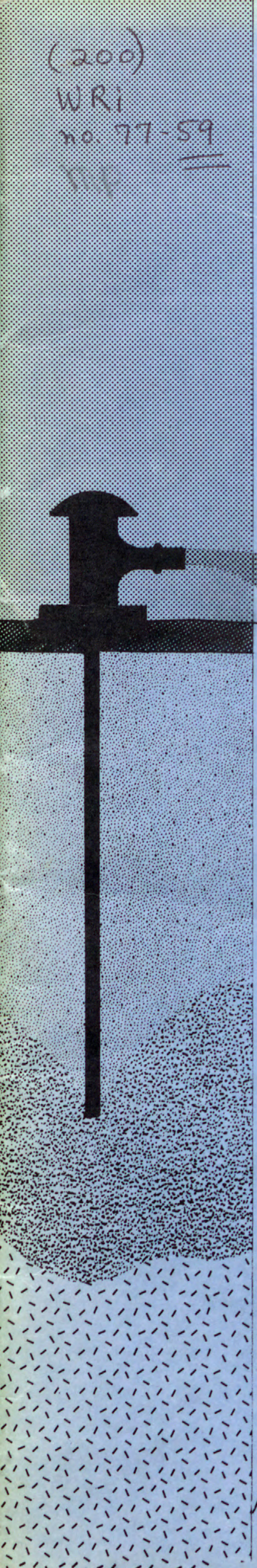
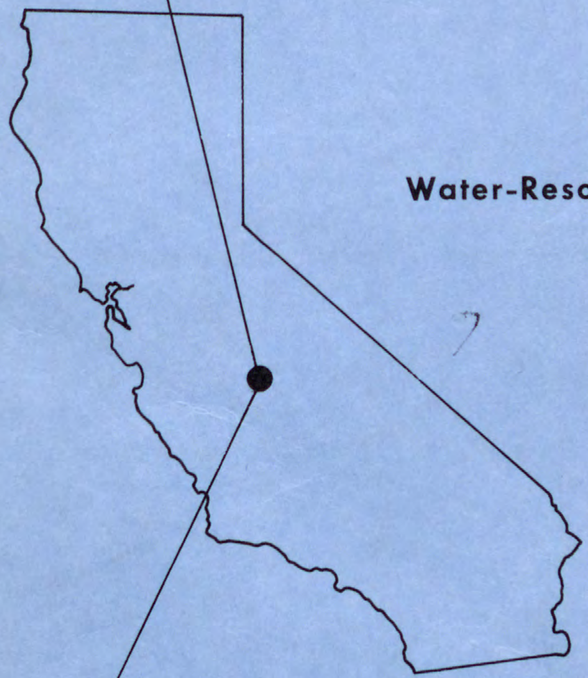
GROUND WATER IN THE FRESNO AREA, CALIFORNIA





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16. Abstracts

The Fresno area of California uses about 140,000 acre-feet of ground water a year for municipal and domestic purposes. An average of 2,000,000 acre-feet of water a year is pumped for irrigation. Major sources of recharge are deep penetration of irrigation water (80 percent) and seepage from canals, rivers, and streams (15 percent). Ground water occurs under unconfined and confined conditions; most water is pumped from the unconfined, alluvial aquifer. Ground-water quality is generally suitable for domestic and irrigation uses, although hardness and concentrations of nitrates and dissolved solids are of local concern. Water levels in the unconfined aquifer declined about 25 feet in the period 1947-1976. Levels in the confined aquifer declined about 100 feet in the period 1954-1976. Increased reliance on ground water for irrigation during the drought period will accelerate water-level declines.

17. Key Words and Document Analysis. 17a. Descriptors

*Aquifer Characteristics, *Domestic Water, *Groundwater Availability, *Municipal Water, California, Groundwater, Water Pollution, Water Quality, Water Utilization

17b. Identifiers/Open-Ended Terms

Fresno area, Fresno County, Sole Source Aquifer, Safe Drinking Water Act, San Joaquin River, Kings River

17c. COSATI Field/Group

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UNITED STATES DEPARTMENT OF THE INTERIOR

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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*
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometers)
ft (feet)	3.048×10^{-1}	m (meters)
ft/d (feet per day)	3.048×10^{-1}	m/d (meters per day)
ft^2/d (feet squared per day)	9.290×10^{-2}	m^2/d (meters squared per day)
gal/min (gallons per minute)	6.308×10^{-2}	L/s (liters per second)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

GROUND WATER IN THE FRESNO AREA, CALIFORNIA

By K. S. Muir

SUMMARY OF FINDINGS

1. The compound alluvial fans, the high alluvial fans, and the river channels are important landforms in the Fresno area because they have an influence on the occurrence, movement, recharge, and development of the ground-water resource.

2. The older alluvium is the most developed water-bearing unit in the Fresno area.

3. The aquifer extends from the foothills of the Sierra Nevada westward beyond the Fresno area. It extends northward from the Fresno area beyond the San Joaquin River and southward beyond the Kings River.

4. Ground water occurs under unconfined conditions from the foothills east of Fresno westward to a northwest-trending line through Kerman and Raisin City. West of that line, ground water occurs under both unconfined and confined conditions.

5. In 1976, ground-water movement was generally southwestward from the mountains toward the center of the San Joaquin Valley.

6. Sources of ground water in the area are: subsurface inflow from adjacent areas; artificial recharge; and natural recharge including deep penetration of local precipitation, seepage from canals, rivers, and streams, and deep penetration of imported surface water and locally pumped ground water used in irrigating crops. About 80 percent of the replenishment is from deep penetration of irrigation water and about 15 percent is from canal, river, and stream seepage.

7. In 1976, ground water was the only source of municipal and domestic water supply, and about 140,000 acre-ft was pumped for this purpose.

8. Nearly 15,000 wells pump an average of 2,000,000 acre-ft of ground water per year for irrigation.

9. Natural ground-water discharge occurs from the Fresno area to the San Joaquin River and the Kings River and as subsurface outflow.

10. Water levels in the unconfined part of the aquifer declined about 25 ft between 1947 and 1976. In the confined part of the aquifer, the water levels declined nearly 100 ft during the period 1954-76.

11. Water-bearing properties of the aquifer vary considerably throughout the area.

12. In general, ground water in the Fresno area is suitable for domestic and irrigation uses. In certain locations hardness and the concentrations of nitrate and dissolved solids are of concern to water users.

13. The aquifer is vulnerable to contamination. Liquid contaminants can enter the aquifer with ease similar to that of recharge water.

14. Water from the San Joaquin River and the Kings River is a potential alternative source of drinking water for the Fresno area.

INTRODUCTION

The purpose of this investigation is to supply the U.S. Environmental Protection Agency (EPA) with the geologic and hydrologic information needed to:

1. Determine if the aquifer in the central part of Fresno County (fig. 1) is the area's sole or principal drinking-water source.

2. Determine if the aquifer can be contaminated and if contamination of the aquifer would create a significant hazard to public health.

3. Evaluate the impact that projects which receive Federal financial assistance would have on the aquifer and its recharge area.

The scope of this investigation includes studying the geology with particular reference to the water-bearing deposits; determining the occurrence, direction of movement, recharge and discharge characteristics, depth to water, and fluctuations of water levels within the aquifer; describing the chemical quality of the ground water; and discussing sources of drinking water other than ground water. The investigation was done using existing information.

