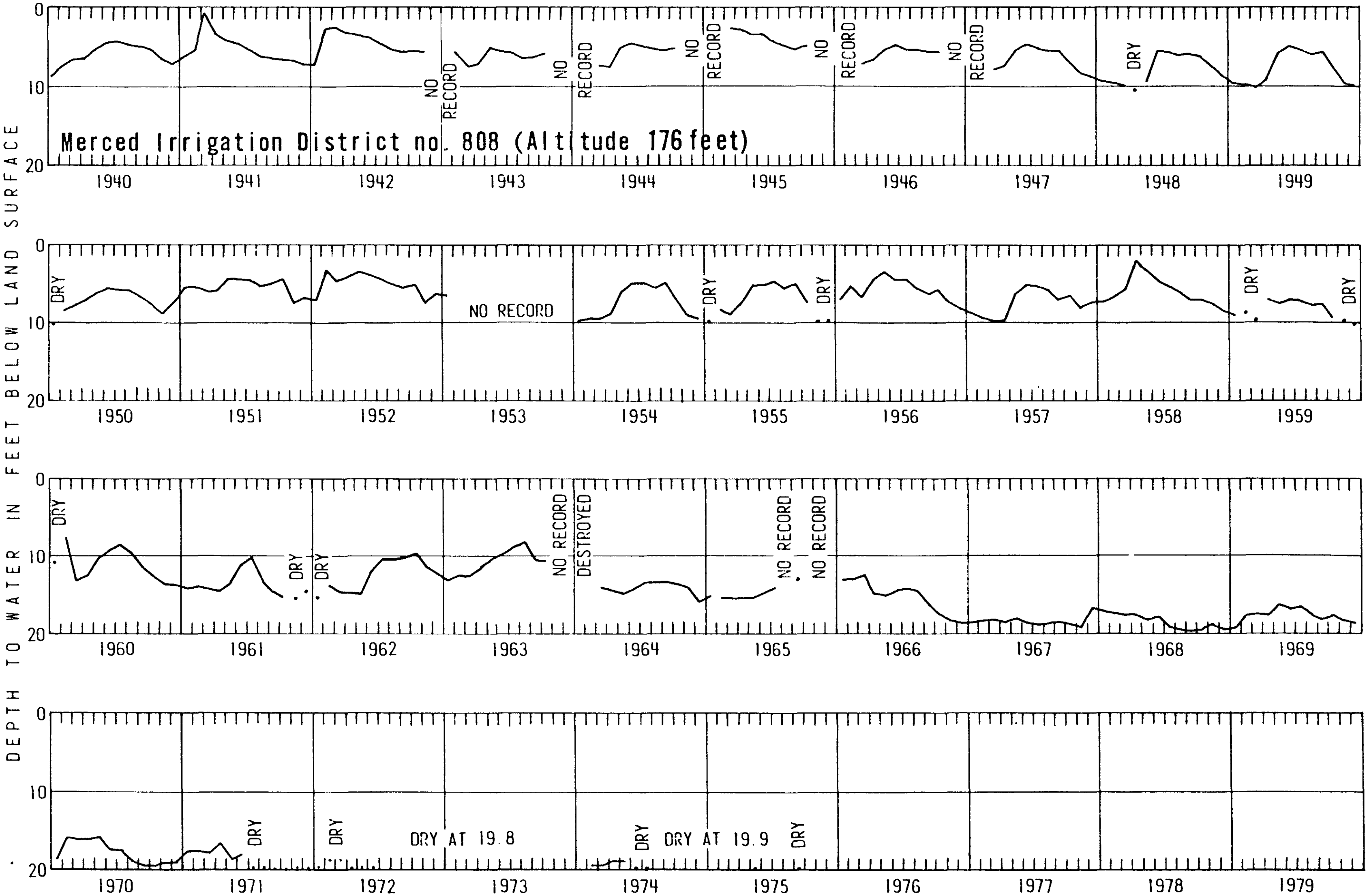
Hydrograph by A.K. Williamson, 1976
Data from Merced Irrigation District

FIGURE 4.--Water-level fluctuations in the shallow aquifer: Well 7S/13E-32N.



Hydrograph by A.K. Williamson, 1976
Data from Merced Irrigation District

FIGURE 5.--Water-level fluctuations in the shallow aquifer: Well 7S/14E-14A.



Hydrograph by A.K. Williamson, 1976
Data from Merced Irrigation District

FIGURE 6.--Water-level fluctuations in the shallow aquifer: Well 7S/14E-18R.

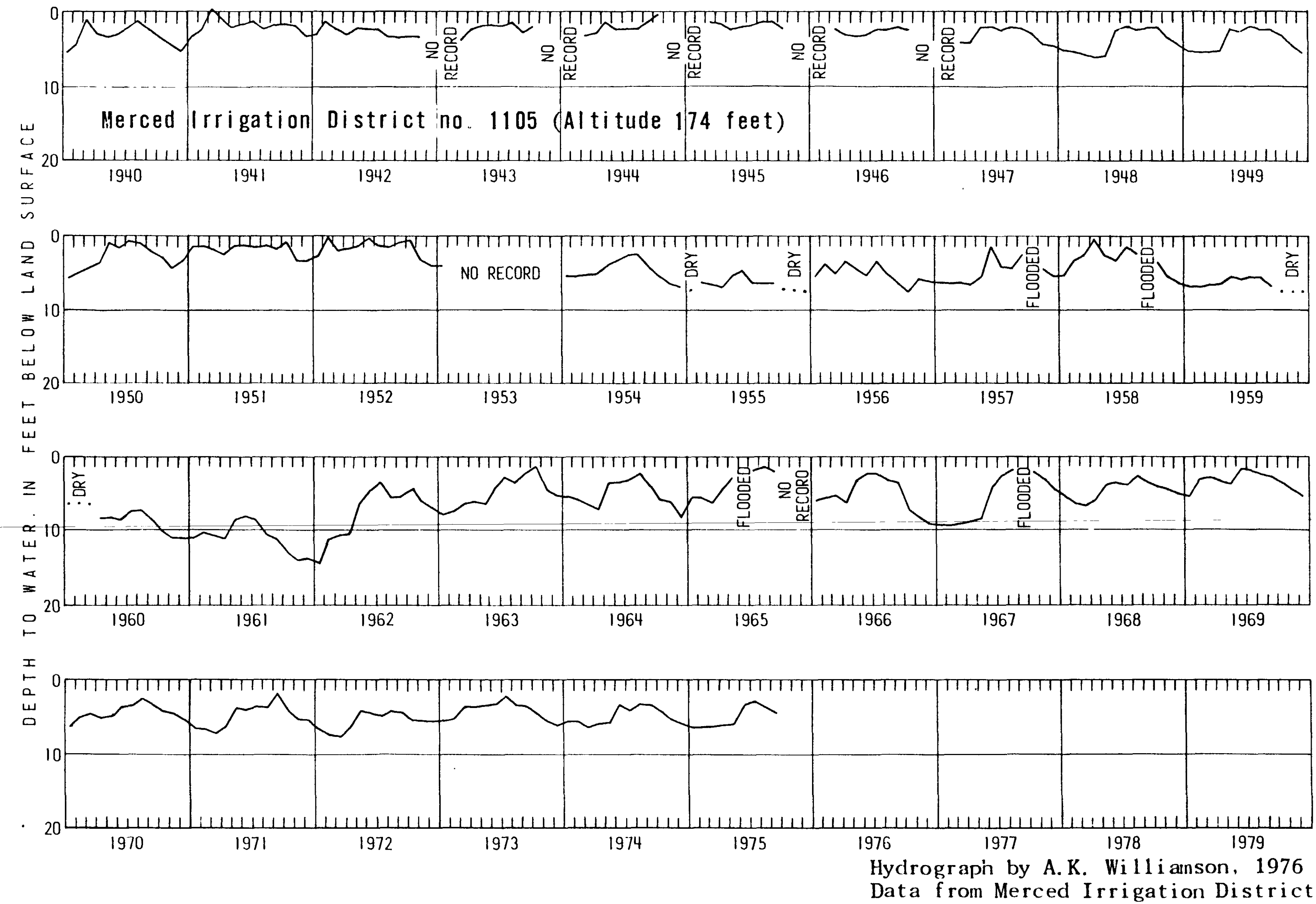


FIGURE 7.--Water-level fluctuations in the shallow aquifer: Well 8S/14E-9A.

