Quaternary Aquifers in the Mississippi Embayment

By E. H. BOSWELL, E. M. CUSHING, *and* R. L. HOSMAN

With a discussion of QUALITY OF THE WATER

By H. G. JEFFERY

WATER RESOURCES OF THE MISSISSIPPI EMBAYMENT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 448-E

A general description of the availability and the chemical quality of ground water from the Quaternary aquifers in the Mississippi embayment

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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QUATERNARY AQUIFERS IN THE MISSISSIPPI EMBAYMENT

By E. H. Boswell, E. M. Cushing, and R. L. Hosman

ABSTRACT

Alluvial deposits of Quaternary age form ground-water reservoirs in an area of about 45,000 square miles in the Mississippi embayment. The Mississippi River valley alluvial aquifer is one of the most prolific sources of ground water in the embayment. Also hydrologically important is the Red River Valley alluvial aquifer in Arkansas, Louisiana, and Texas. Ground water is also available from alluvial deposits along other tributary streams.

The alluvial aquifers are desirable sources of water for irrigation and industry. They are used for public supplies only where an ample supply of water of better quality is not available from deeper aquifers.

Water from the alluvial aquifers is generally a hard to very hard calcium bicarbonate or calcium magnesium bicarbonate type containing excessive iron. Water temperature ranges from 59°F in the northern part of the embayment to 68°F in the southern part but is nearly constant at any locality.

Most industrial and irrigation wells are less than 150 feet deep. Wells yielding 500 gallons per minute or more are common over more than 90 percent of the Mississippi River alluvial plain, and yields of more than 5,000 gallons per minute have been reported. Water levels are generally less than 20 feet below the land surface.

The amount of water stored in the Quaternary deposits is slightly more than 120 trillion gallons. Withdrawals in 1965 averaged about 1,430 million gallons per day, or 1,600,000 acre-feet. About 85 percent of this amount was seasonal pumpage for irrigation. Water-level declines of 20–30 feet are usual in areas of large withdrawal; however, water levels in many areas generally recover to near normal each year.

The principal source of recharge is precipitation. Some recharge occurs locally along streams during high stages, but generally ground water is discharged to the streams.

INTRODUCTION

Water is the most valuable natural resource of the Mississippi embayment (fig. 1), a region of about 100,000 square miles in the Gulf Coastal Plain, and large quantities of fresh water are available from both surface and underground sources. This report describes the occurrence of water in the Quaternary aquifers in the embayment.

In the embayment, aquifers occur in sedimentary deposits ranging in age from Ordovician to Quaternary. About 45,000 square miles of the region is covered by Quaternary terrace deposits and alluvium (fig. 2). Most of these deposits underlie the alluvial plains, the most areally extensive of which is the alluvial plain of the Mississippi River. The terrace deposits are higher than the recent flood plain, but in places they and the alluvium are contiguous (fig. 3) and form a hydrologic unit. Although most of the Quaternary deposits in the smaller stream valleys are water bearing and discharge water to the streams, only the terrace deposits and the alluvium of the Mississippi River and the larger streams are used extensively as sources of water supplies.

In this report the Quaternary deposits are considered to constitute two major aquifer systems. The Mississippi River valley alluvial aquifer includes the Quaternary terrace and alluvial deposits of the Mississippi River and those of the Ouachita and Saline Rivers. The Red River Valley alluvial aquifer includes the Quaternary terrace and alluvial deposits of the Red and Little Rivers.

The investigation and the preparation of this report were under the direction of E. M. Cushing. Fieldwork and data synthesis and analysis for the report were by R. L. Hosman for Arkansas, T. W. Lambert for Kentucky and Illinois, E. H. Boswell for Mississippi, E. J. Harvey for Missouri, G. K. Moore for Tennessee, and A. T. Long for Louisiana and Texas.

The cooperation of the following State officials and members of their staffs is gratefully appreciated: Norman F. Williams, State Geologist, Arkansas Geological Commission; Wallace W. Hagan, Director and State Geologist, Kentucky Geological Survey; William C. Ackermann, Chief, Illinois State Water Survey: Leo W. Hough, State Geologist, Louisiana Geological Survey, Department of Conservation; Jack W. Pepper, Engineer, Mississippi Board of Water Commissioners; William H. Moore, Director and State Geologist, Mississippi Geological, Economic, and Topographical Survey; William C. Hayes, Jr., Director and State Geologist, Missouri Division of Geological Survey and Water Resources; William D. Hardeman, State Geologist, Tennessee Division of Geology; and Joe G. Moore, Jr.,

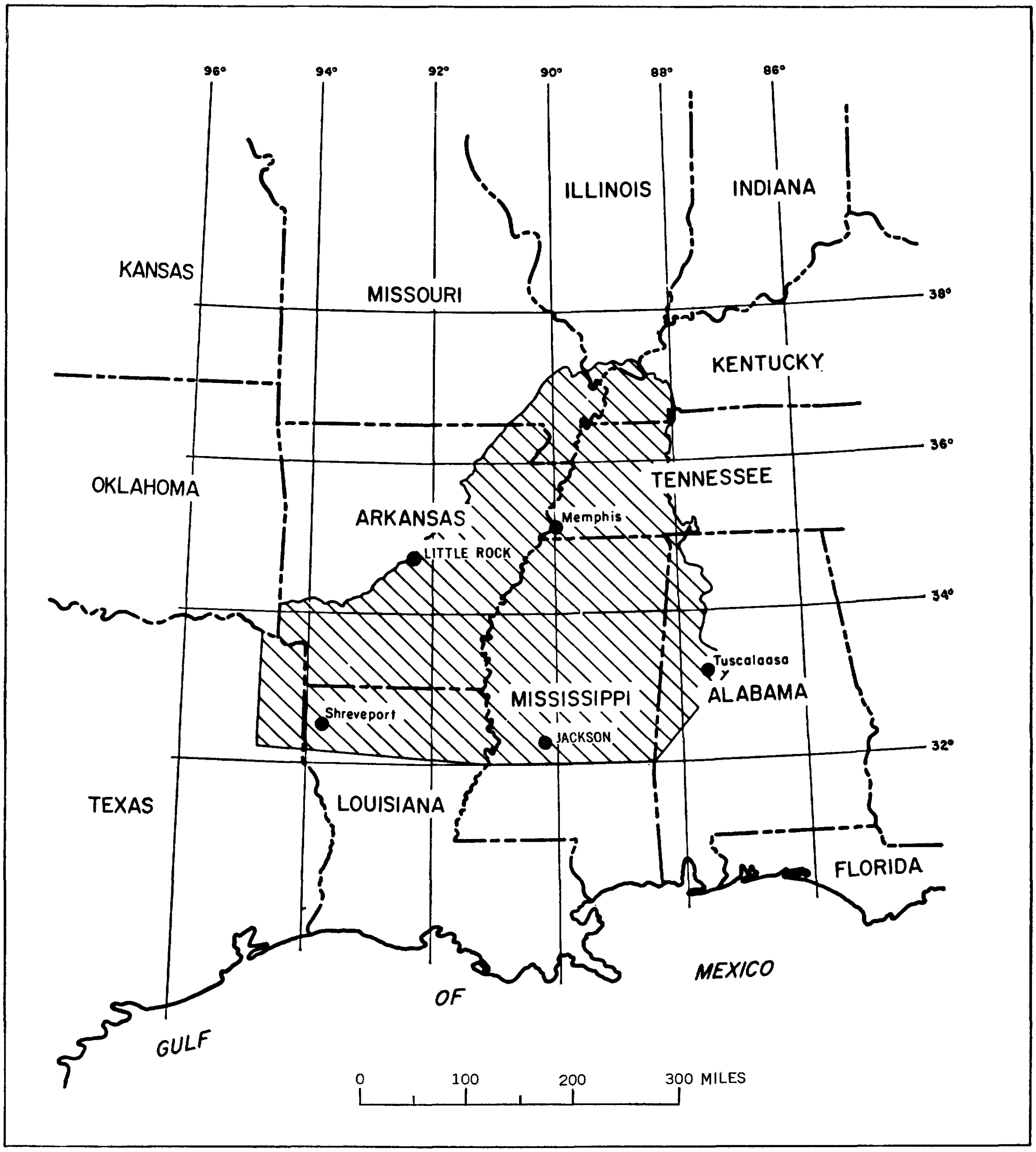

FIGURE 1.—Area of embayment study.