LOCATION AND POPULATION

The Fresno area, as defined in this study and shown in figure 1, occupies about 1,400 mi^2 in the east-central part of the San Joaquin Valley. It is entirely within the boundaries of Fresno County and is bounded on the north by the San Joaquin River, on the south by the Kings River, on the east by the foothills of the Sierra Nevada, and on the west by the Fresno Slough Bypass (fig. 2).

The city of Fresno covers about 80 mi^2 in the north-central part of the study area. The city's population was about 175,000 in 1974. In the same year the total population in the study area was about 440,000. Agriculture is the mainstay of the economy, although manufacturing and petroleum production are also important.

LANDFORMS AND LITHOLOGY

Most of the Fresno area lies within the geomorphic province called "Great Valley of California" where alluvial plains and fans are the dominant features. The eastern part of the area is bounded by the foothills of the Sierra Nevada.

Principal landforms in the Fresno area are shown in figure 2. Not shown in the figure are the narrow ribbons of river channel and the flood plain features adjacent to the San Joaquin and Kings Rivers.

Compound alluvial fans, high alluvial fans, and river channels are hydrologically important because they influence the occurrence, movement, recharge, and development of ground water in the area.

The compound alluvial fans were formed by the intermittent streams. Deposits which make up the fans are characterized by poorly sorted, fine-grained materials.

The high alluvial fans contain deposits of clean, well-sorted gravel, gravel and sand, and sand with minor amounts of silt and clay. The fans were formed over a period of many years by the San Joaquin and Kings Rivers as the rivers overflowed their banks and moved back and forth across the area. Deposits are coarsest near the foothills and become finer grained toward the west.

A vertical section of any of the fans would reveal random layers of gravel, sand, silt, and clay. This heterogeneous layering causes the vertical permeability of the fans to be less than the horizontal permeability. Consequently, ground water in the fans generally moves faster laterally than vertically.

The channel deposits of the San Joaquin and Kings Rivers consist mainly of gravel and sand. These channels are important areas of ground-water recharge.

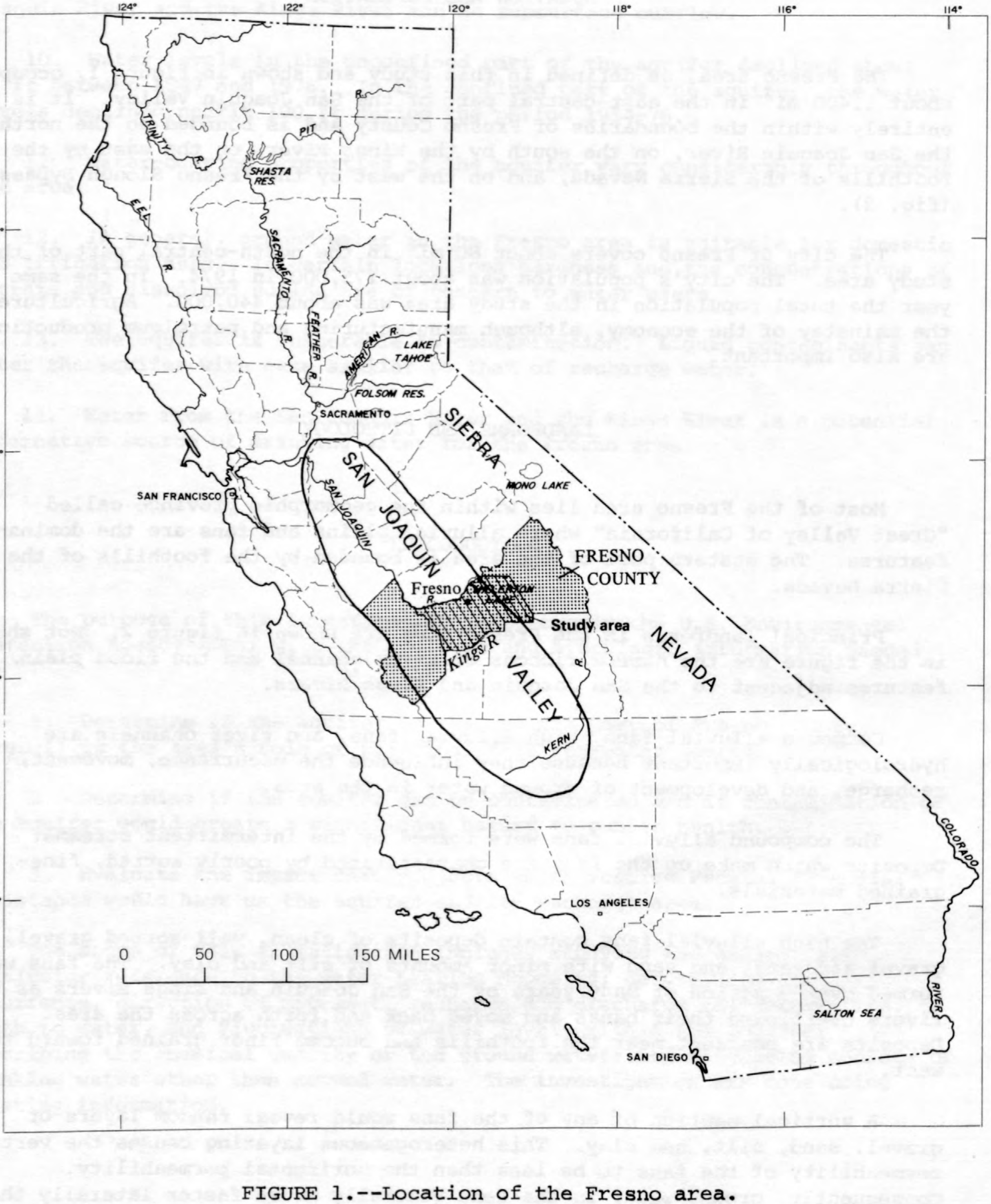


FIGURE 1.--Location of the Fresno area.

