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GEOLOGICAL SURVEY CIRCULAR 373

WATER RESOURCES OF THE MOBILE AREA ALABAMA

With a section on salinity of the Mobile River by the Corps of Engineers, U. S. Army, Mobile District

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

GEOLOGICAL SURVEY
Thomas B. Nolan, Director

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By W. H. Robinson, W. J. Powell, and Eugene Brown

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PREFACE

This report is one of a series concerning the water resources and present water utilization of selected industrial areas of national importance. It has been prepared at the request of and in consultation with the Water and Sewerage Industry and Utilities Division of the Business and Defense Services Administration of the Department of Commerce. The series is designed to serve the dual purpose of providing basic information for national defense and at the same time to render a valuable service to business and industry in the development of water resources for present and future use.

These reports are prepared by the field offices of the Geological Survey. The part of this report which describes surface-water resources was prepared under the supervision of M. R. Williams, district engineer, Surface Water Branch, and the part which describes ground-water resources was prepared under the supervision of P. E. LaMoreaux, district geologist, Ground Water Branch. James H. Kearley assisted in the field study of the ground-water resources of the area, and John S. Stallings made most of the field study of the surface-water resources of the area.

Most of the data summarized in this report were collected over a period of many years by the U. S. Geological Survey in cooperation with the Geological Survey of Alabama and the Corps of Engineers, United States Army. Data on the quality of water of the Mobile River near Mount Vernon were collected in cooperation with the State of Alabama Water Improvement Advisory Commission.

The section on the salinity of the Mobile River was prepared by the Corp of Engineers, based on data collected by that agency.

Among the many business and professional men in the area who have helped in this study are Morgan Stickney, superintendent, Mobile Water Service System; C. D. Lamon, manager, Prichard Water Works; F. B. Smith, engineer, Hollingsworth and Whitney Paper Company; Harlan Shope, engineer, Southern Kraft Corporation; R. W. Leins, engineer, Courtaulds; and the management personnel and employees of the Mobile Sawmill Company, who were especially helpful.

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WATER RESOURCES OF THE MOBILE AREA, ALABAMA

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ABSTRACT

Water is an abundant resource of the Mobile area. The Mobile River has an estimated average flow of 60,000 cubic feet per second (cfs), or about 39,000 million gallons per day (mgd). It is the largest single source of water. Water is available in substantial quantities from the many local streams and extensive water-bearing formations almost anywhere in the area.

Surface water is low in dissolved mineral matter and is extremely soft. Salt water moving up the Mobile River from Mobile Bay during periods of low river flow, however, limits the use of that stream as a source of supply.

The principal water-bearing formations are the alluvium and sediments of Miocene age. The Miocene strata dip toward the southwest, forming an artesian basin in the downtown area of Mobile. Small ground-water supplies can be developed practically everywhere, and supplies for industrial or other large-scale uses are available north of Mobile.

The average use of water from all sources in the area during 1954 was about 356 mgd, of which about 20 mgd was used for domestic supplies and 336 mgd was used by industry. An estimated 42 mgd of ground water is used in the Mobile area. The discharge from wells used by industry ranges from 10 to 1,500 gallons per minute (gpm), and the specific capacity of the large-capacity wells ranges from less than 6 to about 63 gpm per foot of drawdown.

Concentrated pumping in the downtown area of Mobile between 1941 and 1945 resulted in encroachment of salt water from the Mobile River into the alluvium. Because of a decrease in pumping in that vicinity, the sodium chloride content of the water has decreased substantially since 1945.

The quality of ground water is variable. Hardness of waters sampled ranged from 1 to 2,190 parts per million (ppm), the dissolved solids from 27 to 13,000 ppm, and the chloride from 2.2 to 6,760 ppm. The water of best quality occurs between McIntosh and Prichard, and the water of poorest quality occurs in the downtown area of Mobile.

The water-supply systems presently developed in the metropolitan area could furnish a moderate increase without taxing their facilities; with some increase in plant and pumping facilities, they could support a substantial increase. Industries outside the metropolitan area must develop their own supplies from local streams or wells.

INTRODUCTION

The purpose of this report is to provide information on the water resources that may be useful in the location or expansion of water facilities for defense or nondefense industries and for municipalities.

The industrial development of an area is controlled in part by the water supply. The Mobile area has the large quantity of good quality water required for industrial use. This report summarizes the data relating to the use, chemical character, availability, and occurrence of water in the Mobile area.

Description of Area

Location

This report concerns an area of about 1,500 square miles in parts of Mobile and Washington Counties, Ala. Most of the industrial development has been concentrated in, and north of, Mobile along the Mobile River (pl. 1), because of the easy access to river and ocean transportation. The studies were more intensive in the area of concentrated industrial development.

Topography and Geology

The topography of the Mobile area, as of other areas, is determined in part by the rocks that make up the land surface. Rocks that crop out in the Mobile area are sedimentary; that is, they were deposited in shallow inland seas or by streams. The Mobile and Tensaw Rivers have been important tools in sculpturing the present topography. Flood-plain deposits of clay, silt, sand, and gravel, laid down by the Mobile River, form a conspicuously flat surface bordering the rivers. The width of the flood plain ranges from about 6 miles in the vicinity of Mount Vernon to about 11 miles in the vicinity of Saraland. Altitude of the flood plain in Mobile ranges from 5 to 30 feet above mean sea level. Most of the large industrial development has been on this broad flood plain.

The most prominent topographic feature is the series of flat-topped hills that rise west of the flood plain. These hills are capped by deposits of sand, gravel, and clay of the Citronelle formation of Pliocene or early Pleistocene age, those in this area probably having been laid down by the ancestral Alabama River, as suggested by Carlston (1950, p. 1120). Altitude of this ridge between Spring Hill and the town of Citronelle ranges from about 200 to 330 feet. The ridge forms the drainage divide between the Escatawpa and Mobile Rivers.

The Citronelle formation is underlain unconformably by estuarine deposits of Miocene age. These Miocene deposits consist of sandstones, variegated argillaceous sand, and dark variegated clay. Steep slopes are generally typical of outcrops of the Miocene deposits along the sides of the Spring Hill-Citronelle ridge.

Geologic formations that crop out in the area are shown in figure 1. Alluvium beneath the flood plain of the Mobile River is underlain directly by the deposits of Miocene age, because there the Citronelle formation was removed by erosion before the deposition of the alluvium.

Climate

The U. S. Weather Bureau has collected climatological data at Mobile since November 6, 1870. Weather observations were discontinued in 1950 at the downtown station, in the vicinity of the U. S. Court House and Customs House, and were begun at Bates Field, about 12 miles west of the Post Office. Figure 2 shows the annual precipitation at Mobile from 1900 to 1953.

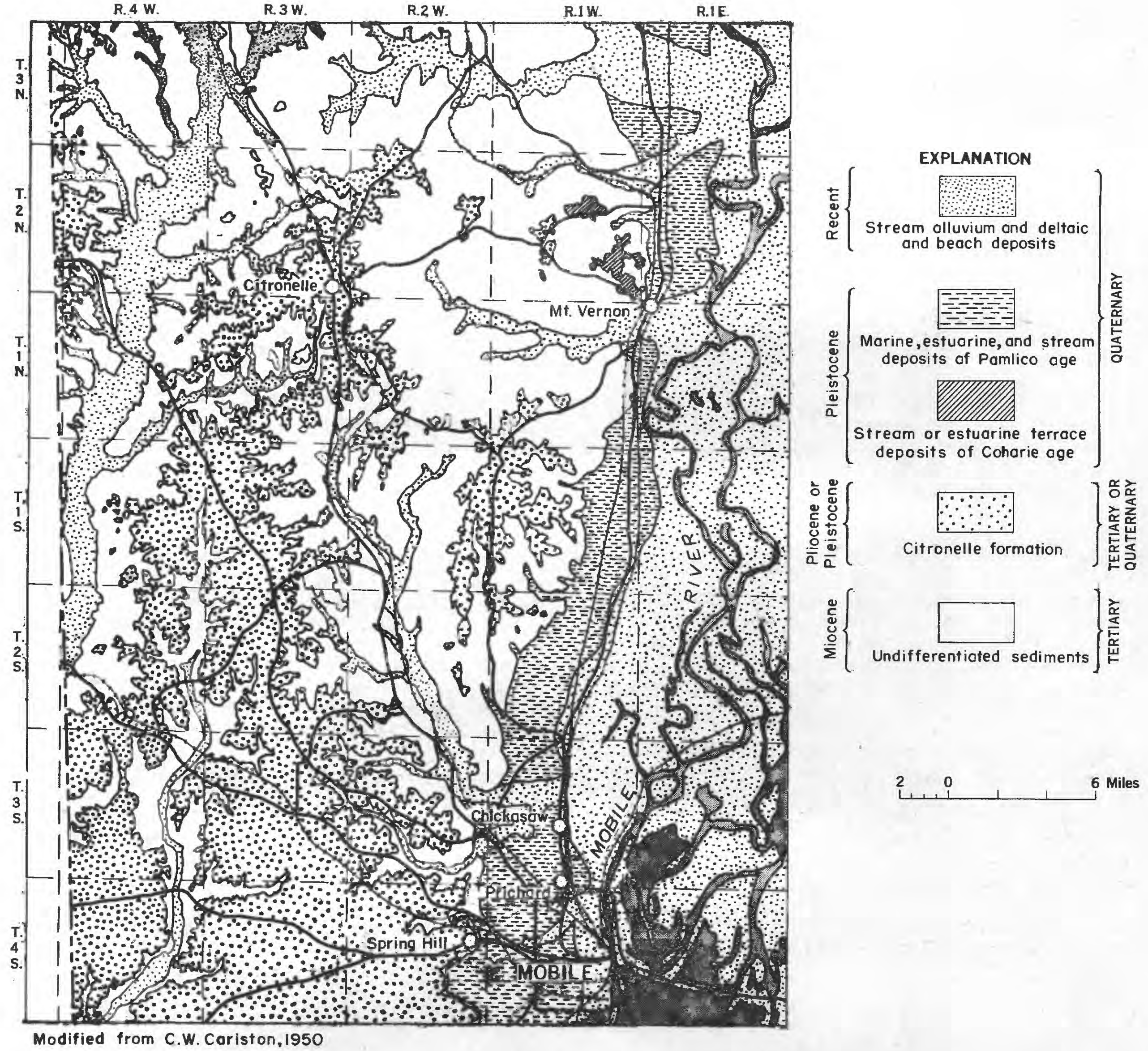

Figure 1.—Geologic map of the Mobile area.

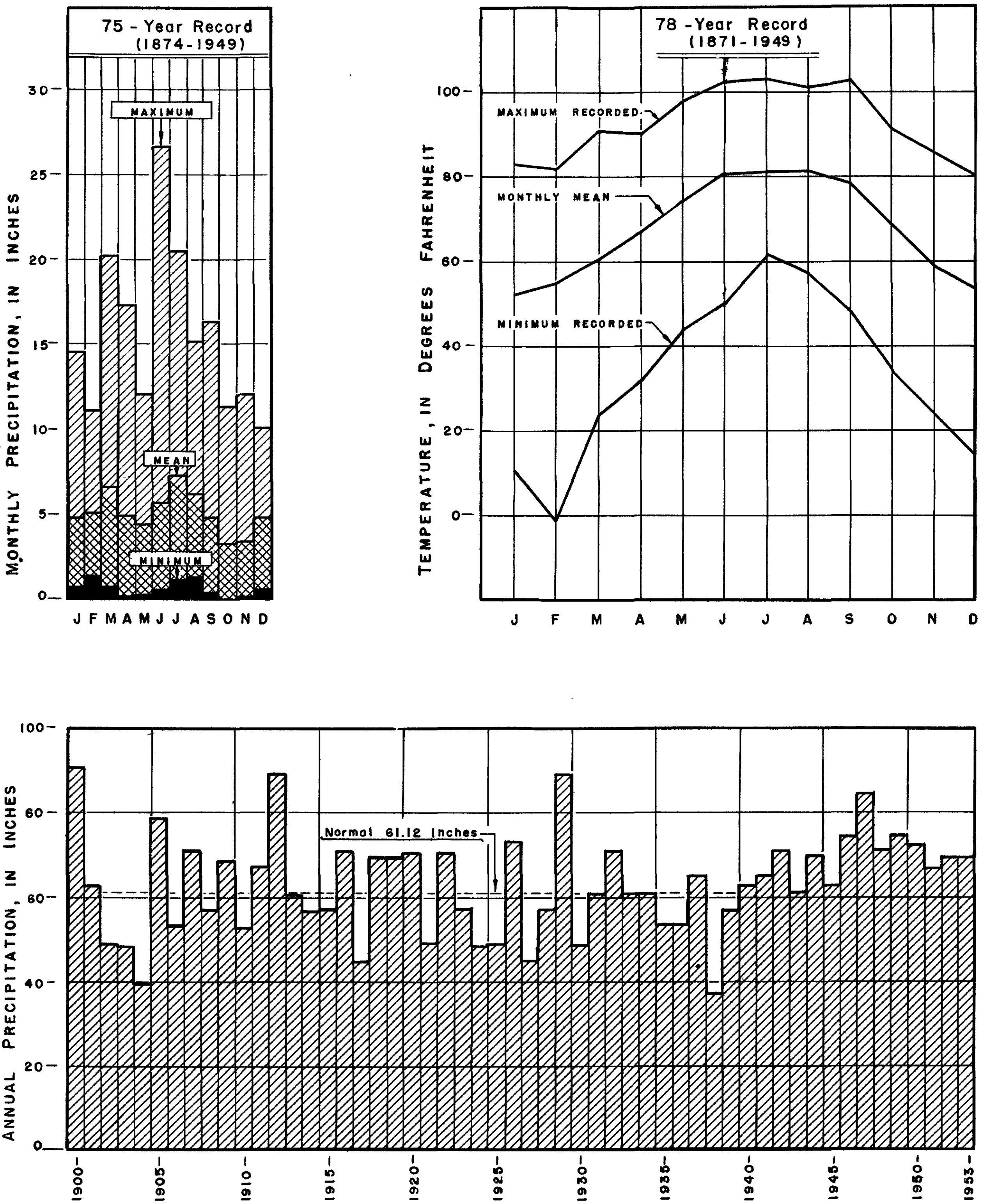

Figure 2.—Temperature and precipitation at Mobile.

During the summer the days are warm, but the nights are generally relatively cool; the heat of the summer days is alleviated to some extent by sea breezes. Winters are generally mild, and the occasional cold periods seldom last longer than 2 or 3 days.

The highest temperature of record at Mobile is 103°F, recorded in September 1925 and July 1930; the lowest recorded temperature is -1°F, recorded in February 1899. The mean annual temperature is about 68°F; the mean daily maximum is about 76°F, and the mean daily minimum is about 59°F. July and August, the warmest months, have an average temperature of about 81°F. January, the coldest month, has an average temperature of 52°F. (See fig. 2.)

Mobile, among the cities of the United States having the highest amount of rainfall, has a mean annual precipitation of 61.12 inches. Rainfall is fairly evenly distributed throughout the year. The greatest annual precipitation recorded is 91.16 inches, in 1900, and the greatest precipitation in one day is 12.98 inches, in June 1900. Figure 2 shows the monthly distribution of precipitation.

The last measurable snow recorded in the area was in 1895, when 6 inches fell. February 16 is the average date of the last killing frost in the spring, and December 7 is the average date for the first killing frost. Average length of the growing season is 274 days.

Mineral Resources

The principal mineral resource of the area, with the exception of water, is the salt domes that occur in the vicinity of McIntosh, Washington County. Published records do not define the extent of these salt domes, but three chemical companies are dependent on them for raw material. Several test wells have been drilled for oil in this area, but none was successful.

Development of the Area and Navigation

The city of Mobile, on the Mobile River where the river enters Mobile Bay, has had its character influenced by its location--it is both seaport and river town. The first settlement of Europeans at the present site was made by the French in 1711. Subsequently, the city was under the flags of France, Great Britain, Spain, the United States, Republic of Alabama, Confederate States, and again the United States. Commerce has been the prevailing interest of the city since its beginning, and its economic health and rate of growth have been largely dependent upon the arteries of commerce that serve the city. This was evident as early as 1717, when shifting sands closed the harbor to larger vessels and the city's growth and activity were retarded.

After the American occupation in 1813, the city grew steadily, serving as the port for the rapidly expanding cotton-growing area developed in the basins of the Alabama and Tombigbee Rivers. The advent of the river steamers, improved river channels and harbors, and the development of railroad systems aided the growth of the city.

During the past 25 years the industrial development of the area has made rapid progress. At present the area has a large paper industry, a recently developed and rapidly expanding chemical industry, and many others, including nonferrous metals, cement, gypsum, oil refining, lumber, and wood products. During World Wars I and II, shipbuilding was a major industry.

Throughout this period of industrial development the city has retained much of its traditional devotion to commerce. The area is served by four railroads, an adequate highway system, and the navigational facilities of Mobile Bay and the Tombigbee-Black Warrior Waterway.

The port of Mobile now ranks among the top ten ports in the nation. It serves as the connecting link between the river waterway, intracoastal waterway, open sea, and railroads. Figure 3, reproduced from the U.S. Corps of Engineers project map, shows the present (1954) deep-water channels. Proposed future developments for the harbor include deepening the channel to 40 feet to accommodate the new fleet of large-capacity ore vessels now being placed in operation. Tonnage handled by the port for each year since 1943 is shown in figure 4 (based on data supplied by the Alabama State Docks Board).

Imports include sugar, rubber, petroleum, molasses, bananas, coffee, tea, and rice; and nitrate, manganese, phosphate rock, iron ore, and bauxite. Imports of high-grade Venezuelian iron ore for the furnaces in the Birmingham area are expected to increase in the near future. Principal exports are paper, cotton piece goods, iron and steel articles, naval stores, lumber, logs, poles, peanuts, fertilizer, cement, coal, oyster shell, ferrophosphate, and coke.

The Tombigbee-Black Warrior Waterway connects the port with the rich mineral and industrial area of Birmingham. A minimum depth of 9 feet and width of 200 feet are maintained between Mobile and Port Birmingham, a distance of 400 miles. Tonnage carried by the waterway for each year since 1943 is shown in figure 4 (based on data supplied by the Corps of Engineers, U. S. Army.) The value of the cargo for 1953 was $81,000,000.

OCCURRENCE OF WATER

Sources

Precipitation is the immediate source of all fresh water on the land's surface. Some of the precipitated water runs directly off the surface of the ground into streams, some is temporarily retained on the surface or on vegetation and is subsequently evaporated, and an important remaining part seeps down into the ground and becomes subsurface water.

Some of this subsurface water adheres to the particles of soil. There it remains until it is evaporated directly or is used by vegetation and transpired. Water not held in the soil zone continues to move by gravity down through the pores in the earth's crust until it reaches the zone of saturation. Water in the zone of saturation is known as ground water, and during periods of no precipitation the discharge of this

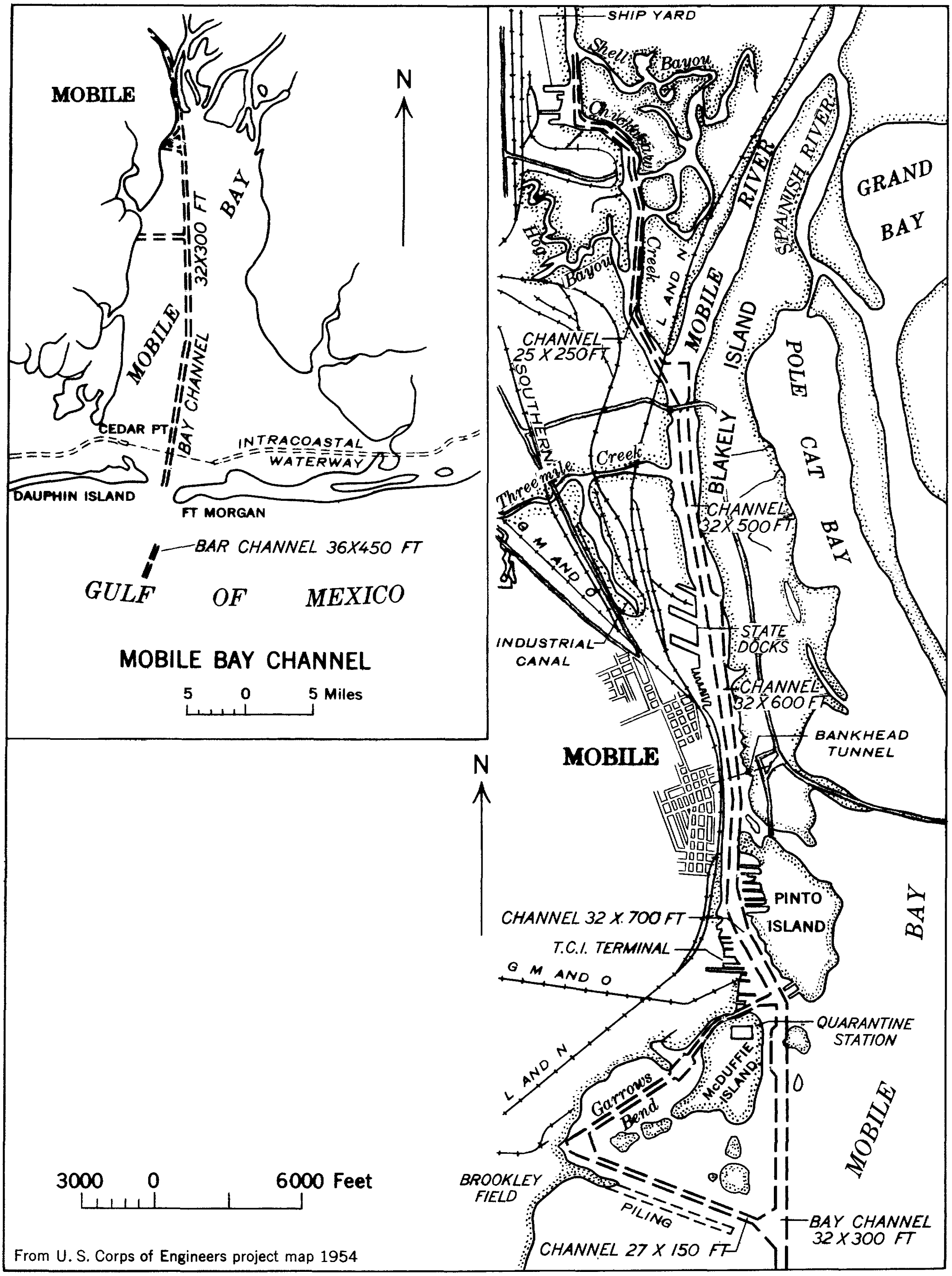

Figure 3.—Mobile harbor.