Executive Director, Texas Water Development Board. These officials furnished geologic and hydrologic information, many electric logs, and sets of well cuttings for this study. Pumping information and water levels supplied by well drillers in the region are also appreciated.

GEOLOGY

GEOLOGIC HISTORY

The Quaternary alluvium of the Mississippi River valley is the product of large-scale erosion and deposition during the Pleistocene and Recent Epochs. Several periods of glaciation in Canada and the northern United States and subsequent seasonal melting released large volumes of water, resulting in several cycles of erosion and alluviation. The sea level gradually rose as the glaciers melted; thus, the gradient of the ancestral streams was reduced. As gradients decreased, aggradation began, and the valley filled with gravel, sand, and clay. As the gradient continued to decrease, finer sediments were deposited by flood waters. During the Pleistocene glacial periods, the valley was partially alluviated by the Mississippi River and by streams

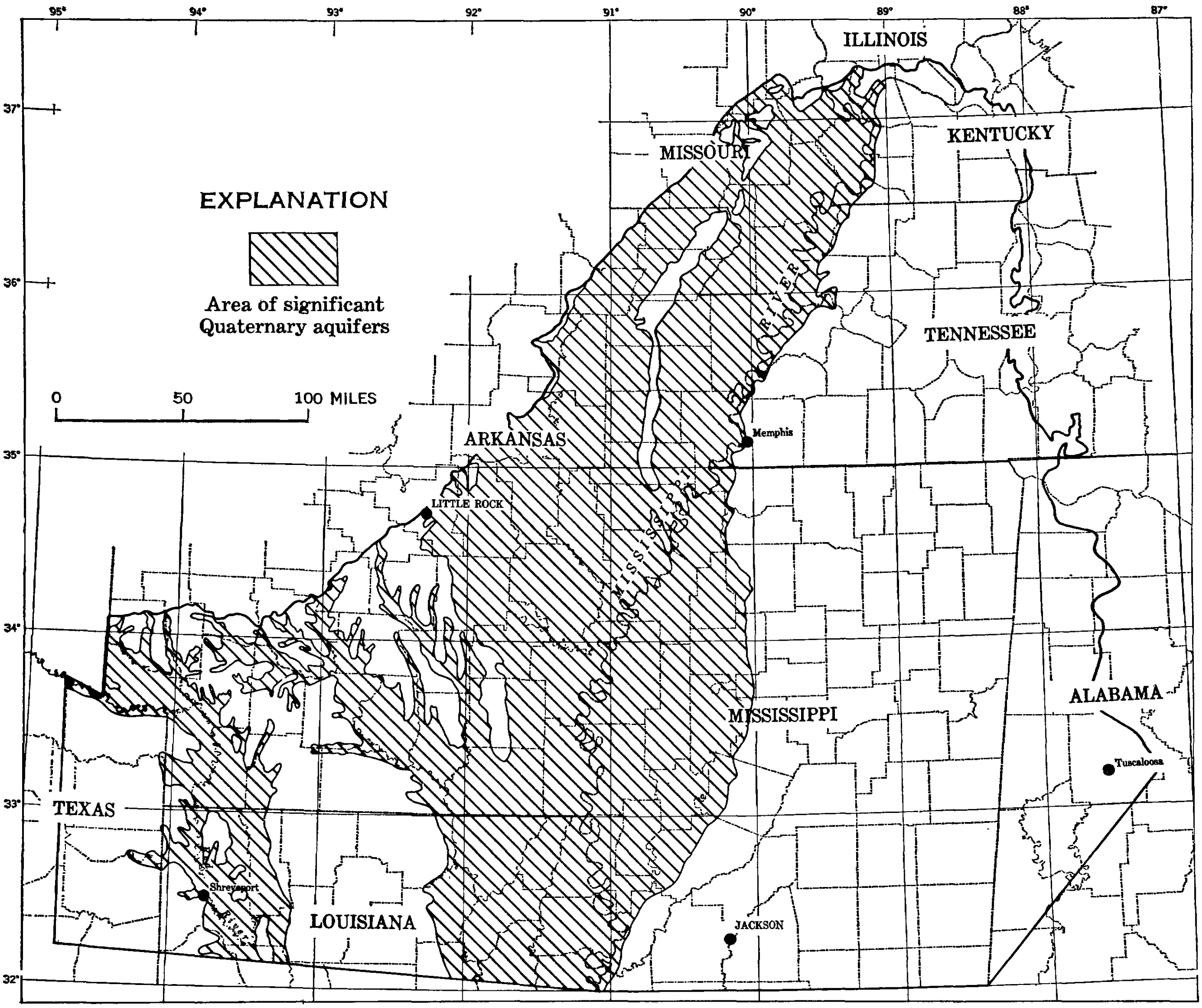

FIGURE 2.—Area where significant aquifers are in Quaternary deposits.

entering the valley. This alluvium was partially eroded, and the surface was dissected and terraced after each glacial period. Recent and Pleistocene alluvium, derived in part from older Pleistocene deposits, now underlies much of the flood plain of the alluvial valley (fig. 3).

Poole (1961) and Turcan and Meyer (1962) reported the Mississippi River alluvium to be primarily of Pleistocene age. Fisk (1944), who described the complex depositional history and geologic aspects in great detail, and Krinitzsky and Wire (1964) reported most of the Mississippi River alluvium to be of Recent age.

The Mississippi River valley was eroded into the geologic units that form the present uplands around the periphery of the valley (fig. 4) and the hill masses of Crowleys Ridge. The subcrop[1] of these geologic units is now covered by alluvial and terrace deposits of regional extent.

The subcrop units are mostly of Eocene age. Included are large areas underlain by clay of the Jackson Group, the Cook Mountain Formation, and the Zilpha Clay, and by parts of the widespread aquifer systems in the region—the Cockfield Formation, Sparta Sand, Tallahatta Formation, Memphis aquifer, and the lower Wilcox aquifer. In the extreme south, Oligocene and Miocene strata underlie the alluvium; in the north, Paleocene, Cretaceous, and Paleozoic rocks underlie small areas (pl. 1). Knowledge of the relation of subcrop units to the Quaternary aquifers is necessary for an understanding of the hydrologic systems in the embayment.

The Red River Valley in the Mississippi embayment is eroded into strata ranging in age from Late Cretaceous to middle Eocene. The valley was filled with al-

[1] Subcrop is here defined as an eroded surface covered by fairly flat-lying and widespread alluvial or terrace deposits of regional extent; for example, the eroded surfaces of the Eocene units beneath the Mississippi River Quaternary deposits.