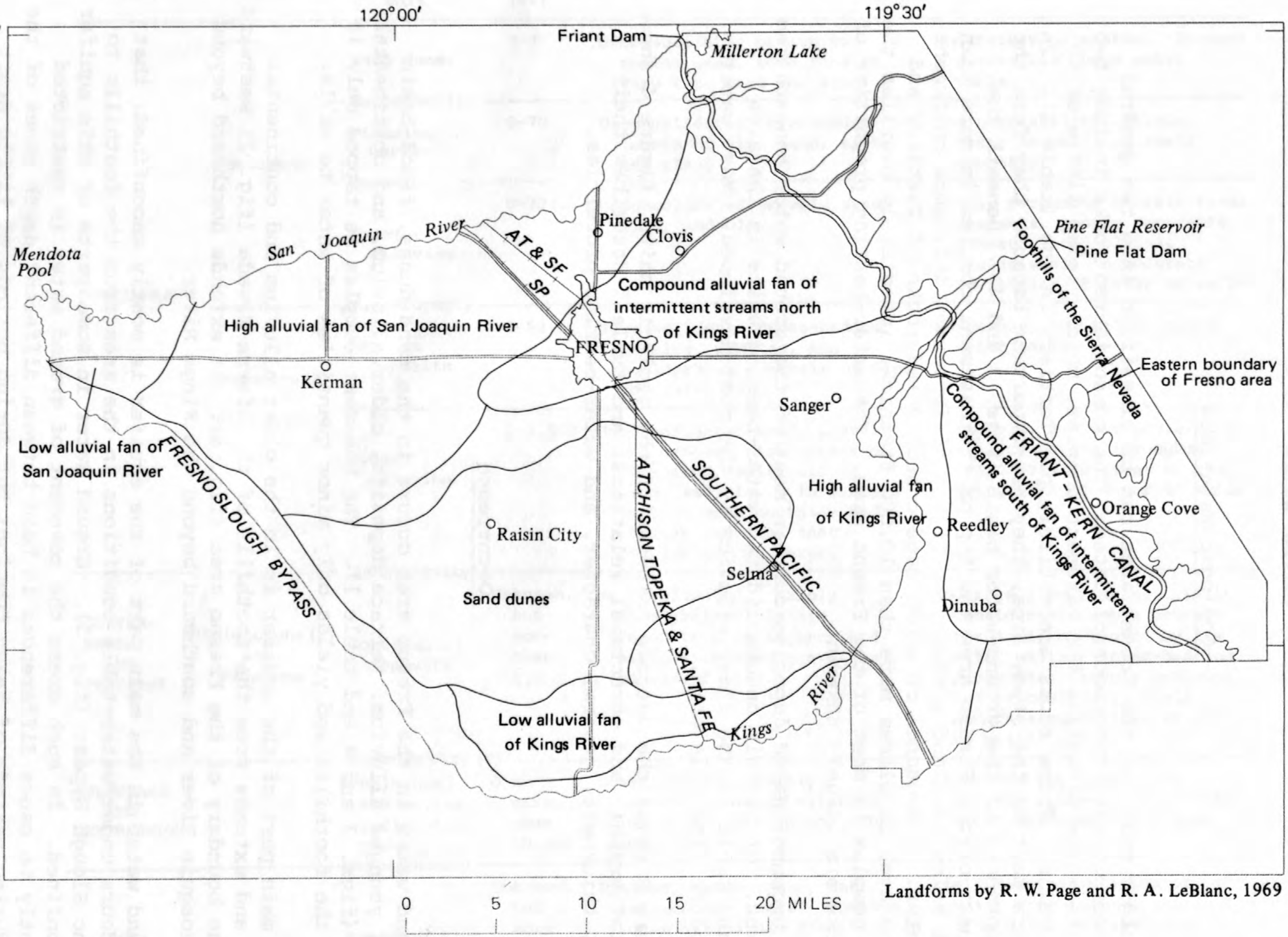


FIGURE 2.--Principal landforms of the Fresno area.

GROUND WATER

Geologic Relations

Geologic units in the Fresno area can be classified into two general groups, consolidated and unconsolidated. The consolidated rocks include two basic units. The oldest is the basement complex, which yields little or no water to wells. These rocks are entirely pre-Tertiary in age (table 1). In the eastern part of the study area, they are important because they form the eastern boundary of the ground-water basin (figs. 3 and 4). Beneath the central part of the Fresno area the top of the basement complex is more than 13,000 ft below the land surface, so it has no important influence on fresh ground water. A sequence of subsurface consolidated rocks of Tertiary and Cretaceous age, in places more than 10,000 ft thick, immediately overlies the basement complex in most of the Fresno area. The water-bearing properties of these rocks are largely unknown.

The unconsolidated deposits contain most of the ground water beneath the Fresno area. Of the six unconsolidated water-bearing units in the area (fig. 3 and table 1) the older alluvium is the most developed. Most water wells produce from this unit.

Figure 3 shows the outcrop patterns of the geologic units, figure 4 shows their stratigraphic and structural relations, and table 1 describes their sequence, thickness, general character, and water-bearing properties.

Occurrence

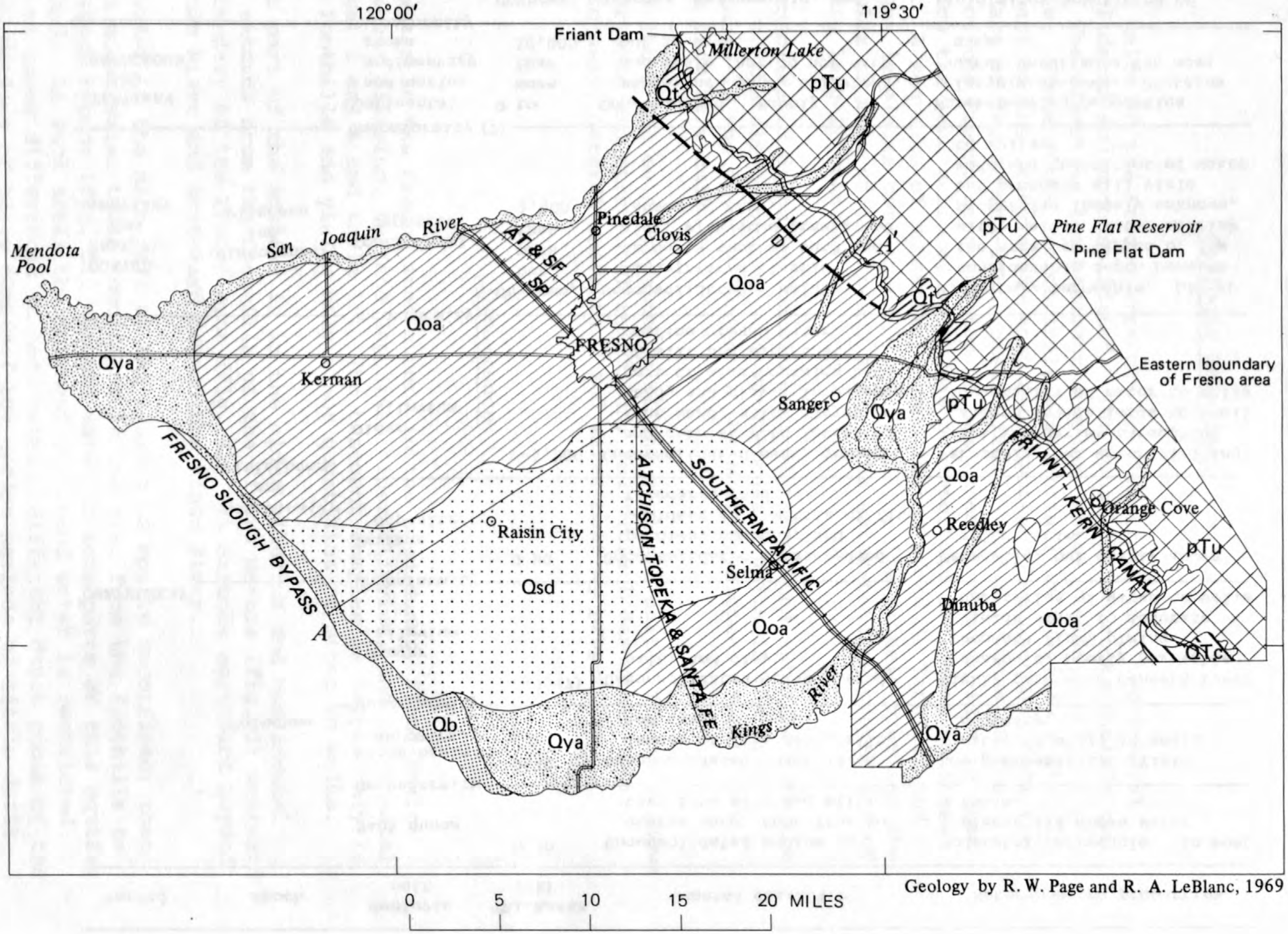
Ground water in the Fresno area occurs in the sand dunes, flood-basin deposits, younger alluvium, terrace deposits, older alluvium, and continental deposits (figs. 3 and 4 and table 1). The basement complex is tapped only in and near the foothills and yields only minor quantities of water to wells.

