Water Resources of the Mississippi Embayment

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WALTER J. HICKEL, *Secretary*

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Availability of Water in the Mississippi Embayment

By E. M. CUSHING, E. H. BOSWELL, P. R. SPEER, R. L. HOSMAN,
and others

WATER RESOURCES OF THE MISSISSIPPI EMBAYMENT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 448-A

Summary of the availability of water in the Mississippi embayment

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UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

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PREFACE

The economy of the Mississippi embayment is basically agricultural, but industry has become increasingly important since World War II. The diversification and mechanization of agriculture have resulted in a surplus of manpower, most of which is being absorbed by the expansion of industry. The available manpower, natural resources, and economical transportation are conducive to further industrial expansion. Increasing demands on the available water supplies will be made, and the future economic growth of the embayment is largely dependent upon the wise utilization and management of the region's water resources.

For many years the need for an appraisal of the water resources of the Mississippi embayment was recognized by people associated with the development of the region. These resources are more than ample to meet the needs for many years in the future, but recent rapid economic development has so increased the consumptive use of water that serious localized shortages have occurred during prolonged periods of drought. The anticipated water problems for the future will be those of distribution and management and of providing storage to meet the demands.

Most of the water-resources investigations in the embayment have been made in cooperation with State, county, and municipal agencies and have been restricted to local areas where the need for information was most urgent. Because these investigations have been local, the results have lacked the benefits that would have accrued from an understanding of the regional hydrologic systems that extend over several States. Proper development, use, management, and conservation of the water resources can be achieved only after the hydrologic systems have been defined, and the manner in which these systems operate has been determined.

The present water-resources study, begun in August 1957, is a part of the Federal program of the U.S. Geological Survey and is aimed specifically toward defining the hydrologic systems of the embayment—the regional aquifers (water-bearing units) and the low flow of streams. In the past, many parts of the Mississippi embayment have been subject to devastating floods, and much attention has been given to flood control and drainage. Studies of flood characteristics would extend far beyond the embayment boundaries and would involve many factors and interests, and such studies are outside the scope and purpose of this phase of the embayment project. Data on floods, therefore, are not included in this study.

Also, low-flow characteristics for the main stems of the Mississippi, Arkansas, Ohio, Red, Tennessee, and White Rivers are not included in the study. The regimen of flow for most of these main stems within the embayment are subject to continuing alteration by man-made changes and developments upstream; for others, such as the Ohio and Mississippi Rivers, the low flows are not critical to their utilization within the embayment. The omission of the low-flow characteristics of the main stems of these streams does not minimize the importance of their contribution to the water resources of the region.

Much of the information that normally appears in the introductory chapter of a report is in chapter B of this professional paper. It includes brief discussions of the general geology, stratigraphy, structure, and physiography of the region, and the authors' first interpretation of the stratigraphy and of the correlation of some of the geologic units in the subsurface. As the analysis of the data progressed, some subsurface correlations were changed as geologic units were found to be more areally extensive and could be correlated over larger areas. The latest interpretations relating to a particular topic or geologic unit is in the most recently published chapter. The chapters were published in the following order: Chapters B, I, C, H, F, G, D, E, and A.

The study and the preparation of the reports were under the direction of E. M. Cushing, project chief. The low-flow studies were under the supervision of Paul R. Speer, staff engineer, who coordinated and reviewed the results and assembled the reports on the low-flow characteristics of the streams (chapters F, G, H, and I). The data on quality of water were analyzed, and the sections in the reports on quality of the water were prepared by H. G. Jeffery and W. J. Welborne, chemists. The collection of data and the analysis of the available information and records were done by district personnel assigned to the project. Because many individuals worked on the project for varying periods of time, these men are not acknowledged here, but they are acknowledged in the chapters to which they contributed.

Numerous persons contributed to the success of this project, and their assistance is appreciated. The excellent cooperation of many State, Federal, and local government agencies, and the enthusiastic support and assistance of the district offices of the U.S. Geological Survey are gratefully appreciated.

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AVAILABILITY OF WATER IN THE MISSISSIPPI EMBAYMENT

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

ABSTRACT

The Mississippi embayment is part of a vast geologic and hydrologic province. Most of the region is underlain by aquifers that will yield large quantities of water to wells, so that ground water is the most readily available source of fresh water.

Ground water having a dissolved-solids content of less than 500 ppm (parts per million) is generally available at depths of less than 1,000 feet, and water having a dissolved-solids content of less than 1,000 ppm is available in some places to depths of more than 2,000 feet. Iron is the most common troublesome chemical constituent in the ground water.

The potential yield of the aquifers that underlie the region is estimated to be about 30,000 mgd (million gallons per day), of which about 3,000 mgd is presently being withdrawn.

Water in varying amounts is also available from streams within the region. The amount of water which originates within the region and which leaves it as streamflow during a year averages about 90 million acre-feet (about 80,000 mgd). An additional 400 million acre-feet (about 360,000 mgd) leaves the region as streamflow during an average year, this amount having originated outside the region. The present withdrawals (1965) from streams within the region are about 1,700 mgd.

INTRODUCTION

The purpose of this report is to summarize the information given in the other chapters of this professional paper regarding the water resources of the Mississippi embayment.

The Mississippi embayment, as defined for this investigation, comprises about 100,000 square miles in the Gulf Coastal Plain. From its apex in southern Illinois the embayment fans out southward to about the 32d parallel and includes parts of Alabama, Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, Tennessee, and Texas (fig. 1). The larger cities within the region are Tuscaloosa, Ala., Jackson, Miss., Memphis, Tenn., Little Rock, Ark., and Shreveport, La.