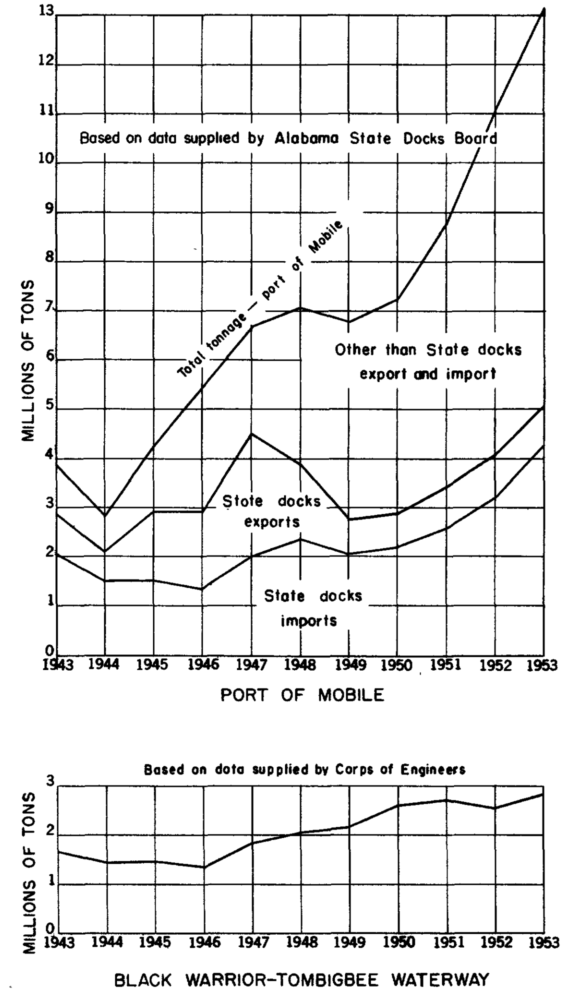

Figure 4.—Tonnage handled by the port of Mobile and Black Warrior-Tombigbee Waterway, 1943-53.

ground water through seeps and springs constitutes most of the streamflow. Although ground water and surface water are closely related, they must be appraised by different methods; thus, data on each are given separately in the following sections.

The water resources in the Mobile area are: (1) the Mobile River, which has the source of most of its water far from Mobile and is not dependent upon local precipitation or ground-water storage; (2) local streams, which are directly dependent upon local precipitation and ground-water storage; and (3) the local ground-water reservoirs themselves.

Quality

Water in its natural state is never pure. During the course of the hydrologic cycle the chemical character of water is often greatly changed. The principal factors affecting the quality of water are:

(1) Natural conditions, such as amount of precipitation, topographic and geologic features, and vegetation.

(2) Human activities related to the use and reuse of water and the disposal of waste materials.

First the precipitated water absorbs gases from the atmosphere and carries them into the soil, where active solution of many salts may occur. The amount and nature of material dissolved is directly related to the solubility of the rock materials and the time they remain in contact with the water. The quantities of salts may be quite large, as in waters percolating deeply into the earth's crust before reappearing at the surface. Conversely, where water passes rapidly over the surface, and contacts soluble rock materials only sparingly, the dissolved solids are apt to be quite small in amount. Geological features determine to some extent the amount of solution that occurs. Waters that have percolated through limestone or dolomite, for example, usually contain much calcium and magnesium bicarbonate and are hard. In general, the quality of ground water from a given part of a water-bearing formation remains nearly constant throughout the year because ground water moves at a slow, relatively uniform speed and is subject to little external contamination. The runoff from swamps will be colored and contain much organic matter, as well as micro-organisms, plant growth, and humic complexes of iron and possibly of other heavy metals. Topographical features also partly determine how fast precipitation drains off the land, and, hence, the length of time the water remains in contact with soluble materials. The chemical quality of some river waters changes rapidly with discharge, whereas others are little affected by wide variations in flow. During dry periods the quality of streamflow approaches the quality of ground-water inflow.

Water flowing over the ground may also carry varying amounts of insoluble or suspended matter, such as silt, decayed organisms, and vegetation. In many river waters the amount of this suspended matter is very large and of considerable importance. In some waters the suspended matter may be colloidal and difficult to remove.

Probably the major human activitity affecting water quality is the industrial and domestic use of water, and the subsequent return of water carrying all manner of sewage and industrial waste to the land and streams. The diversion of water and the effect of deforestation, construction, and farming, which may change the rate of runoff and cause rivers to flood or dry up, can also seriously affect water quality. Storage in large lakes and surface reservoirs tends to reduce the range of extremes in concentrations of dissolved solids, permit settling out of suspended matter, and may even allow precipitation or concentration of soluble material.

The major beneficial uses of water are so many and diversified that it becomes a practical impossibility to devise a single standard of quality that will meet the chemical, physical, and sanitary requirements of all. Many of the uses of water, such as domestic and industrial, are compatible within narrow ranges of water quality, whereas the use of a stream for unregulated waste disposal is in most cases at complete variance with its use for domestic water supply. Inasmuch as the use of water by human beings for drinking and other domestic purposes is generally the most essential use of water, such water may be given the primary procurement rights and may be afforded the highest degree of sanitary protection. However, other beneficial uses may have water-quality criteria that are far more stringent in certain respects than those for drinking water. Many industrial processes, for example, cannot use, without further treatment, water that is suitable for domestic supplies; zeolite-softened water from municipal systems is often detrimental for irrigation; and aquatic life in streams and lakes may be destroyed or inhibited by concentrations of copper or zinc that are permissible in domestic water.

The physical, chemical, and bacterial quality of drinking water in the United States is generally judged in relation to the U. S. Public Health Service Standards of 1946. These standards, which apply strictly only to water supplies used in interstate commerce, have been adopted by most State health departments as criteria for public water supplies. The maximum concentration, in parts per million, of some constituents permitted for potable water under these standards is: lead 0.1, fluoride 1.5, arsenic 0.05, selenium 0.05, and hexavalent chromium 0.05. Appropriate limits for the concentrations of other less critical constituents are recommended, but they are not mandatory.

Because many industrial processes require a water of a definite chemical character, some limits of tolerance for quality, based on experience, have been set up by many industries. These limits serve merely to indicate certain characteristics of a water that enter into its acceptability for different processes, but the limits are affected by variations in the processes and by the quality desired in the final product. When a water does not meet these general requirements it must be treated unless some other suitable supply can be found. Today almost any water can be treated by usual or special methods to produce a water of any desired quality, but economics determines the extent to which treatment is practical.

Chemical analysis of a water is necessary to determine whether treatment is needed to meet limiting requirements, the type of treatment required, and the cost. Therefore, determination of the utility of a water for any industrial process depends largely upon the results of analyses of representative samples of the water.

SURFACE WATER

Water is perhaps the most abundant resource in the Mobile area. In addition to the Mobile River flowing by the city, there are many small streams. Partly because of this abundance of water, records of streamflow are relatively meager. Several gaging stations have been established on small streams in recent years, but the length of such records and extent of coverage is insufficient to appraise properly the water resources of the small streams. Table 1 shows the data available on streamflow in the area.

One of the most useful tools in analyzing streamflow records is the duration curve. This curve shows the percent of time the daily streamflow equals or exceeds the indicated flow. Such curves for the Alabama, Tombigbee, and Mobile Rivers are presented in figure 5. Flow-duration data for the smaller tributary streams are shown in tables 2 and 3.

Records for the Alabama River at Claiborne and the Tombigbee River near Leroy cover the period 1930-54, but all other available records are for a shorter period. Through use of methods of correlation, shorter records can sometimes be extended to cover, with some loss of accuracy, longer periods of time. The 1-year record on the Mobile River was thus extended to cover the 1930-54 period, and records for the smaller streams were extended to cover the period 1939-54 by using part of a record on Escambia River at Flomaton, a stream outside the area of this report. For several streams the only records available are 6 or 7 discharge measurements made in recent times. The flow-duration data for those streams

Table 1.—Records of streamflow in the Mobile area

Reference letter (pl. 1)	Station name	Drainage area (square miles)	Type and length of record
a	Alabama River at Claiborne	22,000	Continuous daily discharge, April 1930–Sept. 1954.
b	Tombigbee River near Leroy	19,100	Continuous daily discharge, Oct. 1928–Sept. 1954.
c	Bassetts Creek near Wagarville	128	7 discharge measurements made during 1953–54.
d	Lewis Creek near McIntosh	43.9	Do.
e	Bilbo Creek near McIntosh	73.2	Do.
f	Bates Creek near Calvert	73.6	Do.
g	Mobile River near Mount Vernon	43,000	Continuous daily discharge, Oct. 1953–Sept. 1954.
h	Cedar Creek near Mount Vernon	71.2	6 discharge measurements made during 1953–54.
i	Bayou Sara near Saraland	13.6	7 discharge measurements made during 1953–54.
j	Chickasaw Creek near Whistler	124	Continuous daily discharge, Oct. 1951–Sept. 1954.
k	Eightmile Creek near Eight Mile	27.0	7 discharge measurements made during 1953–54.
l	Threemile Creek near Crichton	12.1	Do.
m	Escatawpa River near Wilmer	506	Continuous daily discharge, Aug. 1945–Sept. 1954.
n	Big Creek near Mobile	84	Continuous daily discharge, Nov. 1944–Sept. 1950.

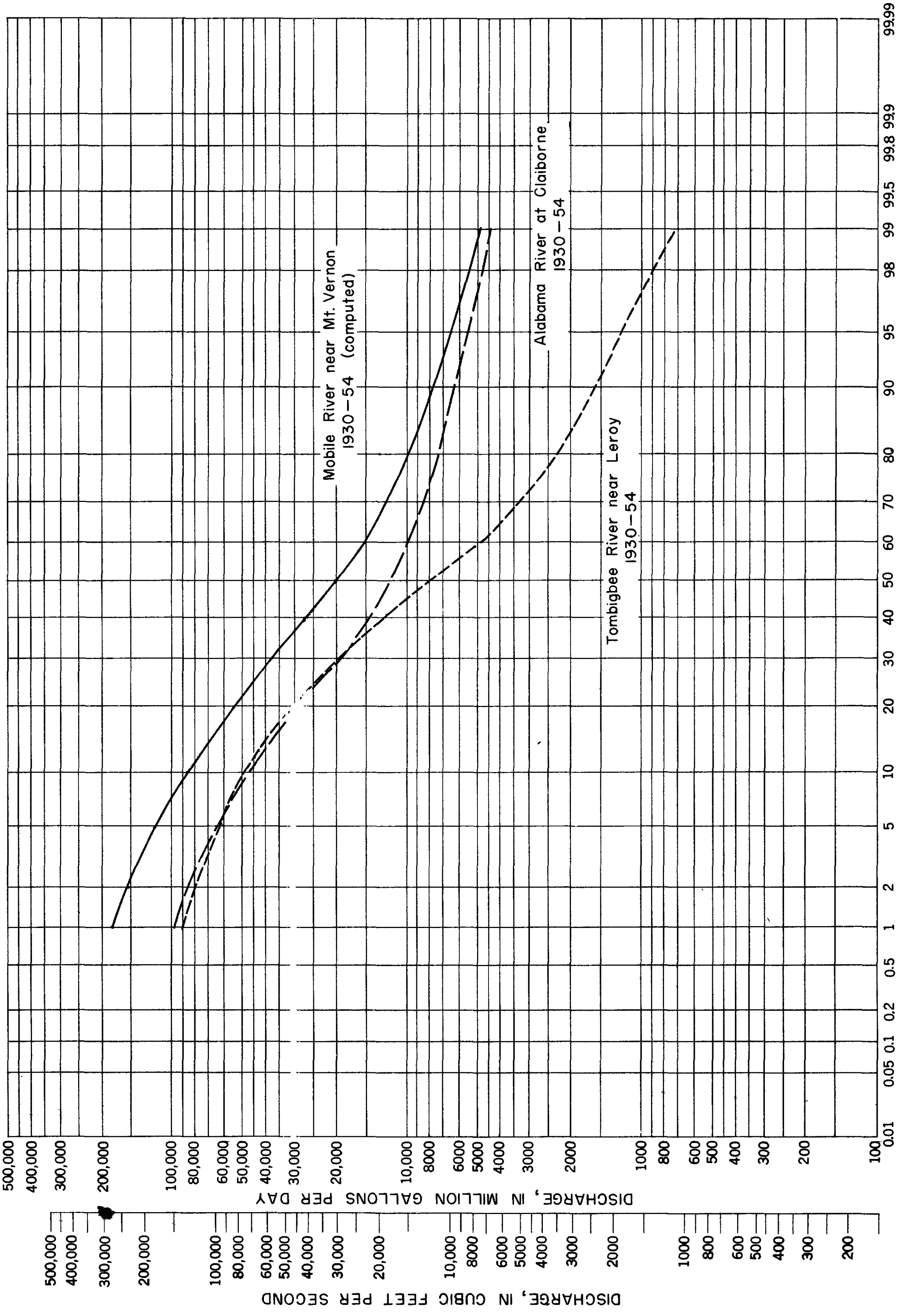

Figure 5.—Duration curve of daily flow, Alabama-Tombigbee-Mobile River system.

Table 2.—Duration of daily flow at gaging stations in the Mobile area

Percent of time discharge indicated was equaled or exceeded	Discharge per square mile of drainage area								
	Chickasaw Creek near Whistler			Escatawpa River near Wilmer			Big Creek near Mobile		
	Water years 1952–54 cfs/sq mi	Water years 1939–54 1/ cfs/sq mi	Water years 1939–54 1/ mgd/sq mi	Water years 1946–54 cfs/sq mi	Water years 1939–54 1/ cfs/sq mi	Water years 1939–54 1/ mgd/sq mi	Water years 1946–50 cfs/sq mi	Water years 1939–54 1/ cfs/sq mi	Water years 1939–54 1/ mgd/sq mi
1	7.55	11.8	7.63	14.2	14.7	9.50	14.2	12.9	8.34
2	6.05	9.90	6.40	11.1	11.5	7.43	10.7	10.0	6.46
3	5.20	8.65	5.59	9.40	9.70	6.27	9.25	8.30	5.36
5	4.22	7.15	4.62	7.30	7.50	4.85	7.40	6.33	4.09
7	3.57	6.15	3.97	6.05	6.10	3.94	6.35	5.27	3.41
10	2.95	5.08	3.28	4.77	4.90	3.17	5.35	4.30	2.78
15	2.28	3.93	2.54	3.50	3.64	2.35	4.31	3.37	2.18
20	1.87	3.32	2.15	2.74	2.84	1.84	3.69	2.87	1.85
30	1.37	2.60	1.68	1.82	1.89	1.22	2.94	2.28	1.47
40	1.06	2.21	1.43	1.27	1.37	.885	2.48	1.95	1.26
50	.855	1.87	1.21	.918	1.00	.646	2.13	1.63	1.05
60	.690	1.52	.982	.650	.742	.480	1.87	1.37	.885
70	.558	1.18	.763	.459	.520	.336	1.63	1.16	.750
80	.451	.880	.569	.332	.378	.244	1.41	.990	.640
85	.402	.748	.483	.279	.317	.205	1.30	.910	.588
90	.352	.618	.399	.231	.264	.171	1.18	.825	.533
93	.311	.538	.348	.199	.230	.149	1.11	.755	.488
95	.278	.472	.305	.174	.205	.132	1.06	.695	.449
97	.237	.390	.252	.144	.171	.111	.980	.605	.391
98	.210	.333	.215	.125	.149	.0963	.935	.540	.349
99	.172	.251	.162	.103	.117	.0756	.875	.442	.286

1/ Computed.

(table 3) cover only the low flows; therefore, the computed values are less accurate than values based on continuous streamflow records.

The purpose of extending records in this manner is twofold: longer records make a more exact definition of streamflow characteristics possible; and records that cover a common period of time make direct comparisons possible.

Flow-duration data for the tributary streams are shown in cubic feet per second per square mile of drainage area, and in million gallons per day per square mile of drainage area. These data can be used to estimate the flow at other places on the stream by assuming equal yield for all parts of the drainage area. For example, if information is desired on Escatawpa River at a place where the drainage area is 400 square miles, the flow-duration data for the site can be estimated by simply multiplying 400 times the listed data for Escatawpa River near Wilmer (table 2). A flow of 53 mgd (400 sq mi x 0.132) may be expected to be equaled or exceeded 95 percent of the time; in like manner, 68 mgd (400 sq mi x 0.171) may be expected to be equaled or exceeded 90 percent of the time.

The computed flow-duration data for the period 1939-54 were used because they are for a longer period and therefore are probably more representative than the data for the period of record, 1946-54.

Care should be exercised in using these data because not all parts of most drainage basins have equal yield or the same runoff characteristics. In general the possible error increases with an increase in the distance between the gaging station and the place about which information is desired. Variation of the geologic structure is the principle cause of the lack of uniformity of dry-weather runoff from various parts of some drainage basins. Streams that cut through sands and gravels will normally have a much better dry-weather yield than streams indented in clays and shales.

Alabama-Tombigbee-Mobile Rivers System

The Mobile River, formed by the confluence of the Alabama and Tombigbee Rivers about 30 miles north of the metropolitan area, flows through the Tensaw swamp for its entire length. The swamp is a labyrinth of channels, lakes, and bayous; and the stream finally flows into Mobile Bay in 5 distinct natural channels. The entire flow is confined to one channel for a distance of only about 5½ miles, from the confluence of the Alabama and Tombigbee Rivers to the division between the lower Mobile River and the Tensaw River. Flows greater than 100,000 cfs (about 65,000 mgd) are in part discharged over the Tensaw swamp.

The Mobile River and the lower reaches of the Tombigbee and Alabama Rivers are affected by tidal fluctuations except during periods when the streams are discharging substantial flood flows. The many

Table 3.—Probable duration of low flow at supplemental gaging sites in the Mobile area

Percent of time discharge indicated was equaled or exceeded	Discharge per square mile of drainage area							
	Bassett Creek near Wagerville (Water years 1939-54)		Lewis Creek near McIntosh (Water years 1939-54)		Bilbo Creek near McIntosh (Water years 1939-54)		Bates Creek near Calvert (Water years 1939-54)	
	cfs/sq mi	mgd/sq mi	cfs/sq mi	mgd/sq mi	cfs/sq mi	mgd/sq mi	cfs/sq mi	mgd/sq mi
70	0.47	0.30	0.40	0.26	0.40	0.26	0.37	0.24
80	.27	.17	.18	.12	.16	.10	.14	.090
85	.20	.13	.11	.071	.10	.065	.075	.048
90	.14	.090	.070	.045	.063	.041	.043	.028
93	.11	.071	.047	.030	.042	.027	.026	.017
95	.092	.059	.036	.023	.032	.021	.019	.012
97	.066	.043	.022	.014	.020	.013	.010	.0065
98	.052	.034	.015	.0097	.013	.0084	.0064	.0041
99	.034	.022	.0082	.0053	.0069	.0045	.0029	.0019

Percent of time discharge indicated was equaled or exceeded	Discharge per square mile of drainage area							
	Cedar Creek near Mount Vernon (Water years 1939-54)		Bayou Sara near Saraland (Water years 1939-54)		Eightmile Creek near Eight Mile (Water years 1939-54)		Threemile Creek near Crichton (Water years 1939-54)	
	cfs/sq mi	mgd/sq mi	cfs/sq mi	mgd/sq mi	cfs/sq mi	mgd/sq mi	cfs/sq mi	mgd/sq mi
70	0.53	0.34	1.1	0.71	1.9	1.2	1.6	1.0
80	.38	.25	.81	.52	1.7	1.1	1.4	.90
85	.32	.21	.68	.44	1.6	1.0	1.3	.84
90	.27	.17	.56	.36	1.5	.97	1.2	.78
93	.23	.15	.48	.31	1.5	.97	1.2	.78
95	.21	.14	.42	.27	1.4	.90	1.1	.71
97	.17	.11	.34	.22	1.3	.84	1.0	.65
98	.15	.097	.29	.19	1.2	.78	.95	.61
99	.12	.078	.21	.14	1.1	.71	.83	.54

channels, bayous, and lakes fill on a rising tide and empty on a falling one. The tidal effect is known to be sufficient at times to cause the Mobile River at Mount Vernon to flow upstream.