The main part of the aquifer is in the older alluvium and continental deposits and extends from the foothills of the Sierra Nevada (fig. 2) westward beyond the boundary of the Fresno area (fig. 4). It extends northward beyond the San Joaquin River and southward beyond the Kings River.

Ground water in the main part of the aquifer is mostly unconfined; that is, it occurs under water-table conditions in the area from the foothills to the Fresno Slough Bypass (fig. 5). Ground water in some parts of this aquifer is semiconfined. In such areas the movement of ground water is restricted sufficiently to cause differences in head between different depth zones of the aquifer during periods of heavy pumping; but during periods of little draft the water levels recover to a level coincident with the water table. The semiconfinement results from the lenticular nature of the older alluvium and continental deposits in which permeable sand and gravel strata are sandwiched between relatively impermeable clay and silt beds of local extent.

TABLE 1.--*Geologic units in the Fresno area*

Period	Epoch	Geologic unit	Thickness (ft)	General character	Water-bearing properties
QUATERNARY	Holocene	Sand dunes	0-30	Unconsolidated medium to coarse sand, some fine to very fine sand and silt.	Moderately permeable. In most places lie above water table.
		— Unconformity —			
		Flood-basin deposits	0-70	Unconsolidated interbedded lenses of fine sand, silt, and clay.	Low permeability. Yield water to wells in small quantity.
		— Unconformity —			
		Younger alluvium	0-70(?)	Unconsolidated gravel, sand, silt, and clay.	Highly permeable beneath river channels, poorly permeable beneath flood plains. Yields small to moderate quantities of water to wells
		— Unconformity —			
	Holocene(?) and Pleistocene	Terrace deposits	0-50	Unconsolidated cross-bedded pebbles, cobbles, and boulders in a matrix of fine to coarse sand.	Permeable, but mainly above water table.
		Older alluvium	0-1,200	Unconsolidated sand, gravel, and cobbles with lenses of fine sand, silt, clayey sand, and clay. In western part of area contains beds of silt and clay that confine ground water.	Permeable, but water-yielding ability varies throughout area. Yields large to small quantities of water to wells
		— Unconformity —			
QUATERNARY(?) AND TERTIARY	Pleistocene(?) and Pliocene	Continental deposits	Unknown, but more than 1,000	Unconsolidated. Mainly fine-grained clastic deposits such as sand and silt, with some gravel and lenses of clay.	Moderately permeable. Lie at considerable depth beneath the area, so tapped by few water wells. Water-bearing properties largely unknown, but probably will yield moderate quantities of water to wells.
		— Unconformity (?) —			
TERTIARY AND CRETACEOUS		Continental and marine sedimentary rocks	0 to more than 10,000	Consolidated. Mainly sandstone, sand, siltstone, and shale that do not crop out in area.	Water-bearing properties largely unknown. Contains water unsuitable for most uses.
		— Unconformity —			
Pre-TERTIARY		Basement complex	Unknown, but more than 1,000	Igneous, metamorphic, and sedimentary rocks. Igneous rocks are mainly granitic, in some places deeply weathered, jointed, and fractured. Metamorphic and sedimentary rocks are compact and highly cemented.	Yield minor quantities of water from joints, fractures, and weathered zones.



Geology by R. W. Page and R. A. LeBlanc, 1969

CORRELATION OF MAP UNITS

Qsd	Holocene	QUATERNARY
Qb		
Qya		
Qt	Holocene (?) and Pleistocene	
Qoa		
QTc	Pleistocene (?) and Pliocene	QUATERNARY(?) AND TERTIARY
pTu		PRE-TERTIARY

DESCRIPTION OF MAP UNITS

Qsd	Sand dunes
Qb	Flood-basin deposits
Qya	Younger alluvium
Qt	Terrace deposits
Qoa	Older alluvium
QTc	Continental deposits
pTu	Basement complex

CONTACT

U / D FAULT – Dashed where approximately located; U, upthrown side; D, downthrown side

A——A′ TRACE OF GEOLOGIC SECTION (fig. 4)

FIGURE 3.--Geology of the Fresno area.