The Mississippi embayment is a geosyncline plunging gently to the south, the axis of which roughly follows the present course of the Mississippi River. During the geologic past the region was periodically occupied by an arm of the sea, and sediments ranging in age from Jurassic to Quaternary have been deposited on the Paleozoic rocks. Units ranging in age from Cretaceous to Quaternary crop out within the area of study (fig. 2). These units of gravel, sand, silt, clay, lignite, marl, chalk, and limestone range in thickness from zero at the outcrop of Paleozoic rocks to several thousand feet at the axis of the geosyncline. In most of the region the dip of the beds generally is toward the axis of the geosyncline, except where it is influenced locally by structural features.

The embayment is drained by several large streams; most of them are in the Mississippi River system. An area in the southeastern part of the region is drained by tributaries of streams that flow separately into the eastern Gulf of Mexico.

The region has a moderate climate. The mean annual air temperature ranges from about 58°F in the northern part of the region to 66°F in the southern part (fig. 3), and the mean annual precipitation ranges generally from 48 inches in the northern part of the embayment to 56 inches in the southern part (fig. 4). Although the annual precipitation is high, most of it occurs during the winter and spring; droughts are common during the summer and fall.

Because most of the region is underlain by aquifers that yield large quantities of water to wells, ground water is the most readily available source of fresh water in the embayment. Surface water is available to those persons who have access to the streams. In considering the water resources of the region, ground water and the low flow of the streams are virtually "one water," so that the results of the studies on ground water given in chapters C, D, and E of this professional paper and the results of the studies on surface water given in chapters F, G, H, and I are complementary to each other in the definition of the hydrologic systems—the regional aquifers (water-bearing units) and the low flow of streams.

In delineating the aquifers within the embayment it was found that over much of the region more than one aquifer is available for use and development (fig. 5 and table 1). In many areas only the shallowest aquifer has been used or is being used as a source of water supply.

TABLE 1.—*Area of use and of potential use by aquifer, in square miles*

Unit or aquifer	Occurrence (States)	Area of use	Area of potential use	Total area
Lower Cretaceous Series	Ala. and Miss	0	4,000	4,000
Trinity Group	Ark	750	250	1,000
Coker Formation	Ala. and Miss	2,500	6,500	9,000
Gordo Formation	do	8,000	4,000	12,000
Woodbine Formation	Ark	75	425	500
Eutaw Formation	Ala., Miss., and Tenn	11,000	1,000	12,000
Tokio Formation	Ark	1,000	250	1,250
Coffee Sand	Miss. and Tenn	2,000	5,000	7,000
Ripley Formation	Ill., Ky., Miss., Mo., and Tenn.	8,000	12,000	20,000
Nacatoch Formation	Ark. and Tex	1,500	0	1,500
Wilcox Group or Formation.	Ala., Ark., Ill., Ky., La., Miss., Mo., Tenn., and Tex.	23,000	19,000	42,000
Carrizo Sand, and Meridian-upper Wilcox aquifer.	Ala., Ark., La., Miss., and Tex.	17,000	9,000	26,000
Cane River Formation and its equivalents.	Ark., La., Miss., and Tex	17,000	3,000	20,000
Sparta Sand	Ark., La., and Miss	37,000	0	37,000
Memphis aquifer	Ark., Ill., Ky., Miss., Mo., and Tenn.	12,000	6,500	18,500
Cockfield Formation	Ark., La., and Miss	[1] 23,000	[1] 5,500	[1] 28,500
Quaternary deposits	Ala., Ark., Ill., Ky., La., Miss., Mo., Tenn., and Tex.	45,000	0	45,000

[1] Possibly more than figure given, pending positive identification and mapping of Cockfield Formation or its equivalent in northern part of embayment.

Each regional aquifer has been defined within the area where it contains fresh water [1]; in some parts of the embayment the base of fresh water is more than 2,000 feet below mean sea level (fig. 6).

In the chapters on aquifers and low flow, stratigraphic columns are given for each State; but no attempt was made to show the correlation of the geologic units, some of which have nomenclature changes at State boundaries. Table 2 shows the relation between the geologic units ranging in age from Late Cretaceous to Oligocene.

RIVER BASINS

To summarize the information given in the other chapters of this professional paper and to facilitate the use of the data, the embayment is divided into seven areas, each area including one or more river basins or subbasins (fig. 7). The delineation and grouping of the basins and subbasins correspond generally to those used by the U.S. Geological Survey. In a few places the delineations were modified to improve the homogeneity of the data groupings. Block diagrams (pls. 1–7) of each area show schematically the subsurface units, the extent of the fresh water in each aquifer, the generalized surface geology, the major drainage, and the location and low-flow index (7-day 2-yr low flow [2]) for gaging stations. Also included on each plate are graphs of flow-duration and low-flow frequency curves for selected gaging stations; chemical-analyses diagrams of the low flow at some stations; the maximum, median, and minimum values of the chemical constituents of water from each aquifer within each basin; the water use and source in each river basin; and the hydraulic characteristics of the aquifers.

The geologic sections on the block diagrams show the relation of the aquifers and the subsurface geologic units. The surface geology shown on the block diagrams is very generalized. The loess and terrace deposits capping the hilly part of the embayment and the alluvial deposits of some of the streams are not shown either on the sections or as a part of the surface geology.

The number shown for each gaging station is the permanent nationwide number for the station. The low-flow index (7-day 2-yr low flow), shown in parentheses, is an indication of the degree to which the low flow of the stream is sustained at that point. Generally, a stream having a high low-flow index has a better sustained low flow than a stream having a low low-flow index. For example, on plate 1, the lower ends of the low-flow frequency curve and the flow-duration curve for Buttahatchie River near Caledonia, Miss. (2B4395), low-flow index 0.16 cfs per sq mi (cubic foot per second per square mile), are flatter than the lower ends of the corresponding curves for Sipsey River at Moores Bridge, Ala. (2B4460), low-flow index 0.09 cfs per sq mi. Hence, the low flow of Buttahatchie River near Caledonia is better sustained than the low flow of Sipsey River at Moores Bridge. Similarly, the low flow of Sipsey River at Moores Bridge is better sustained than that of Oldtown Creek at Tupelo, Miss. (2B4340), low-flow index 0.001 cfs per sq mi. Generally then, gradations from higher to lower indices and from the flatter to the steeper slopes of the lower ends of the low-flow frequency and flow-duration curves are relative indications of how well the low flows of the streams are sustained. For the purpose of this report the low flow of streams having a low-flow index greater than 0.08 cfs per sq mi is described as very well sustained, those having an index from 0.08 to 0.01 cfs per sq mi as well sustained, and those having an index less than 0.01 cfs per sq mi as poorly sustained.