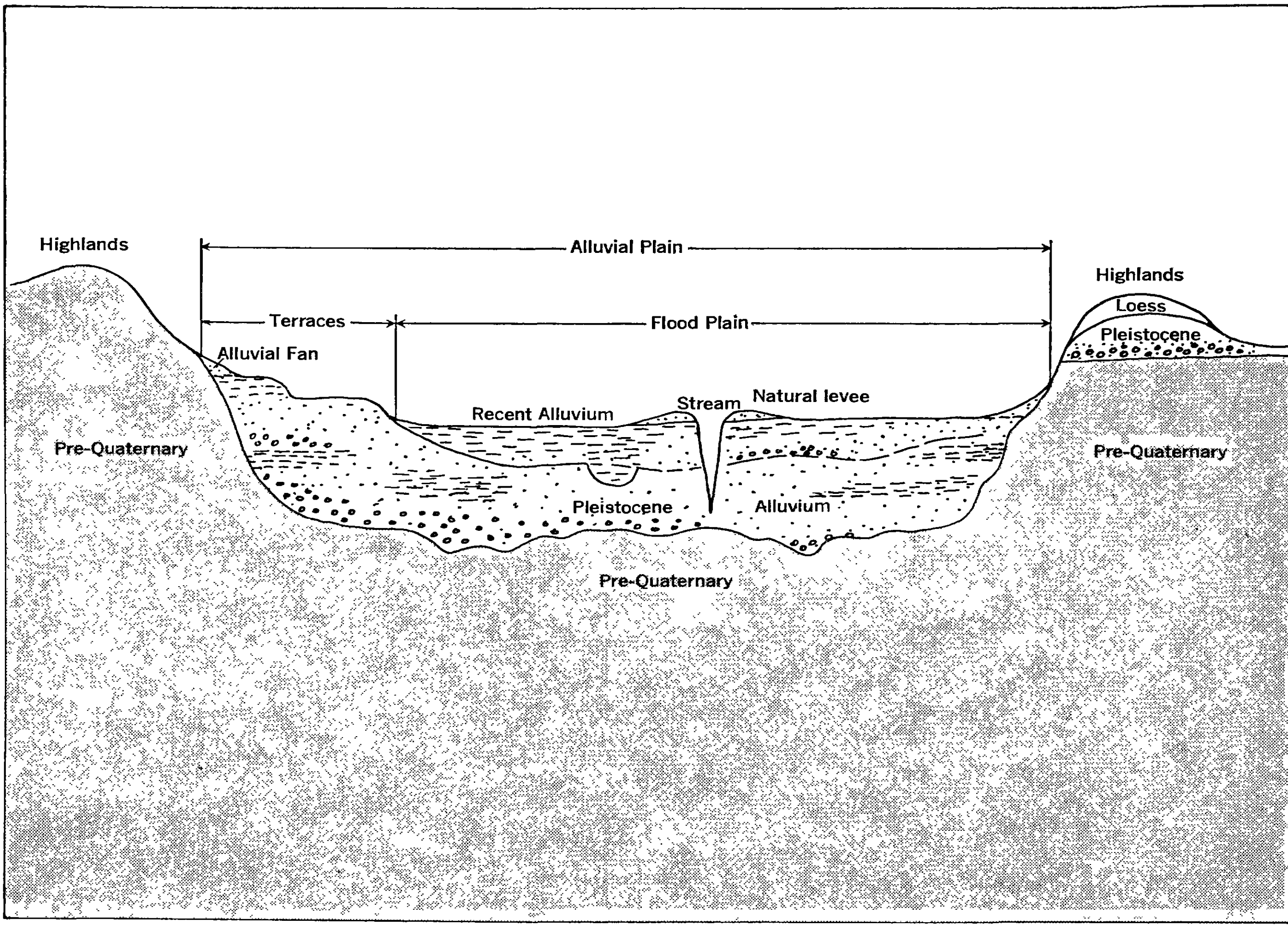

FIGURE 3.—Relations of pre-Quaternary, Pleistocene, and Recent deposits.

luvial material during the Pleistocene. This alluvium, eroded and terraced, is present along the valley walls and beneath the Recent alluvium in the flood plain.

LITHOLOGY AND THICKNESS

The Quaternary alluvium in the embayment consists of two units: a lower, sand and gravel unit, grading into an upper, silt and clay unit. The surface of the alluvium is predominantly clay or silt. The basal part of the lower unit is usually composed of coarse sand and gravel. The gravel is mostly chert, but the many kinds of rocks present indicate the diverse sources of the alluvial sediments. The relative thickness of the two units is extremely variable.

The Quaternary terrace deposits (fig. 3) are similar in lithology to the younger alluvial deposits. In areas of Louisiana, where detailed work has been done, the terrace deposits are considered to be a separate aquifer system.

The Quaternary deposits in the Mississippi River alluvial plain average slightly more than 100 feet thick (pl. 1); the maximum thickness is probably about 250 feet. The Quarternary deposits of the Red River average less than 100 feet thick. In most of the region the thickness is related to the configuration of the prealluvium surface upon which the deposits lie.

HYDROLOGY

HYDROLOGIC SYSTEMS

The Mississippi River valley alluvial aquifer extends about 380 miles from north to south, includes an area of about 40,000 square miles, and covers most of the west side of the embayment.

Although the alluvial plain overlying the aquifer is nearly flat, it is not featureless. Abandoned meanders, oxbow lakes, and natural levees are common, and alluvial fans occur at the bluffs along the east side of the plain. Regionally, the land surface slopes southward; however, the slope is also perpendicular to natural levees along the Mississippi River and some smaller streams. Extensive marshes have formed where drainage is obstructed.

Because the Mississippi River is incised deeply into this aquifer and, in many places, into the underlying

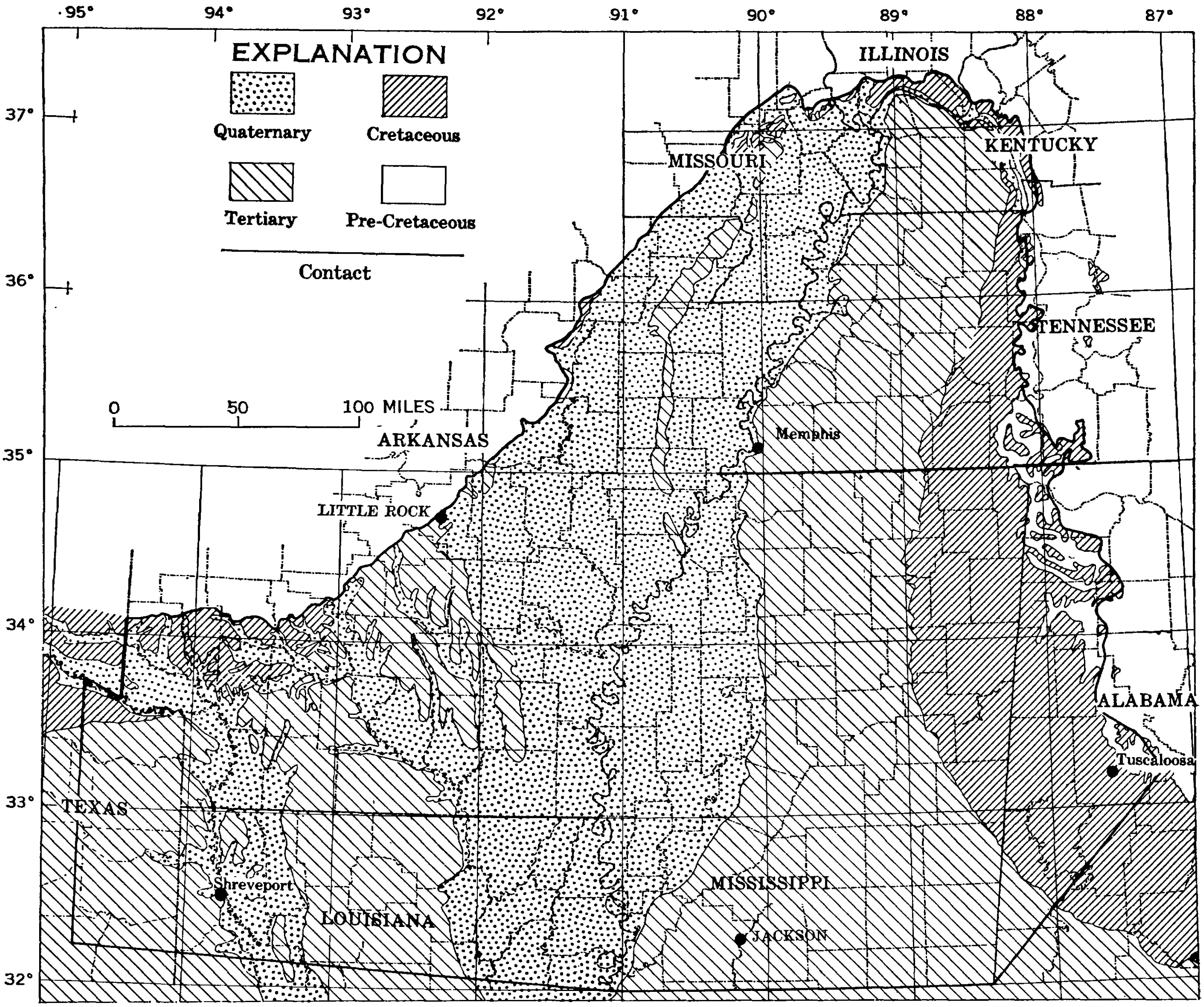

FIGURE 4.—Generalized geologic map.

pre-Quaternary strata, it is a boundary in the Mississippi River valley alluvial aquifer. Crowleys Ridge also is a barrier to the movement of ground water in this aquifer. This abrupt ridge averages less than 10 miles in width and extends 200 miles from the apex of the embayment in Illinois to Helena, Ark. It is an erosional remnant of Cretaceous and Tertiary strata that are much less permeable than the alluvial sand and gravel. The Mississippi River and Crowleys Ridge, thus, separate the Mississippi River valley alluvial aquifer into three aquifers, none of which is appreciably affected by ground-water conditions in the others.