Discharge

Discharge of ground water in the area occurs by evapotranspiration, outflow to adjacent areas, pumping, and probably by seepage into streams.

Discharge from the shallow aquifer occurs in part by downward leakage through the shallow clay bed and probably through some wells. It is not known if downward leakage occurs from the other aquifers. Because the head in the shallow aquifer is at times higher than that in nearby streams, ground water probably discharges into the streams during those times (pl. 2 and figs. 3-7).). The high water table in the shallow aquifer induces evapotranspiration.

Discharge of ground water by outflow is toward the west and southwest in at least the confined aquifer and the shallow aquifer. Outflow from the Mehrten Formation and the intermediate aquifer probably is toward the west and southwest also.

Pumpage varies considerably from year to year (table 5, fig. 8) and is largely dependent upon the quantity of available surface water. For example, in 1967 when surface water delivered through the main canal of the Merced Irrigation District was about 576,000 acre-ft, ground-water pumpage in the area was about 48,000 acre-ft; in 1966 when surface water delivered was only about 287,000 acre-ft, ground-water pumpage was about 115,000 acre-ft. Although pumpage in the city of Merced has varied from year to year because of deliveries of surface water, its pattern through the years has been one of steady growth (fig. 9) closely correlated with population growth. In fact, the correlation coefficient (Hoel, 1967, p. 196) between municipal pumpage and population for the period shown in figure 9 was 0.992.

Table 5.--*Estimated total ground-water pumpage*

Year	Pumpage (acre-ft)	Year	Pumpage (acre-ft)
1963	48,000	1969	51,000
1964	70,000	1970	66,000
1965	52,000	1971	107,000
1966	115,000	1972	93,000
1967	48,000	1973	47,000
1968	120,000		

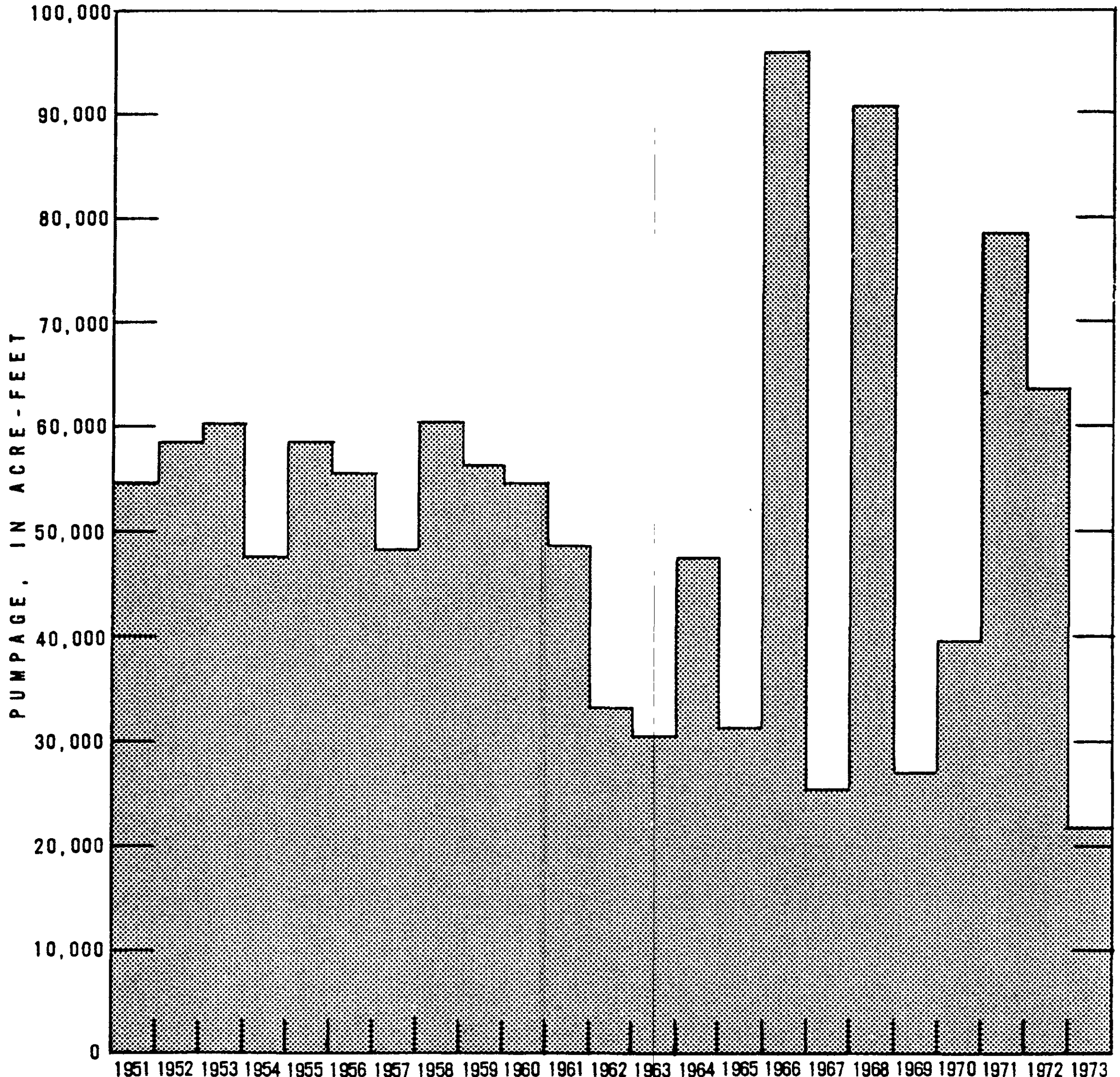


FIGURE 8.--Estimated pumpage of Merced Irrigation District in Merced study area, 1951-73.

Most of the pumping in the area occurs during the irrigation season from April to September. In years when surface water is not readily available, irrigation pumping sometimes begins as early as February or March. Municipal pumping shows a similar pattern with the largest municipal pumping occurring during June, July, and August (fig. 10).

Most of the ground water being pumped in the area is from the intermediate and the confined aquifers. Some water is pumped from the Mehrten Formation, and probably small quantities of water are pumped from the shallow aquifer. City of Merced wells derive water from the Mehrten, the intermediate aquifer, and the confined aquifer (table 6).