The slope of the low-flow end of the flow-duration curve, when plotted as shown on plates 1–7, is a quantitative measure of the variability of low streamflow. The low-flow frequency and flow-duration curves shown for the selected gaging stations on each plate indicate

[1] Fresh water, as defined for this professional paper, is water that has a dissolved-solids content of less than 1,000 ppm.

[2] The 7-day 2-year low flow is the annual minimum 7-day flow having an average recurrence interval of 2 years.

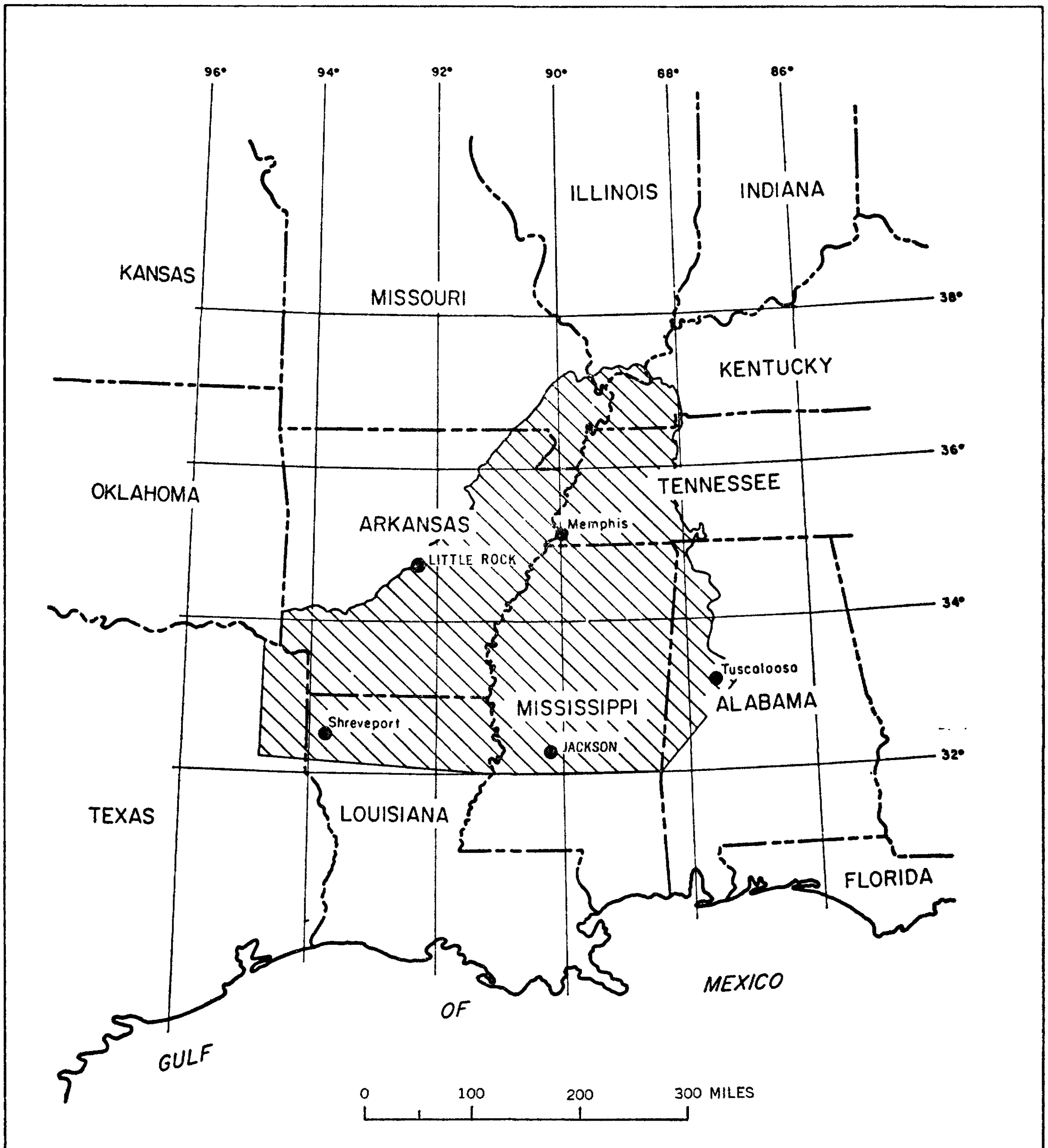

FIGURE 1.—Area of study.