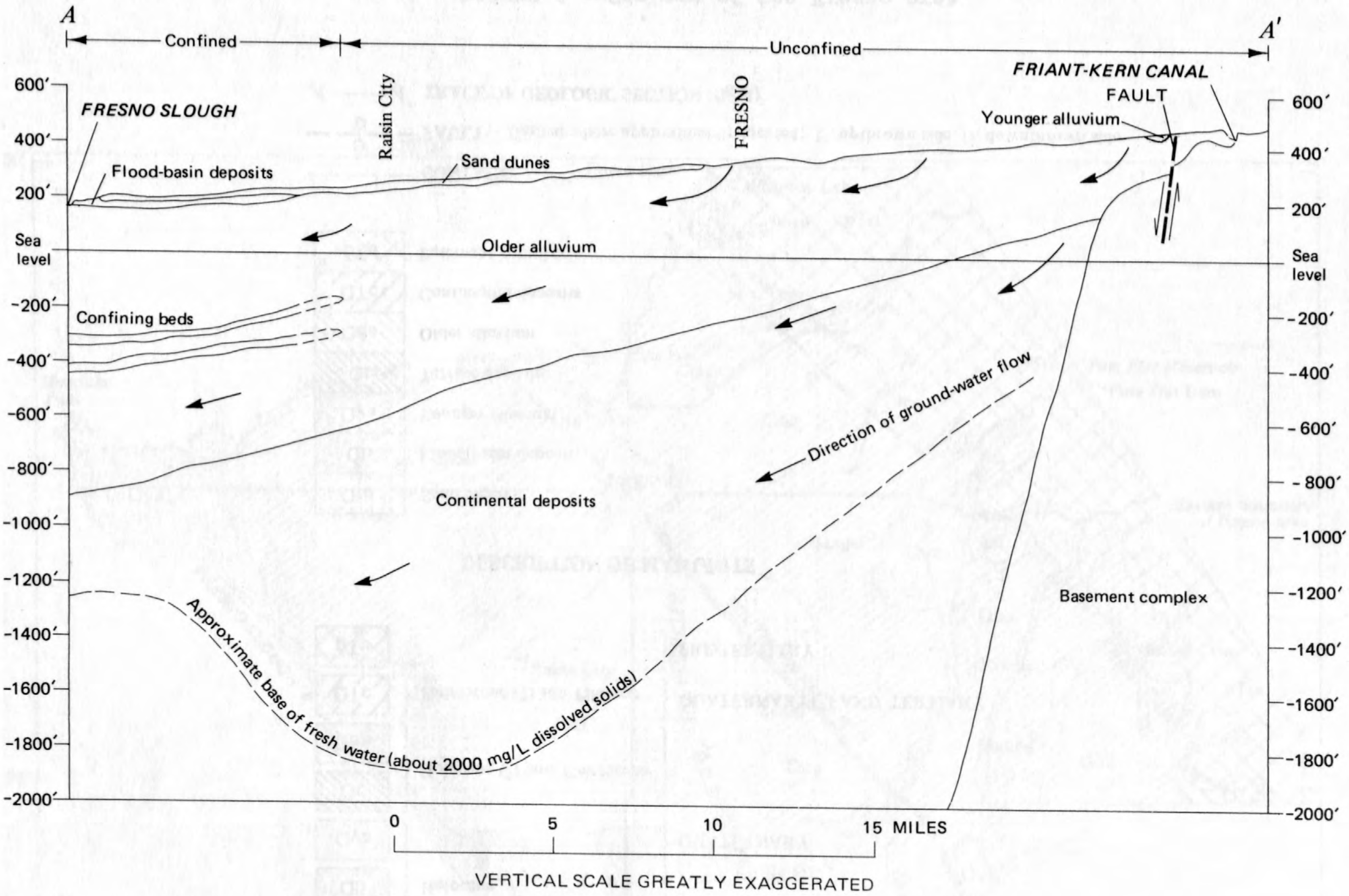


FIGURE 4.--Diagrammatic geologic section across the Fresno area showing stratigraphic relations, area of confined and unconfined ground water, base of fresh water, and direction of ground-water flow.

West of an imaginary line passing near Kerman and Raisin City (fig. 5), the aquifer has both unconfined and confined (artesian) zones (fig. 4). Ground water that is confined rises in well casings above the level in which it was first encountered when drilling. Extensive clay beds cause this confinement (fig. 4), and water in a well completed below a confining bed has a level different from water in a well completed above it.

A shallow unconfined zone occurs in the younger alluvium and flood-basin deposits (fig. 3) in the northwestern and southwestern parts of the Fresno area. Water is perched or semiperched in this shallow part of the aquifer system and separated from the underlying part of the aquifer system by a confining bed at shallow depth. This shallow zone does not yield large quantities of water to wells. Where the shallow unconfined zone is absent, ground water in the main part of the aquifer system is generally unconfined above the deeper confining beds and confined below them.

Movement

Ground water moves from areas of high head to areas of low head. Its direction of movement and its velocity are important considerations in ground-water management. Under natural conditions, ground water in the Fresno area moved generally southwestward from recharge areas in and west of the mountains toward discharge areas in the center of the San Joaquin Valley. Some upward movement of ground water occurred through confining layers in response to a pressure differential whereby hydraulic pressure was greater in the confined aquifer than in the overlying sediments.

In 1976, ground-water movement was still generally southwestward from the mountains toward the center of the San Joaquin Valley. Large withdrawals of ground water, however, especially near Fresno and Raisin City, have caused local changes in the direction of ground-water movement. Also, pumping from the confined area has caused changes in the vertical movement between zones--with some downward movement occurring in 1977. Figure 5 shows the general direction of ground-water movement in the Fresno area in spring 1976 and the depth at which water will stand below land surface in a tightly cased well.

The velocity with which ground water moves through an aquifer depends upon the porosity and transmissivity of the aquifer and the ground-water gradient. All are variable in the Fresno area.

Recharge

Sources of ground-water in the Fresno area are: subsurface inflow from adjacent areas; artificial recharge; and natural recharge including deep penetration of local precipitation, seepage from canals, rivers, and streams, and deep penetration of excess crop-irrigation water derived from imported surface water and locally pumped ground water.

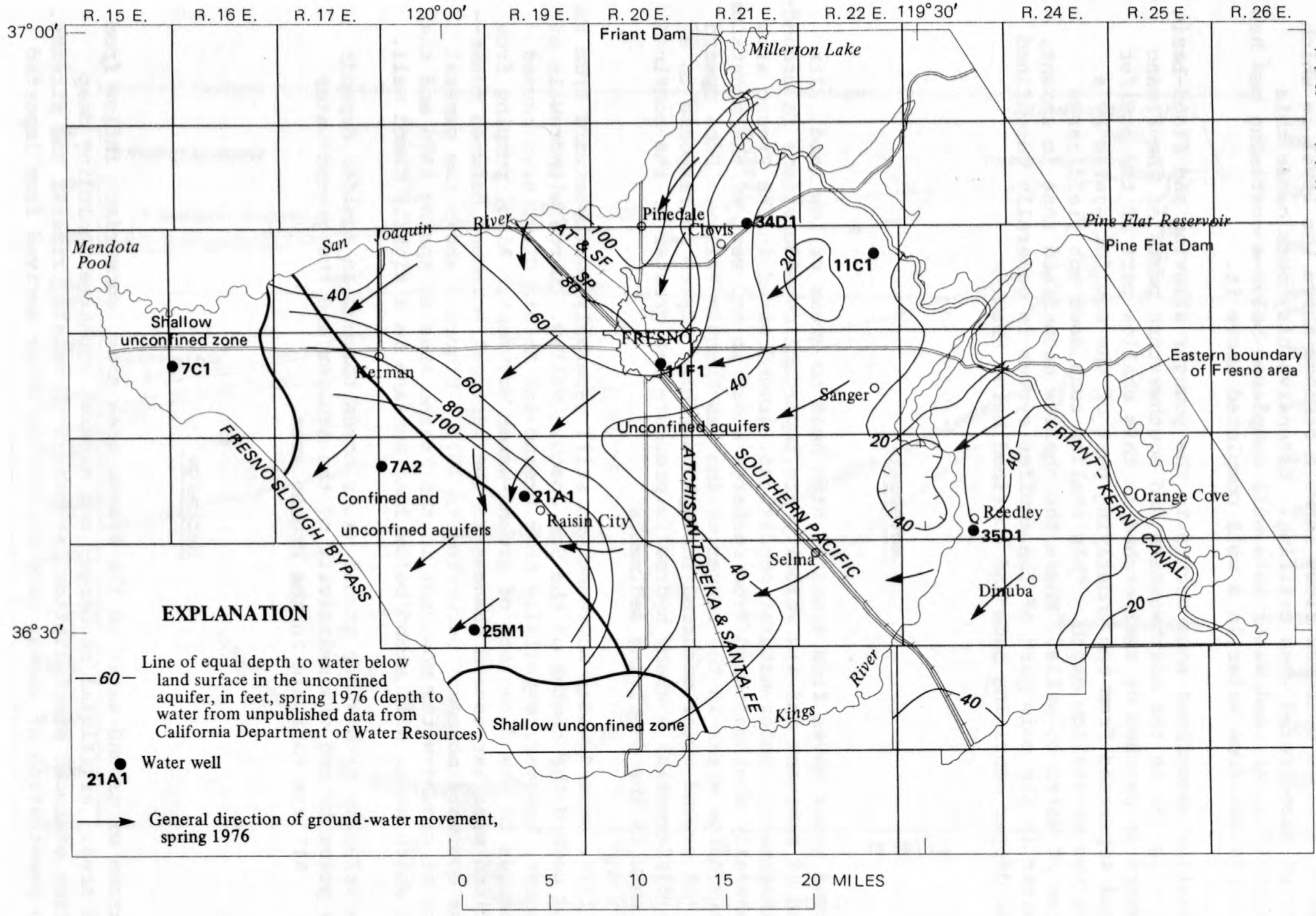


FIGURE 5.--Areas of the unconfined and confined aquifers, shallow unconfined zone, general direction of ground-water movement, and depth to ground water in 1976.