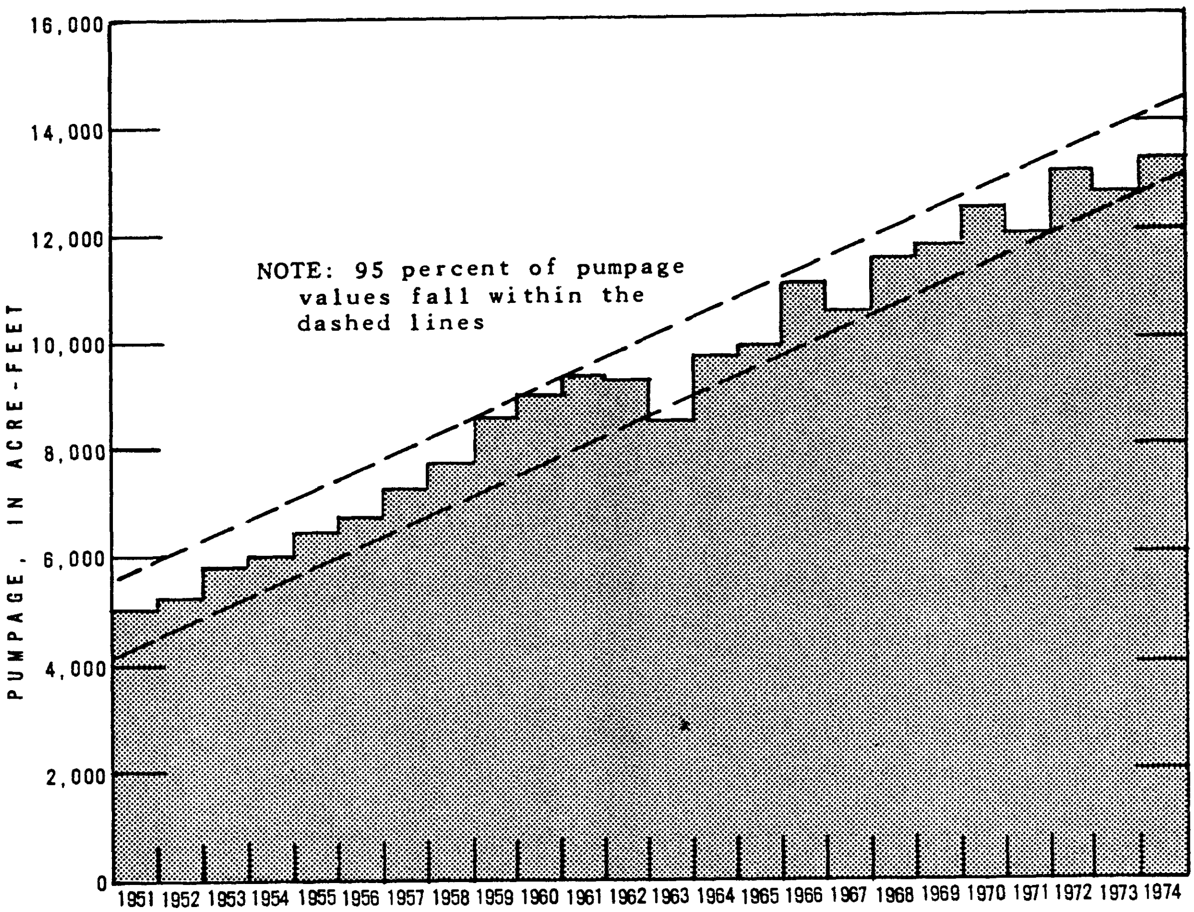


FIGURE 9.--Pumpage, city of Merced, 1951-74.

Table 6.--*Aquifers tapped by Merced wells*

City of Merced well number	Aquifer	City of Merced well number	Aquifer
1A	Intermediate	4	Intermediate
1B	Intermediate	5	Confined
1C	Intermediate	6	Confined
2A	Confined	7A	Intermediate and Mehrten Fm
2B	Confined	7B	Intermediate and Mehrten Fm
3A	Confined	8	Confined
3B	Confined		

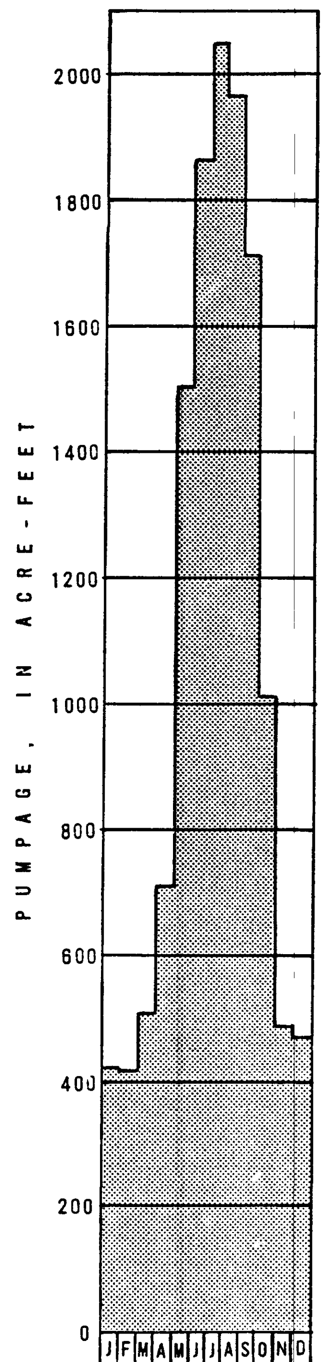


FIGURE 10.--Monthly pumpage, city of Merced, 1974.

Water-Level Fluctuations

Long- and short-term trends in the available ground-water supply in the study area are indicated by hydrographs and by tables (figs. 3-7, 11-12; tables 7 and 8). A change in the rate of decline or rise in the water level, or potentiometric surface, indicates a change in discharge or recharge.

The distribution of potentiometric head in the Mehrten Formation is not known.

Because water in the confined aquifer is confined by the Corcoran Member, it will at least rise above the base of the Corcoran, and the head is the altitude at which the water level stands in a well. Fluctuations and long-term trends of heads in the confined aquifer vary from place to place. For example, southwest of Atwater, in well 7S/12E-23D1, heads from one year to another have fluctuated a maximum of about 5 ft and have recovered to about 119 ft (table 7). Near Merced, in well 7S/14E-31M1, heads have fluctuated a maximum of 13 ft from one year to another and have indicated a declining trend from 1969 through 1974 (table 7). In Merced the head, as measured in an unpumped well in the confined aquifer, remained fairly stable from 1951 to 1958, declined slightly from 1958 to 1961, remained fairly stable until the latter part of 1966, then declined, and, except for 1972, has remained fairly stable through 1974 (fig. 11). Also in Merced, the difference between nonpumping heads and pumping heads in the confined aquifer generally has increased through the years. In 1956 the difference between the two heads at well 5 (fig. 11) was about 20 ft, whereas in 1974 the difference was about 42 ft.

Water in the intermediate aquifer is both confined and unconfined (tables 2 and 3), and in places seasonal rises and declines in water level probably result in alternate confined and unconfined conditions. In addition, water-level decline caused by pumping results in unconfined conditions (fig. 12, table 3).

Annual fluctuations and long-term trends in the intermediate aquifer have been similar from place to place. For example, northeast of Atwater, in well 6S/12E-26N2, heads from one year to another have fluctuated a maximum of about 14 ft (table 8), and near Merced, in well 7S/14E-28A2, heads have fluctuated a maximum of about 18 ft (table 8). In well 26N2, heads declined from 1958 to 1961, alternately rose and declined from 1962 to 1969, remained steady from 1969 to 1972, declined in 1973, and rose slightly in 1974 (table 8). In well 28A2, heads have indicated a similar pattern, except that they remained nearly stable from 1970 to 1974. In Merced, nonpumping heads remained nearly stable through the latter part of 1958, declined from 1958 to the first part of 1962, rose from 1962 to 1963, remained nearly stable from 1963 to the first part of 1966, declined during the last part of 1966, and remained fairly stable from 1966 to the first part of 1975 (fig. 12). Also, in Merced, the difference between nonpumping heads and pumping heads remained nearly constant ranging from about 36 ft to 42 ft until 1967 when the difference increased to about 51 ft. Since 1967 the difference has remained at about 50 ft (fig. 12).