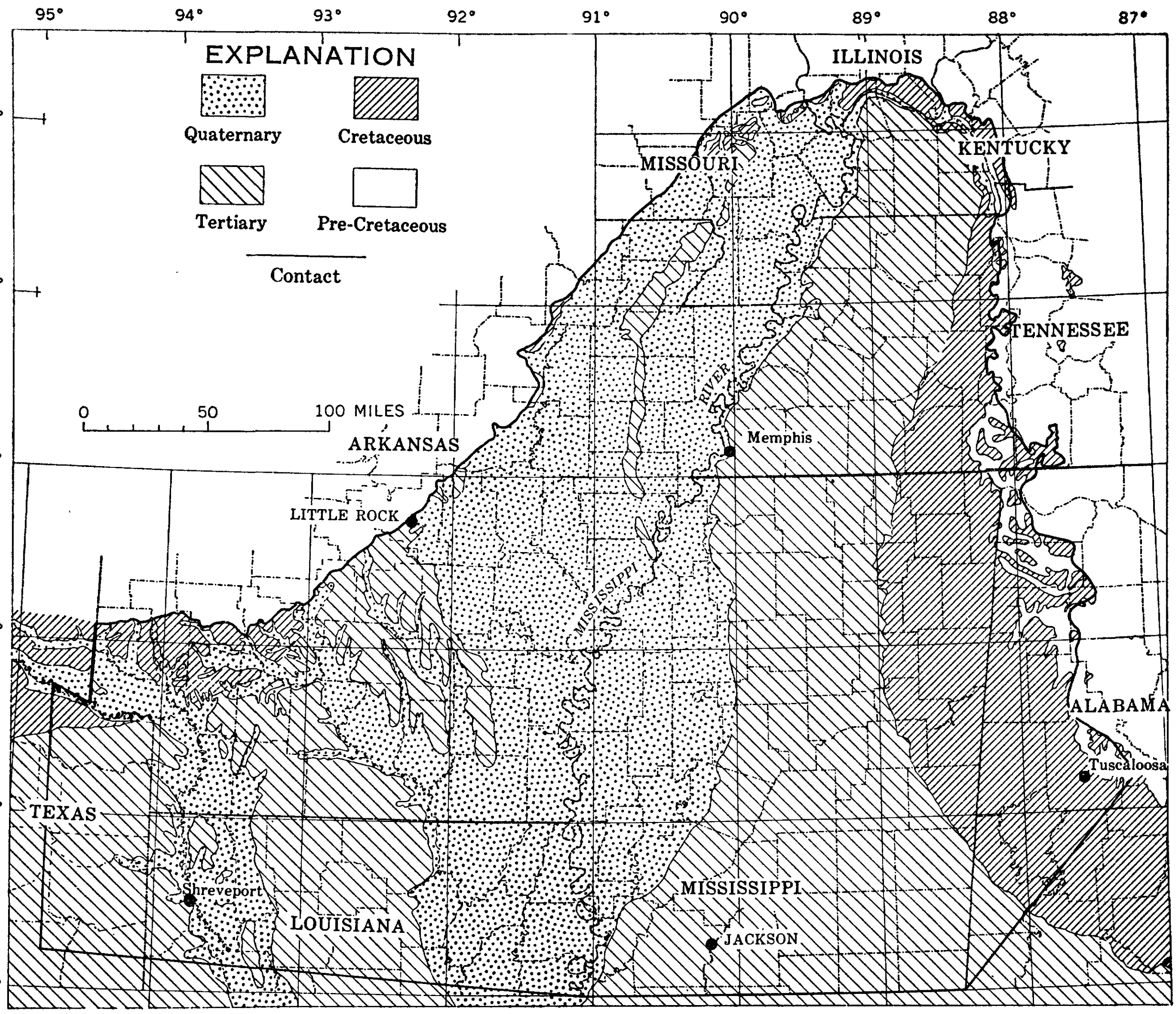

FIGURE 2.—Generalized geologic map.