It has been generally recognized that the flow in the Mobile River is practically equal to the combined flow of the two headwater streams. Until recently more accurate definition of the pattern of flow did not appear to be warranted. Now, however, questions have arisen in connection with recent developments on the Mobile River that show the need for more nearly accurate information.

Discharge

In times of low flow the Alabama River is the major contributor to the Mobile River. Its naturally good low-flow characteristics are improved by considerable storage capacity at power-plant reservoirs on its headwater streams.

The Tombigbee River at the gaging station near Leroy has a drainage area comparable to the drainage area of the Alabama River at Claiborne. However, in periods of low water, the yield of this stream is much less than that of the Alabama River. Some regulation is exercised over the low flows in the stream by the navigational locks and dams. It is expected that additional control will be exercised by the new lock and dam at Demopolis.

The annual runoff of the Mobile River is the combined runoff of the Alabama River at Claiborne and the Tombigbee River near Leroy, and a small runoff from the drainage area between the gaging stations and the confluence of the rivers. However, the flow of the Mobile River for any particular time can not be so easily related to the flow at the upstream gaging stations. Channel storage and tide have a substantial effect on the rate of flow of the Mobile River.

A gaging station was established on the Mobile River at Mount Vernon and operated for 1 year to make possible some appraisal of the flow characteristics of the Mobile River and evaluation of the relation between the combined flows at the upstream gaging stations and the flow in the Mobile River. This station was located about 2 miles above the division into the Tensaw River and the lower Mobile River on the reach of river where the flow is generally confined to one channel. Except during times of flood, the discharge at the station varied considerably during the daily tidal cycle. Negative, or upstream, flow occasionally occurred for a few hours on the right combination of high tides and low flows. Typical stage and discharge hydrographs for selected tidal cycles are shown in figure 6.

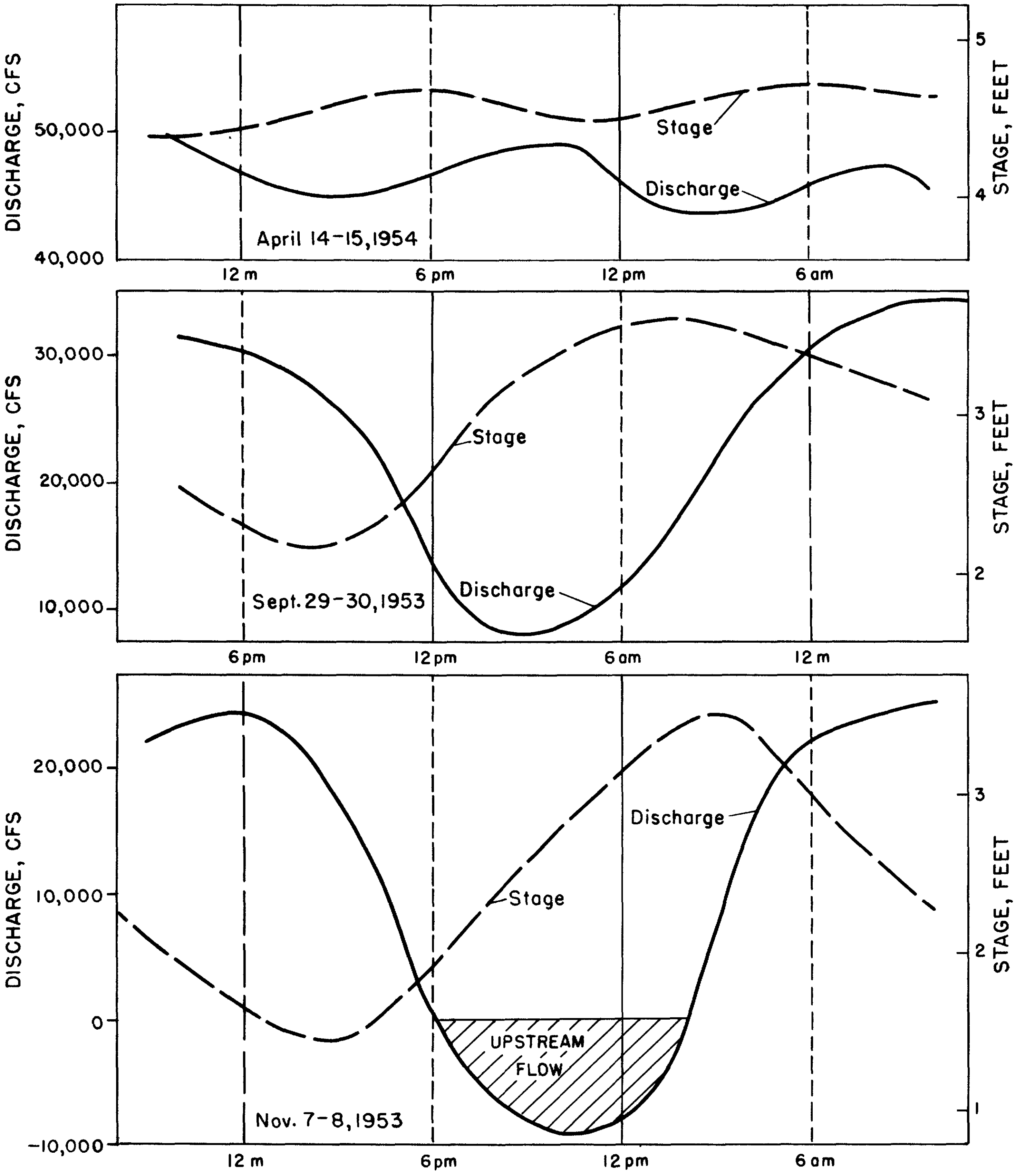

Figure 6.—Discharge of the Mobile River near Mount Vernon during typical tidal cycles.

Daily discharges were affected by the tide to a lesser degree; however, the daily discharges did vary conversely with the variation in the daily mean tide. A high daily mean tide held water in storage in the channels, bayous, and lakes above the station, and a low daily mean tide allowed water to escape from these storage areas.

Average discharges for a week or longer will generally not be subject to these variations caused by

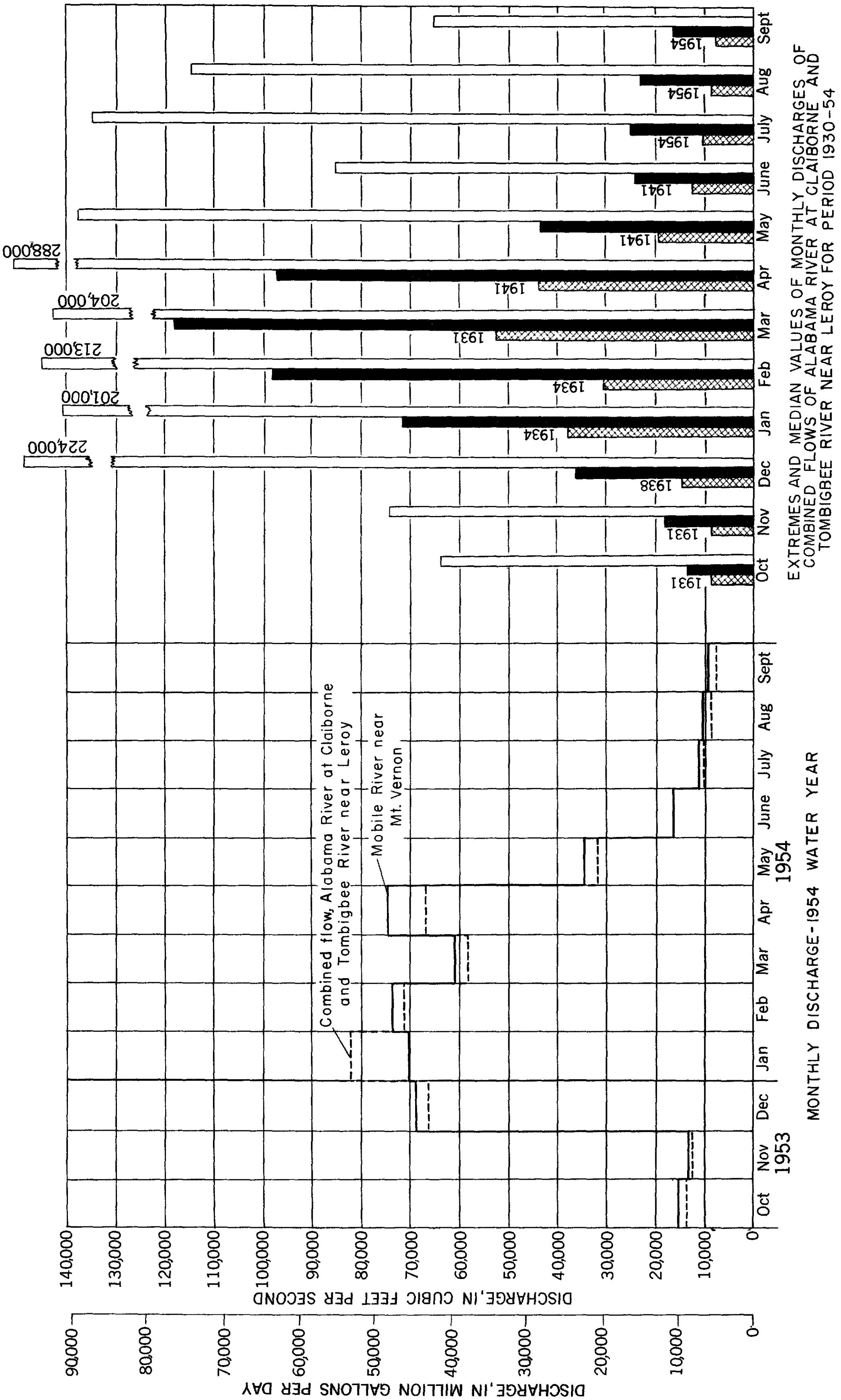

Figure 7.—Monthly discharge, Mobile River near Mount Vernon.

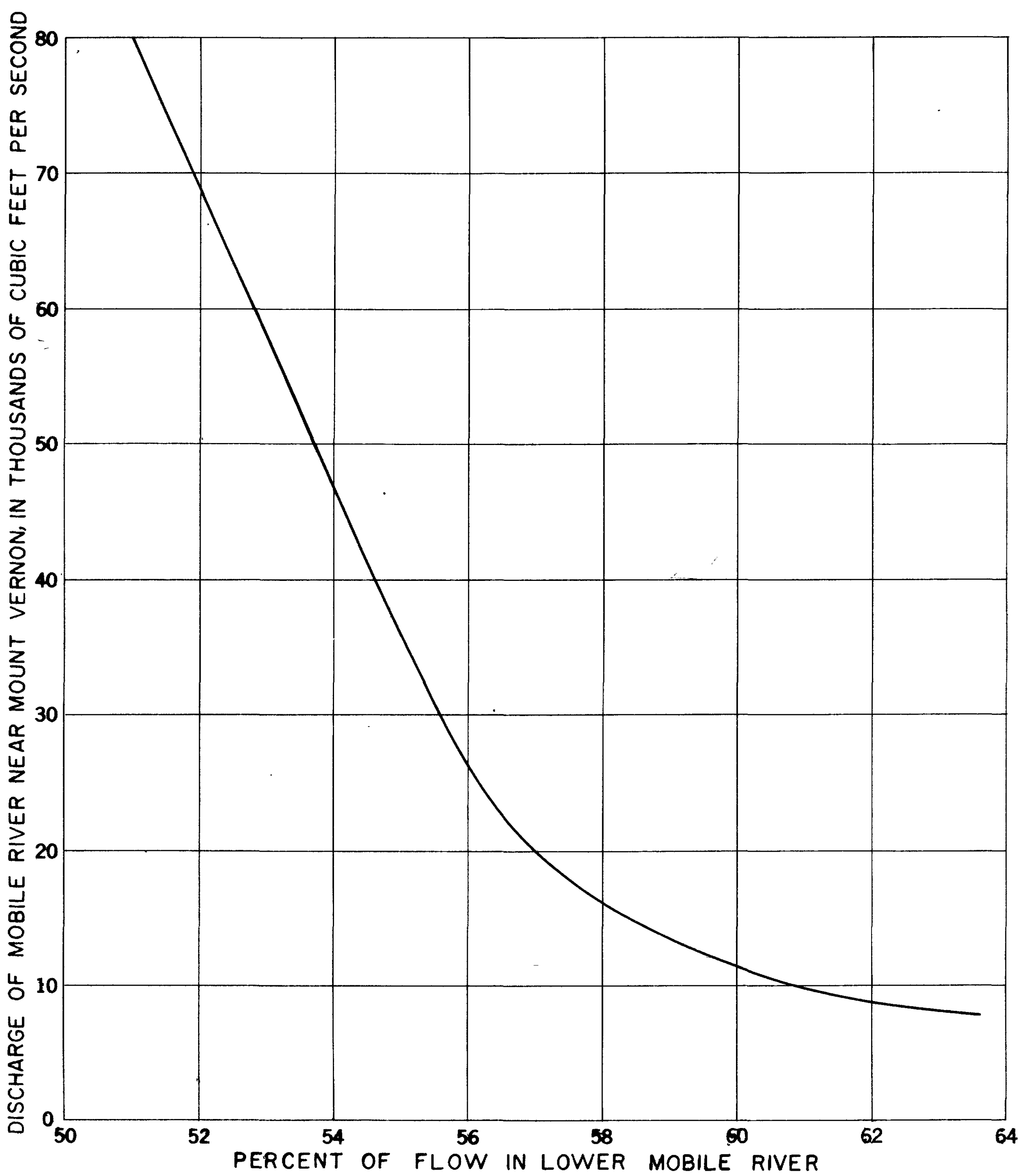

Figure 8.—Division of flow between Mobile and Tensaw Rivers.

tides, but they will be subject to the effect of water going into or coming out of storage on a generally rising or falling stage. Average discharges for the months from October 1953 through September 1954 are shown in figure 7. For comparison, the combined flow of the upstream stations is also shown in this figure. It is evident that a considerable amount of water is retained in storage on a generally rising stage and is released on a generally falling one. For this reason, months of high average flow are not always closely comparable to the combined flows of the upstream stations. On the other hand, the monthly averages for periods of low flow appear to be quite closely comparable to the monthly average of the combined flow, especially if the combined flow is corrected for the inflow in the intervening area between gaging stations.

Duration of flow data for the Mobile River at Mount Vernon are shown in figure 5. The maximum, minimum, and median values of the average discharge for each month for the combined flows of the upstream stations for the period 1930 to 1954 are shown in figure 7. As occurrences in the past are indications of occurrences in the future, the diagram can be used to estimate the probable range of conditions that may be generally expected.

The Mobile River first divides into the Tensaw and lower Mobile Rivers. The flow in these two streams is about equally divided at bankful stage, but at lower stages the more efficient channel of the lower Mobile River carries an increasingly larger proportion of the total flow (fig. 8). Although this relation is believed to be reliable for mean daily flows, it is not necessarily reliable if used for average flows for shorter periods or for estimating the division of flow for any particular instant, especially when varying tidal effects occur within a tidal cycle. Once, for a short period, water was known to flow simultaneously up the Tensaw River and down the lower Mobile River.

The Tensaw River divides several times before it empties into Mobile Bay. No information is available on the distribution of flow at these divisions. The Mobile River does not divide further until just north of the metropolitan area, nor do any streams of appreciable size flow into this reach.

Floods

Not much information is available on floods in the Mobile River. Large floods occurred in 1929, 1938, and 1948. Information is available on these floods at the upstream gaging stations, but because the flood flows were mostly confined to the uninhabited swampland little information is available about them on the Mobile River. Water-surface profile data on a lesser flood in April 1951 were obtained from the Corps of Engineers and are shown in figure 9. For comparison, a reported water-surface elevation of the 1929 flood at the Mount Vernon gaging station and the approximate elevation of the 25-year flood are shown in the same figure. A "25-year flood" is a flood of the magnitude that would be equaled or exceeded on the average of once in 25 years.

Floods of another type occur on the lower reach of the Mobile River when strong winds from the Gulf of Mexico cause the water of Mobile Bay to pile up at the head of the bay. When these winds reach the velocities attained in the infrequent hurricanes, the piling up of water floods low-lying areas in the city. The most destructive hurricanes of this century occurred in September 1906 and in July and October 1916. The July 1916 storm is reported to have produced a tide of 11.6 feet above mean sea level at Mobile.

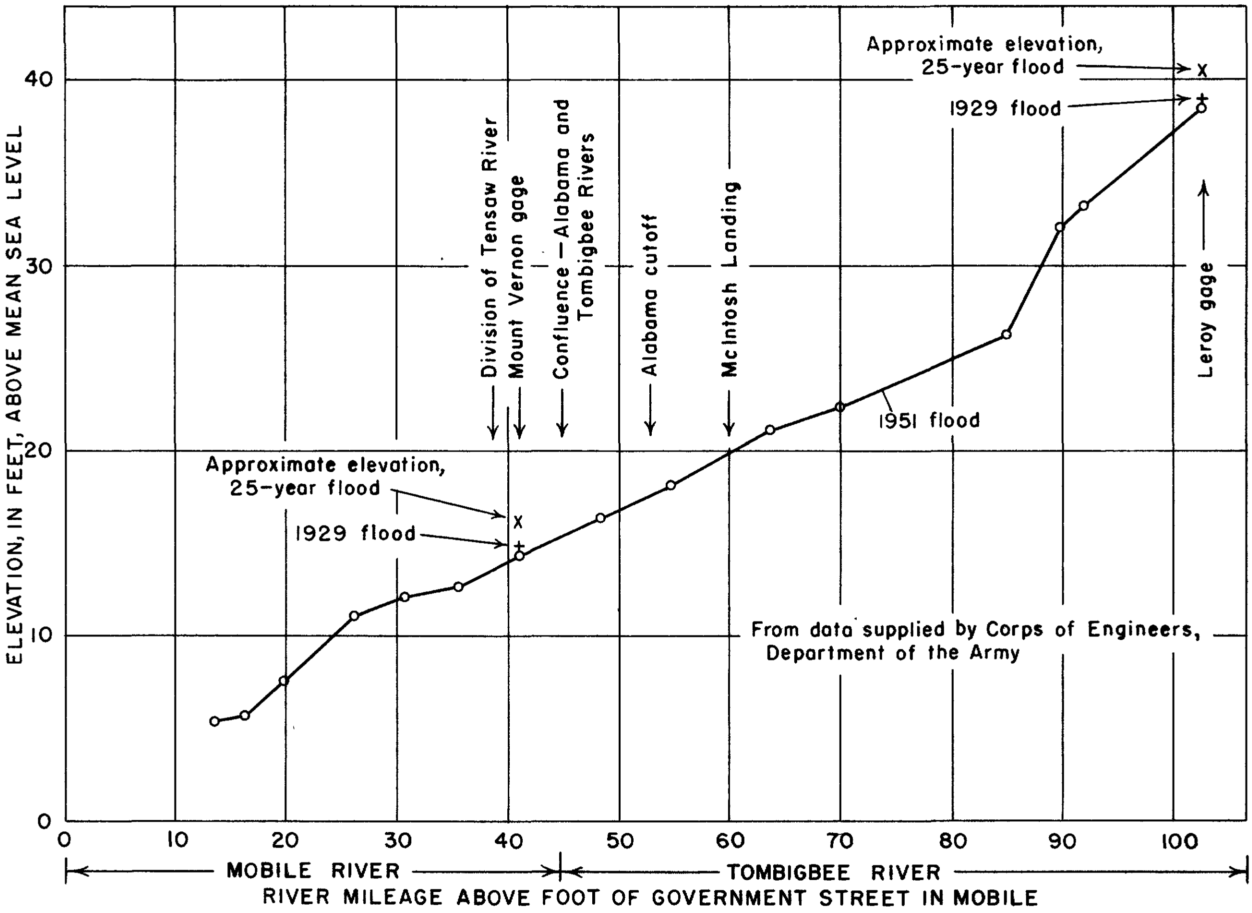

Figure 9.—Profile of April 1951 flood on Mobile River.