The amount of recharge to the aquifer from these different sources varies widely year by year. The controlling factor is precipitation. In wet years, with abundant amounts of surface water available, recharge is large; and conversely, in dry years, with little runoff, recharge is small.

The aquifer is recharged by direct infiltration through streambeds and the land surface in areas where the aquifer is unconfined. Water removed from storage in the confined part of the aquifer is replaced by subsurface inflow from the unconfined part of the aquifer. Most of the recharge, therefore, occurs in the eastern half of the Fresno area.

Recharge to the aquifer from precipitation is generally small because most of the precipitation is lost to evapotranspiration or held in the near-surface unsaturated zone to satisfy soil-moisture deficiencies.

Subsurface inflow of ground water from adjacent areas to the Fresno area is also small. It occurs along the eastern boundary and in the southwest corner of the area. In the east, recharge is mostly seepage from fractured bedrock and infiltration from streams. In the southwest, the shallow unconfined zone receives some water by inflow from south of the Kings River.

Artificial recharge, which probably constitutes 2 percent of the average recharge to the aquifer, occurs through the use of spreading basins and injection wells. The city of Fresno, the Fresno Irrigation District, the Consolidated Irrigation District, and the Metropolitan Flood Control District are active in artificial-recharge programs. The sources of water for the artificial-recharge operations are sewage plant effluent, cooling water, flood runoff, and water from the San Joaquin River and the Kings River. Most of the recharge operations are near or east of the city of Fresno.

Seepage losses from the extensive network of irrigation canals and ditches that traverses the Fresno area are an important source of recharge to the aquifer. Also, seepage from the San Joaquin River and the Kings River is a significant source of recharge to the aquifer. The intermittent streams in the area between the San Joaquin River and the Kings River contribute little recharge to the aquifer. Canal, river, and stream seepage to the aquifer is about 15 percent of the total yearly recharge.

Deep penetration of water applied to irrigate crops is the most important source of recharge to the Fresno area. It probably accounts for about 80 percent of the total recharge to the system in a year of normal rainfall. The sources of this water are the San Joaquin River, the Kings River, and locally pumped ground water. Dams on the two rivers impound runoff which is delivered to the areas to be irrigated via an extensive network of canals and ditches.

Discharge

Pumpage

For drinking-water use.--Historically, ground water has been the only source of municipal and domestic supplies for the Fresno area. In 1976 about 100,000 acre-ft of water was pumped from wells by municipal waterworks and private water companies for domestic use (unpublished data, city of Fresno). The city of Fresno pumped about 70 percent of this total from their system of about 80 wells.

Most of the rural and a portion of the urban population of the Fresno area are not supplied water from municipal waterworks or water companies. They obtain their water for domestic use from private wells. These private wells pump about 40,000 acre-ft per year.

Pumping ground water for domestic use has increased slightly over the past 20 years in response to increased demand from the urban population. It is anticipated that urban population will continue to grow in the Fresno area, with a consequent increase in ground-water pumpage for domestic use.

In summary, about half a million people in the Fresno area rely upon ground water for their domestic water supply. Most of this ground water is pumped from the unconfined aquifer in or near the cities and towns shown in figure 2.

For irrigation and industrial use.--Ground-water pumpage for irrigation serves mainly to supplement surface water brought into the area via canals and ditches from the San Joaquin River and the Kings River. Irrigation pumpage varies considerably from year to year, depending upon the availability of surface water. In wet years, with abundant surface water available, ground-water pumpage for irrigation is small compared to pumpage in a dry year. In drought years the reverse is true, and large quantities of ground water are pumped for irrigation.

The nearly 15,000 irrigation wells in the Fresno area pump, on the average, a total of about 2,000,000 acre-ft of water per year (Grunwald, 1970).

Most of the water used by industries in the Fresno area is ground water pumped from their own wells. No estimates of amounts pumped for this purpose have been made for this study.

Other Forms of Discharge

Some ground-water discharges into the San Joaquin River and the Kings River. The amount varies from year to year, depending on the local relation between river stages and ground-water levels adjacent to the rivers. Inflow to the rivers may be as great as 90,000 acre-ft in some years and almost nothing in others (Page and LeBlanc, 1969).

Ground water discharges from the Fresno area by subsurface outflow in the southeastern and western part of the area. The average yearly amount of water discharged in the southeastern area is unknown. Ground-water discharge by subsurface outflow along the western boundary of the area has been estimated by Page and LeBlanc (1969, p. 35) to average 100,000 acre-ft per year.

Evapotranspiration demand, or consumptive use, includes all evaporation and transpiration from vegetation and land surfaces. It is the largest form of ground-water discharge in the Fresno area. Probably 70 percent of all ground water pumped each year in the Fresno area is lost to evapotranspiration (Page and LeBlanc, 1969).

Water-Level Fluctuations and Depth to Ground Water

Typical water-level fluctuations in the Fresno area are illustrated by the hydrographs in figure 6, which are representative of water-level fluctuations in the unconfined and confined aquifers. Locations of wells represented by the hydrographs are shown in figure 5. The hydrographs show long-term trends and seasonal response to recharge and discharge. Declining water levels indicate decreases in ground-water storage, and rising water levels indicate increases in ground-water storage. The hydrographs also show the approximate depth to water in the vicinity of each of the wells. Figure 5 shows lines of equal depth to water below land surface in the unconfined aquifer in the spring of 1976. It shows that the depth to water increases westward and northward.

The hydrographs of wells 12S/21E-34D1, 14S/20E-11F1, and 15S/23E-35D1 are representative of water-level fluctuations in the unconfined aquifer. The three graphs show virtually the same trends: (1) a water-level decline averaging about 33 ft from 1947 to 1962, (2) a rise of about 18 ft from 1962 to 1970, and (3) a decline of about 12 ft from 1970 to 1976.