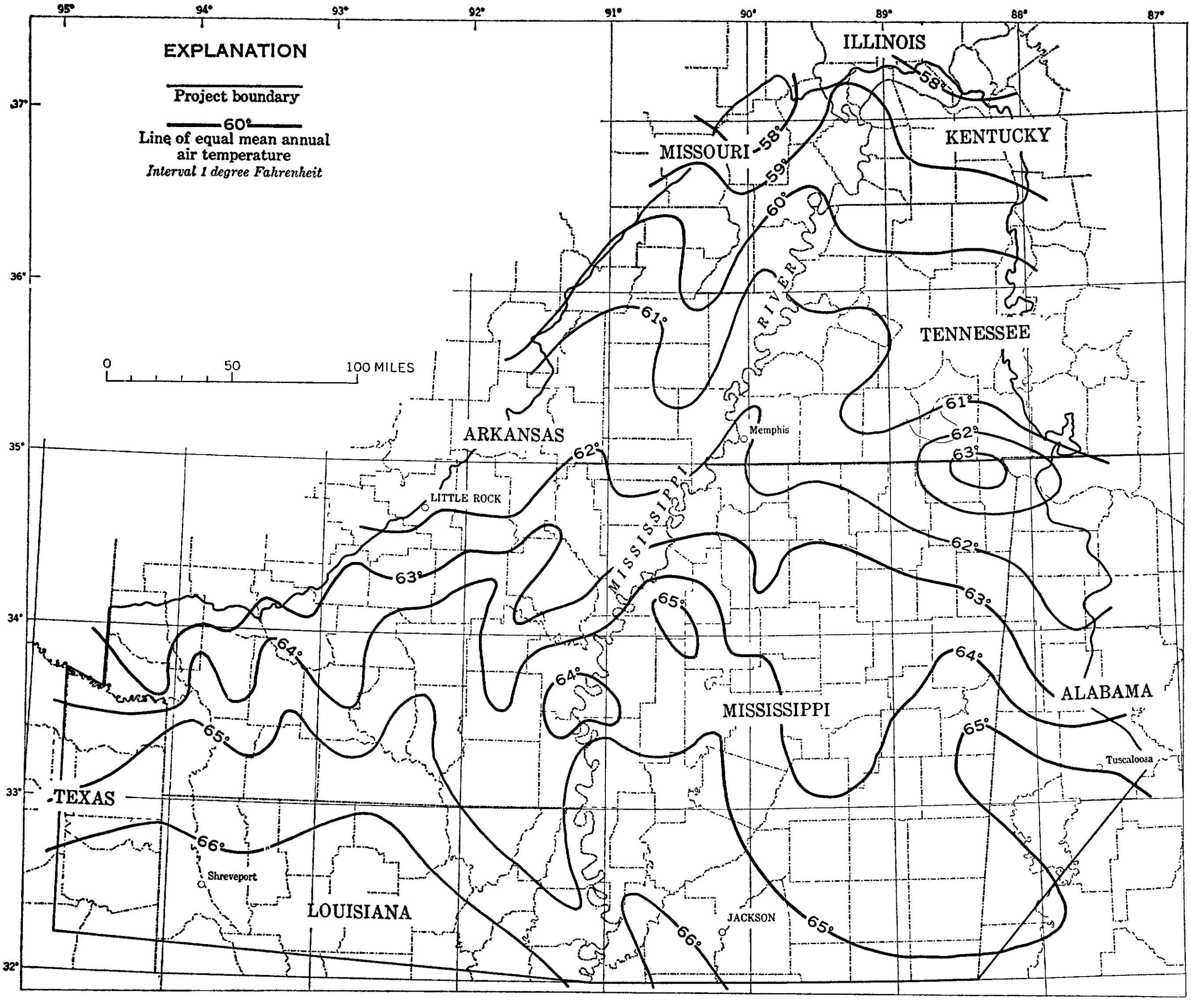

FIGURE 3.—Mean annual air temperature. Data from records of U.S. Weather Bureau.

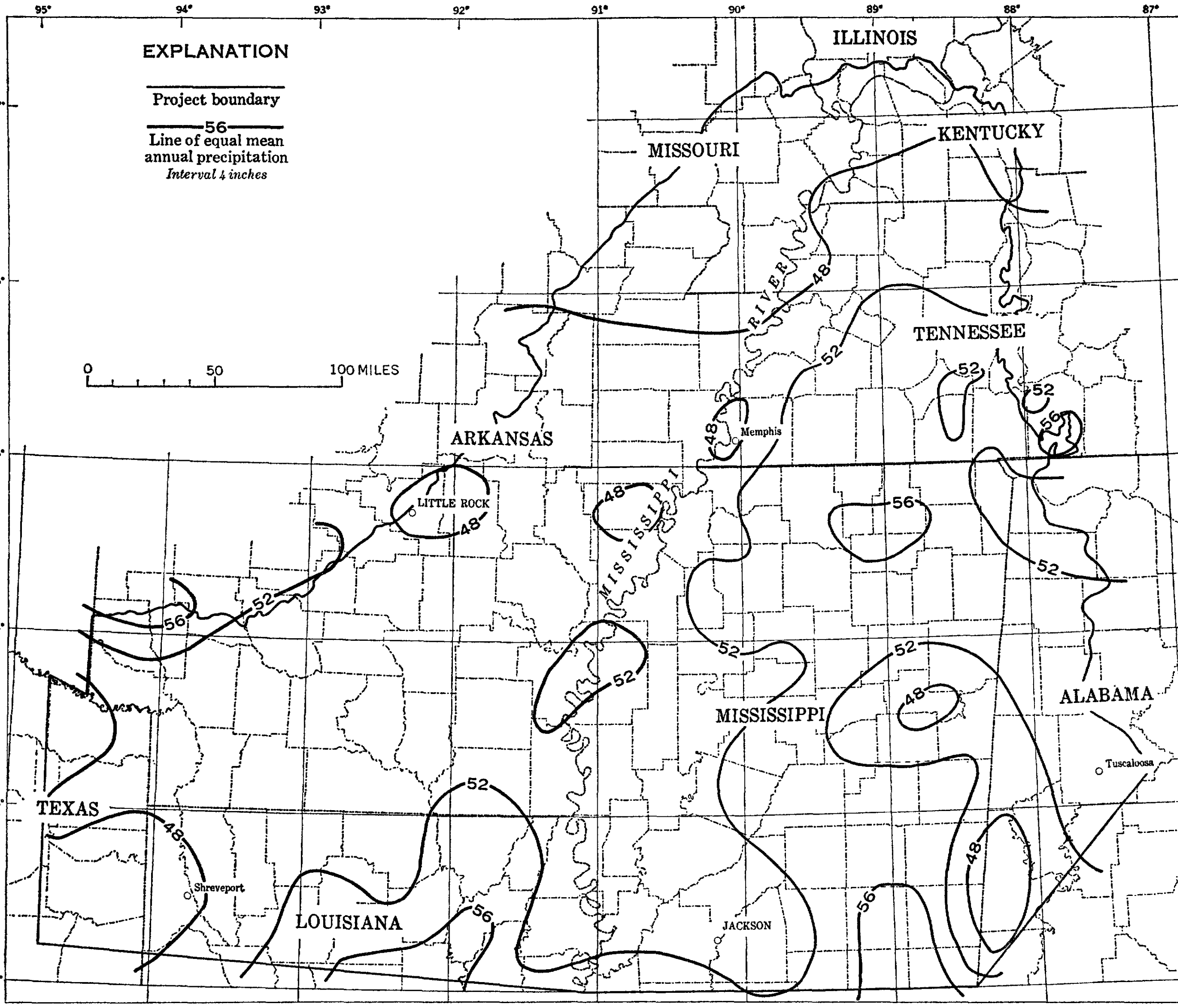

FIGURE 4.—Mean annual precipitation. Compiled from maps of U.S. Weather Bureau and records of Tennessee Valley Authority.