Table 7.--*Heads in wells in the confined aquifer*

[Date indicates period in which only one head measurement was made. Head is in feet above mean sea level. Measurements were made by personnel of the Merced Irrigation District]

Date	Head	Date	Head
Well 7S/12E-23D1, Depth 127 ft, Altitude 129 ft (land-surface datum)			
Oct. 1-Nov. 26, 1958	119	Dec. 21-Dec. 28, 1966	116
Oct. 12-Nov. 26, 1959	118	April 4, 1967	117
Nov. 15-Dec. 6, 1960	118	Nov. 13-Dec. 17, 1968	119
Oct. 12-Nov. 19, 1961	115	December 1969	120
Oct. 23-Nov. 19, 1962	120	Dec.-Jan., 1970-71	119
Nov. 12-Dec. 12, 1963	120	Nov. 24-January 1971-72	116
Dec. 8-Dec. 28, 1964	118	Dec.-Jan., 1973-74	119
Dec. 6-Jan. 26, 1965-66	121	Oct. 15-Dec. 11, 1974	119
Well 7S/14E-31M1, Depth 127 ft, Altitude 160 ft (land-surface datum)			
Oct. 1-Nov. 26, 1958	147	Dec. 21-28, 1966	146
Oct. 12-Nov. 26, 1959	148	Nov. 2-Jan. 18, 1967-68	147
Nov. 15-Dec. 6, 1960	135	Nov. 13-Dec. 17, 1969	137
Oct. 12-Nov. 19, 1961	140	December 1969	147
Oct. 23-Nov. 19, 1962	148	Nov. 9-Jan. 6, 1970-71	144
Nov. 12-Dec. 12, 1963	151	Nov. 24-January 1971-72	144
Dec. 8-Dec. 28, 1964	149	Dec.-Jan. 1973-74	143
Dec. 6-Jan. 26, 1965-66	151	Oct. 15-Dec. 11, 1974	138

Fluctuations of head in the shallow aquifer, where water is unconfined, are generally similar throughout the study area, but long-term trends differ from place to place (figs. 3-7). Seasonal head fluctuations in the shallow aquifer range from virtually 0 to about 10 ft with the highest generally occurring any time from June to September. Since 1972, in the extreme northwestern part of the area, the highest heads have been occurring in February, March or April (fig. 3). Long-term trends indicate that in some areas heads have remained nearly constant through the years (figs. 4, 5, and 7), but that in other areas heads have declined (figs. 3 and 6).

Table 8.--*Heads in wells in the intermediate aquifer*

[Date indicates period in which only one measurement was made. Head is in feet above mean sea level. Measurements were made by personnel of the Merced Irrigation District]

Date	Head	Date	Head
Well 6S/12E-26N2, depth 130 ft, altitude 153 ft (land-surface datum)			
Oct. 1-Nov. 26, 1958	150	Dec. 21-28, 1966	137
Oct. 12-Nov. 26, 1959	150	Nov. 2-Jan. 18, 1967-68	149
Nov. 15-Dec. 6, 1960	148	Nov. 13-Dec. 17, 1968	132
Oct. 12-Nov. 19, 1961	143	December 1969	143
Oct. 23-Nov. 19, 1962	143	Nov. 9-Jan. 6, 1970-71	144
Nov. 12-Dec. 12, 1963	149	Nov. 24-Jan. 1972	144
Dec. 8-28, 1964	146	Dec.-Jan., 1973-74	138
Dec. 6-Jan. 26, 1965-66	149	Oct. 15-Dec. 11, 1974	140
Well 7S/14E-28A2, depth 145 ft, altitude 184 ft (land-surface datum)			
Oct. 1-Nov. 26, 1958	170	Dec. 21-28, 1966	156
Oct. 12-Nov. 26, 1959	167	Nov. 13-Dec. 17, 1968	161
Nov. 15-Dec. 6, 1960	167	December 1969	165
Oct. 12-Nov. 19, 1961	159	Nov. 9-Jan. 6, 1970-71	165
Oct. 23-Nov. 19, 1962	174	Nov. 24-Jan. 1972	166
Nov. 12-Dec. 12, 1963	174	Dec.-Jan. 1973-74	165
Dec. 8-28, 1964	169	Oct. 15-Dec. 11, 1974	166
Dec. 6-Jan. 26, 1965-66	174		

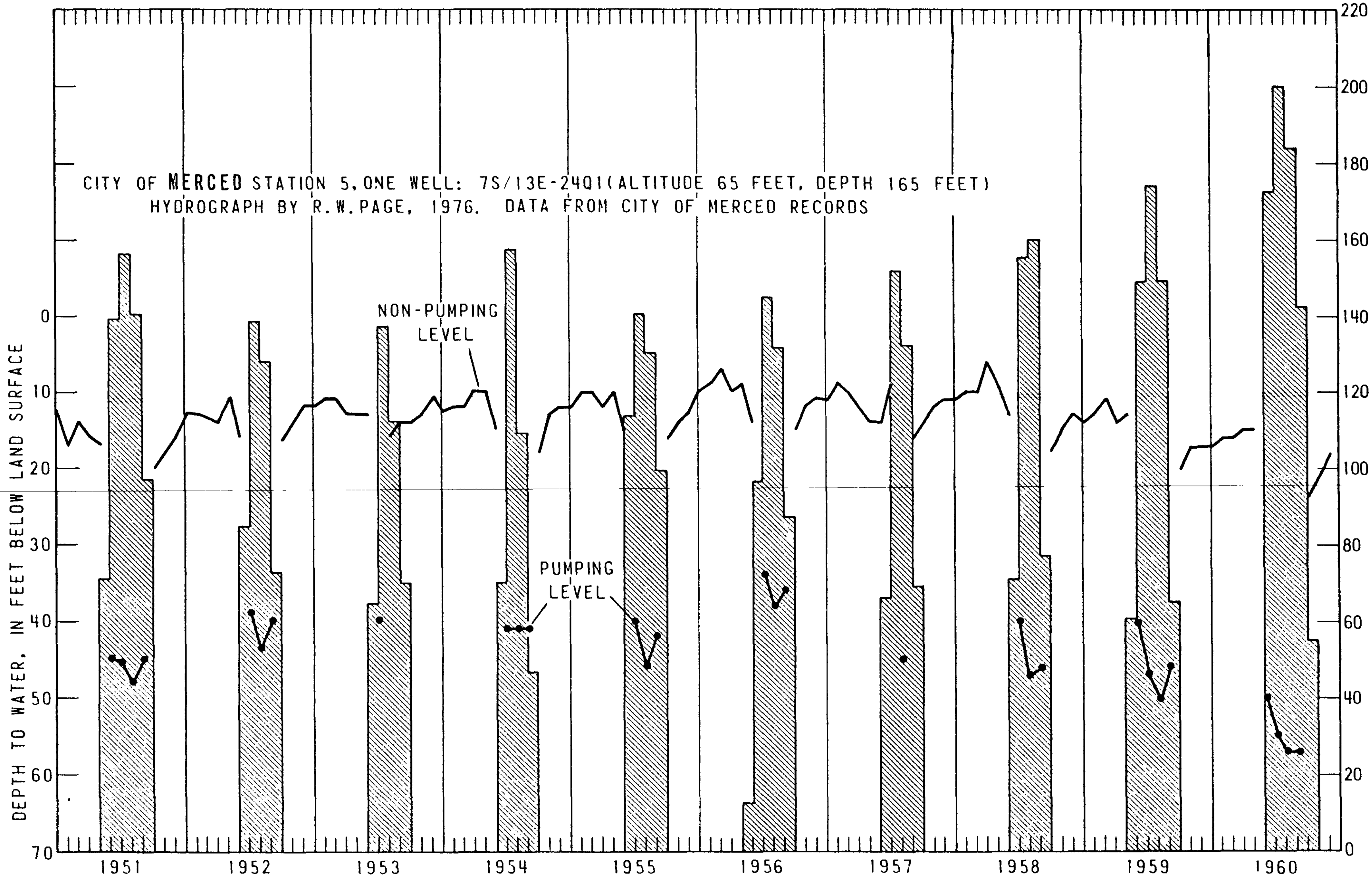


FIGURE 11.--Pumpage and water-level fluctuations, confined aquifer.
(Continued on following pages.)