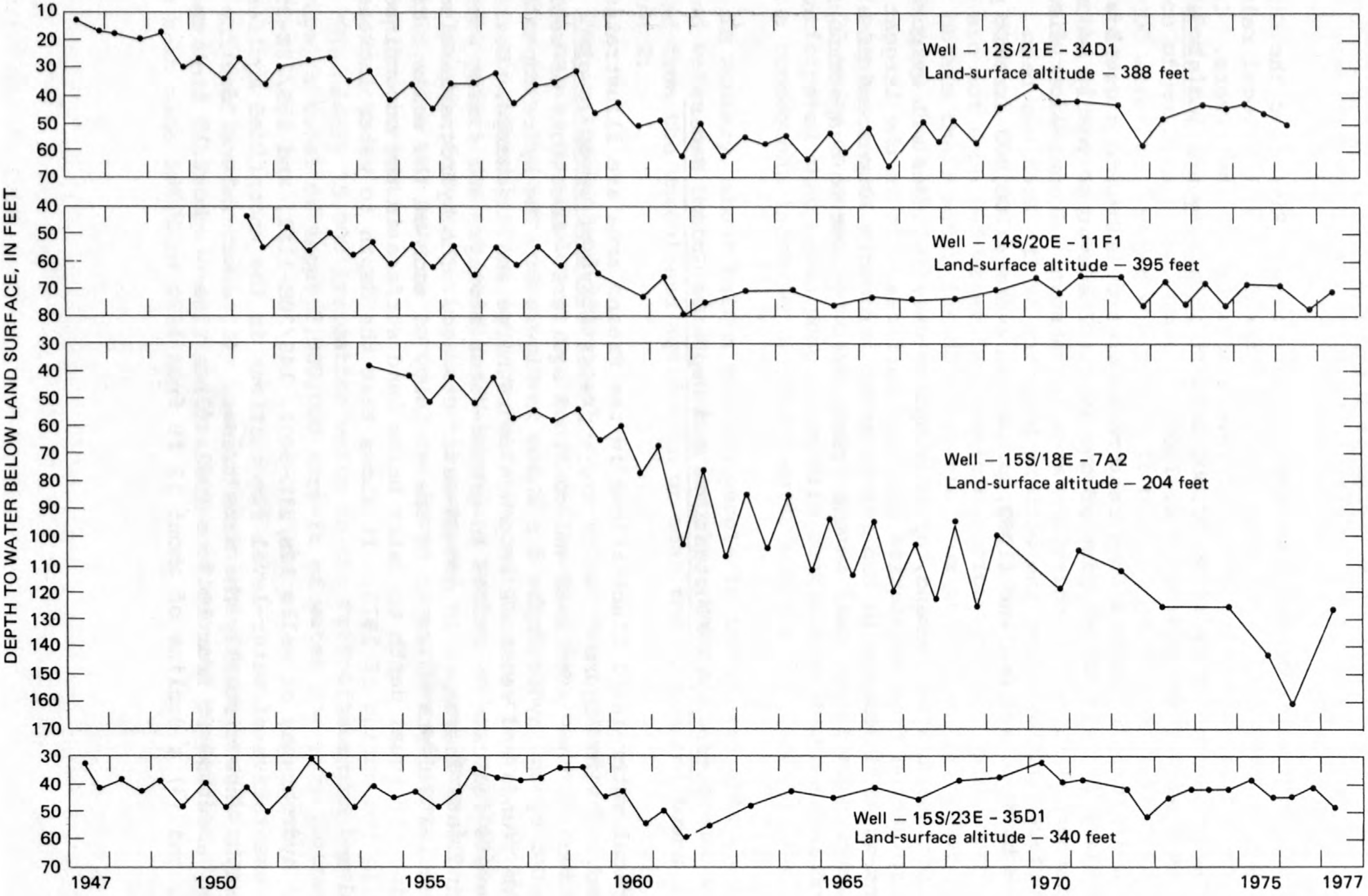


FIGURE 6.--Fluctuation of water levels in four wells in the Fresno area. Location of wells shown in figure 5.

The hydrograph of well 15S/18E-7A2, which indicates water-level fluctuations in the confined aquifer, shows an overall pattern different from that of wells in the unconfined aquifer. It shows a decline of about 60 ft for the 1954-65 period. For the 1965-76 period the decline moderated slightly to 40 ft. The hydrograph indicates no recovery of water levels in the confined aquifer for the period 1962-70.

Drought conditions prevalent in 1976 and 1977 have caused increased reliance on ground water for irrigation in the Fresno area, so water-level-decline rates can be expected to accelerate.

Hydraulics of the Aquifer

The water-bearing properties of the aquifer vary considerably throughout the area, and little information is available for any specific location. Following is a summary of the range in hydraulic properties, as indicated by the California Department of Water Resources (1965), Carollo (1969), Davis and others (1959), Davis and others (1964), Grunwald (1970), Page and LeBlanc (1969), and Page (1975).

1. Transmissivity--5,100 to 40,000 ft^2/d
2. Hydraulic conductivity--0.001 to 470 ft/d
3. Specific yield--0.2 to 36 percent
4. Porosity--34 to 50 percent
5. Well yields--20 to more than 3,000 gal/min

Quality of the Water

In general, ground water in the Fresno area is of a suitable quality for domestic purposes. In certain locations the hardness and the concentrations of nitrate and dissolved solids are of concern to water users. Table 2 lists representative chemical analyses of water from the Fresno area.

In the Fresno area, 95 percent of the ground water is a bicarbonate type containing calcium, magnesium, or sodium as the predominant cations and having an average dissolved-solids concentration of 250 mg/L (milligrams per liter). This type of water is in the unconfined aquifer. It reflects the chemical composition of the recharge water, which is mainly surface water from the San Joaquin River and the Kings River (table 2). As the ground water moves downgradient and to increased depth its chemical character changes as it dissolves the mineral constituents of the aquifer and mixes with water already in the aquifer. These changes result in increased dissolved-solids concentration and different water types. Figure 4 shows the depth below which the dissolved-solids concentration is more than 2,000 mg/L. The U.S. Environmental Protection Agency (1972) considers 2,000 mg/L a limiting dissolved-solids concentration for the irrigation of most crops. By the time the ground water has reached the west end of the Fresno area it has been altered to a chloride bicarbonate type or a bicarbonate chloride type. Sodium chloride type water is in the aquifer at certain places along the west edge of the Fresno area (table 2).

TABLE 2.--*Representative chemical*

[µg/L, micrograms per liter; a, analysis by
b, analysis by Twinning

Site number	Date of collection	Total iron (Fe) µg/L	Calcium (Ca) mg/L	Magnesium (Mg) mg/L	Sodium (Na) mg/L	Potassium (K) mg/L	Bicarbonate (HCO_3) mg/L	Sulfate (SO_4) mg/L
							Water from streams tributary	
San Joaquin River at Friant Dam a11S/21E-7	5-27-75	-	3.9	1.1	4.8	-	20	1.0
Kings River below Pine Flat Reservoir a13S/24E-2	5-28-75	-	4.2	1.1	3.4	-	20	3.0
							Water from wells	
a13S/22E-11C1	7-27-76	-	40	31	18	2.6	274	10
a14S/16E-7C1	7-27-76	-	51	3.9	822	5.0	194	133
b14S/20E-11F1	6-75	<2	42.6	24.1	46.0	-	268.4	20.6
a15S/19E-21A1	7-26-76	-	38	22	44	10	225	26
a16S/18E-25M1	7-26-76	-	21	2.1	38	2.0	85	15

analyses of water

California Department of Water Resources; Laboratories, Fresno, California]

Chloride (Cl)	Fluoride (F)	Nitrite plus nitrate as N	Dissolved solids (residue on evaporation at 18°C)	Hardness as $CaCO_3$	Noncarbonate hardness	Specific conductance	pH	Water temperature	Boron (B)
mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	micromhos at 25°C	Units	°C	µg/L
to the Fresno area									
4.2	-	-	35	14	0	100	7.5	11.7	0.00
1.4	-	-	43	15	0	40	7.2	12.5	.00
in the Fresno area									
15	-	3	288	229	-	484	8.2	-	.0
1150	-	0	194	143	-	3990	7.9	-	90
28.4	0.20	6.6	-	190.7	-	480	7.4	-	-
41	-	5.9	401	185	-	582	8.2	-	.0
42	-	0	224	61	-	317	8.3	-	10

In addition to the naturally occurring constituents in the aquifer, which result in changes in the chemical composition of the ground water, certain manmade contaminants relating to water use also cause chemical changes. The sources of these contaminants are municipal and industrial liquid wastes, liquid wastes from individual waste-disposal systems, and agricultural return water.