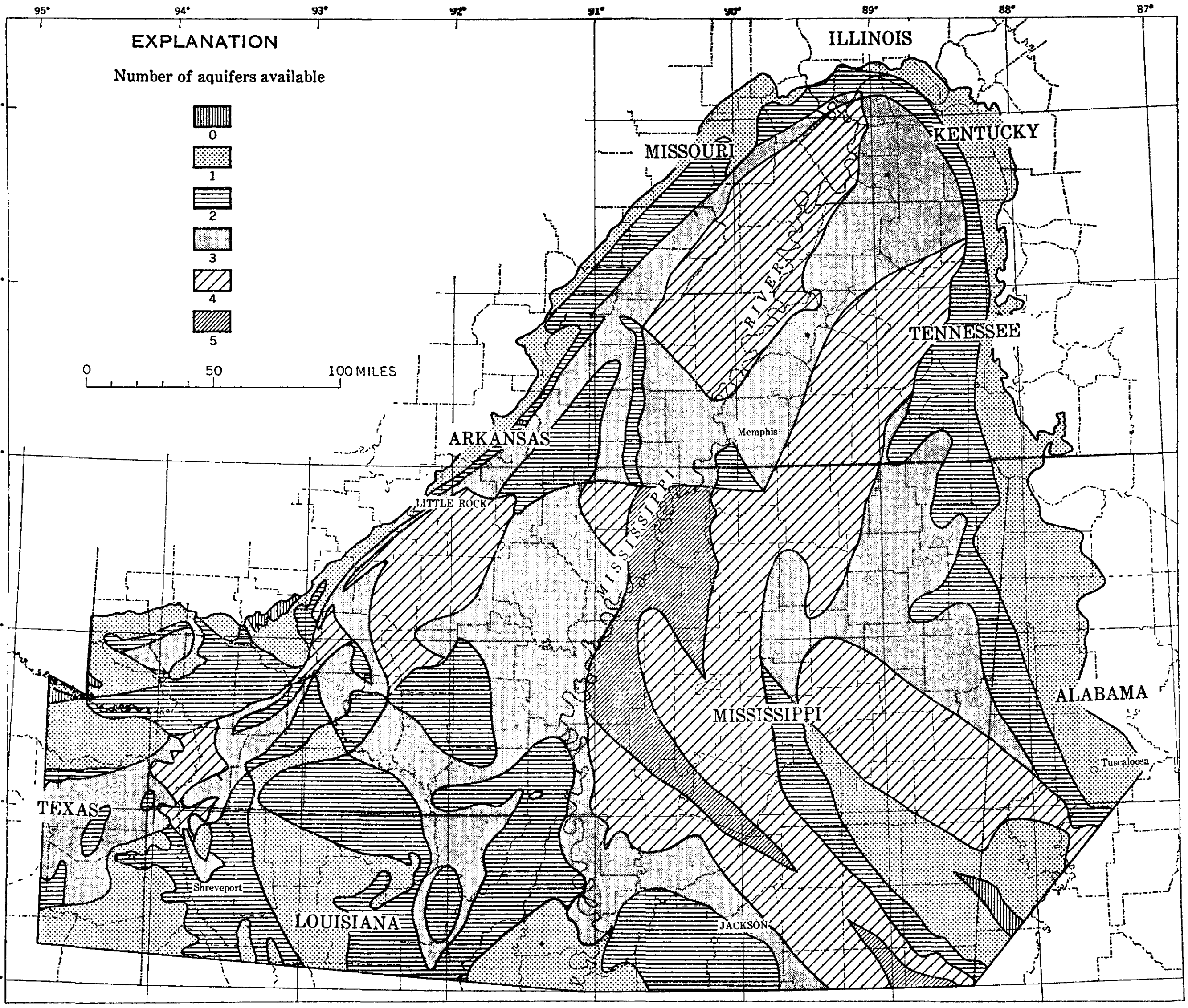

FIGURE 5.—Number of aquifers available.