Quality of Water

In order to determine the daily variation in the chemical and physical character of the water of the Mobile River, samples were collected daily at the Mount Vernon gaging station from October 1, 1953, to September 30, 1954. Ten daily samples were composited for each sample for comprehensive chemical analysis, the results of which are given in table 4. Data in this table indicate only a very general relation between the discharge of the river and the quality of its water. Probably the most significant quality feature, at least for industrial consumers, is the lack of extreme variation in the chemical character of the water. Although the 10-day averages of river discharge ranged from 5,278 mgd to 76,970 mgd, the dissolved solids ranged from only 73 to 126 ppm and averaged 95 ppm. The rather unusual uniform composition of the Mobile River water is shown graphically in figure 10.

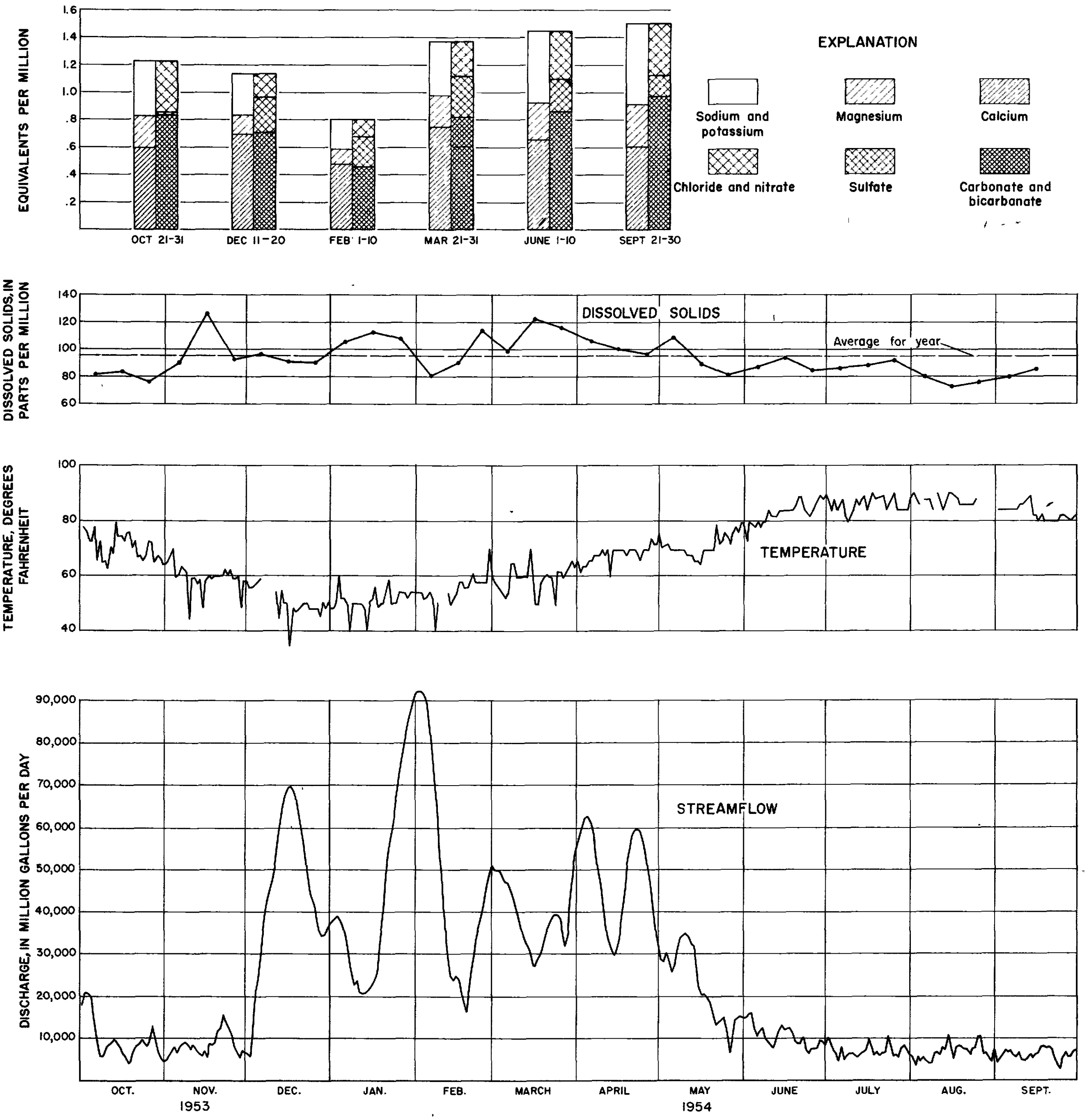

Figure 10.—Relation between streamflow and the chemical and physical character of the Mobile River water near Mount Vernon from October 1953 to September 1954.

Table 4.—Chemical quality of Mobile River water near Mount Vernon

[Chemical constituents are in parts per million]

Date of collection	Discharge (mgd)	Silica (SiO2)	Iron (Fe)[1]	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO3)	Dissolved solids	Hardness as CaCO3: Calcium, magnesium	Hardness as CaCO3: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color	Alumium (Al)	Sediment
Oct. 1-10, 1953	13,960	6.3	0.18	12	2.6	5.1	1.5	48	2.0	6.0	0.1	0.9	82	41	1	109	7.5	12	0.19	20
Oct. 11-20	7,477	6.8	.13	12	2.7	7.0	1.2	49	.5	8.5	.1	.6	84	41	1	122	7.5	15	.08	27
Oct. 21-31	8,745	4.7	.05	12	2.8	8.3	1.0	51	.5	9.0	.1	.2	76	41	0	125	7.4	4	.05	44
Nov. 1-10	7,581	9.7	.09	13	3.3	9.8	1.2	56	.5	10	.1	.2	90	46	0	137	7.7	7	.05	38
Nov. 11-20	8,221	29	.10	14	3.5	11	1.2	66	5.0	9.0	.3	.2	126	49	0	152	8.0	17	.06	25
Nov. 21-30	10,320	6.3	.07	12	3.4	11	1.2	51	5.0	14	.3	.2	94	44	2	145	7.3	9	.00	24
Dec. 1-5	14,360	11	.00	13	3.2	14		51	9.8	16	.1	.5	96	46	4	160	7.5	......	....	25
Dec. 11-20	63,980	9.9	.06	14	1.7	5.1	1.6	44	12	5.2	.1	.8	92	42	6	119	7.2	30	.19	83
Dec. 21-31	42,350	13	.03	12	3.3	5.9	1.3	39	14	7.0	.1	.9	91	44	12	124	7.2	30	.16	64
Jan. 1-10, 1954	32,640	17	.09	14	3.3	7.7	1.4	47	15	9.0	.1	1.1	105	48	10	143	7.4	23	.11	87
Jan. 11-20	26,990	18	.18	16	2.9	9.9	1.4	52	18	9.5	.1	1.1	112	52	9	160	7.6	11	.02	66
Jan. 21-31	74,060	16	.20	15	2.9	6.0	1.6	48	16	4.5	.1	1.1	109	49	10	135	7.2	26	.14	164
Feb. 1-10	76,970	7.4	.07	9.7	1.4	3.8	1.5	29	10	3.5	.1	1.1	81	30	6	90.4	7.3	18	.20	98
Feb. 11-20	24,470	10	.26	12	2.3	5.7	1.3	38	12	7.8	.1	1.2	91	39	8	118	7.2	50	.04	85
Feb. 21-28	40,270	21	.33	14	3.1	8.4	1.2	47	12	8.2	.1	1.1	114	48	9	146	7.5	50	.05	91
Mar. 1-10	46,150	14	.27	14	2.7	6.2	1.3	42	15	6.0	.1	1.1	99	46	12	136	7.3	80	.07	46
Mar. 11-20	31,570	10	.23	13	3.5	6.5	1.2	54	12	7.5	.1	1.2	123	47	3	130	7.9	50	.02	85
Mar. 21-26, 29-31	41,980	12	.28	15	2.8	6.7	1.4	50	14	8.5	.4	1.4	116	49	8	141	7.3	25	.15	48
Apr. 1-10	55,630	9.0	.22	13	2.9	5.6	1.3	46	14	6.2	.4	1.5	106	44	7	125	7.0	15	.55	55
Apr. 11-20	39,440	9.7	.23	14	2.7	5.8	1.5	46	13	7.0	.1	1.3	102	46	8	134	7.3	15	.00	52
Apr. 21-24, 26-30	49,460	13	.28	15	2.7	5.2	1.4	51	12	8.0	.1	1.1	97	49	7	128	7.2	40	.08	59
May 1, 3-10	30,790	20	.14	15	2.9	7.6	1.5	56	13	9.0	.1	1.3	109	49	3	144	7.3	18	.00	49
May 11-20	24,280	11	.16	14	2.8	5.3	1.4	52	10	8.0	.1	1.3	90	46	4	128	7.1	23	.02	47
May 21-31	13,310	8.0	.03	13	3.4	6.3	1.3	51	10	10	.1	1.2	82	46	5	132	7.1	6	.00	29
June 1, 2, 4-10	11,980	8.6	.01	13	3.4	8.2	1.3	52	12	12	.1	1.0	88	46	4	143	7.3	4	.00	30
June 12, 13, 15-20	11,090	5.6	.02	14	3.8	9.5	1.3	54	13	13	.1	.6	94	51	6	157	7.2	5	.00	22
June 21, 22, 24-30	8,473	5.6	.01	13	3.8	9.2	1.3	54	12	13	.1	.7	85	48	4	147	7.2	3	.01	26

July 1-8, 10	7,180	7.3	.02	13	3.8	9.6	1.3	56	10	13	.1	.9	87	48	2	150	7.2	4	.00	30
July 11-15, 17-18	6,689	7.2	.02	14	3.4	10	1.2	55	11	13	.1	.7	89	49	4	154	7.3	4	.11	26
July 21, 22, 24-28, 30, 31	6,773	13	.01	14	3.9	9.5	1.2	59	9.8	11	.1	.6	92	51	3	156	7.4	5	.15	34
Aug. 1, 3-10	5,278	9.8	.08	12	3.8	8.3	1.2	56	7.8	9.0	.1	.5	80	46	0	139	7.2	7	.05	19
Aug. 12, 14-15, 17-18	8,777	8.8	.00	11	3.3	7.6	1.2	50	7.5	8.0	.1	.7	73	41	0	125	7.4	6	.11	28
Aug. 23, 24, 29	7,038	14	.04	12	3.9	12	1.6	60	10	13	.1	.4	94	46	0	159	7.5	7	.11	41
Sept. 1, 2, 4, 8-10	5,670	14	.00	12	3.4	9.1	1.3	57	8.0	8.5	.1	.6	80	44	0	137	7.4	4	.12	13
Sept. 13-18	6,780	16	.02	11	3.3	10	1.2	55	7.5	9.0	.2	.3	85	41	0	136	7.4	7	.06	19
Sept. 21-25, 28, 30	5,313	15	.02	12	3.7	13	1.3	58	8.0	12	.2	.4	96	45	0	147	7.6	7	.03	17
Maximum	76,970	29	.33	16	3.9	14	1.6	66	18	16	.4	1.5	126	52	12	160	8.0	80	.55	164
Minimum	5,278	4.7	.00	9.7	1.4	3.8	1.0	29	.5	3.5	.1	.2	73	30	0	90.4	7.0	3	.00	13
Average	24,330	12	.11	13.1	3.1	8.0	1.3	51	10	9.2	.1	.8	95	46	4	137	7.4	18	.09	48

1/ In solution at time of analysis.

As the discharge of the river increased, a general increase was noted in the concentration of silica, sulfate, color, and sediment; objectionable concentrations, however, were observed only for iron, color, and sediment. The generally good quality of the water is shown in figure 10.

The temperature of industrial water supplies is of great economic importance because of the enormous volume used for cooling. For this reason, daily water temperature readings were taken at the Mount Vernon station (fig. 10).

Salinity of Mobile River
By Corps of Engineers, Mobile District

The Mobile River, formed by the confluence of the Tombigbee and Alabama Rivers, flows southward 46 miles to empty into Mobile Bay, an estuary of the Gulf of Mexico at Mobile. Six miles below its source, the Mobile River divides; the west fork is the Mobile River and the east fork is a branch of the Tensaw River. The Mobile River follows a winding course from its head to Mobile Bay. In general, the banks are from 3 to 8 feet high. Between miles 20 and 45 (miles above Government Street in Mobile), the river has cut into the hills at several places along the west bank to form bluffs 20 to 40 feet high. The river upstream from the Louisville & Nashville Railroad bridge at mile 13.6 varies from 500 to 1,200 feet in width. The Tensaw is also a tortuous stream, flowing southward in the same general direction; it enters Mobile Bay about 2 miles to the east of the Mobile River. The area between these two rivers consists of heavily wooded swampland in the upper reaches and low marshland in the lower reaches. The Tensaw River is now used as a harbor for a reserve fleet of ships, but it is not maintained for navigation by the Corps of Engineers.

Determination of the salinity line in the Mobile River and its tributaries was first undertaken in compliance with a resolution by the Committee on Rivers and Harbors of the House of Representatives, which was adopted October 16, 1944. Observations in the river were made from November 9, 1944, to January 9, 1946, and a report was prepared (U. S. Congress Documents, 1949). Additional salinity investigations were authorized by the Committee on Public Works of the House of Representatives in a resolution adopted June 11, 1952.

In connection with this latter resolution, observations to determine salt-water encroachment in the lower Mobile River were made during the low-water seasons, September through December, 1952, 1953, and 1954. Between July 31 and August 4, 1954, samples were collected at 2-hour intervals for a period of 96 hours. The ranges sampled were at about 1-mile intervals between mile 13.6 (Louisville & Nashville Railroad bridge) and mile 18, the uppermost point of salt-water encroachment. During this period, the Tombigbee and Warrior Rivers were being impounded by the new Demopolis lock and dam and presumably no flow entered the Mobile River from this source. Sampling for the 1954 low-water season began on September 14 and ended December 23. A total of 2,246 samples collected during this period have been analyzed.

The location of the salinity line in the river was determined from a series of water samples analyzed in the field by a volumetric titration method. Other basic data, such as streamflow and tidal characteristics, were also observed during the sampling periods.

Water sampling

For the studies made in 1944–46, sampling ranges were established at intervals of 3 to 7 miles for the length of the Mobile River. Salinity samples were taken at all ranges about every 2 weeks for the entire period. It was found that salt water invaded the Mobile River below the Louisville & Nashville Railroad bridge (mile 13.6) about 60 percent of the time during a year of normal low water. Because salt water prevailed most of the year below the bridge, it was decided that this study would investigate principally the ingress of salt water above the bridge.

In the 1952, 1953, 1954 investigations the river-mile points were located and marked between the Louisville & Nashville tide gage at mile 13.6 and the Barry gage at mile 31.0. (See fig. 11.) Sampling stations identified by miles above the foot of Government Street in Mobile, were established at each mile and at some half-mile intervals, as shown in figure 12. In general, samples were taken at three depths along the right bank, in the middle, and along the left bank of the river. During the 1953 and 1954 seasons, water samples were analyzed in the field so that the location of the salinity line could be established immediately. This permitted sampling to be concentrated in the reach extending a mile above and below the uppermost limits of the salt-water wedge.

Tidal characteristics

Three recording tide gages have been operated by the Corps of Engineers in the lower Mobile River during these investigations. They are located at Alabama State Docks, mile 1.0, the Louisville & Nashville Railroad bridge, mile 13.6, and the Alabama Power Company's Barry steam plant, mile 31.0. In addition to these tide gages, the U. S. Geological Survey operated a recording gage in the upper Mobile River near Mount Vernon landing from October 1953 through January 1955. Mount Vernon landing is at mile 41.3, about 2.5 miles above the head of the Tensaw River.

All four gages recorded the same general shape and trend, except for time lag and difference in high and low elevation. Tides at Mobile are diurnal; that is, only one high and one low tide occur during a lunar day, except at the moon's quadrature when two highs and lows (neap tide) may occur with very little difference in vertical rise and fall. The amplitude of the tide depends in part upon the stage of the Mobile River and the distance upstream from the river mouth. At Mount Vernon, for example, the tidal effect practically disappears when the river reaches a stage of 7.5 feet above mean sea level. Spring tides, which occur at new and full moon, produce the greatest variation in the rise and fall of the tide.

Streamflows

For this investigation the upper Mobile River has been generally referred to as the reach between the formation of the Mobile and Tensaw Rivers, at mile 39, and the head of the Mobile River, at mile 45. Lower Mobile River extends from mile 39 to the mouth. Flows in the upper Mobile River as measured by the Geological Survey at Mount Vernon in 1953 and 1954 have been used. The Geological Survey developed the discharge-percentage curve (fig. 8), which shows the distribution of flow between the Tensaw and Mobile Rivers. Before 1953, the flow in the upper river had been determined by combining the flows measured at Leroy on the Tombigbee River and Claiborne on the

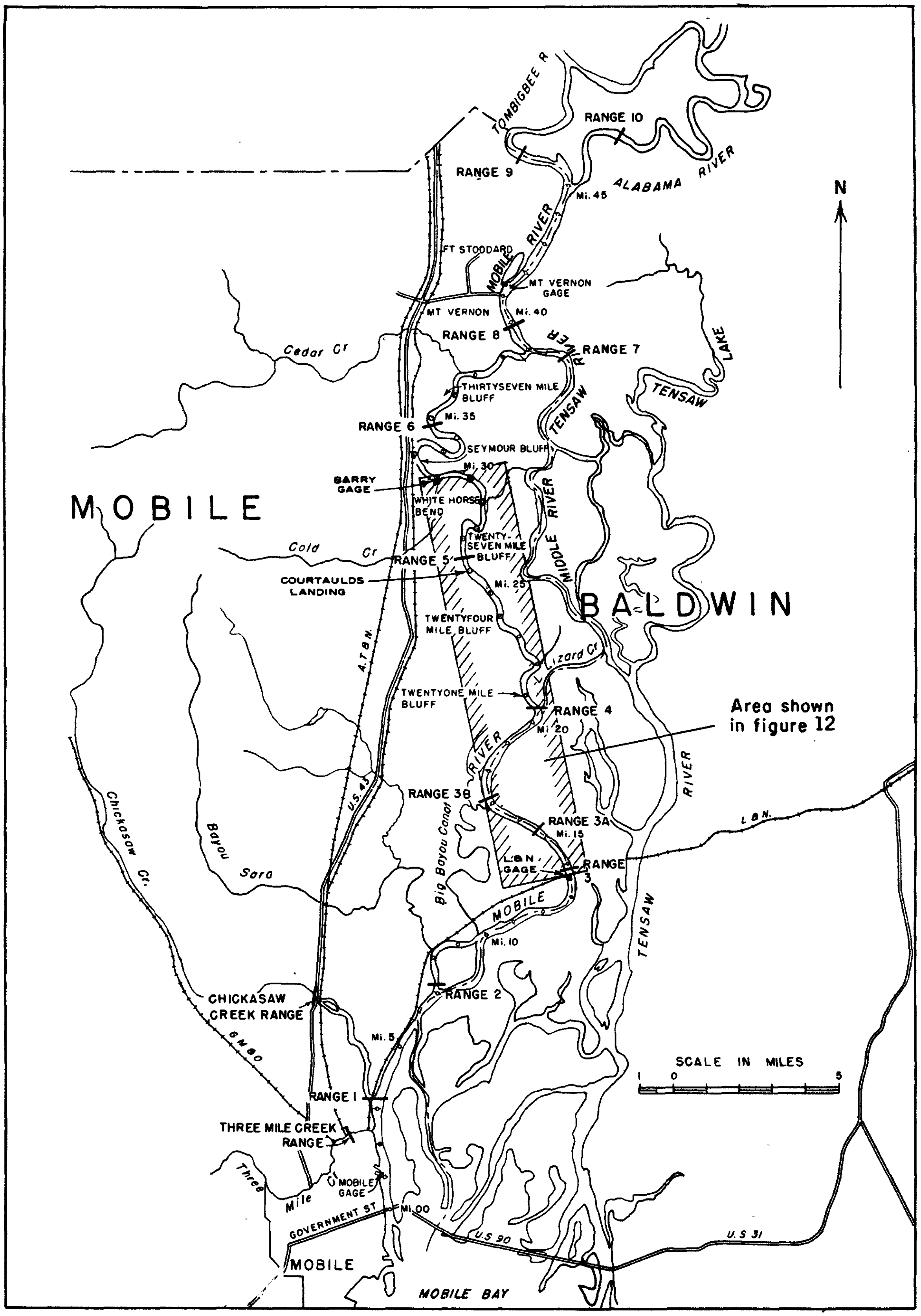

Figure 11.—Map of the Mobile River showing salinity sampling points (from Corps of Engineers).