Streams tributary to the Mississippi River flow through alluvial valleys which coalesce with the alluvial plain. The larger streams entering from the west flow through deeply entrenched and alluviated valleys. These saturated valley deposits are hydraulically connected with, and are important parts of, the Mississippi River valley alluvial aquifer.

Drainage from most of the area underlain by the Mississippi River valley alluvial aquifer east of the Mississippi River is to the Yazoo River system, whereas most of that west of the Mississippi River is to the St. Francis, White, Arkansas, and Ouachita Rivers. Drainage from a small part (mostly within the levee system) is directly to the Mississippi River. All these large tributary river systems have part or most of their basins in the highlands around the periphery of the alluvial plain; the basins of the major streams and larger tributaries are well defined, but those of smaller tributaries entirely within the alluvial plain are complex and often indefinite. Most of the streams are regulated.

The Red River Valley alluvial aquifer in the Mississippi embayment includes an area of about 5,000 square miles that extends from the west boundary of the project area through the northern part of Bowie County, Tex., the southwestern part of Arkansas, and the northwestern part of Louisiana to about the 32d parallel. The flood plain of the Red River is generally 8–10 miles wide and is flanked by terraced and dissected Pleistocene alluvial deposits. The maximum thickness is slightly more than 100 feet. These terrace deposits and alluvium form a major aquifer in the southwestern part of the embayment.

Many other larger streams not tributary to the Mississippi River, such as the Pearl and Tombigbee Rivers, have associated alluvial and terrace deposits. These deposits are generally less than 50 feet thick and generally are not capable of yielding large quantities of water to wells.

RECHARGE, WITHDRAWAL, AND MOVEMENT OF GROUND WATER

The chief source of recharge to the Quarternary aquifers is precipitation. The annual precipitation is about 50 inches (fig. 5), half of which occurs during the growing season, and the average annual runoff is less than 20 inches, so that about 30 inches is available for evaporation, transpiration by vegetation, and replenishment of the ground-water reservoir. Conditions for infiltration into the ground-water reservoir are excellent where the surface is permeable, and in these areas ground-water levels rise rapidly after heavy rains. Where an almost impermeable silt and clay layer, which ranges in

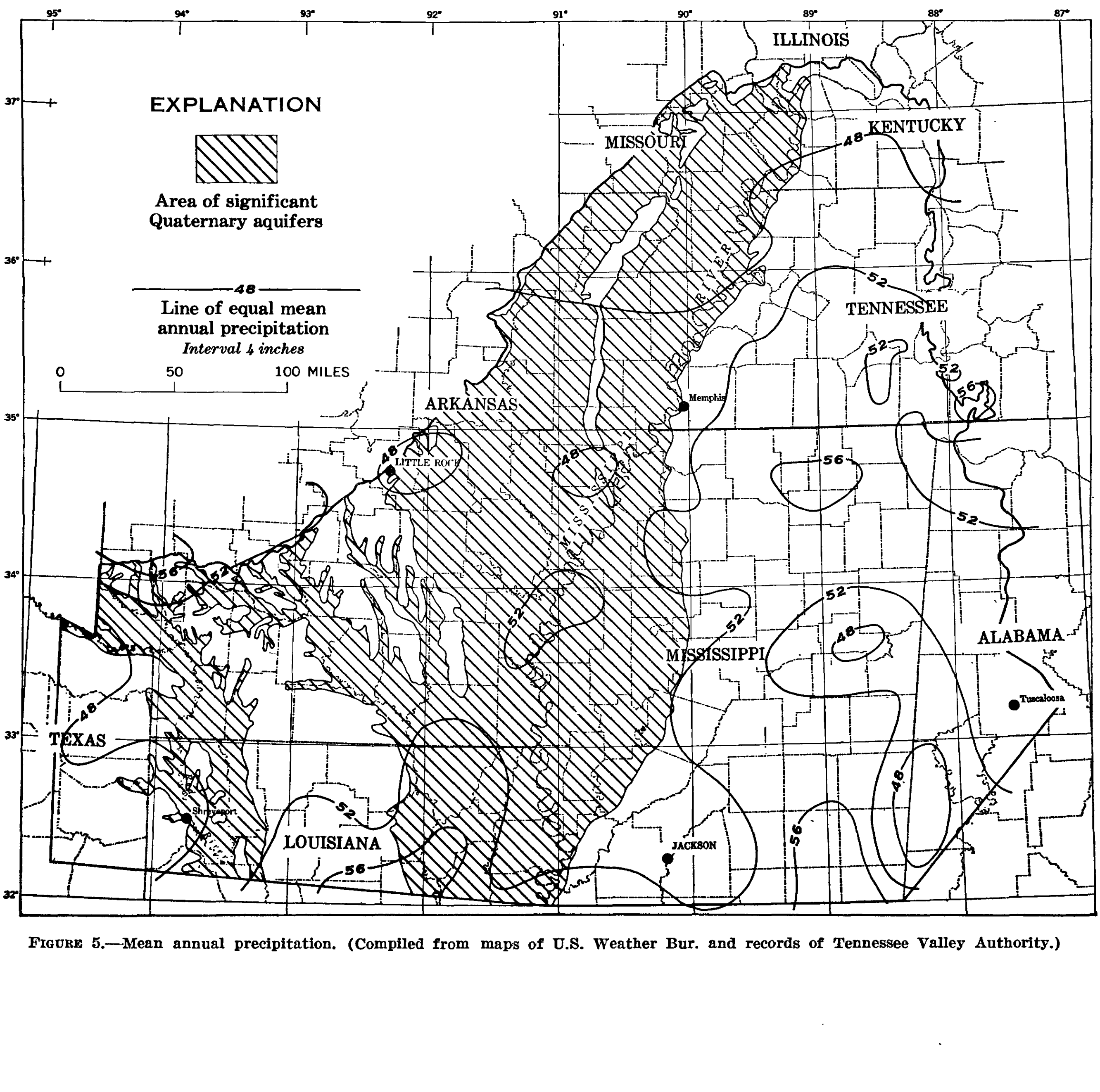

FIGURE 5.—Mean annual precipitation. (Compiled from maps of U.S. Weather Bur. and records of Tennessee Valley Authority.)

thickness from a few feet to more than 50 feet, forms the surface, most of the recharge is from underflow from adjacent areas having more favorable recharge conditions.

Recharge to the Quarternary deposits may also occur from streams and lakes during floods, from upward movement from older aquifers, from surface runoff onto the alluvial plain from adjacent highlands, and from downward seepage from irrigated lands.

During most of the year, the water level in wells along the river is higher than that in the river; and the movement of ground water, mainly from infiltration of precipitation, is toward the river. In the spring, however, the river rises, and the hydraulic gradient flattens. For several weeks the gradient may locally be landward (reversed), so that the water level in wells along the river rises; but the contribution to ground water from the river during high stages probably is small.

The alluvial aquifers are sources of ground water for many uses. Because water occurs at shallow depths, usually within 20 feet of the land surface, and is readily available to shallow driven wells, the alluvium is a source of ground water for domestic and stock use where its chemical quality can be tolerated.

Where an ample supply of water of better quality is not available from deeper aquifers, some public water supplies are developed in the alluvial aquifers. The water is satisfactory for most uses after treatment for hardness, removal of iron, and free carbon dioxide. Generally, the alluvial water is more readily treated than water from streams because the chemical and physical characteristics of ground water are more constant.

Industrial use of untreated alluvial water is predominantly for cooling. The low constant temperature, general availability, and regular replenishment of the water in the alluvial aquifers are conducive to more industrial development.

Presently, the largest use of ground water from the alluvial aquifers is for irrigation. Most of the water is pumped for the irrigation of rice, but supplemental irrigation of other crops is becoming routine rather than unusual. Pumping for rice irrigation has caused a large cone of depression, centered in Arkansas County, Ark. (pl. 1), in the piezometric surface. In Bolivar and Washington Counties, Miss., the effect of present pumping is only a seasonal depression in the piezometric surface. Elsewhere the effects of pumping are insignificant.