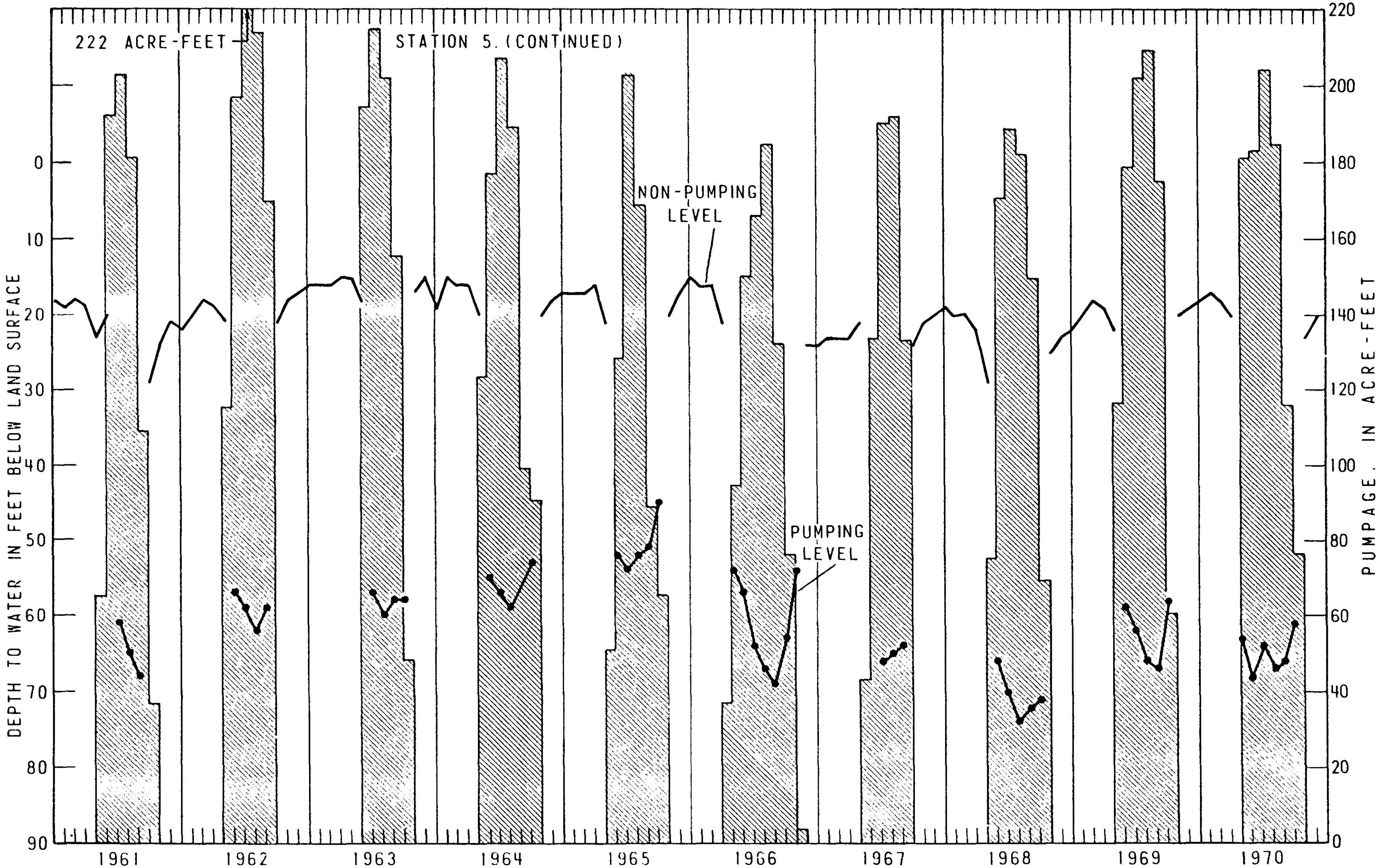


FIGURE 11.--Pumpage and water-level fluctuations, confined aquifer--Continued.

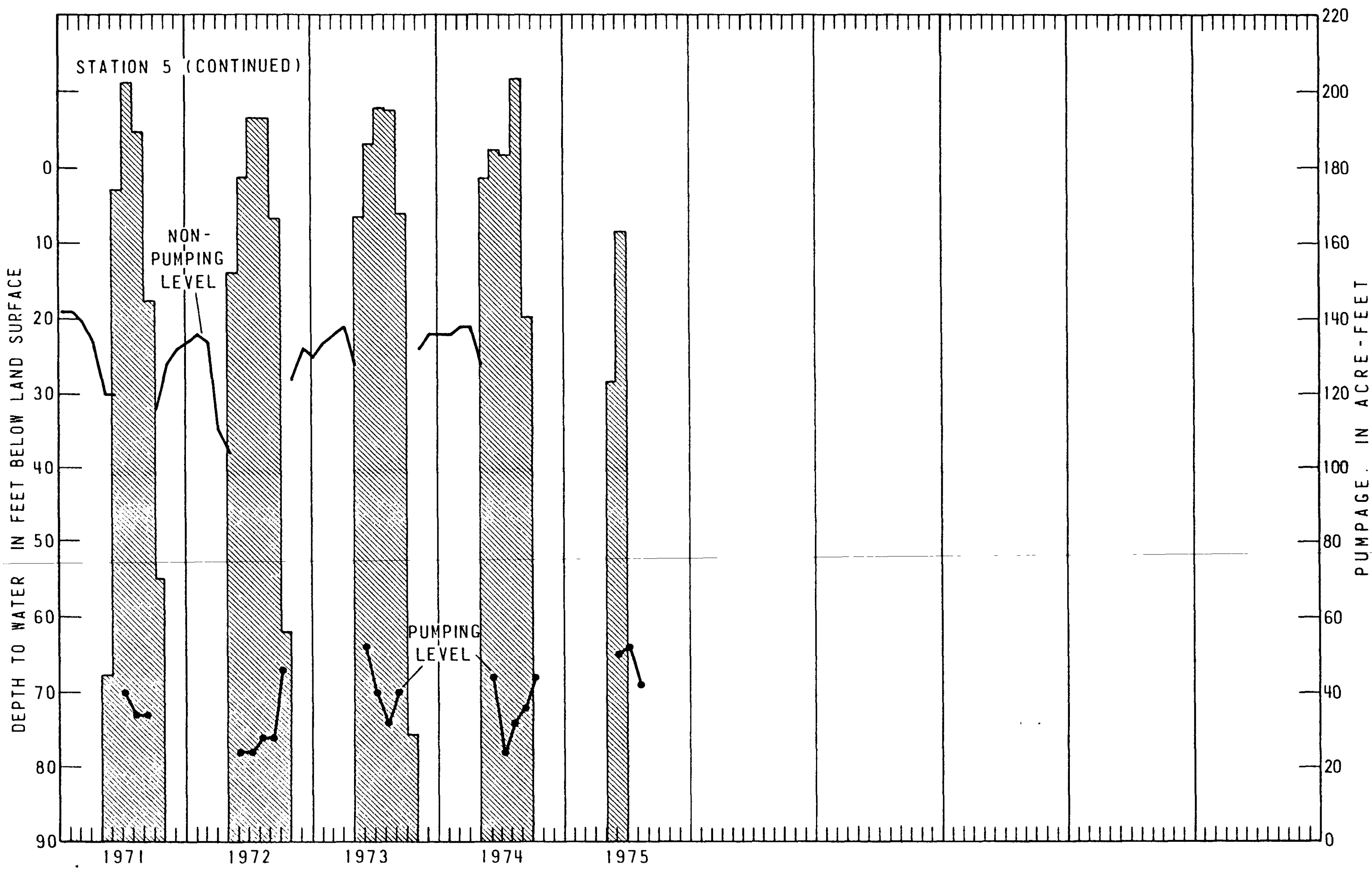


FIGURE 11.--Pumpage and water-level fluctuations, confined aquifer--Continued.