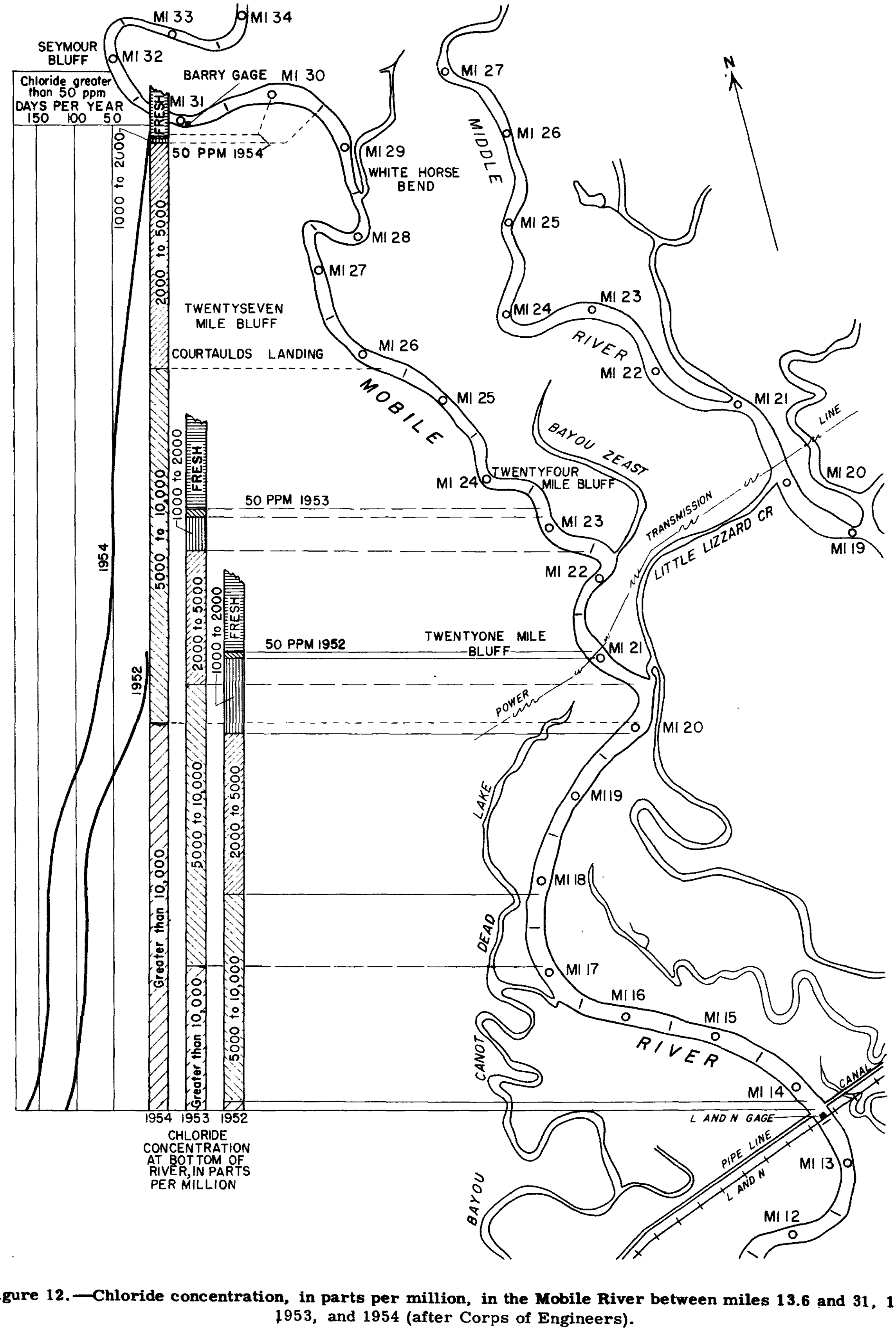

Figure 12.—Chloride concentration, in parts per million, in the Mobile River between miles 13.6 and 31, 1952, 1953, and 1954 (after Corps of Engineers).

Alabama River. The maximum, minimum, and average discharges for the sampling periods in 1952, 1953, and 1954 are shown in table 5.

Table 5.—Discharge of upper Mobile River and extent of chloride encroachment

Sampling period	Discharge in cubic feet per second			Position of 50 ppm chloride	
				River mile 1/	
	Max	Min	Daily average	Max	Min
1952	Combined discharge of Alabama and Tombigbee Rivers				
Sept. 1–30..	16,400	8,320	12,295	19.0	....
Oct. 1–31..	18,800	7,450	10,700	21.0	....
Nov. 1–30..	16,720	7,620	11,352	20.5	13.0
Dec. 1–17..	43,700	14,210	27,908	Below mile 13	
Mean	23,977	9,310	15,564		
1953	Discharge of Mobile River at Mount Vernon				
Oct. 1–31..	33,700	6,450	15,500	21.0	16
Nov. 1–30..	24,500	7,960	13,470	23.3	....
Dec. 1– 8..	65,300	9,780	35,197	....	....
Mean	41,166	8,063	21,390		
1954	Discharge of Mobile River at Mount Vernon				
Sept. 14–30..	12,800	4,310	9,709	27.5	20.0
Oct. 1–31..	15,800	5,840	9,850	30.0	17.5
Nov. 1–30..	15,300	6,150	10,400	29.0	14.0
Dec. 1–31..	16,600	4,310	10,800	17.5	13.5
Mean	15,125	5,153	10,190		
1955	Discharge of Mobile River at Mount Vernon				
Jan. 1–11..	52,700	15,300	39,500	9.5	....

1/ Mile 0: The foot of Government Street, Mobile.

The low-water period of 1954 was the lowest of record. September was the ninth consecutive month in which below normal precipitation occurred in the headwaters of the Mobile River system. The average for the 9-month period was about 58 percent of normal. Precipitation for the months of November and December were more nearly normal.

Results of investigation

The results of the analyses of samples for the July 31 to August 4, 1954, period are shown in figure 13, and the results for the 1954 low-water period are shown in figure 14.

Figure 13 further shows that discharges less than 6,000 cfs (3,880 mgd) in the lower Mobile River will not be sufficient to prevent the ingress of salt water. However, the influence of day-to-day changes in discharge on chloride concentrations and the position of the salinity line is apparent. The effect of sudden decreases in discharge on the ingress of salt water was shown clearly on August 2 when a pronounced decrease in discharge produced a rapid increase in the rate of salinity invasion. (See fig. 13.) An increase in discharge on the following day also showed a rapid decrease in the rate of salinity invasion.

Variations in chloride concentration definitely appear to be influenced by the rise and fall of the tide. Although the tidal variations are small during a neap tide, the effects on chloride concentrations are nonetheless evident. Figure 13 also shows that peak salinity concentrations may occur at any time during the 3 hours following high tide.

A chloride concentration of 50 ppm has been considered as a definite indication of salt-water encroachment. The maximum salinity encroachments in 1952, 1953, and 1954 are shown in figure 12. Figure 14 shows that the movement of saline water, as indicated by the position of water of 50 ppm concentration, follows the range of tide more closely than it follows the discharge. This is true only if the mean daily discharge is less than 6,000 cfs (3,880 mgd) in the lower Mobile River, which is about 62 percent of the flow at the head of the Mobile River. Previous studies indicated that the displacement of salt water in the upper reaches of the marginal zone is noticeable when the average flow exceeds 6,000 cfs. During September and October 1954, water of 50 ppm concentration advanced upstream as the tidal range increased from neap to spring tide, regardless of discharge, and receded downstream as the tidal range decreased from spring to neap tide. The effects of mean daily flows in excess of 6,000 cfs during the months of November and December are shown in figure 14.

Wind affects the tide and salinity. Strong north winds were responsible for the extreme low tides occurring on October 5, November 2, and December 6 (fig. 14).

The general conclusions that can be derived from the graphs, table, and results of tests presented here and from prior studies are as follows:

1. The invasion of salt water in the Mobile River during September and October 1954 is considered to have been greater than normal. River discharges for this period were the lowest of record, with the minimum at Mount Vernon being 4,310 cfs (2,790 mgd). The minimum discharges at the head of Mobile River were 7,450 cfs (4,820 mgd) in 1952 and 6,450cfs (4,169 mgd) in 1953.

2. The farthest point upstream reached by water of 50 ppm or more of chloride was observed at mile 30.0 on October 27, 1954, when the presence of water with 2,000 ppm chloride was found at mile 29.5 at a depth of 37.5 feet near the left bank of the river. Water with 50 ppm of chloride also reached mile 29.5 on October 13 and probably sometime between November 3 and 7, 1954, but it remained for only a short time (fig. 14).

3. The encroachment of salt water in 1954 does not depict normal salinity conditions in the Mobile River. Salt water will probably not advance farther than mile 23 during a normal low-water period and to this point for only a short time.

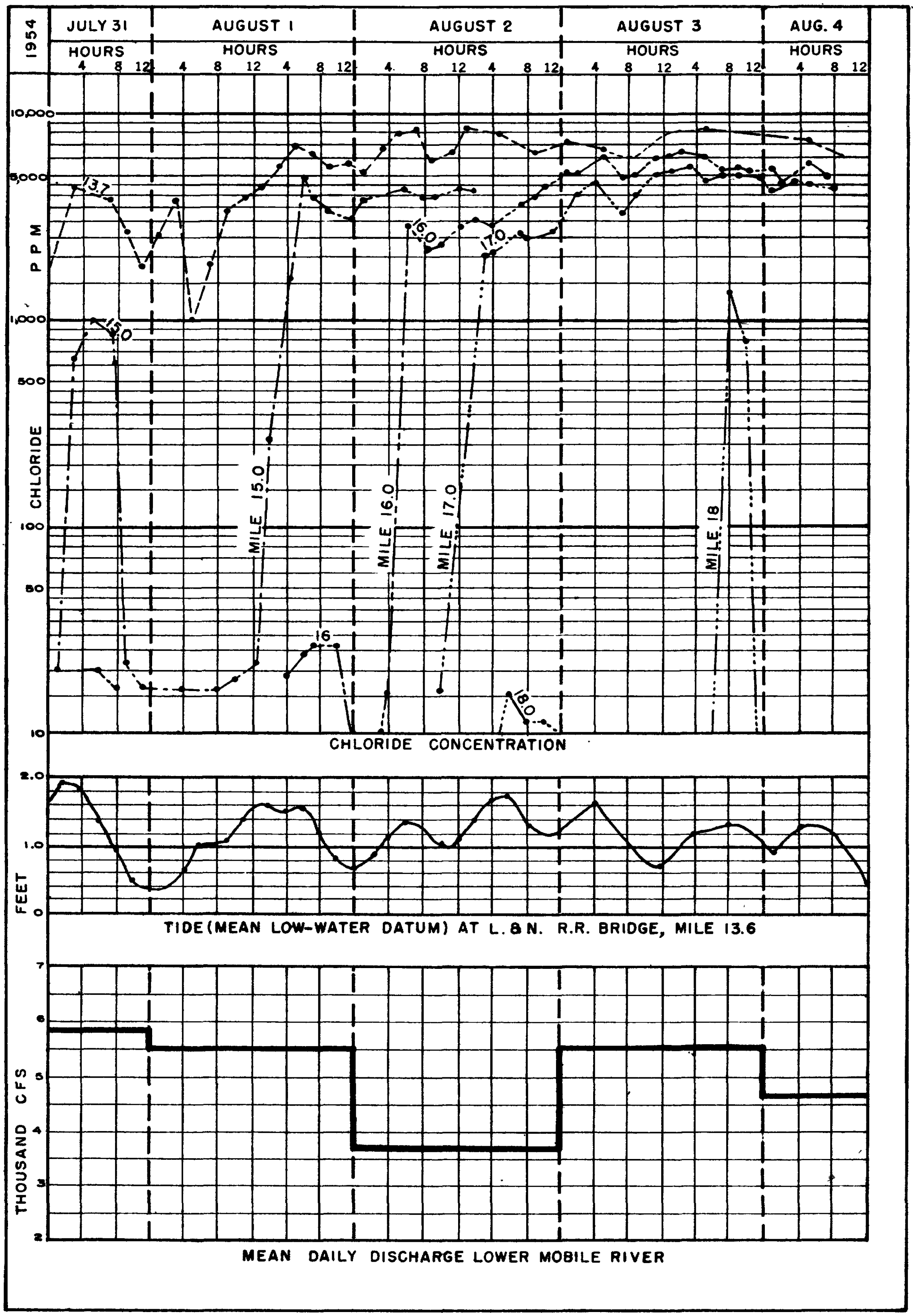

Figure 13.—Relation between discharge, in thousands of cubic feet per second, and chloride concentration, in parts per million, lower Mobile River (from Corps of Engineers).

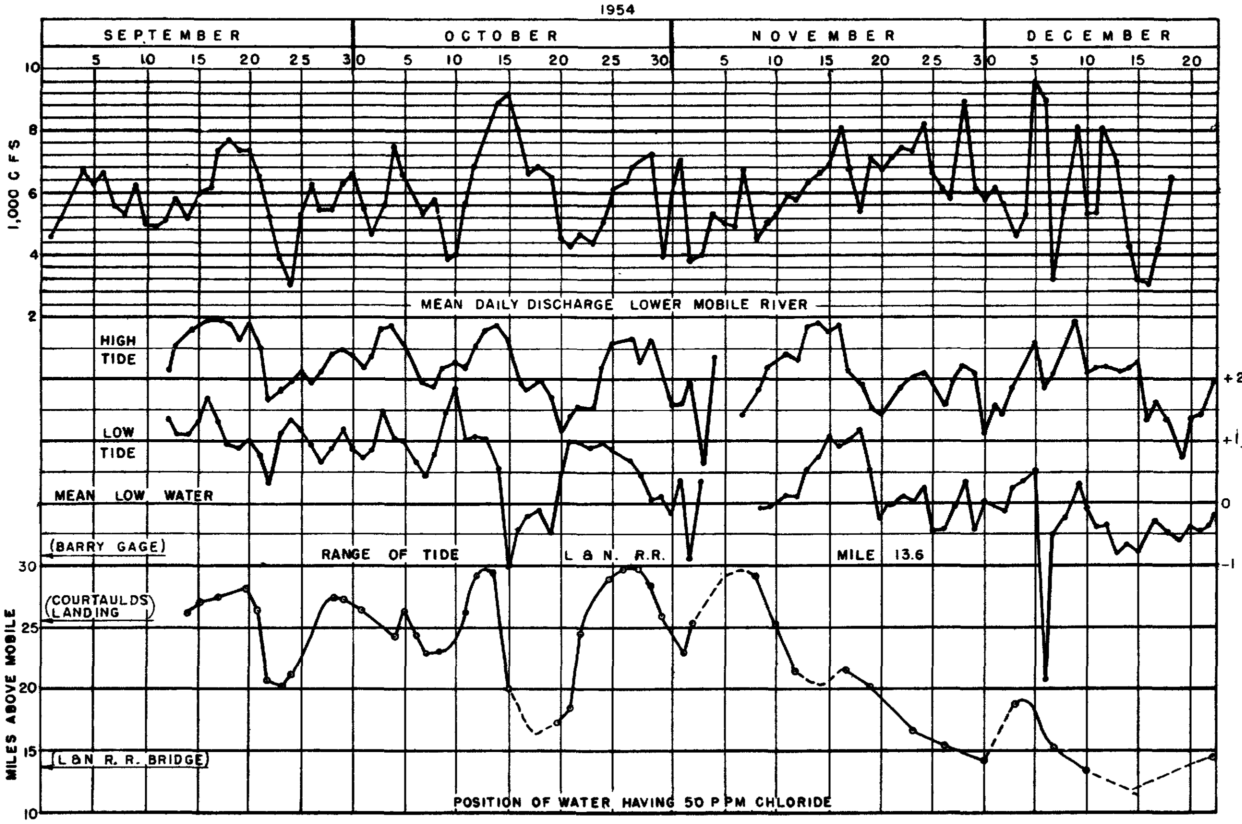

Figure 14.—Relation between discharge, in thousands of cubic feet per second, and tide and the position of water having a chloride content of 50 parts per million (from Corps of Engineers).

4. Under conditions existing at the time of this study, it was found that when the river flow decreased to a daily average of 6,000 cfs (3,880 mgd) in the lower Mobile River, the variation and extent of salt-water encroachment depended mostly upon tidal conditions. When the discharge exceeds a daily average of 6,000 cfs, the encroachment of salt water depends principally on discharge.

5. The extent of salt-water ingress or egress can be reasonably estimated when tidal conditions and river discharges are known.

6. The results obtained during normal low-water years indicate that water from the Mobile River from its head, at mile 45, to mile 21 will be satisfactory for industrial supply most of the time. Frequent occurrences of the extreme salinity of 1954 are unlikely.

Escatawpa River

The Escatawpa River drains an area immediately to the west of the Mobile River. It flows generally southward along the Alabama-Mississippi State line, finally crossing into Mississippi and flowing into the Pascagoula River a short distance upstream from where that stream flows into the Gulf of Mexico.

Daily discharge records have been collected since August 1945 at a site in the NW¼ sec. 19, T. 2 S., R. 4 W., at a bridge on State Highway 42 at the Alabama-Mississippi State line and 26 miles northwest of Mobile (drainage area, 506 square miles). The average discharge for the 9 water years (1946–54) was 987 cfs (638 mgd). The maximum discharge for the period of record was 35,000 cfs, on November 28, 1948; the minimum was 37 cfs (24 mgd), on September 2, 3, and 4, 1954. Additional information on the flow characteristics is given as flow-duration data in table 2.

Chickasaw Creek

Chickasaw Creek flows into the Mobile River at the northern edge of the metropolitan area. It drains a generally hilly, wooded area and flows through dense swamplands for its last 7 miles.

Daily discharge records have been collected since October 1951 at a site in the NW¼ sec. 2, T. 3 S., R. 2 W., at a bridge on a county road, 12 miles upstream from the mouth and 11 miles northwest of Mobile (drainage area, 124 square miles). The average discharge for the 3 water years (1952–54) was 167 cfs (108 mgd). The maximum discharge was 1,920 cfs, on April 26, 1953; the minimum was 18 cfs (12 mgd), on September 3 and 4, 1954.

Big Creek

Big Creek, a tributary to the Escatawpa River, drains an area to the west of Mobile. This stream is the present source of Mobile's public water supply. Water for domestic and industrial use is pumped from the recently completed Big Creek Reservoir.

Daily discharge records were collected from November 1944 through September 1950 at a site in the NW¼ sec. 1, T. 4 S., R. 4 W., at a bridge on a county road, 1 mile upstream from Hamilton Creek and 19 miles west of Mobile (drainage area, 84 square miles). The average discharge for the 5 water years (1946-50) was 242 cfs (156 mgd). The maximum discharge was 3,460 cfs, on July 12, 1950; the minimum observed was 65 cfs (42 mgd), on July 1 and 2, 1950.

Big Creek Reservoir, formed by a dam on Big Creek just below the mouth of Hamilton Creek, has backed water over the gage site. The drainage area at the dam site is 110 square miles. Besides the obvious changes caused by storage and diversion of water, the reservoir has altered the normal regime of the stream in other ways. Evaporation from the reservoir's surface of 3,593 acres is a considerable factor; but this loss is in part offset by the elimination of evapotranspiration losses that previously occurred from the vegetation in the area now covered by the reservoir.

Flow-duration data for Big Creek for the base period 1939-54, shown in table 2, do not take into account the changes in regime which may have resulted from the construction of the reservoir.

Other Streams in the Area

There are many other streams in the area. The flow of eight of the larger streams were measured at intervals during dry periods in 1953–54, and data were computed on the basis of these measurements and on records at gaging stations in the area. These data are shown in table 3. Descriptions of the streams follow.

Bassett Creek

Bassett Creek, in the extreme northern part of the area, flows generally eastward, draining into the Tombigbee River near mile 83, as measured from Mobile.

Seven discharge measurements were made at a site near Wagarville, in the N½ sec. 25, T. 6 N., R. 1 W., at a bridge on U. S. Highway 43, 10 miles upstream from the mouth and 54 miles north of Mobile. The drainage area at the site is 128 square miles.

Lewis Creek

Lewis Creek flows generally eastward, draining into Three Rivers Lake, which drains into the Tombigbee River at about mile 65.

Seven discharge measurements were made near McIntosh, in the S½ sec. 37, T. 4 N., R. 1 W., at a bridge on U. S. Highway 43, 4 miles upstream from the mouth and 45 miles north of Mobile. The drainage area at the site is 43.9 square miles.