The present withdrawals of ground water from the alluvial aquifers are negligible in comparison with the potential yield. The total withdrawal from the Mississippi River valley alluvial aquifer in 1965 was slightly more than 1,400 mgd (million gallons per day) (table 1), of which about 1,200 mgd (about 1,340,000 acre-ft) was pumped for irrigation during the growing season.

TABLE 1.—*Water use from Quaternary aquifers, 1965*

[Million gallons per day]

MISSISSIPPI RIVER VALLEY ALLUVIAL AQUIFER

Use	Arkansas	Louisiana	Mississippi	Missouri	Tennessee	Total
Industrial	112	12	53	0.5	1	178.5
Irrigation	918	38	160	76	.7	1,192.7
Public Supply	9	2.5	0	2	0	13.5
Other	14	4.5	8	4.5	.3	31.3
Total	1,053	57	221	83	2	1,416.0

RED RIVER VALLEY ALLUVIAL AQUIFER

Use	Arkansas	Louisiana	Texas	Total
Industrial	1.3	0	0.2	1.5
Irrigation	6.0	1.9	.1	8.0
Public Supply	.7	.5	0	1.2
Other	.6	1.2	.1	1.9
Total	8.6	3.6	.4	12.6

The total ground-water withdrawal from the Red River Valley alluvial aquifer was about 12 mgd, of which 8 mgd (about 8,700 acre-ft) was for irrigation.

Ground-water movement in the Mississippi River valley alluvial aquifer is generally southward, but locally it is toward streams and toward areas of large withdrawal. The movement is regionally controlled by the gentle southward slope of the Mississippi River alluvial plain (pl. 1). The ground-water surface slopes from an altitude of about 340 feet in the north to about 40 feet near the 32d parallel (about 0.8 ft per mile).

Ground-water movement in the Red River Valley alluvial aquifer generally is toward the streams. This movement may be temporarily stopped or reversed during periods of high river stage. Movement of water in the terrace deposits is controlled mostly by topography and is generally toward and into the alluvium, toward streams, or downward where underlying older strata are permeable.

When the Mississippi valley was entrenched during Pleistocene time, the Tertiary aquifers (the Memphis aquifer and aquifers in the Cockfield Formation, Sparta Sand, and Tallahatta Formation) were cut and drained along the valley walls. This drainage still occurs, but at a diminishing rate, both onto the alluvial surface and horizontally into the alluvium. Water levels in older aquifers probably were maintained somewhat higher than levels in the alluvium owing to vertical movement of water from deeper aquifers and lateral movement from untruncated areas; however, most of the water in the alluvium, because of the much greater permeability, was from surface sources.

At present time, pumping from pre-Quaternary aquifers has in some areas reversed the direction of ground-water movement, and the alluvial aquifers are a major source of recharge for these aquifers. Pumping from wells screened in sand and gravel at the base of the alluvium may, in some places, induce upward movement of water from deeper aquifers.

Water levels fluctuate seasonally in the alluvial aquifers. The highest levels occur in April, May, or June, usually as a result of the large amount of precipitation during the winter and early spring. During these months, water levels average a few feet below land surface, and generally, artesian conditions prevail; shallow driven wells may flow in some localities. Water levels begin to decline in the early summer and reach the seasonal low in late fall or early winter (pl. 1).

During the period of decline, water-table conditions become more widespread as the upper part of the aquifer becomes dewatered in places, but artesian conditions probably continue to predominate. Where large withdrawals are made, movement is toward the center of pumping, and much sharper and more marked declines occur (pl. 1). Where the water-level decline is caused by pumping for irrigation, the seasonal fluctuation is greatly amplified. Withdrawals of water for rice irrigation over a period of 20 years have resulted in a large cone of depression centered in Arkansas County, Ark. (pl. 1), an area where recharge from precipitation is negligible due to the impermeable surficial material. The cone of depression has now reached the White River, and movement of water from the stream into the region apparently has begun.

Water-level changes may be large where streams are incised into the alluvial deposits, particularly along the Mississippi River. The magnitude of the fluctuations diminish with distance; a few miles from the river the effect is negligible because of damping by storage of water in the ground water reservoir.

Regionally, the general continued water-level decline characteristic of pre-Quaternary artesian aquifers in the region is not a factor in the hydrology of the alluvial aquifers except where the alluvium is a source of recharge to underlying aquifers. During an average year, withdrawals and losses are compensated for by recharge during winter and spring. The present rate of pumping must be increased many times to change this natural cycle.

AQUIFER CHARACTERISTICS

The water-bearing zones of the Quaternary aquifers are overlain by sediments that have a wide range in permeability, and the water generally is partially confined; these conditions may change as withdrawals are made. The Mississippi River valley alluvial aquifer is capable of yielding moderate to large supplies of ground water almost everywhere in the alluvial plain. In many places yields of as much as 5,000 gpm (gallons per minute) are obtained from properly constructed wells, but yields of 2,000 gpm or less are more common.

The hydraulic characteristics of the alluvial aquifer depend mostly on the size and sorting of material in the lower sand and gravel unit. These characteristics vary considerably from place to place, and the results of aquifer and pumping tests reflect these variations (table 2).

If an average sand thickness of 70 feet for the Mississippi River valley alluvial aquifer and 30 feet for the

TABLE 2.—*Results of aquifer and pumping tests in the Quaternary aquifers*

[Results averaged by county or parish. Number in parenthesis denotes number of tests used to compute average. Results obtained from published reports and from files of U.S. Geol. Survey Water Resources Division districts]

State and county or parish	Coefficient of: Transmissibility (gpd per ft)	Coefficient of: Permeability (gpd per sq ft)	Coefficient of: Storage	Specific capacity (gpm per ft of drawdown)
Mississippi River valley alluvial aquifer				
ARKANSAS				
Arkansas	(8) 120,000	(8) 1,670	(2) 0.0016	(1) 33
Ashley	(1) 200,000		(1) .08	
Chicot	(1) 110,000		(1) .0003	
Crittenden	(1) 140,000	(1) 1,250	(1) .0005	
Desha	(4) 130,000	(4) 1,520	(4) .002	
Drew	(1) 65,000	(1) 930		
Jackson	(2) 70,000	(2) 425	(1) .07	
Jefferson	(4) 290,000	(1) 2,300	(2) .004	
Lincoln	(3) 190,000	(3) 2,100	(3) .002	
Lonoke	(5) 120,000	(5) 1,600	(2) .021	
Mississippi	(4) 190,000	(4) 1,950	(4) .0007	(3) 70
Prairie	(2) 120,000	(2) 1,700		
Pulaski	(1) 260,000			
St. Francis	(2) 300,000	(1) 2,500	(2) .02	
White	(3) 39,000	(3) 730	(1) .14	
LOUISIANA				
East Carroll	(3) 110,000	(3) 1,670	(3) .0007	(23) 53
Franklin				(7) 35
Madison	(1) 240,000	(3) 1,720	(1) .002	(5) 71
Morehouse				(4) 45
West Carroll	(1) 94,000	(1) 1,300	(1) .0016	(4) 52
MISSISSIPPI				
Bolivar				(8) 90
Coahoma				(3) 94
Humphreys				(4) 58
Issaquena				(1) 100
Leflore				(1) 47
Sharkey				(2) 130
Sunflower				(1) 77
Tallahatchie				(1) 82
Tunica				(1) 72
Warren	(3) 150,000	(3) 2,050	(2) .0006	(3) 29
Washington				(5) 95
MISSOURI				
Dunklin	(1) 600,000	(1) 3,400	(1) .02	(3) 56
Mississippi				(10) 63
New Madrid				(6) 79
Scott				(7) 61
Stoddard				(7) 82
TENNESSEE				
Dyer	(2) 170,000	(2) 2,000	(2) .0011	
Red River Valley alluvial aquifer				
ARKANSAS				
Little River	(2) 16,000	(1) 170	(2) 0.0016	
LOUISIANA				
Bossier	(3) 56,000	(3) 1,270	(3) .0005	(3) 14
Caddo	(2) 70,000	(2) 1,450	(2) .0004	
Red River	(3) 76,000	(3) 1,630	(3) .0003	(3) 12
Webster	(1) 6,500	(1) 290	(1) .0004	

Red River Valley alluvial aquifer, and an average specific yield of 0.2 are used (that is, 0.2 ft of water can be obtained from each vertical foot of sand, or 0.2 cu ft of water from each cubic foot of sand), the amount of water available in the Quaternary aquifers is slightly more than 120 trillion gallons.