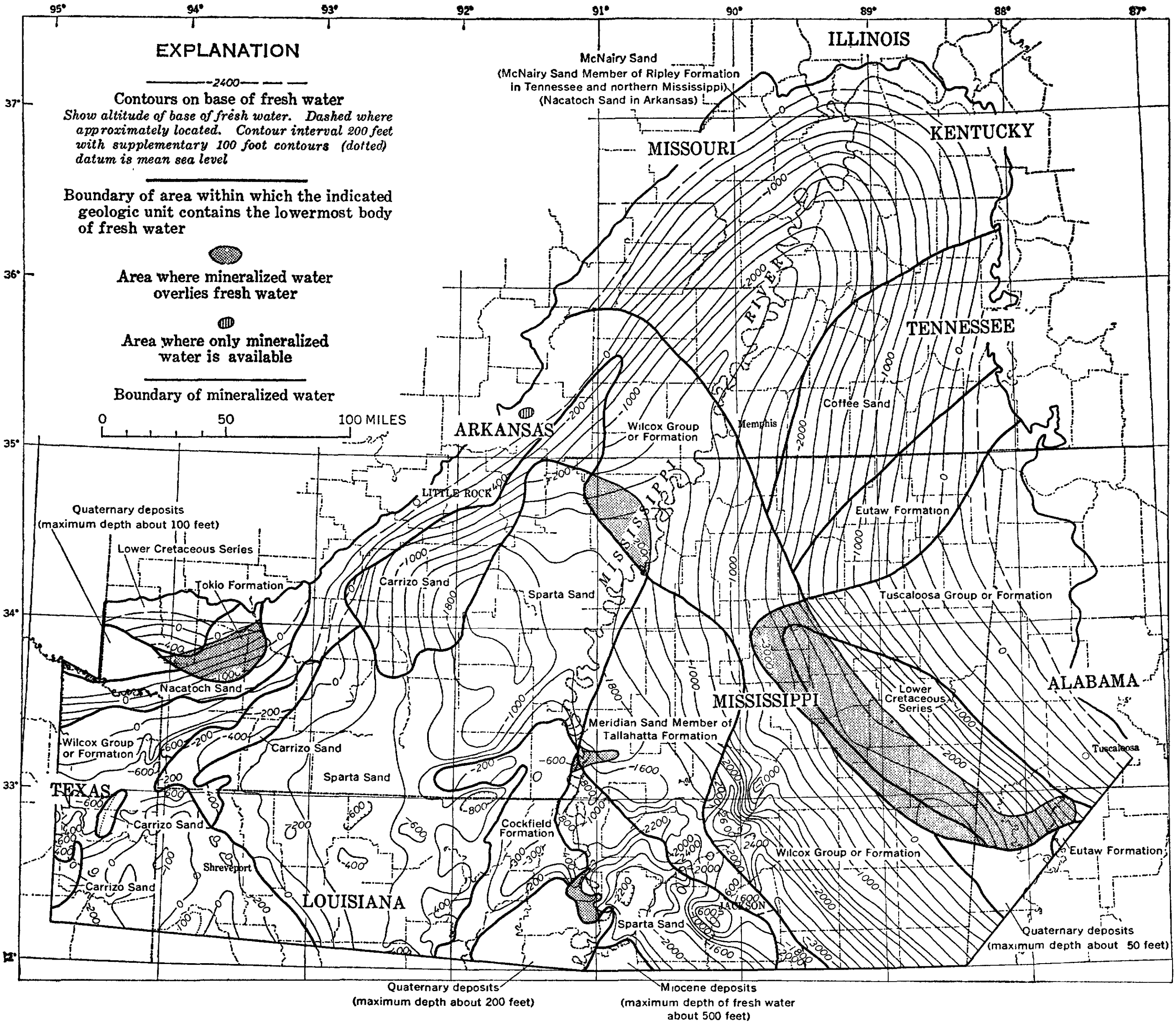

Figure 6.—Altitude of base of fresh water.

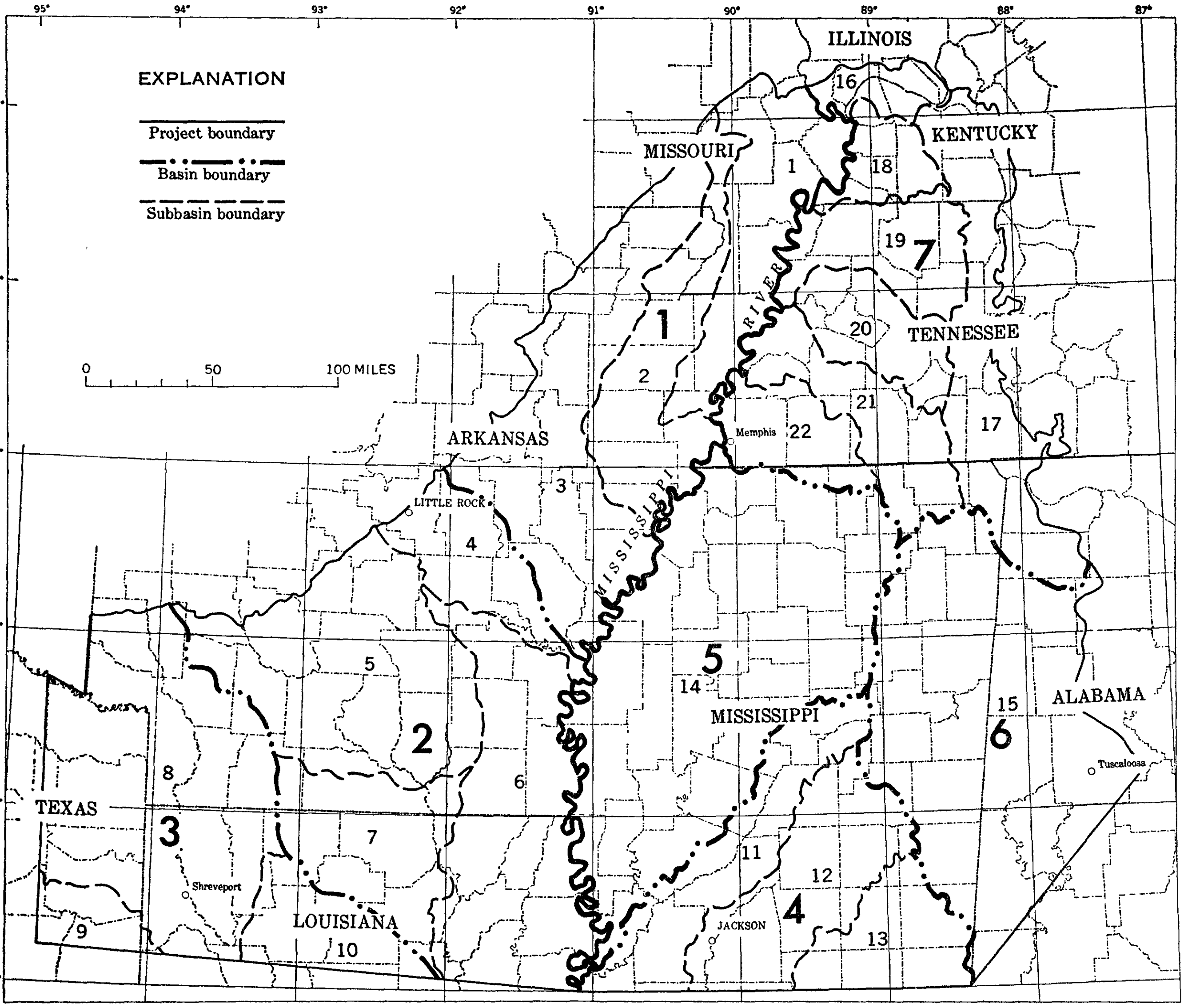

Plate 1:
Basin 1. Headwater diversion channel, St. Johns Bayou, and Little River basins.
2. St. Francis River basin, except Little River basin.
3. White River basin.

Plate 2:
Basin 4. Arkansas River basin.
5. Upper Ouachita River basin to, and including, Saline River basin.
6. Bayou Bartholomew, Boeuf and Tensas River basins.
7. Lower Ouachita River basin, below Saline River basin, except Bayou Bartholomew, Boeuf, Tensas, and Dugdemona River, and Castor Creek basins.

Plate 3:
Basin 8. Red River basin, except Saline Bayou basin.
9. Sabine River basin.
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Basin 11. Big Black River and Bayou Pierre basins.
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Plate 5:
Basin 14. Yazoo River basin.

Plate 6:
Basin 15. Tombigee River basin.

Plate 7:
Basin 16. Obion and Cache River basins.
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18. Shawnee, Mayfield and Obion Creeks, and Bayou du Chien basins.
19. Ohio River basin, except Forked Dear River basin.
20. Forked Deer River basin.
21. Hatchie River and Cold Creek basins.
22. Loosahatchie and Wolf River, and Nonconnah Creek basins.