Bilbo Creek

Bilbo Creek drains into a side channel of the Tombigbee River, which in turn, joins the main channel near mile 56.

Seven discharge measurements were made near McIntosh, in the SW¼ sec. 30, T. 3 N., R. 1 E., at a bridge on U. S. Highway 43, 5 miles upstream from the mouth and 38 miles north of Mobile. Drainage area at the site is 73.2 square miles.

Bates Creek

Bates Creek is a tributary to Bilbo Creek. Seven discharge measurements were made at a site near Calvert, in the SW¼ sec. 46, T. 3 N., R. 1 E., about half a mile upstream from a bridge on U. S. Highway 43, 8 miles upstream from the mouth and 36 miles north of Mobile. Drainage area at the site is 73.6 square miles.

Cedar Creek

Cedar Creek flows eastward into the Mobile River near mile 36 above Mobile. Six discharge measurements were made at a site near Mount Vernon, in the SW¼ sec. 10, T. 1 N., R. 1 W., just below Cedar Falls, 6 miles upstream from the mouth and 25 miles north of Mobile. Drainage area at the site is 71.2 square miles.

Bayou Sara

Bayou Sara flows into the Mobile River a short distance above Mobile. Its lower reaches are swampy, and the upper reaches drain a rolling, hilly area.

Seven discharge measurements were made near Saraland, in the NW¼ sec. 32, T. 2 S., R. 1 W., at the upper end of the swamp area at a bridge on a county road, 2 miles upstream from U. S. Highway 43 and 12 miles north of Mobile. Drainage area at the site is 13.6 square miles.

Eightmile Creek

Eightmile Creek drains the area to the immediate northwest of the metropolitan area. It is a tributary to Chickasaw Creek, flowing into that stream about 5 miles upstream from its mouth.

Seven discharge measurements were made at a site near the community of Eight Mile, in the N½ sec. 36, T. 3 S., R. 2 W., at Bear Fork Road, approximately 7 miles northwest of the center of Mobile. Drainage area at the site is 27.0 square miles. About 2½ miles downstream from the measuring site the city of Prichard diverts approximately 4 cfs (2.6 mgd) from the stream for its municipal supply.

Threemile Creek

Threemile Creek drains the area immediately to the west of Mobile. The stream skirts the northern edge of the city and empties into the Mobile River just north of the city. The stream is somewhat polluted in its lower reaches.

Seven discharge measurements were made at a site near Crichton, in the SE¼ sec. 12, T. 4 S., R. 2 W., at bridge on State Highway 43, 5 miles west of center of the city and 6 miles upstream from the mouth. Drainage area at the site is 12.1 square miles.

Halls Mill Creek

Halls Mill Creek, south of the city, appears to have excellent dry-weather flow. Several reconnaissance trips were made to locate a suitable site to gage the stream, but tidal effect made it impractical. However, on the basis of observations made on these trips, the low-water yield per square mile of drainage basin should be comparable to that for Eightmile Creek.

Floods on Tributary Streams

Information on the magnitude and frequency of floods on small streams in the Mobile area is very limited. Peirce (1954), in his study of flood frequency and magnitudes for streams in Alabama, developed a means of estimating the probable magnitude and frequency of floods on any stream in the State with a drainage area of more than 100 square miles. These curves, based on the combined records of all streams in and adjacent to Alabama, are probably the most reliable means of estimating probable floods in the Mobile area, even though Peirce had some rather serious reservations on accuracy of the definition of the curves applicable to this part of the State.

Figure 15, based on Peirce's curves for tributary streams in southwestern Alabama, can be used to estimate the probable magnitude of floods having a frequency of 10, 25, or 50 years for the larger tributary streams in the area. It should be recognized, however, that the recurrence interval does not imply any regularity of occurrence. It is only the probable average period between the floods equal to, or greater than, a given magnitude in a long period of time. Two 50-year floods could conceivably occur in consecutive years or even in the same year. For any given year, there is 1 chance in 50 that the 50-year flood will be equaled or exceeded.

Quality of Water of Tributary Streams

The general chemical character of water from the smaller streams in the Mobile area is indicated by the analyses of two samples from each of six selected streams. (See fig. 16). Water from these streams was found to be of excellent quality and suitable for most uses with little or no treatment. Although data on the daily quality of water were not available, the analyses given in table 6 are believed to be representative of nearly maximum concentration, because the samples analyzed were taken during essentially base-flow periods. Of the supplies examined, the maximum concentration of dissolved solids was 120 ppm; the minimum, 20 ppm; and the average, 50 ppm.

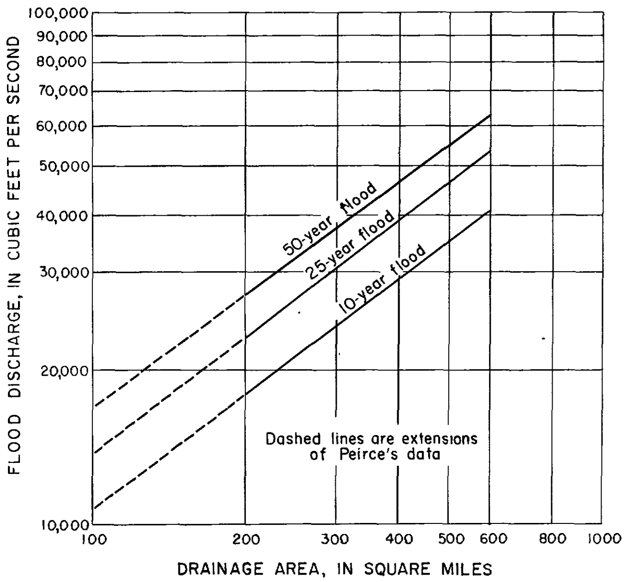

Figure 15.—Magnitude and frequency of floods on tributary streams in southwestern Alabama.

GROUND WATER

General Principles

Occurrence and Storage

Ground water in the Mobile area occurs in strata of Tertiary age and unconsolidated alluvial and terrace deposits, and is used to some extent by almost all the industries. The rural population outside the area served by the cities of Mobile and Prichard is dependent on ground water as a source of supply. Thus, ground water is a valuable and essential natural resource in the Mobile area.

The quantity of water available to wells is dependent on the type of rocks penetrated by a well and the local and regional geology of the water-bearing rocks, as well as on the climate. Therefore, some knowledge of the geology and occurrence of ground water is necessary before the ground-water resources can be appraised.

Rocks that form the outer crust of the earth generally contain many open spaces, called voids or interstices. These open spaces are the receptacles that hold the water found below the surface of the land. Part of this water is recovered through wells and springs. A body of rock that will yield water to wells is defined as an aquifer. The amount of water that can be stored in any rock depends on the volume of the rock that is occupied by open spaces, or the porosity of the rock. The ability of a rock to transmit water under pressure is defined as its permeability. Rocks that will not transmit water are said to be impermeable. Some deposits, such as

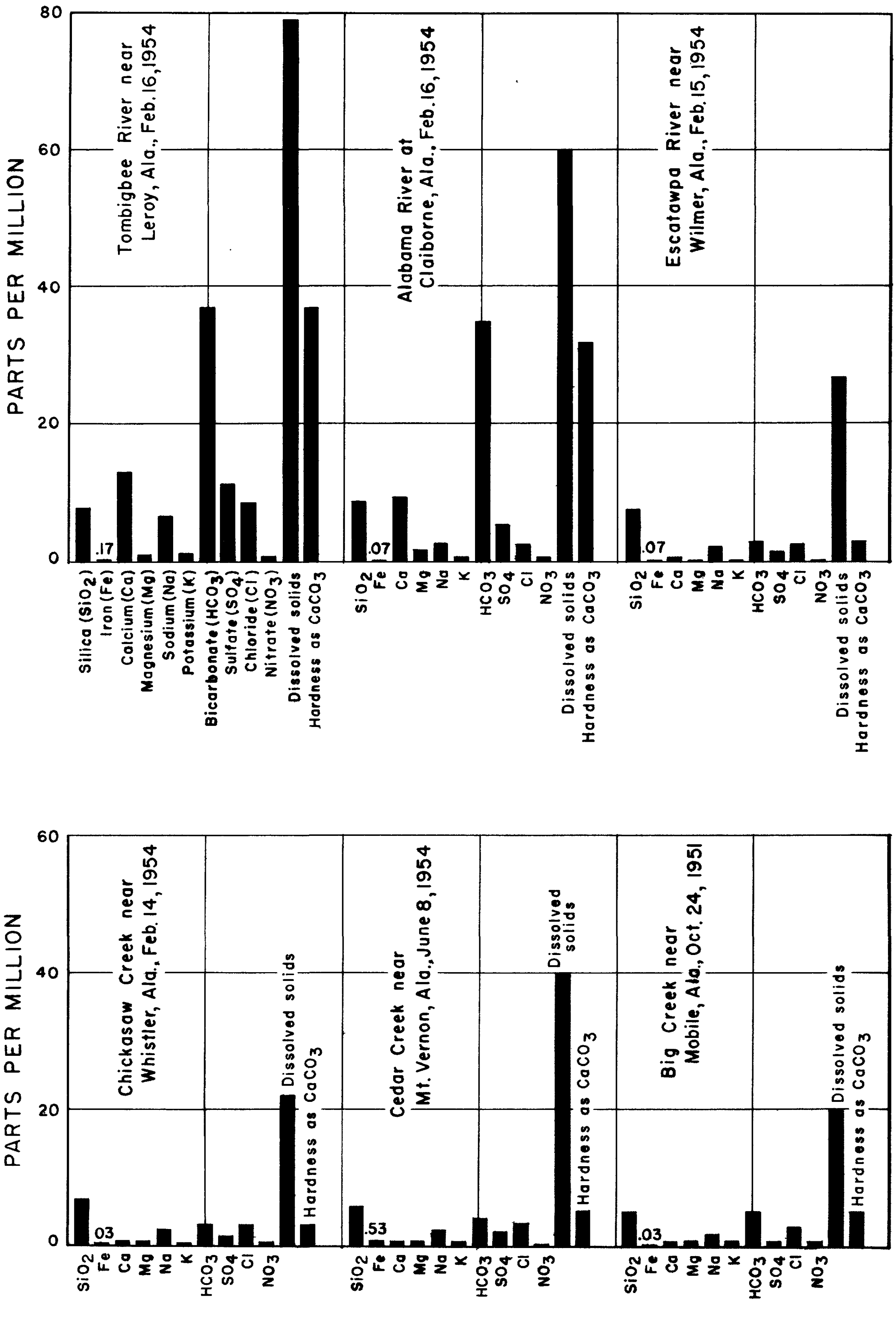

Figure 16.—Chemical quality of selected surface waters.

Table 6.—Chemical quality of selected surface waters

[Chemical constituents are in parts per million]

Source and location	Date of collection	Discharge (mgd)	Silica (SiO_2)	Iron (Fe)[1]	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Aluminum (Al)	Manganese (Mn)	Sediment	Temperature (°F)
Tombigbee River near Leroy......	Oct. 4, 1953	1,247	0.7	0.01	0.24	21	2.1	18	1.4	68	16	24	0.1	0.1	120	61	5	222	7.4	14	0.00	0.00	14	78
	Feb. 16, 1954	6,398	7.8	.17	.70	13	1.0	6.4	1.0	37	11	8.5	.1	.8	79	37	6	115	7.0	7	.00	....	27	54
Alabama River near Claiborne...	Oct. 4, 1953	12,860	5.4	.23	.53	9.8	1.8	3.1	1.6	37	5.5	2.4	.2	.4	72	32	2	84.7	7.1	24	.30	.00	65	76
	Feb. 16, 1954	11,760	7.9	.07	.56	9.5	1.9	2.8	.8	35	5.2	2.5	.1	.7	60	32	3	80.9	7.2	16	.08	....	43	56
Escatawpa River near Wilmer.....	Oct. 3, 1953	71	7.9	.24	.51	.6	.4	2.5	.2	4	2.0	3.2	.1	.2	30	3	0	22.3	6.1	30	.10	.00	13	79
	Feb. 15, 1954	138	7.8	.07	.16	.8	.2	2.2	.1	3	1.5	2.8	.1	.2	27	3	0	20.2	5.7	7	.05	....	4.0	60
Chickasaw Creek near Whistler...	Oct. 3, 1953	56	7.1	.23	.40	.4	.6	2.5	.2	4	2.5	2.8	.1	.1	33	3	0	20.3	5.9	50	.20	.00	10	76
	Feb. 14, 1954	62	6.7	.03	.09	.4	.4	2.1	.2	3	1.2	3.0	.1	.2	22	3	0	20.7	5.7	4	.05	....	3.0	56
Cedar Creek at Cedar Creek Falls near Mount Vernon.	June 8, 1954	5.65	5.8	.53	.61	.6	.9	2.2	.3	4	2.0	3.2	.0	.1	40	5	2	23.0	6.2	45	.00	....	......	85
Big Creek near Mobile..............	Oct. 24, 1951	....	5.0	.03	....	.8	.8	1.8	.5	5	.7	2.8	.1	.6	20	5	1	17.7	6.2	27	....	.00	......	70

[1] In solution at time of analysis.

well-sorted silt or clay, may have a high porosity, but, because of the minute size of their pores, they transmit water slowly. Other deposits, such as well-sorted gravel, that contain large, freely interconnected openings will transmit water readily.

Ground water in the Mobile area occurs under both water-table and artesian conditions. Under water-table conditions, the ground water is unconfined; under artesian conditions, the water is confined under pressure between relatively impermeable strata. Artesian conditions generally exist in sands of Miocene age, because these sands are confined by layers of clay or shale. The hydrostatic pressure in these aquifers is caused by the weight of water at higher levels in the recharge area. If there were no leakage from the confined aquifer and no frictional resistance to the movement of water in the aquifer, the pressure on the confined aquifer would raise the water level to the same altitude it is in the recharge area; but because such losses in head do occur, the head is always lower down the dip from the recharge area.

The imaginary surface or level to which water will rise from an artesian aquifer is called the piezometric surface. A well fed by an artesian aquifer will flow if the piezometric surface is above the land surface. Both flowing and nonflowing artesian wells are found in the Mobile area. In metropolitan Mobile, water-table conditions generally occur in the alluvium and terrace deposits to a depth of about 150 feet. Wells that tap the permeable water-bearing material of Miocene age to a depth of about 550 feet are nonflowing, and those that penetrate water-bearing material below 550 feet generally flow. Water-table and artesian conditions are illustrated in figure 17.

Movement

Ground water in the unconfined aquifer is derived from local precipitation. Water in the artesian aquifers is from precipitation in areas at a considerable distance to the north, where those aquifers crop out at the land surface. The rate of movement of water through the artesian aquifers from the recharge areas to the points of discharge probably ranges from a fraction of a foot to a few feet per day.

The water table is defined as the upper surface of the zone of saturation, except where that surface is formed by an impermeable body (Meinzer, 1923, p. 32). It may also be regarded as the boundary between the zone of saturation and the zone of aeration. The water table is not a level surface, but is generally sloping, with many irregularities caused by differences in permeability, topography, or by additions to or withdrawals from the ground-water reservoirs.

The water table is not stationary but fluctuates, like the water level in a surface reservoir. If the withdrawal from an aquifer exceeds the recharge or replenishment, the difference is supplied from storage and the water level declines; conversely, if the recharge exceeds withdrawal, the water level rises. Where the water is unconfined, the response to local precipitation is generally reflected in a rise in the water table within a 24-hour period. Water levels rise as a result of recharge during the heavy rains and high streamflow in the spring. During the summer, except for local rises caused by occasional rainstorms, water levels decline because of the increased rate of evapotranspiration and pumping.

Wells that are too closely spaced interfere with one another, resulting in an accelerated decline in water levels and a reduction in the yield of wells. Slight declines in water levels have been noted in Prichard and southwest Mobile (pl. 2). Water levels in the vicinity of well 43 (pl. 2) are reported to have declined about 20 feet since 1937. Water levels in the vicinity of well 65 are reported to have declined about 5 feet since 1950, or at an average rate of about 1 foot per year. Overpumping of shallow wells in the downtown area of Mobile in the vicinity of well 55 (pl. 2) caused a decline in the water table and encroachment of salt water from the Mobile River during the period 1941-45. A reduction in pumping since that time has resulted in a lessening of the encroachment.

Recovery from Wells and Springs

When a well is pumped or allowed to flow, the water table or piezometric surface in the vicinity of the well declines and takes a form similar to that of an inverted cone; this is called the cone of depression. The cones of depression of a water-table well and a flowing and a nonflowing artesian well are shown in figure 17. The area around a well that is affected by the decline in water level resulting from withdrawals is called the area of influence. When a well is pumped, the water level drops rapidly at first and then more slowly, but it may continue to drop for several hours or even for many days. Under artesian conditions, if pumping causes a decline of the piezometric surface below the confining bed, water-table conditions will exist in the vicinity of the pumped well. The greater the pumping rate of a well, the greater the drawdown (difference between static and pumping water levels—fig. 17) and the larger the cone of depression. The rate of discharge of a well per unit of drawdown is the specific capacity of the well. Well 47 (pl. 2 and table 7), for example, yielded 280 gpm with a drawdown of 23 feet; hence, its specific capacity was 12.1 gpm per foot.

The discharge from industrial wells in the area range from 10 to 1,500 gpm and average about 450 gpm. Data on the specific capacities are not complete, but in those wells for which they are known they range from about 6 to 65 gpm per foot of drawdown. The discharge from wells is the amount of water pumped by the industries; it is not necessarily the maximum yield, because discharge from the wells is governed by the quantity of water required by the users. Well 51, for example, has a reported maximum yield of 1,000 gpm, but the regulated discharge is about 550 gpm. Well 1 is pumped at a rate of 650 gpm, but the maximum yield of the well is reported to be about 1,600 gpm. There are no reports of any serious declines in water levels in the industrial area north of Mobile.

Wells in the Mobile area are generally drilled by the rotary method. Test drilling a 5- or 6-inch hole to determine the character and thickness of the water-bearing material and the chemical character of the ground water generally precedes the development of any but a domestic ground-water supply.

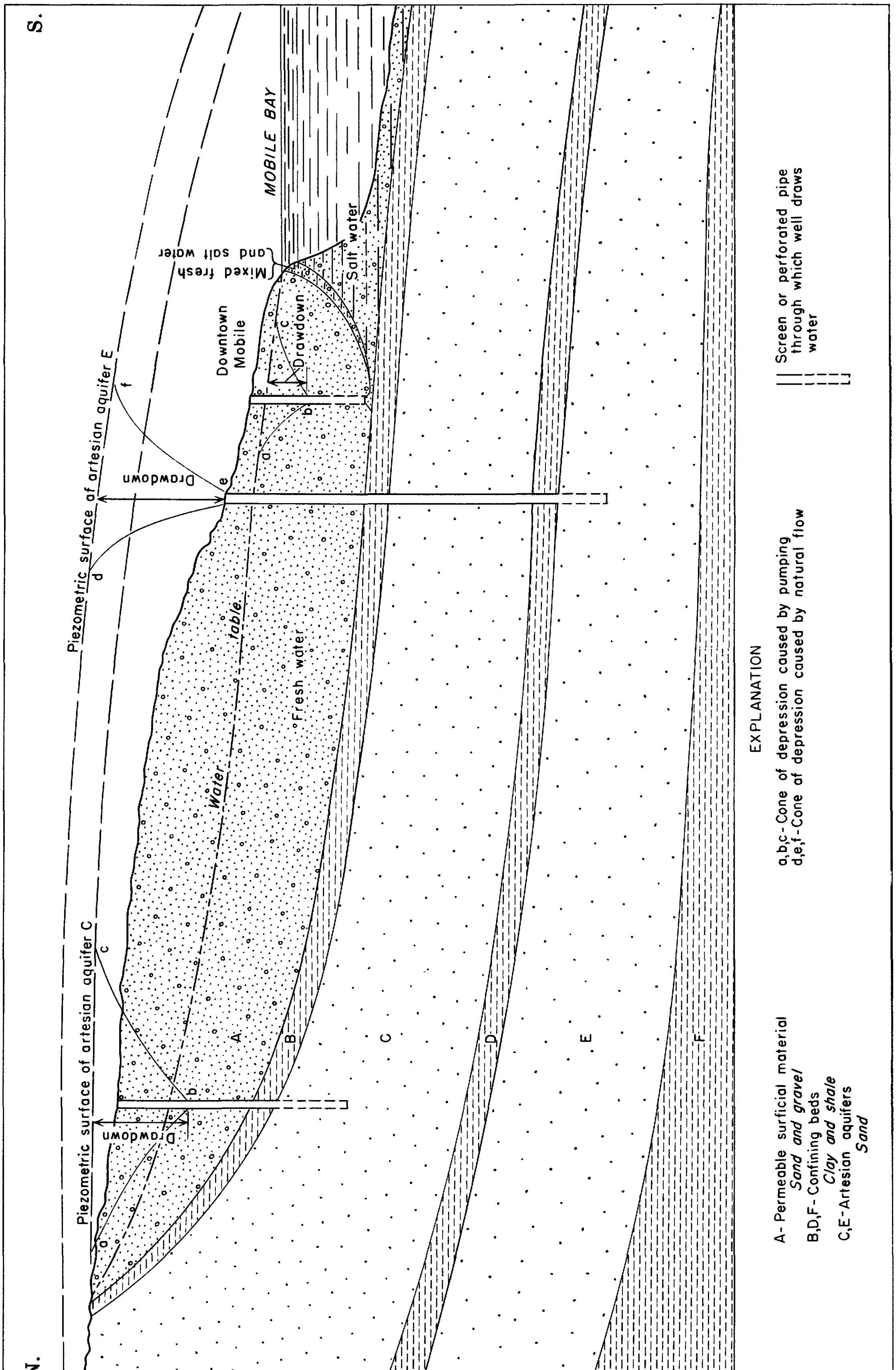

Figure 17.—Generalized diagram showing artesian and water-table conditions in the Mobile area.