QUALITY OF THE WATER

By H. G. JEFFERY

The suitability of water for most uses is governed largely by the chemical and physical properties of the water (table 3). Water containing less than 500 ppm (parts per million) of dissolved solids generally is satisfactory for most domestic and industrial uses; excessive iron or hardness, however, may cause difficulty in some uses. Water containing more than 1,000 ppm of dissolved solids is likely to include large quantities of some constituents that will make it unsuitable for domestic or industrial uses. Water used for irrigation generally should have a moderate to low dissolved-solids content, and the percent sodium should not exceed 50–60, depending upon the amount of dissolved solids.

TABLE 3.—*Source and significance of dissolved mineral constituents and physical properties of natural waters*

Constituent or physical property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 ppm. Higher concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam from high-pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softners.
Iron (Fe)	Dissolved from practically all rocks and soils. Waters having a low pH tend to be corrosive and may dissolve iron in objectionable quantities from pipe, pumps, and other equipment. More than 1 or 2 ppm of soluble iron in surface waters generally indicates acid wastes from mine drainage or other sources.	More than about 0.3 ppm stains laundry and utensils reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacturing, brewing, and other processes. Large quantities cause unpleasant taste and favor the growth of iron bacteria. On exposure to air, iron in ground water usually is oxidized and forms a reddish-brown precipitate. "Public Health Service Drinking Water Standards" (1962) [1] recommend that iron in water supplies not exceed 0.3 ppm.
Manganese (Mn)	Dissolved from some rocks and soils. Not as common as iron. Large quantities often associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark-brown or black stain. Maximum concentration recommended by the drinking-water standards is 0.05 ppm.
Calcium (Ca) and magnesium (Mg).	Dissolved from practically all rocks and soils, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming. (See "Hardness.") Waters low in calcium and magnesium are desired in electroplating, tanning, dyeing, and textile manufacturing.
Sodium (Na) and potassium (K).	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, some industrial brines, and sewage	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers, and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3).	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon-dioxide gas. In combination with calcium and magnesium they cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Large amounts have a laxative effect on some people and, in combination with other ions, give a bitter taste. Sulfate in water containing calcium forms a hard scale in steam boilers. The drinking-water standards recommend that sulfate in water supplies not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial wastes.	Large quantities increase the corrosiveness of water and, in combination with sodium, give a salty taste. The drinking-water standards recommend that chloride in water supplies not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, the amount of drinking water consumed, and the susceptibility of the individual. The maximum concentration of fluoride recommended by the drinking-water standards varies with the annual average of maximum daily air temperatures and ranges downward from 1.7 ppm for an average maximum daily temperature of 50.0°F to 0.8 ppm for an average maximum daily temperature of 90.5°F. Optimum concentrations for these ranges are from 1.2 to 0.7 ppm.
Nitrate (NO_3)	Decaying organic matter, legume plants, sewage, nitrate fertilizers, and nitrates in soil.	Nitrate encourages growth of algae and other organisms that cause undesirable tastes and odors. Concentrations much greater than the local average may indicate pollution. The drinking-water standards recommend that the nitrate content not exceed 45 ppm, as there is evidence that higher concentrations may cause methemoglobinemia (an often fatal disease in infants).
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils Includes any organic matter and some water of crystallization.	The drinking-water standards recommend that the dissolved solids not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form, and deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. In general, waters of hardness as much as 60 ppm are considered soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; >180 ppm, very hard.
Specific conductance (micromhos at 25°C).	Mineral content of the water	Indicates degree of mineralization and is a measure of the capacity of the water to conduct an electric current. This property varies with concentration and degree of ionization of the constituents, and with temperature (therefore reported at 25°C).
Hydrogen-ion concentration (pH).	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Color	Usually caused by organic matter	Refers to the appearance of water that is free of suspended matter. Color of 10 units or less usually goes unnoticed. The drinking-water standards recommend that color not exceed 15 units. Color in water is objectionable in food and beverage processing and in many manufacturing processes.
Temperature		Affects usefulness of water for many purposes. Most users desire water of uniformly low temperature. In general, temperatures of shallow ground waters show some seasonal fluctuation, whereas temperatures of ground waters from moderate depths remain near the mean annual air temperature of the area. In deep wells the water temperature generally increases 1°F for each 60–80 feet of depth.

[1] "Public Health Service Drinking Water Standards", revised 1962, apply to drinking water and water-supply systems used by carriers and others subject to Federal quarantine regulations.

Water temperature is a major factor in determining the suitability of water for industrial use. The temperature of ground water from deposits of Quaternary age may be expected to range from 59°F in the north to about 68°F in the south; it generally is about 1° to 2°F above the mean annual air temperature for the area (fig. 6).

Water in streams in the alluvial plain is usually a mixture of water from headwater tributaries in the uplands and ground water discharged from the alluvium. Water in upland streams is generally soft and has a low dissolved-solids content (pl. 2, Tallahatchie and Yalobusha Counties, Miss.). As streams enter the alluvial plain, the dissolved-solids content increases as the alluvial ground-water increment increases. The quality of water from streams deriving their base flow entirely from alluvial aquifers is similar to that of water from wells screened in the aquifers.

MISSISSIPPI RIVER VALLEY ALLUVIAL AQUIFER

Ground water from deposits of Quaternary age generally is a moderately mineralized hard to very hard calcium bicarbonate or calcium magnesium bicarbonate type containing excessive iron (pl. 2). Locally, the water may contain appreciable quantities of sodium, sulfate, chloride, and nitrate in addition to the calcium, magnesium, and bicarbonate. The dissolved-solids content of the water generally is less than 500 ppm; locally, however, the dissolved-solids content may be as much as 4,000 ppm. Water containing the larger amounts of dissolved solids generally is a sodium chloride or a sodium sulfate type. The dissolved-solids content of the water can be grouped into rather broad ranges (pl. 2), but considerable variation occurs within each range. The areas where water of lower dissolved-solids content occurs are believed to correspond generally with areas