FIGURE 7.—River basins and subbasins.

the flow characteristics of the stream. Data for other locations must be obtained from the tables of low-flow characteristics, magnitude and frequency of annual low flow, and flow duration in chapters F–I.

Many factors affect the low flow of streams, and, as a consequence, the low flow of some streams does not conform to the general pattern of the curve.

Within the Yazoo River basin (pl. 5), analysis of streamflow characteristics in the Quaternary deposits is impracticable because the terrain is so flat that the limits of drainage basins are poorly defined, the streamflow of any one basin is subject to inflow from other basins, continuing changes in drainage patterns modify the hydrologic characteristics, and numerous withdrawals are made from the streams for irrigation.

Curves for the two records available in the area, Sunflower River at Sunflower, Miss. (7–2885), and Quiver River near Doddsville, Miss. (7–2885.7), are shown and are considered indicative of the highly variable conditions within the alluvial plain.

The chemical quality of the low-flow waters of the streams is shown by means of chemical-analyses diagrams. Generally, one or two samples were collected at a selected stream site. If the chemical quality of samples at a site were nearly identical, the average for each constituent, in equivalents per million, is used for the chemical-analyses diagram; otherwise, two superimposed diagrams are shown.

Equivalents per million can be converted to parts per million by dividing equivalents per million by the following factors.

Ion	*Factor*
Ca	0.04990
Mg	.08224
Na+K (as Na)	.04350
Fe	.03581
CO_3+HCO_3 (as HCO_3)	.01639
SO_4	.02082
Cl	.02820
NO_3	.01613

Chemical quality of water from aquifers in each basin is shown in tables of maximum, median, and minimum values. The values derived from the analyses of a number of samples from each aquifer result from differences in quality of the water with respect to location, depth, and geochemical environment within the basin.

SUMMARY

Large quantities of water from streams and subsurface water-bearing sands are available in the Mississippi embayment (table 3). Most of the region is underlain by aquifers that yield large quantities of water to wells, so that ground water is the most readily available source of fresh water. About 65 percent of the water used in the region is obtained from wells. Streams are used primarily to dispose of, and to dilute, wastes that have been dumped into them. Many of the larger streams serve also as a means of transportation.

Most of the streams within the region are perennial. This condition exists because the aquifers in their areas of outcrop generally are saturated and are receiving as much recharge as they can under the prevailing hydrologic conditions; the excess water is being discharged into the streams and sustains the flow during periods of no precipitation.

The quantity of water that originates within the region and leaves it as streamflow during an average year is about 90 million acre-feet (about 80,000 mgd). This amount is approximately the perennial yield of the region under the existing climatic and hydrologic conditions. An additional 400 million acre-feet (about 360,000 mgd) during an average year leaves the region as streamflow, this quantity having originated outside of the region. The present water withdrawals (1965) from streams within the region is about 1,700 mgd.

Although these values give the amount of annual runoff in the region, water from streams is readily available only to those that have access to the streams, and it is generally the magnitude of the low flow and the amount of storage that can be provided that determine a stream's suitability for a water-use project. The low flow of the streams within the region is extremely variable. Using the low-flow index (7-day 2-yr low flow) as a means of comparison, the indices for 519 stations range from 0 to 2 cfs per sq mi.

Surface water during periods of low flow is ground water discharged from the outcrop areas of saturated aquifers. The water in the streams is chemically similar to ground water from shallow depths in the outcrop areas but is generally lower in dissolved solids.

Ground water is available in the embayment from 18 regional aquifers and from several that are of local extent. Although some of these regional aquifers are geologic-equivalent units, they are separated by an intervening zone containing saline water and are considered to be two aquifers having individual geologic names. Others are geologic-equivalent units constituting a single aquifer but having two or more geologic names.

Ten regional aquifers are in deposits of Cretaceous age; these include the Lower Cretaceous Series in Alabama and Mississippi, the Trinity Group, the Coker, Gordo, Woodbine, Eutaw, and Tokio Formations, the Coffee Sand, the Ripley Formation or McNairy Sand, and the Nacatoch Formation. Six regional aquifers are in deposits of Tertiary age; these include the Wilcox Group or Formation, the Carrizo Sand and Meridian-upper Wilcox aquifer, sands in the Cane River Formation and their equivalents (the Reklaw Formation, Queen City Sand, and Weches Greensand; and the Winona-Tallahatta aquifer), the Sparta Sand, the Memphis aquifer, and the Cockfield Formation. Two aquifers are in deposits of Quaternary age—the Mississippi River valley alluvial aquifer and the Red River valley alluvial aquifer.

Some aquifers of local extent in the embayment are the Ozan Formation, Forest Hill Sand, Catahoula Sandstone, terrace deposits of Pliocene and Pleistocene age, and terrace and alluvial deposits of Quaternary age in the larger stream valleys.

The potential yield of the regional aquifers is estimated to be about 30,000 mgd, of which about 3,000 mgd is presently being withdrawn. If the aquifers were developed to their full potential, the flow of the streams under the present climatic and hydrologic conditions would be drastically altered.

Ground water in the Cretaceous and Tertiary aquifers in the outcrop areas and at shallow depths generally has a low dissolved-solids content, is slightly acid, and often contains excessive amounts of iron. The water usually is a calcium or sodium bicarbonate type, or a mixture of these two types.

As water moves downdip the iron content decreases; the water becomes softer and a sodium bicarbonate type; and the dissolved solids increase. At greater depths the chloride content increases, and as the downdip limit of fresh water is approached, the water becomes a sodium chloride type or a sodium bicarbonate chloride type.

The water in the Quaternary aquifers generally is moderately hard, moderate in dissolved solids, contains iron, and may have a pH of less than 7.0. The temperature of the water is slightly higher than the mean annual air temperature.

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