Many of the large-capacity wells pump fine sand and silt. Occasionally the wells become filled with sand to the extent of reducing the discharge; these wells then require cleaning to restore their capacity. The screens of wells in the alluvium and terrace deposits become corroded and plugged with iron oxide. As a result, the screens of large-capacity wells require cleaning every 3 or 4 years.

Many small springs and seeps occur in the Mobile area, particularly in draws and along the steep slopes on the Spring Hill-Citronelle ridge. These springs supply small quantities of water for domestic and stock use.

The water from Cherokee Spring (no. 18), east of Citronelle, is highly mineralized (table 7). Smith (1907, p. 304) gives an analysis of the water from Cherokee Spring. The water was bottled and sold for a few years for its reported medicinal qualities. Discharge from Cherokee Spring was estimated to be about 1 gpm.

A spring (no. 8), owned by B. C. Pringle, has a wooden reservoir constructed around the outlet, and the water is pumped from the reservoir to an elevated storage tank. The discharge from this spring was estimated to be 3 gpm.

Water-Bearing Formations

Ground water occurs throughout the Mobile area in the alluvium and Quaternary terrace deposits, the Citronelle formation, and Miocene deposits.

Water in the alluvium, Quaternary terrace deposits, and Citronelle formation is unconfined, and it occurs under water-table conditions except where the water-bearing material may be locally confined by lenses of clay. Water in the Miocene deposits is confined by layers of clay or shale, and it occurs under artesian conditions. The distribution of the water-bearing formations is shown in figure 1.

The chemical quality of the water in the Mobile area varies, particularly in the metropolitan section; in some places it contains large amounts of chloride.

Miocene Deposits, Undifferentiated

Deposits of Miocene age have not been fully penetrated by wells in the area; however, from data on wells in adjacent areas, the thickness is estimated to be about 1,000 feet. The regional dip of the Miocene is to the southwest at the rate of 15 to 25 feet per mile. The deposits of Miocene age are of estuarine origin and consist of sediments ranging in texture from clay and silt to fine gravel. The character of the material composing the upper part of the Miocene is given in the following sample log of a test hole drilled near the intersection of Royal and St. Francis Streets.

	Thickness (feet)	Depth (feet)
Fill	15	15
Alluvium:		
Sand, fine to coarse, subangular; contains some fragments of pink, yellow, and gray clay	3	18
Sand, fine, subangular; contains fragments of pink, yellow, and gray clay	12	30
Sand, fine to medium, subangular, buff to white; contains some coarse sand and mica	18	48
Sand, fine to medium, subangular, buff to white; contains some coarse sand and limonite	6	54
Sand, fine to medium, subangular; contains fragments of gray micaceous clay	7	61
Sand, fine to medium, subangular, white; contains some fine to coarse sand and limonite	7	68
Sand, fine to medium, subangular, buff to white; contains some yellow and pink sand	6	74
Sand, fine to medium, subrounded; contains some coarse sand and fine gravel	6	80
Sand, fine, to gravel, fine; contains some limonite and mica	9	89
Sand, fine to medium, subangular, yellow; contains some clay, limonite, and mica	3	92
Sand, fine to medium, and clay, micaceous, sandy, gray to green	8	100
Clay, sandy, micaceous, gray.	8	108
Sand, fine to coarse, yellow and blue; contains fine gravel	18	126
Miocene, undifferentiated:		
Sand, very fine to fine, subangular, gray, tan to white; contains some light-tan clay and mica	2	128
Sand, very fine to fine, subangular, gray, tan to white; contains clay, mica, and carbonaceous material	18	146
Sand, very fine to fine, subangular, gray, tan to white; contains some clay, mica, carbonaceous material, and a trace of glauconitic sand	25	171
Sand, fine	42	213
Clay, sandy	10	223
Sand, fine to medium	8	231
Sand, fine to medium, subangular, buff to white; contains some reddish-brown siderite, limonite and mica	10	241

	Thickness (feet)	Depth (feet)
Sand, fine to medium, white....	30	271
Sand, very fine, buff; contains clay and mica....................	19	290
Peat, woody, carbonaceous, black..............................	6	296
Sand, fine, subangular, gray; contains some fine-grained chert and yellow clay..........	11	307
Sand, fine to medium, subangular, white; contains pyrite, limonite, and a few siderite nodules.................	16	323
Sand, fine to medium, white....	21	344

It is beyond the scope of this study to correlate the principal aquifers in the deposits of Miocene age because of the lenticular character of the sands in the deposits. The top of the Miocene has been placed arbitrarily at the first persistent clay bed.

Yield of wells

Most of the large-capacity wells in the metropolitan area of Mobile tap aquifers in the deposits of Miocene age, and all the flowing wells are in the Miocene below a depth of about 550 feet. Well 53, drilled to a depth of 800 feet, is reported to flow about 400 gpm and is pumped at the rate of 600 gpm. Well 52, 749 feet deep, flows at the rate of 160 gpm. Well 50, 800 feet deep, is reported to flow at the rate of 300 gpm. This well is pumped at the rate of 1,500 gpm, with a reported pumping level of 30 feet below the land surface.

Large-capacity nonflowing wells obtaining water from the Miocene are common. Two wells at Brookley Field obtain water from the upper sands at a depth of 179 feet. These two wells have discharges of 980 and 1,200 gpm and specific capacities of 24 and 33 gpm per foot of drawdown, respectively.

Wells in the vicinity of Prichard (pl. 2) tap the upper part of the Miocene at depths of 253 to 353 feet, and their discharges range from 400 to 570 gpm. In the vicinity of McIntosh (pl. 1), wells obtain water from sediments of Miocene age at depths ranging from 240 to 400 feet, and have discharges of 650 to 800 gpm.

The municipal well at Citronelle (well 22), which obtains water from deposits of Miocene age at a depth of 639 to 727 feet, is pumped at the rate of 500 gpm.

Chemical quality

Nine wells and 1 spring that tap deposits of Miocene age were sampled for complete analysis, and 18 wells were sampled for partial analysis. The results of these analyses and of 5 analyses made before the present investigation are given in table 7. The chemical character of water from 3 wells in the Miocene is shown in figure 18. The amount of dissolved solids in samples of water from Miocene deposits ranged from 34 to 4,780 ppm, and the hardness ranged from 1 to 166 ppm. (See fig. 19.)

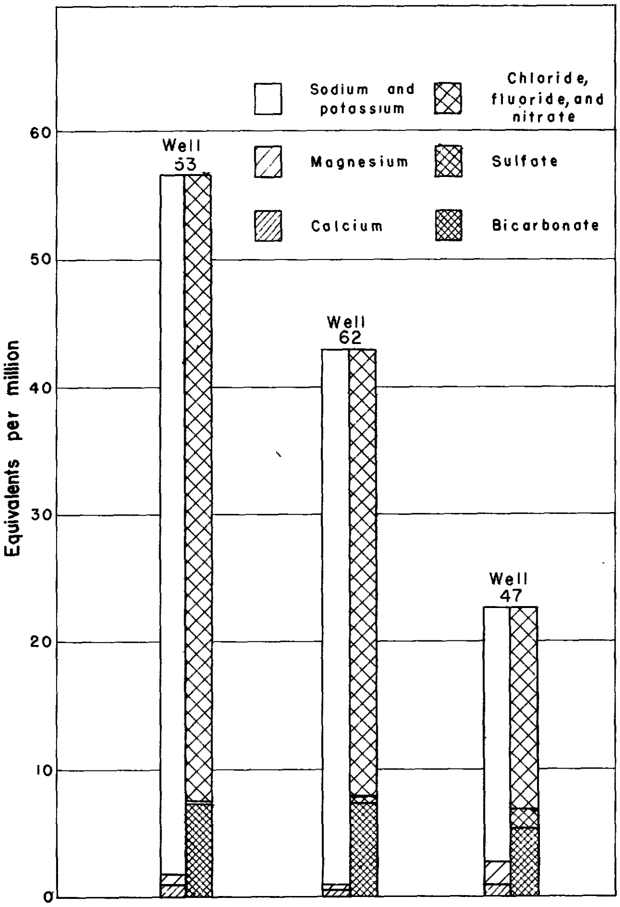

Figure 18.—Chemical character of water from selected wells in the Miocene.

Chloride concentration in the water in the Miocene increases downdip from McIntosh to Mobile, the highest concentrations occurring in the vicinity of Mobile. The chloride content of 27 water samples collected between McIntosh and Mobile is shown in figure 20. Concentration of chloride in the water from the Miocene from McIntosh to Prichard ranged from 2 to 314 ppm and averaged about 50 ppm. Depths of the wells sampled ranged from 30 to 400 feet.

Chloride in water from wells near the waterfront in Mobile ranged from 620 to 2,630 ppm and averaged about 1,300 ppm. Depths of the wells sampled ranged from 210 to 800 feet. The high chloride content of water from wells in this area may be derived from water that has remained in the aquifers since the time of deposition (connate water), or salt water that entered the aquifers at some subsequent time prior to the present physiographic cycle.

Iron in the water from wells sampled ranged from 0.06 to 2.3 ppm. The pH of the waters from the Miocene ranged from 4.3 to 8.4 and averaged 7. Water having a pH (hydrogen ion concentration) greater than 7 is considered alkaline, and water having a pH less than 7, acid.

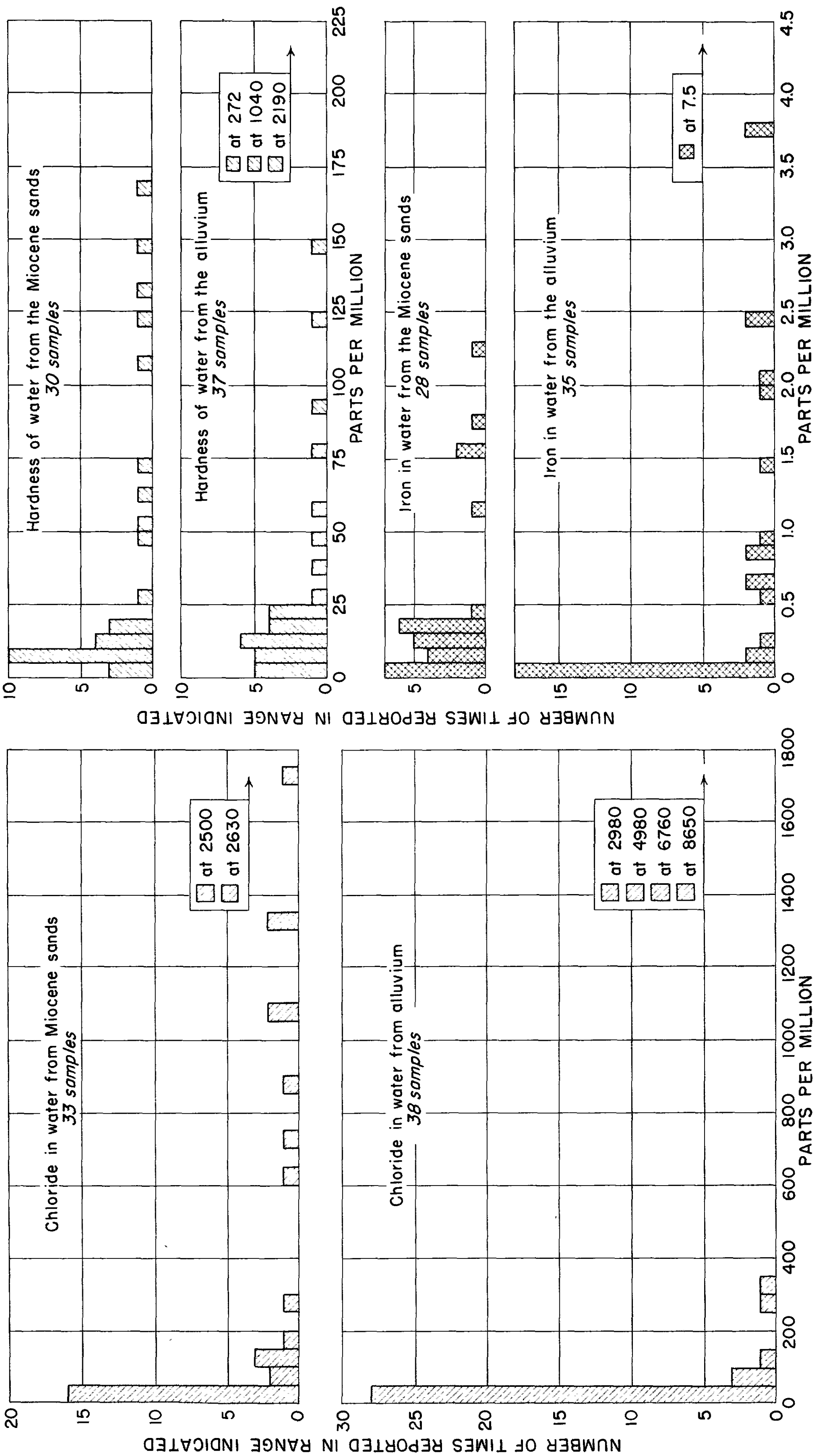

Figure 19.—Frequency distribution graphs of iron, hardness, and chloride in water from the Miocene sands and alluvium.

Table 7. —Chemical quality of ground water

[Use of water: D, domestic; I, industrial; N, none; PS, public supply; S, stock. Chemical constituents are in parts per million. Iron is reported in solution unless otherwise indicated]

Index no. (plates 1 and 2)	Location	Owner	Use of water	Date of collection	Depth (feet)	Water-bearing bed	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
1	McIntosh	Mathieson Chemical Corp. well 3	I	8-13-54	400	Miocene sands		0.06					80		10				7	0	167	7.7		70
2	do.	Mathieson Chemical Corp. well 1	I	do.	290	do.	11	[1].31	1.0	0.4	58	0.7	69	6.8	58	0.2	0.1	204	4	0	312	7.3	8	70
3	do.	Mathieson Chemical Corp. well 2	I	do.	240	do.		.17					100		48				9	0	326	7.7		70
4	do.	Geigy Chemical Co.	I	8-12-54	400	do.	18	[1]1.6	.2	.1	33	.9	72	8.0	5.5	.1	.1	112	1	0	141	7.8	11	72
5	do.	Estate of John A. Richardson	I	do.	64	Quaternary terrace deposits.		.01					13		5.5				8	0	41.4	5.6		
6	do.	Calabama Chemical Co.	I	do.	70	do.	15	[1].67	2.9	1.0	18	.6	30	2.2	14	.1	.3	86	11	0	112	6.6	5	
7	do.	Chester W. Orso	D	8-17-54	78	do.		.02					23		5.5				9	0	49.9	6.8		70
8	Sims Chapel	B. C. Pringle	D, S	do.	Spring	Alluvium		.03					6		16				12	7	72.9	5.4		71
9	Mt. Vernon	Mobile River Sawmill Corp.	I	8-10-54	27	Quaternary terrace deposits.		.01					6		7.5				10	5	39.2	5.6		71
10	do.	John Simison	D, I	do.	13	do.		.04					12		7.5				10	0	51.9	5.8		71
11	do.	Mt. Vernon Ice Co.	I	8-16-54	172	Miocene sands		.09					103		5.0				64	0	181	7.8		69
12	do.	Marvin Rivers	D	8-19-54	30	do.		.24					20		15				27	11	156	7.1		71
13	do.	St. Theresa Catholic School	PS	do.	105	do.		.06					23		4.0				12	0	52.3	6.8		
14	do.	Searcy Hospital (State of Alabama)	PS	10-30-48	240	do.		.08					9.6	4	8.0	.0	.0		[2]6.5		161			70
15	Citronelle	J. J. Gartman	D	8-18-54	67	Citronelle formation		.03					11		8.0				8	0	51.7	5.9		70
16	do.	J. R. Meinhardt	D, S	8-20-54	85	Miocene sands		.02					34		5.5				9	0	68.5	6.4		75
17	do.	Mrs. Robert Miller	D	8-18-54	40	Citronelle formation		.01					20		4.0				7	0	34.8	6.7		70
18	do.	J. L. Vinson	PS	7-12-46	Spring	Miocene sands							19	1	1	.0	.0		[2]10					67
18	do.	Mrs. J. L. Vinson	N	8-20-54	Spring	do.	14	[1]1.8	1.7	1.2	3.8	.8	18	2.2	2.2	.0	.0	34	9	0	73.0	6.2	27	72
19	do.	Fulton Ice Co.	I	8-16-54	109	do.		.01					4		7.0				10	7	60.0	4.9		68
20	do.	M. J. Plemmons	D, S	do.	61	Citronelle formation		.03					4		6.0				12	9	61.6	5.5		70
21	do.	O. Earle	D	8-18-54	110	Miocene sands		.38					9		5.5				8	1	34.2	5.8		73
22	do.	City of Citronelle	PS	8-16-54	735	do.	15	[1].11	4	.1	49	1.0	125	3.2	11	.2	.4	152	1	0	231	8.1	5	75
23	Chastang	Catholic Church	PS	8-19-54	35	Quaternary terrace deposits.		.18					3		28				22	20	126	5.1		76
24	Bucks	Alabama Power Co.	I	7-23-54	120	do.	12	[1].85	1.0	.5	16	.7	34	3.0	11	.1	.2	67	5	0	92.0	7.3	5	78
25	Movico	J. C. Prine	D, S, I	8-19-54	22	do.		.06					0		16				15	15	135	4.6		72
26	Bucks	L. R. Zakary	PS	do.	70	do.		[1]3.8					10		3.5				6	0	27.4	6.0		72
27	Salco	Stauffer Chemical Co.	I	8-10-54	140	do.	11	[1].07	.8	.7	2.2	.6	6	2.0	2.8	.2	.1	28	5	0	24.3	8.2	3	71
28	do.	do.	I	do.	135-140	do.		[1].69					34		6.0				18	0	69.7	6.4		71
29	do.	Courtaulds well 1	I	6-18-54	124	do.	9.4	[1].14	.6	.2	2.5	.5	6	2.5	2.8	.0	.1	27	2	0	24.0	5.7	2	68
30	do.	Courtaulds well 4	I	do.	140	do.	10	[1].22	1.0	.4	2.5	.6	6	3.8	3.2	.1	.4	32	4	0	28.7	5.5	3	69
31	Axis	Carl Bretzman	D, I	8-19-54	110	do.		[1].89					15		12				11	0	62.5	5.7		
32	Chunchula	Newton Merchant	D	8-18-54	130	Miocene sands		[1]2.3					13		4.0				9	0	34.2	6.1		71
33	do.	Geneva Davis	D, S	8-20-54	90	do.		.11					86		6.0				15	0	152	8.5		69
34	Mobile	Hollingsworth and Whitney Paper Mill well 9-D.	I	6-17-54	253	do.	14	[1].25	2.7	.5	136	1.7	189	5.0	109	.3	.6	396	8	0	670	7.8	30	71
35	do.	Hollingsworth and Whitney Paper Mill well 9-S.	I	do.	64	Alluvium		.10							7.0				13		62.6	5.8		69
36	do.	Hollingsworth and Whitney Paper Mill well 8-D.	I	do.	291	Miocene sands		1.6							135				14		816	7.8		72
37	do.	Hollingsworth and Whitney Paper Mill well 7-S.	I	do.	71	Alluvium		.03							12				20		101	5.7		71
38	do.	Hollingsworth and Whitney Paper Mill well 6-S.	I	do.	81	do.		.05							6.5				13		69.0	5.6		70
39	do.	Hollingsworth and Whitney Paper Mill well 6-D.	I	do.	290	Miocene sands		.35							155				19		902	8.2		74
40	do.	Hollingsworth and Whitney Paper Mill well 5-D.	I	do.	294	do.		.37							150				16		878	8.1		74
41	do.	Hollingsworth and Whitney Paper Mill well 5-S.	I	do.	86	Alluvium	14	[1]1.5	1.0	.5	4.3	.7	6	5.8	4.8	.1	.1	47	5	0	39.7	5.4	3	74
42	do.	Hollingsworth and Whitney Paper Mill well 3-D.	I	do.	379	Miocene sands	13	[1].24	5.8	1.3	296	3.0	322	6.0	314	1.1	2.8	836	20	0	1,520	7.8	70	71
43	Prichard	Electric Ice Co.	I	8-6-54	138	Alluvium		[1]3.8					0		315				125	125	1,170	4.3		70
44	do.	Coleman's Dairy	I	8-5-54	100	do.		.01					6		7.5				12	7	55.2	5.6		72
45	Mobile	Haas-Davis Packing Co.	I	8-6-54	75	do.	11	[1].52	8.1	6.5	60	1.8	4	14	114	.2	11	264	47	44	460	5.5	3	72