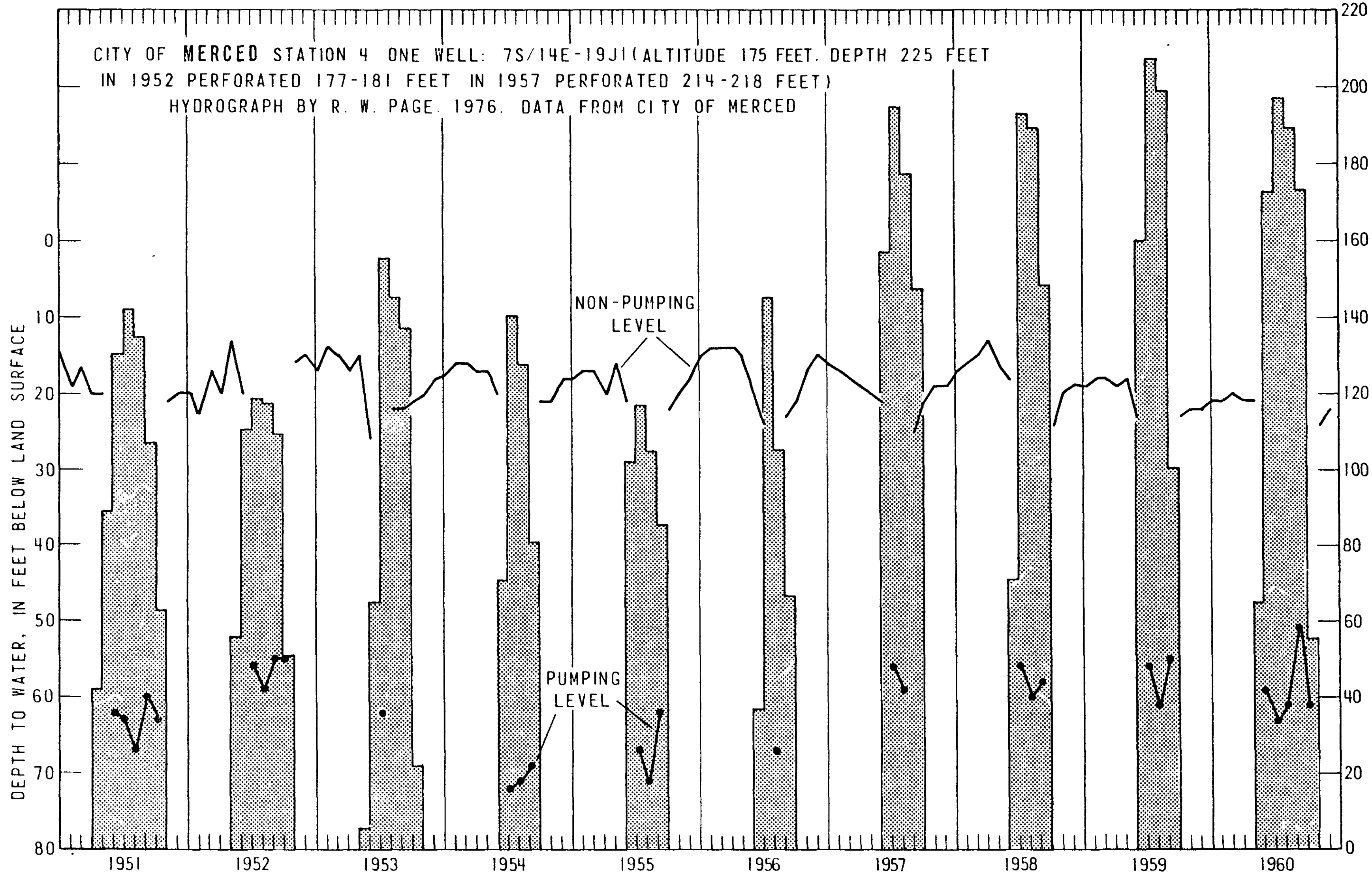


FIGURE 12.--Pumpage and water-level fluctuations, intermediate aquifer.
(Continued on following pages.)

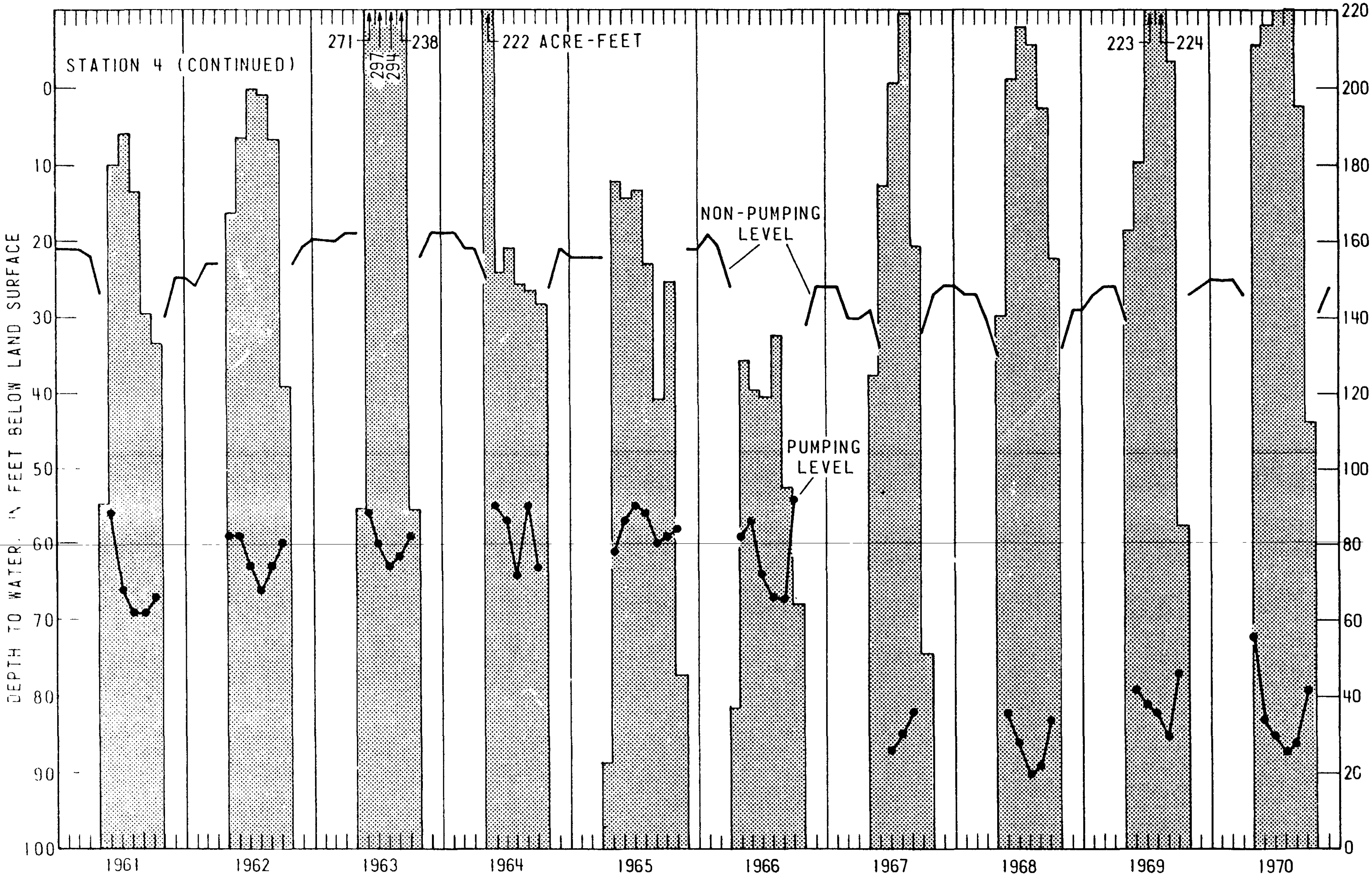


FIGURE 12.--Pumpage and water-level fluctuations, intermediate aquifer--Continued.