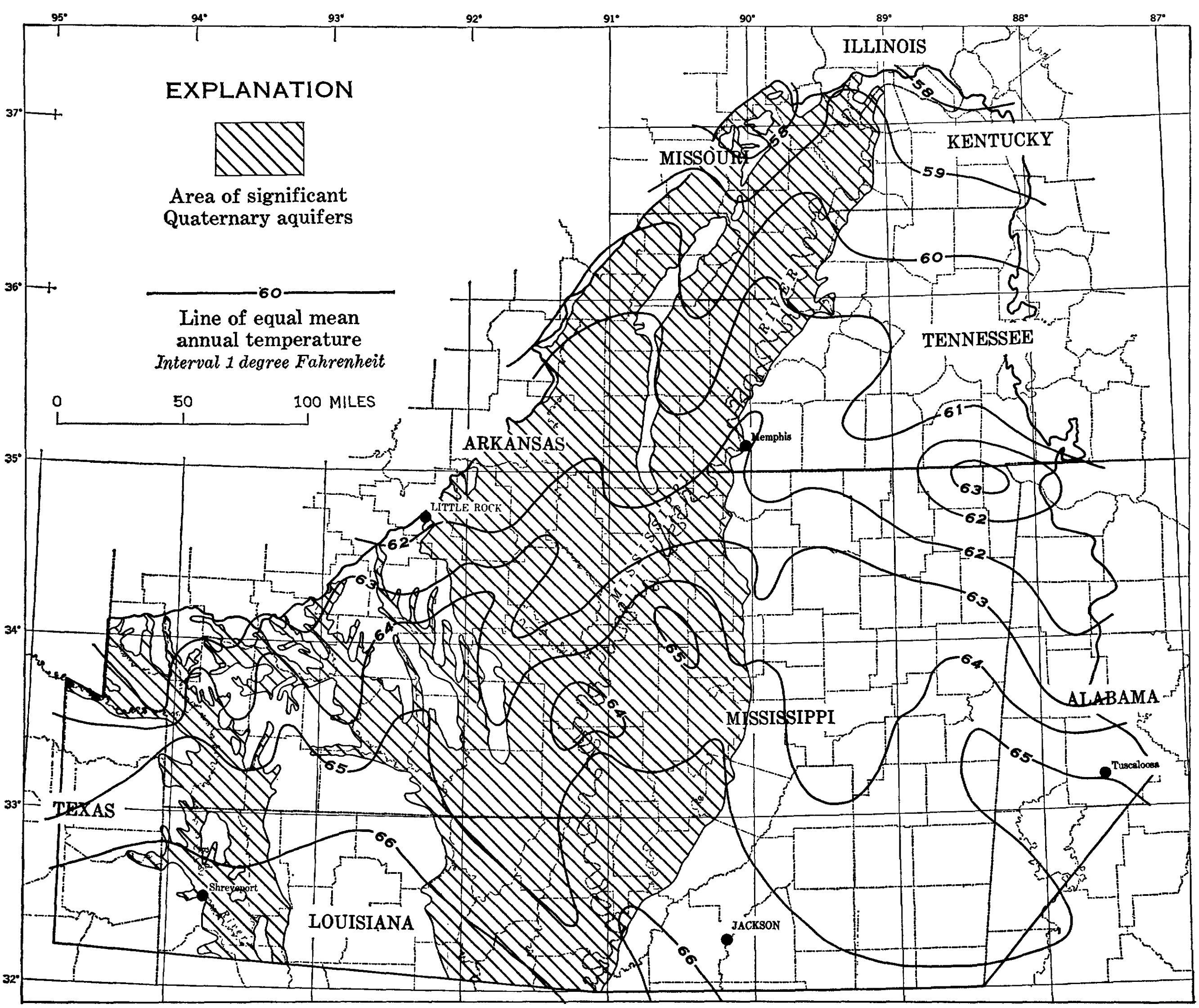

FIGURE 6.—Mean annual air temperature. (Data from records of U.S. Weather Bur.)

which receive greater amounts of seasonal recharge. Calcium, magnesium, and bicarbonate generally are the principal constituents in the water in these areas, but in adjacent areas sodium, sulfate, and chloride may be a significant part of the dissolved solids in the water. In some places chloride is the dominant anion.

The dissolved-solids content of water from the alluvial aquifer is higher along the Mississippi River, and the predominant constituents are calcium, magnesium, and bicarbonate. In some areas south of the Arkansas River, sodium, sulfate, and chloride are an appreciable part of the dissolved solids in the water from the aquifer.

The highest dissolved-solids content in water from the alluvial aquifer occurs in White, Prairie, and Monroe Counties, Ark., in southeastern Arkansas, and in northeastern Louisiana; this high dissolved-solids content results from the upward movement of more saline water from the underlying aquifers. In White, Prairie, and Monroe Counties, the more mineralized water is a sodium chloride type, but in southeastern Arkansas and northeastern Louisiana the more mineralized water is a sodium chloride sulfate type.

The relation of the different ions in the water to the total ionized concentration (figs. 7 and 8) indicates that increases in total concentration up to about 18 epm (equivalents per million)—approximately 500 ppm of dissolved solids—are principally in calcium, magnesium, and bicarbonate. Variations in the relative proportions of the different constituents are caused by differences in the composition of the aquifer material and in the length of time the water is in contact with the aquifer material. The apparent tendency toward a more mixed character of water at concentrations above about 18 epm is due to water from the areas of anomalous water quality. The chemical quality diagrams (pl. 2) indicate that in most of the area calcium, magnesium, and bicarbonate are the principal constituents in the water.

The maximum and minimum values for constituents in water from the Mississippi River valley alluvial aquifer (table 4) show a wide range in the concentration of most constituents. The maximum value for most constituents is for water from the anomalous areas and is not indicative of concentrations in most of the area. For example 95 percent of the calcium values were less than 120 ppm; 96 percent of the magnesium values were less than 40 ppm; 85 percent of the sodium values were less than 50 ppm; 86 percent of the bicarbonate values were less than 450 ppm; 86 percent of the sulfate values were less than 50 ppm; 80 percent of the chloride values were less than 50 ppm; and 87 percent of the samples contained less than 500 ppm of dissolved solids. The median values (table 4) are typical of the chemical characteristics in most of the area. The iron content of the water usually is more than 1 ppm and varies considerably from place to place. According to Plebuch (1961) and Ryling (1960), the iron content of the water also varies with time. Plebuch reported a range in iron from 2.1 to 14 ppm in water from a well in Crittenden County, Ark. The high amounts of nitrate indicate local contamination, probably from surface sources.

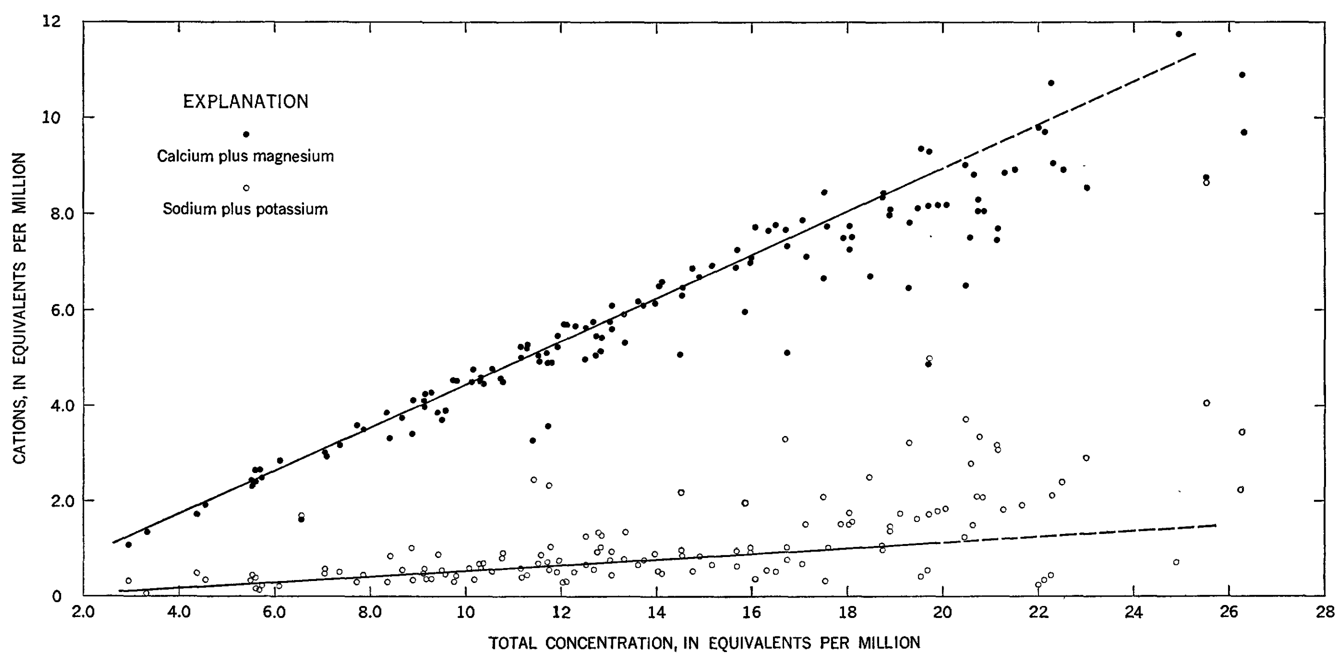

FIGURE 7.—Relation of cations to total concentration in water from Quaternary aquifers.