The major ground-water quality problems associated with liquid-waste disposal in the Fresno area are excessive dissolved solids and increased nitrate concentrations.

For each cycle of municipal or industrial water use, an incremental increase in the concentration of dissolved solids results. The amount of increase is generally between 200 and 500 mg/L.

Nitrogen (N) in most municipal and industrial wastes is generally in the form of ammonia nitrogen, organic nitrogen, nitrate, and small quantities of nitrite. The concentration of total nitrogen (N) is normally about 20 mg/L for municipal wastes. The bulk of this converts to the stable form of nitrate (NO^{3-}). Excessive nitrate in drinking water is associated with methemoglobinemia in infants, and the maximum allowable concentration of nitrate-nitrogen (N) is 10 mg/L (U.S. Environmental Protection Agency, 1972, p. 73). Based on the conversion of the various forms of nitrogen in sewage to nitrate, the ultimate concentration in the liquid waste would be about 20 mg/L nitrate-nitrogen (N) or double the allowable maximum.

All liquid wastes in the Fresno area are disposed of by placing them back onto or into the ground. As a consequence, much of the wastewater ultimately gets back into the ground-water system. This is accomplished either through the use of percolation ponds or by using the treated liquid wastes for irrigation. The disposal sites are generally adjacent to, or in, the urban areas, and consequently the concentration of nitrate and dissolved solids in the ground water in these areas is increasing. This is especially so in the city of Fresno, where water from some wells sampled has had nitrate-nitrogen (N) concentrations exceeding 10 mg/L. The concentration of nitrate-nitrogen (N) in uncontaminated areas averages about 2 mg/L. As the population of Fresno County grows, so will the problem of contamination of the ground water by liquid wastes.

The other source of manmade contamination of the ground water in the Fresno area is agricultural return water. The major problems associated with return water are excessive dissolved-solids and nitrate concentrations.

The accumulation of salts in agricultural soils results from evaporative and consumptive extraction of water from the soil during the production of crops. If the salts that accumulate are not removed, the soil will ultimately be unable to support production of crops. To maintain the concentration of salts at an acceptable level, water in excess of that required for the crops is applied. Through this process, the salts that have accumulated in the soil mantle are dissolved by the excess water, which in turn infiltrates as agricultural return water and ultimately reaches and mixes with the ground water.

The presence of excessive nitrate in agricultural return water is normally associated with the use of fertilizers in crop production. The quantity of nitrate returned to the ground water by agricultural activities is unknown, and it varies depending on individual crop fertilizing practices.

The contamination of ground water by agricultural return water in the Fresno area is areawide and subtle. It is one of the reasons why the concentration of dissolved solids in ground water increases as the ground water moves to the west from the recharge areas in the east.

It is obvious from the preceding discussion that the aquifer is vulnerable to contamination. Liquid contaminants can enter the aquifer with the same ease as recharge water. Several State and local agencies in the Fresno area are concerned with this problem and maintain active monitoring and surveillance programs.

OTHER SOURCES OF DRINKING WATER

Water from the San Joaquin River and the Kings River could be another source of drinking water for the Fresno area. It could be delivered to the areas of need via the vast network of canals and ditches maintained by the various irrigation districts.

The city of Fresno has water rights to 60,000 acre-ft of water from the San Joaquin River. Also, the city is entitled to Kings River water in the same proportion that the water service area of the city is to the area of the Fresno Irrigation District, which includes the city. No water from either of these sources had been used by 1977 by the city of Fresno for direct domestic use. The surface water received by the city has been used for ground-water recharge.

A problem with using surface water for either irrigation or domestic purposes is that the amount available depends directly on the amount of precipitation in the preceding year and on the size of surface storage facilities. Consequently, in years of drought the surface water can be in short supply.

SELECTED REFERENCES

Boyer, M. C., 1963, Water needs of Fresno County east of Fresno slough: Natural Resources Coordinator, Fresno County, 57 p.

Boyle Engineering, and Harold Tokmakian and Associates, 1971, Comprehensive water and sewer plans for Fresno County rural communities--volume 2, eastside valley: 13 sec.

California Department of Water Resources, 1965, Fresno-Clovis metropolitan area water quality investigation: Bull. 143-3, 27 p.

______1975, Hydrologic data--volume 4, San Joaquin Valley: Bull. 130 series (published annually).

California State Water Resources Control Board, 1975, Water quality control plan report for Tulare Lake basin: Central Valley Regional Water Quality Control Board, 17 chaps.

Carollo, John, Engineers, 1964, Joint water utilization report for city of Fresno and Fresno Irrigation District: Phoenix, Lafayette, and El Paso, 48 p.

Carollo, John, Engineers, and Harshbarger and Associates, 1969, Report on water resources, city of Fresno, State of California: Phoenix, Lafayette, and El Paso, 7 secs.

Crawford, C. B., Jr., Page, R. W., and LeBlanc, R. A., 1965, Data for wells in the Fresno area, San Joaquin Valley, California: U.S. Geol. Survey open-file rept., 264 p.

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.

Davis, G. H., Lofgren, B. E., and Mack, Seymour, 1964, Use of ground-water reservoirs for storage of surface water in the San Joaquin Valley, California: U.S. Geol. Survey Water-Supply Paper 1618, 125 p.

Fresno City Public Works Department, 1977, Report on water conservation: 24 p.

Fresno County Public Works Department, 1976, Northeast Fresno ground water study: 73 p.

______1976, Results of Fresno County ground water information service: 12 p.

Grunwald, Crawford, and Associates, and Engineering Science, Inc., 1970, Central Fresno County, water and liquid waste: Fresno, 5 v.

Nightingale, H. I., Bianchi, W. C., and Day, B. A., 1972, Ground-water quality in eastern Fresno County, California, interim research report: Agricultural Research Service, U.S. Dept. Agriculture, 68 p.

Page, R. W., 1971, Base of fresh ground water (approximately 3,000 micromhos) in the San Joaquin Valley, California: U.S. Geol. Survey open-file rept., 13 p.

______1975, Ground-water reconnaissance in the Fresno northeast area, Fresno County, California: U.S. Geol. Survey Open-File Rept. 75-315, 34 p.

Page, R. W., and LeBlanc, R. A., 1969, Geology, hydrology, and water quality in the Fresno area: U.S. Geol. Survey open-file rept., 70 p.

Schmidt, K. D., 1972, Nitrate in ground water of the Fresno-Clovis metropolitan area, California: Ground Water, v. 10, no. 1, p. 50-64.

U.S. Congress, 1974, Safe Drinking Water Act: Public Law 93-523, 88 Stat. 1660, 42 U.S.C. 300.

U.S. Environmental Protection Agency, Environmental Studies Board, 1972, Water quality criteria 1972--a report of the committee on Water Quality Criteria: Washington, U.S. Govt. Printing Office, 594 p.

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