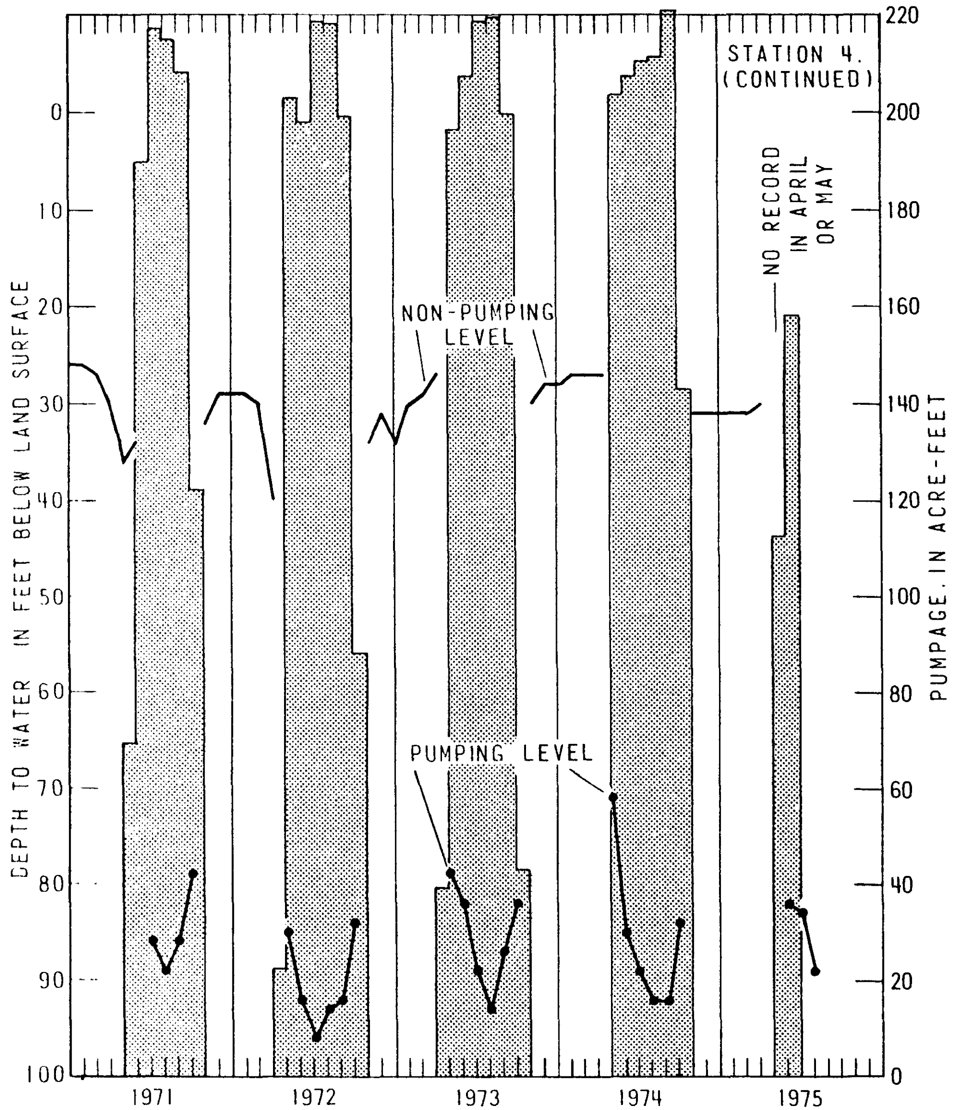


FIGURE 12.--Pumpage and water-level fluctuations, intermediate aquifer--Continued.

GROUND-WATER QUALITY

Ground-water quality was studied in an attempt to determine the relationship between occurrence of water and its chemical type and to identify zones of water of poor quality that could affect utilization of the ground-water reservoir.

Terms used to describe chemical types of water in this report follow the usage of Piper, Garrett, and others (1953, p. 26 footnote) as in the following examples:

(1) Calcium bicarbonate designates a water type in which calcium amounts to 50 percent or more of the cations and bicarbonate amounts to 50 percent or more of the anions in milliequivalents per liter.[3]

(2) Sodium calcium bicarbonate designates a water type in which sodium and calcium are first and second in order of abundance of the cations, but neither is 50 percent or more of the total cations.

(3) Sodium chloride bicarbonate designates a water type in which chloride and bicarbonate are first and second in order of abundance of the anions, but neither is 50 percent or more of the total anions.

The effective base of the ground-water basin in the study area is the base of a zone where the dissolved-solids concentration is less than 2,000 mg/L. The base of that zone in the area is at a depth of about 1,200 ft. A sodium chloride water probably occurs below that depth (Page, 1973).

Wells in the Merced area are completed above the 1,200-ft depth, and all of them yield bicarbonate-type water, generally with calcium or sodium predominant among the cations (pls. 2 and 5). In places, however, magnesium is a major cation (pl. 5).

Water from wells in the study area is of good chemical quality, and analyzed constituents do not exceed the limits recommended by the U.S. Environmental Protection Agency (EPA) (tables 9 and 10). Although EPA (1972, p. 68) does not specify a limit on the hardness of water, hardness in excess of 120 mg/L (as $CaCO_3$) is objectionable in water for domestic supplies because it reduces cleaning properties of water and causes scaling (Sawyer, 1960, p. 233). In the study area hardness in places exceeds 120 mg/L (pl. 5).

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[3]Milliequivalents per liter = $\frac{\text{milligrams per liter}}{\text{ionic weight/valence}}$.

Table 9.--*Some standards of quality for drinking water*

[U.S. Environmental Protection Agency, 1972, p. 48-104; 1975, p. 11990-11998]

	Maximum concentration	
Constituent[1]	Milligrams per liter	Micrograms per liter
Arsenic		50
Chloride	250	
Copper		1,000
Fluoride[2]	1.6	
Iron		300
Lead		50
Manganese		50
Nitrate-nitrogen	10	
Selenium		10
Sulfate	250	
Zinc	5	

[1]Not a complete list.

[2]Based on annual average of maximum daily air temperature of 77°F at Merced for the 5 years between 1966 and 1970 (Page and Balding, 1973, table 6).

Table 10.--*Chemical analyses*

[Concentration, in milligrams per liter (mg/L) or micrograms per liter (µg/L). Resources; G-U.S. Geological Survey; T-Twinning, Fresno, Calif.]

Well number	Depth (feet)	Geologic section	Date of sample	Dissolved silica (SiO_2) (mg/L)	Dissolved iron (Fe) (µg/L)	Dissolved manganese (Mn) (µg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)
										Intermediate aquifer			
6S/12E-23H1[1]	76	--	7-15-65	--	--	--	16	5.8	6.2	0.9	48	17	2.5
6S/13E-31F1	93	--	7-12-61	68	--	--	18	5.4	18	1.7	86	16	3.2
7S/12E-1Q1	145	B-B'	7-12-61	79	--	--	33	8.9	26	1.9	144	22	15
7S/12E-22H1[1]	50	B-B'	7-15-65	--	--	--	42	16	24	3.6	196	8.6	7.5
											Intermediate		
6S/12E-35K1	316	A-A'	3-16-72	35	2.0	15	30	11	26	3.0	152	37	14
6S/13E-28P1	80	B-B'	3-27-74	--	1.7	.0	16	6.0	23	1.3	85	8	13
6S/13E-32P1	290	B-B'	3-27-74	--	.0	.0	22	5.4	22	7.2	112	9.9	11
7S/12E-1J1	230	--	3-16-72	26	2	--	32	13	24	3.0	177	20	14
7S/13E-4P1	302	--	7-30-62	60	--	--	31	7.9	27	3.3	147	6.7	11
7S/14E-9R1	148	C-C'	7-15-65	--	--	--	21	9.6	18	2.8	126	2.0	9.4
7S/14E-19B3	228	C-C'	6-24-75	--	<2	<10	29	12	24	--	177	4.5	14
												Confined	
7S/13E-15G1	130	A-A'	5-12-64	--	<10	<50	26	9.9	25	5.0	154	6.9	13
7S/13E-24M1	400	A-A	6-24-75	--	<20	<10	27	12	23	--	162	9.9	11
7S/13E-24Q1	167	C-C'	6-24-75	--	<20	<10	48	19	35	--	244	19	25
7S/14E-29R1	254	--	6-24-75	--	<20	<10	39	14	38	--	241	15	14
7S/14E-30E1	187	A-A'	6-24-75	--	<20	<10	46	19	38	--	241	17	36
7S/14E-31C1	267	A-A'	6-24-75	--	<20	<10	24	7.7	36	--	134	37	11
8S/14E-2D1	190	D-D'	7-18-61	40	--	--	23	7.9	29	2.4	160	9.0	8.1
										Mehrten Formation and			
7S/14E-16L1	358	C-C'	6-24-75	--	<20	<10	24	12	21	--	150	9.9	14
												Mehrten	
7S/14E-26K1	595	D-D'	10-72	75	--	--	22	10	20	--	126	5.0	11