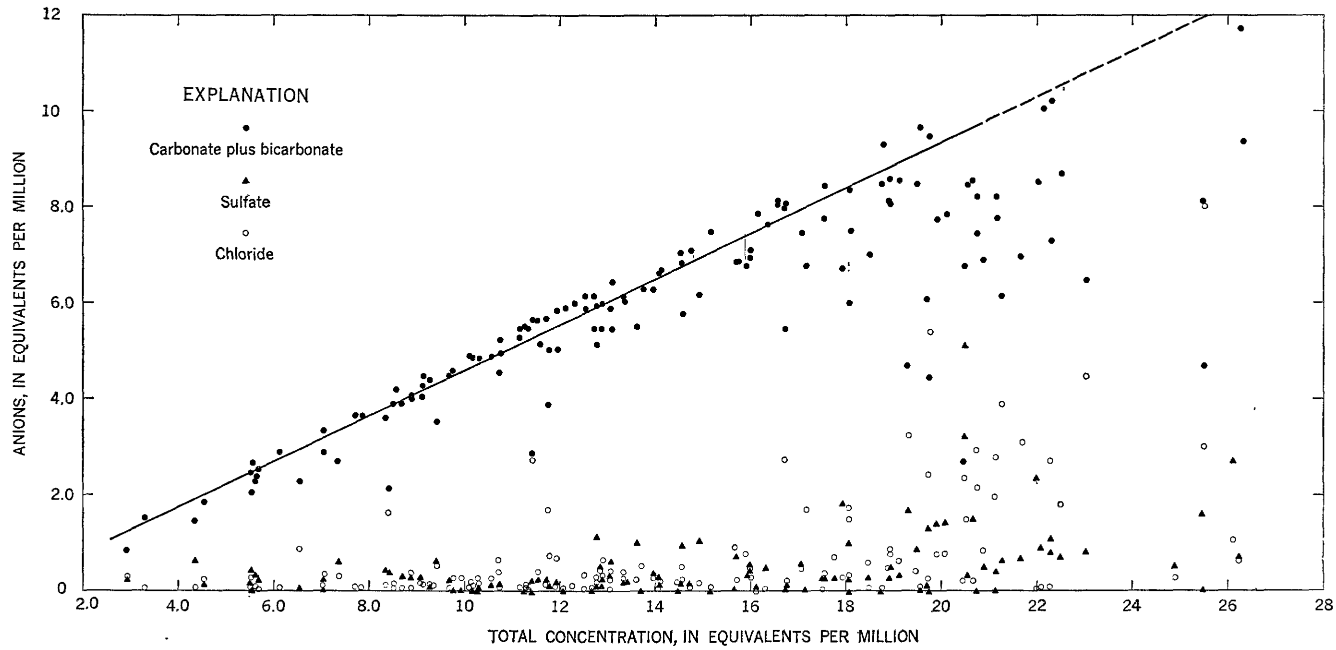

FIGURE 8.—Relation of anions to total concentration in water from Quaternary aquifers.

TABLE 4.—*Maximum, minimum, and median concentrations of constituents dissolved in water from the Mississippi River valley alluvial aquifer*

[Constituents in parts per million]

Constituent or property	Maximum	Minimum	Median
Silica (SiO_2)	70	1. 6	26
Iron (Fe)	62	. 00	5. 2
Calcium (Ca)	432	. 1	66
Magnesium (Mg)	174	. 3	18
Sodium (Na)	943	2. 2	21
Potassium (K)	35	. 0	2. 0
Carbonate plus bicarbonate (CO_3+HCO_3)	716	0	291
Sulfate (SO_4)	1, 000	. 0	11
Chloride (Cl)	1, 870	. 3	19
Fluoride (F)	. 8	. 0	. 2
Nitrate (NO_3)	132	. 0	. 7
Dissovled solids	4, 190	18	331
Hardness as $CaCO_3$	1, 790	0	246
Specific conductance (micromhos at 25°C)	6, 430	32	552
pH	8. 9	4. 3	7. 5
Color	40	0	5

RED RIVER VALLEY ALLUVIAL AQUIFER

Water from the Red River Valley aquifer is extremely variable in chemical characteristics and dissolved-solids content (table 5 and pl. 2). The water generally is a calcium bicarbonate type, but at higher concentrations of dissolved solids the water may also contain appreciable quantities of sodium and sulfate or chloride. The occurrence of a high dissolved-solids content is variable, but the larger amounts generally are in the water adjacent to the Red River. Newcome (1960) stated that in some places the aquifer is contaminated by upward leakage of salty water from underlying formations, and that the quality of the water is best in areas where recharge to the alluvium is from fresh-water lakes.

POTENTIAL USE OF GROUND WATER

Supplemental irrigation of crops and of grazing lands and supplies for industrial cooling and for minnow and fish farming are increasing. Generally, wells yielding from 500 to 2,000 gpm are constructed for these purposes. The Mississippi River valley alluvial aquifer is capable of supplying 500 gpm of water almost everywhere. In a few localities the pumping of water to

TABLE 5.—*Maximum, minimum, and median concentrations of constituents dissolved in water from the Red River Valley alluvial aquifer*

[Constituents in parts per million]

Constituent or property	Maximum	Minimum	Median
Silica (SiO_2)	56	15	21
Iron (Fe)	28	. 01	1. 3
Calcium (Ca)	248	3. 3	62
Magnesium (Mg)	147	. 6	40
Sodium (Na)	242	5. 6	39
Potassium (K)	7. 7	. 6	1. 8
Carbonate plus bicarbonate (CO_3+HCO_3)	911	4	279
Sulfate (SO_4)	544	. 0	10
Chloride (Cl)	610	4. 5	52
Fluoride (F)	1. 0	. 0	. 2
Nitrate (NO_3)	560	. 0	2. 2
Dissolved solids	1, 850	51	490
Hardness as $CaCO_3$	1, 180	10	266
Specific conductance (micromhos at 25°C)	2, 680	54	905
pH	8. 2	5. 1	7. 4
Color	20	4	10

supply generating plants and industrial cooling needs has created local problems, most of them attributable to improper well spacing.

Municipal water supplies are generally obtained from the Tertiary, Cretaceous, and Paleozoic aquifers underlying the alluvial aquifers. In some places the older aquifers, however, do not yield the required quantity of water or do not contain fresh water. In such places, alluvial water after treatment is generally satisfactory. Vicksburg, Miss., is presently developing (1966) a well field in the alluvial aquifer to replace its present source, the Mississippi River. One reason for the change from a surface-water supply to a ground-water supply is that the chemical quality of ground water is more constant than that of surface water, and, consequently, the treatment of the water is less expensive.

Although large quantities of water are pumped from the alluvial aquifers, the aquifers are capable of supplying additional large quantities. The quantity of water available each spring in the alluvial aquifers is estimated to be sufficient to cover the entire alluvial plain to a depth of about 13 feet. Most of the alluvial plain will be extensively cultivated; water is available for supplemental irrigation throughout most of the area. The Mississippi River valley alluvial aquifer in the future probably will be the source of water supply for industrial complexes along the Mississippi River. Many of these installations, because of their location, will probably pump water indirectly from the river because the pumping will induce recharge to the aquifer from that source.

Water problems in the alluvial aquifer are and will be related to concentrated withdrawals in places where vertical recharge is restricted, horiontal inflow is insufficient, and the aquifer is thin, or to a combination of these factors. In most of the area the available ground-water supply is extremely large and is replenished each year by precipitation.

CONCLUSIONS

The Mississippi River valley alluvial aquifer is one of the largest sources of readily available ground water in the embayment. The water from the alluvial aquifers is clear, has a low constant temperature, and is used for some purposes without treatment.

The most important potential uses for the alluvial water are for irrigation and heat exchange. With treatment, the water is suitable for public water supplies and industrial uses.

Most wells developed in the alluvial aquifers are less than 200 feet deep, and water levels are commonly within 20 feet of the land surface. In many places yields of as much as 5,000 gpm are obtained from properly constructed wells, but yields of 2,000 gpm or less are more common.

Most of the water withdrawn from the alluvial aquifers is for irrigation. Generally, water is withdrawn for municipal use only in those areas where water of better quality cannot be obtained from pre-Quaternary aquifers.

Water levels in the alluvial aquifers fluctuate seasonally in response to rainfall, to natural discharge, and to withdrawals of water from the aquifers. In areas where the surface materials are permeable, rainfall is usually sufficient to replace the water withdrawn, and, as a result, the water levels recover each year to about the same altitude. In the areas where the surface materials are not permeable, the rainfall cannot percolate downward rapidly, and the water-level recovery is slower and less complete.

The alluvial aquifers are a source of recharge to the underlying pre-Quaternary aquifers. Ground water discharged from the alluvium is the source of base flow in streams originating in the alluvial plain, and the water in the streams is chemically similar to the water in the aquifers.

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