[1]Data near well are not conclusive as to the absence or presence of the shallow aquifer.

of water from selected wells

Laboratories: C-Calgon, Pittsburgh, Pa.; D-California Department of Water

Dissolved fluoride (F) (mg/L)	Dissolved nitrate (N) (mg/L)	Total nitrite plus nitrate (N) (mg/L)	Dissolved solids, sum (mg/L)	Dissolved solids, residue at 180°C (mg/L)	Hardness (Ca,Mg) (mg/L)	Percent sodium	Specific conductance (micromhos)	pH (units)	Temperature (degrees C)	Dissolved arsenic (As) (µg/L)	Dissolved boron (B) (µg/L)	Dissolved copper (Cu) (µg/L)	Dissolved lead (Pb) (µg/L)	Dissolved selenium (Se) (µg/L)	Dissolved zinc (Zn) (mg/L)	Laboratory
and shallow aquifer																
--	4.5	--	--	128	64	17	162	8.1	19	--	0	--	--	--	--	D
0.2	4.5	--	192	--	67	36	220	7.9	20	--	70	--	--	--	--	D
.2	3.8	--	274	--	119	32	347	8.0	19	--	80	--	--	--	--	D
--	2.7	--	263	--	170	23	438	8.8	20	--	0	--	--	--	--	D
aquifer																
.2	6.8	--	--	305	122	32	--	7.8	--	--	--	--	--	--	--	T
.2	--	5.3	--	173	65	43	239	7.3	21.5	--	--	--	--	--	--	G
.1	--	5.0	--	209	77	36	273	7.4	21	--	--	--	--	--	--	G
.2	4.9	--	--	284	134	28	--	7.9	--	--	--	--	--	--	--	T
.1	4.1	--	--	270	110	34	330	8.6	19	--	0	--	--	--	--	D
--	1.3	--	--	203	92	29	282	8.6	19	--	--	--	--	--	--	D
.2	--	.8	171	--	120	30	310	7.7	--	<5	100	<2	5	<5	.2	T
aquifer																
.1	3.2	--	253	--	104	33	--	8.0	--	--	--	--	--	--	--	C
.1	--	2.3	164	--	116	30	300	7.7	--	<5	70	<2	5	<5	.2	T
.2	--	5.2	272	--	198	28	480	7.6	--	<5	80	4	5	<5	.4	T
.1	--	1.8	242	--	157	34	400	7.8	--	<5	130	4	8	<5	.2	T
.2	--	3.2	278	--	184	30	495	7.6	--	<5	140	<2	5	<5	.2	T
.1	--	1.6	183	--	91	46	275	7.8	--	<5	110	<2	<5	<5	.3	T
.2	1.6	--	206	--	90	40	296	7.9	21	--	60	--	--	--	--	D
intermediate aquifer																
.2	--	.8	155	--	107	30	265	7.7	--	<5	150	<2	5	<5	.2	T
Formation																
--	3.4	--	222	--	94	31	285	8.0	--	--	--	--	--	--	--	C

CONCLUSIONS AND HYDROLOGIC DATA REQUIREMENTS FOR QUANTITATIVE PREDICTIONS

Although heads near Merced have declined, at the present time ground-water quantity and quality seem to be adequate to meet immediate future demands. The collection of data and the analysis of the hydrologic system that would be necessary for quantitative predictions can therefore be done over a period of years. The hydrologic system of the Merced area is complex, however, and present understanding of the system is inadequate for making long-term quantitative predictions. To develop a more thorough understanding of the hydrologic system and to make quantitative predictions, it is necessary to collect detailed records of water levels, pumpage, surface-water inflow and outflow, and distribution and types of crops. In addition, it is necessary to determine values of transmissivity and storage coefficient and to obtain a better knowledge of the areal extent of the aquifers, aquifer geometry, and the hydrologic boundaries controlling flow. Transmissivity is the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. The storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In the Merced area values of transmissivity and storage coefficient can be approximated for the confined, shallow, and intermediate aquifers, but data are lacking for calculating them for the Mehrten Formation.

The areal extent and geometry of the aquifers in the Merced area are partly defined in a number of earlier reports by the Geological Survey and are further defined in this report. Additional work will be necessary to define the nature and extent of the Corcoran Clay Member of the Tulare Formation and the shallow-clay bed, which are barriers to flow. Also, additional work will be necessary to define the nature and extent of the probable unconfined aquifer.

Because quantitative predictions of results of possible management alternatives are needed, it will be necessary to define better the full extent of the pumping depression or incipient depression around Merced in order to help define subsurface recharge and discharge boundaries. It will also be necessary to evaluate quantitatively the following: (1) The gain or loss of water from Bear Creek, especially along the reach that passes through Merced, (2) the gain or loss of water from the other small creeks that pass through the area, (3) the loss of water from the shallow aquifer to underlying aquifers, (4) the gain or loss of water from the intermediate and confined aquifers, (5) the gain or loss of water from the Mehrten Formation, and (6) recharge to the shallow aquifer from precipitation and irrigation return. Further, in ground-water systems, there are recharging boundaries at which water enters the system, discharging boundaries at which water leaves the system, and no-flow boundaries at which water neither enters nor leaves the system. Most of the hydrologic boundaries needed to define the hydrologic system lie beyond the city limits of Merced.

In gaining knowledge of the above hydrologic features and boundary conditions, all or part of the hydrologic equation must be solved. The hydrologic equation is a statement of the law of conservation of matter related to water (table 11). The relation between the factors listed in table 11 is simple and direct: when recharge exceeds discharge the quantity of water in storage increases and the water table or potentiometric surface rises; conversely, when discharge exceeds recharge, the quantity of water stored decreases and the water table or potentiometric surface declines.

Some of the items in table 11 are included in the following discussion. Although good records of precipitation are available, data on the quantity of direct recharge from precipitation to the shallow aquifer are lacking and probably will continue to be lacking. Consumptive use by irrigated crops in the area can be estimated for at least two periods by using crop surveys completed for 1957 and 1968 by the California Department of Water Resources. Consumptive use for some urban areas in the Merced area can be estimated from the same source. In addition, consumptive use for years other than 1957 and 1968 can be estimated from records of the Merced Irrigation District, whose personnel, from year to year, determine total acreage for each crop in the district.

Records are available for calculating the importation of water in the Merced area, and some records are available for calculating the export of water. Ponding occurs behind several small dams in the area, but compared to ground-water storage, the surface-water storage is small. Pumpage data are available for the wells of the city of Merced, Castle Air Force Base, and the Merced Irrigation District. Some pumpage data are available for the other communities in the area, but little information is available for the large private wells.

Table 11.--*Increments of the hydrologic equation*

[After American Society of Civil Engineers, 1961]

Items of supply	Items of disposal
Surface inflow	Surface outflow
Subsurface inflow	Subsurface outflow
Precipitation on area	Total evapotranspiration (consumptive use) in area
Imported water and sewage	Exported water and sewage
Decrease in surface storage	Increase in surface storage
Decrease in soil moisture storage	Increase in soil moisture storage
Decrease in ground water storage	Increase in ground water storage
Total, Items of supply = Total, Items of disposal	

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