Table 7.—Chemical quality of ground water—Continued

Index no. (plates 1 and 2)	Location	Owner	Use of water	Date of collection	Depth (feet)	Water-bearing bed	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color	Temperature (°F)
46	Mobile	Haas-Davis Packing Co	I	8- 6-54	80	Alluvium		0.01					7		69				21	27	293	5.4		73
47	do	Ideal Cement Co	I	7-29-54	210	Miocene sands	9.8	1.33	21	23	447	6.3	334	70	620	.8	5.0	1,410	147	0	2,490	8.2	90	75
48	do	Alabama State Docks	I	8- 6-54	254	do		1.27					358		715				135	0	2,750	7.6		70
49	do	Southern Oyster & Milling Co	I	8- 3-54	60-90	Alluvium		17.5					76		280				150	88	1,140	7.6		
50	do	Industrial Ice Co	I	8- 4-54	800	Miocene sands		1.2					458		2,500				125	0	7,750	7.8		72
51	do	G. M. & O. RR. Terminal	I	8- 6-54	89	Alluvium	13	12.1	16	9.1	32	3.1	22	16	66	.1	18	228	77	59	561	7.3	3	78
52	do	Dixie Marine and Supply Co	N	do	749	Miocene sands	16	1.43	35	19	1,680	11	408	6.0	2,630	.8	.5	4,780	166	0	7,840	7.6	110	77
53	do	G. M. & O. RR.	I	9-15-45	676	do							439		1,190				296				170	76
53	do	do	I	8- 6-54	800	do	16	.32	23	12	1,250	7.5	444	11	1,740	1.2	.6	3,200	107	0	5,650	8.2	100	78
54	do	First National Bank	I	9-15-45	717	do							444	3	1,060				239				130	75
54	do	do	I	8- 9-54	750	do		1.24					434		890				75	0	3,900	8.4		77
55	do	Hammell's Dept. Store	I	9-15-45	60	Alluvium							465	980	8,650	.8	22		[2]3,490					70
55	do	do	I	8- 6-54	70	do	5.5	11.9	156	439	3,840	136	427	706	6,760	1.0	.3	13,000	2,190	1,840	16,700	7.7	23	74
56	do	Baker's Shoe Store	I	8- 9-54	67	do		.06					100		88				272	190	667	7.5		77
57	do	T. V. Headquarters	I	8- 6-54	30	do		.01					52		29				94	51	433	6.2		77
58	do	LaClede Hotel	I	9-15-45	60-65	do							120	580	4,900		10		[2]1,700					72
58	do	do	I	8- 9-54	60	do		12.5					98		2,980				1,040	960	9,490	6.6		70
59	do	Bear Ice Cream Co	I	8- 4-54	80	do		1.97					9		31				37	30	199	5.3		73
60	do	Crystal Ice Co	I	9-15-45	85	do							3.0	53	29	.2	30		[2]58					70½
61	do	Alabama United Ice Co	I	do	750	Miocene sands							505		1,350 / 1,310	1.4			[2]50				100	77
62	do	do	I	5-28-54	787	do	15	1.19	12	6.1	956	6.0	442	7.0	1,310	1.4	.1	2,550	55	0	4,670	8.2	60	78
63	do	Ruberoid Co	I	8- 3-54	136	Alluvium		.03					9		14				21	14	119	5.6		
64	do	Loop Nursery	I	do	70	do		.10					22		10				22	4	95.9	6.0		70
65	do	Fulton Ice & Fuel Co	I	9-17-45	270	Miocene sands							5.0	6	8	.1	.1		[2]12				2	70
66	do	Loop Fish & Oyster Co	I	8- 4-54	100	Alluvium		12.5					13		6.8				14	3	74.6	6.3		70
67	do	Malbis Bakery	I	8- 9-54	85	do		.01					3		25				27	25	191	5.1		72
68	do	Oakdale Ice Co	I	9-15-45	87	do							4.0	11	13	.1	10		[2]18					74
69	do	Southern Dairies	I	8- 5-54	35	do		.01					21		18				24	7	157	6.1		68
70	do	Bates Air Field	I	8- 9-54	212	Miocene sands		.10					36		3.0				7	0	63.8	6.2		

[1]Total iron.
[2]Hardness determined by soap method.

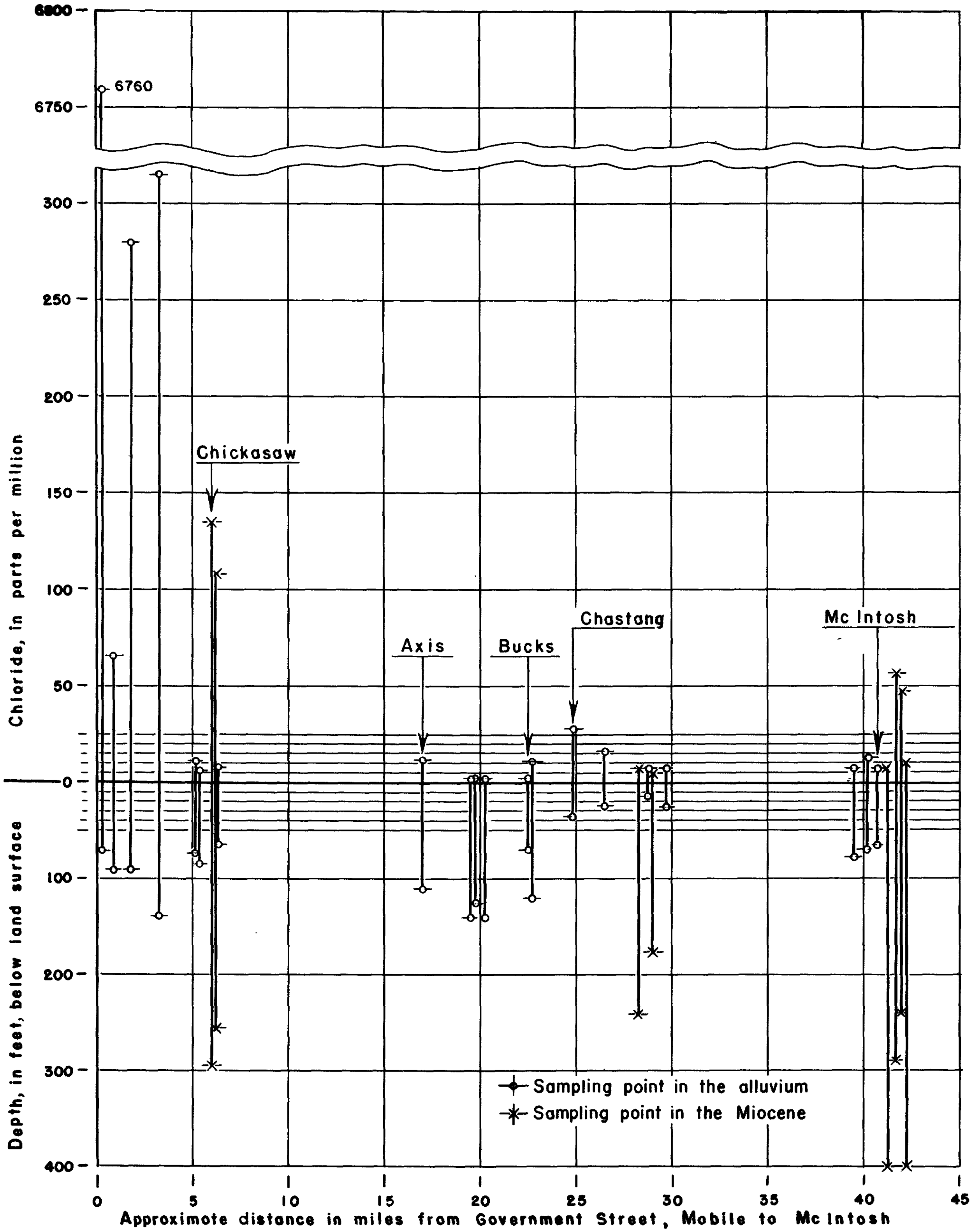

Figure 20.—Profile of chloride concentration in ground water, Mobile to McIntosh.

The temperature of water from the Miocene ranged from 68° to 78°F.

Citronelle Formation

The Citronelle formation consists of fine to coarse sand and fine to coarse gravel and lenses of clay. According to Carlston (1950, p. 1120), the thickness of the Citronelle formation ranges from 40 to 130 feet in coastal Alabama. The distribution of the Citronelle formation in the Mobile area is shown in figure 1, and in coastal Alabama it is shown on a map prepared by MacNeil (1946).

Streams originating along the Spring Hill-Citronelle ridge have cut through much of the Citronelle formation to the underlying Miocene, as shown in figure 1; therefore, in parts of the area the Citronelle formation may be drained. At some other places in the area the formation is too thin to yield large quantities of water to wells and is not considered to be a good aquifer. In most areas, however, it will yield enough water for domestic use, and it is widely used for that purpose in the vicinity of, and south of, Citronelle. The discharge from wells in the Citronelle formation range from 3 to 7 gpm.

Chemical quality

Water samples were obtained for chemical analysis from 3 wells in the Citronelle formation. The water was soft, ranging from 1 to 12 ppm in hardness; and the concentration of dissolved solids was low, ranging from 112 to 204 ppm. Chloride content of these waters ranged from 5.5 to 58 ppm.

Alluvium

The alluvium, for the purpose of this report, includes stream, deltaic, and beach deposits of Recent age; and marine, estuarine, and stream deposits of Pamlico age (fig. 1). Carlston (1950, p. 1123) recognized five terrace levels formed during late Pliocene or early Pleistocene time when the Mobile area was partly covered by the sea. Carlston recognized the Coharie terrace at an altitude of 190 to 210 feet, only small patches of which are present in the Mobile area (fig. 1), and the Pamlico terrace of late Pleistocene age at an altitude of 20 to 30 feet above the present level of the sea. A terrace of Pamlico age west of the Mobile River, extending from north of the area mapped south to Mobile, is shown in figure 1. The contact between the terrace and Recent deposits was not determined during the present investigation. Drillers' logs are generally the only source of information on the material cut in wells in the area, and these logs lack the detail necessary to reveal the contact between the Recent and terrace deposits.

Thickness of the alluvium ranges from a featheredge near the outcrop area of the Miocene deposits to more than 150 feet near Mobile. The alluvium consists of fine to very coarse sand, fine to coarse gravel, and layers of clay and carbonaceous material. The alluvial material is lenticular and individual beds cannot be correlated from well to well. Most of the large-capacity wells in the alluvium in the Mobile area obtain water from the coarser and more permeable sands at the base of the deposits. An aquifer test run on a well in the vicinity of Axis indicated that the coarse material near the base of the alluvium had a coefficient of transmissibility of about 300,000 gpd per foot, a high value indicating a very productive aquifer.

Yield of wells

The discharge from large-capacity wells in the alluvium range from about 50 to about 800 gpm. However, the maximum discharge possible from some of these wells, as determined from tests made at the time the pumps were installed, is more than 1,000 gpm. Wells discharging from less than 10 to about 25 gpm are commonly used for domestic supplies and cooling. Wells used for air conditioning and cooling in the Mobile area range in depth from about 30 to 90 feet.

Well 55, which obtains water from the alluvium at a depth of 70 feet, has a reported discharge of 300 gpm.

Wells in the vicinity of Prichard (pl. 1) obtain water from the alluvium at depths ranging from 64 to 130 feet. Discharge from wells in this area ranges from about 150 to 600 gpm and averages about 400 gpm. Wells in the vicinity of Bucks (pl. 1), about 20 miles north of Mobile, obtain water from sand and gravel in the alluvium at depths ranging from 82 to 132 feet. Discharge from wells in this area ranges from 100 to 550 gpm.

Well 6 at Mobile, obtains water from the alluvium (Quaternary terrace deposits) at 70 feet. Discharge from this well is reported to be about 50 gpm. The well is reported to have a maximum yield of 200 gpm.

Chemical quality

Water from nine wells in the alluvium was sampled for complete analysis, and water from 23 wells and 1 spring was sampled for partial analysis. The results of these analyses and 4 analyses made before the present investigation are given in table 7. The chemical character of water from the alluvium is shown in figure 21.

Dissolved solids in the water ranged from 27 to 13,000 ppm. Hardness was generally less than 25 ppm, but 2 samples had a hardness greater than 1,000 ppm. (See fig. 19.) The chloride content ranged from 2.8 ppm at Salco to 6,760 ppm in downtown Mobile. Concentration of chloride in the vicinity of McIntosh to Prichard ranged from 2.8 to 315 ppm and averaged about 28 ppm. Chloride in the waters from Prichard to downtown Mobile ranged from 29 to 6,760 ppm. (See fig. 20.) The depths of the wells sampled in the downtown area ranged from 30 to 90 feet.

According to Peterson (1947, p. 10), the reasons for the high chloride content of water in the downtown area of Mobile are the development of closely spaced wells in the area for air conditioning and other industrial uses and the heavy withdrawal made in 1941 during the construction of the Bankhead Tunnel. The heavy withdrawals were concentrated in a very small area within a radius of 4 or 5 blocks of the intersection of Dauphin and St. Joseph Streets. (Well 56, pl. 2, is near the intersection.) The cone of depression caused by this

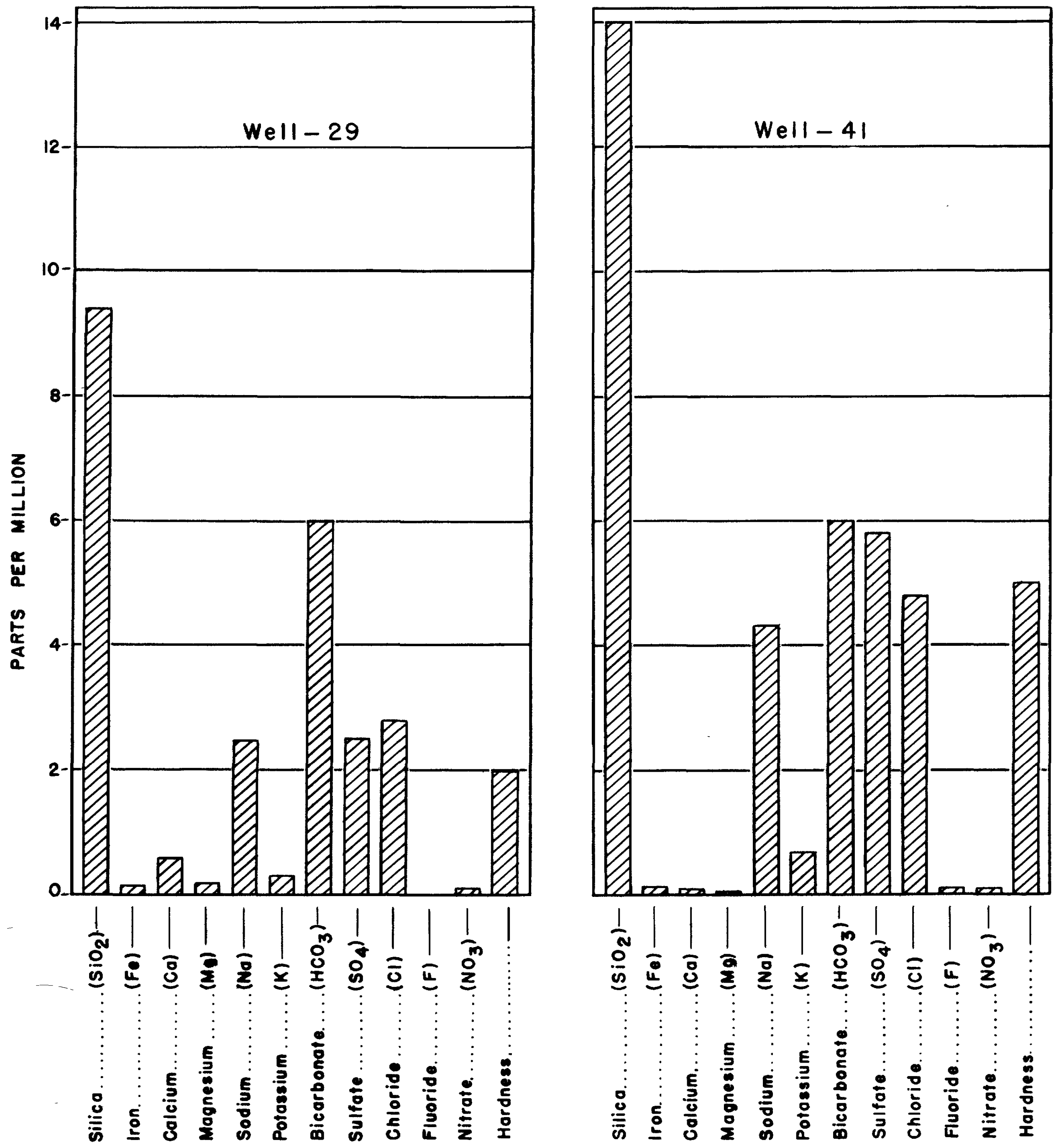

Figure 21.—Chemical character of water from selected wells in the alluvium.

concentrated withdrawal caused a movement of water of high chloride content from the Mobile River into the ground-water reservoir. Well 55 was drilled in 1937, and the owner reports that the first indication of high chloride content was in the summer of 1941. Since 1941 about 20 wells in the area either have been abandoned or have been drilled to deeper aquifers because of corrosion caused by high chloride-content water; however, a few wells are still being used for air conditioning.

The analyses of water from these wells during the present investigation indicated a freshening of the water since 1945. According to the chemical analyses contained in the report by Peterson (1947, p. 25–32), the chloride content of ground water in this area increased rapidly between 1942 and 1945. The chloride content of water from well 56 was 264 ppm in 1942 and 2,490 ppm in 1945, but an analysis of this water made in 1954 showed a chloride content of only 88 ppm. The chloride content of water from well 57 was 177 ppm in 1945; by 1954 the chloride content had decreased to

29 ppm. A decrease in chloride content in several other wells sampled in downtown Mobile is shown in figure 22. Since 1945 recharge to the shallow aquifer through local precipitation has apparently exceeded the pumpage in this area, and the water of high chloride content is gradually becoming diluted with water of lower mineral content. Pumping rates from individual wells has had no apparent effect on the rate of decrease or increase in the chloride content of water; nevertheless, the decrease in the chloride since 1945 can be attributed to the significant decrease in the total withdrawal from the alluvium. Discharge from well 55 has remained about the same since 1937, but the chloride content increased from 7,250 ppm in 1942 to 8,650 ppm in 1945, and it decreased to 6,760 ppm in 1954.

Well 51, drilled in 1948, about 10 blocks north of well 55, has a reported discharge of 550 gpm. Analyses of water from this well by the A. W. Williams Inspection Co. at Mobile on April 27, 1948, showed a chloride content of 58 ppm, and on January 19, 1953, analyses showed a chloride content of 40 ppm. A sample collected on August 6, 1954, and analyzed during the present investigation by the U. S. Geological Survey, showed a chloride content of 66 ppm. Similar conditions were found in the area north of well 51. These data indicate that adequate spacing of wells will minimize salt-water encroachment from the Mobile River.

The iron content of water from the alluvium ranged from 0.01 to 7.5 ppm. (See fig. 19.) Temperature of the water ranged from 68° to 78°F.

WATER SUPPLY SYSTEMS

Mobile Water Service System

The municipally owned Mobile Water Service System serves 150,000 people in Mobile and suburban communities. Until April 1952, the raw water supply was obtained from Clear Creek (a tributary to Eightmile Creek) and from Threemile Creek. Since that time the city has purchased raw water from the Mobile Industrial Water Supply System, which pumps the water from Big Creek Reservoir.

The raw water is treated at the filter plant about 7 miles west of the center of the city. The plant has a rated capacity of 20 mgd, with overload capacity of 22½ mgd. Plans are being made to double the plant capacity soon. Treatment consists of prechlorination, coagulation with lime and alum, sedimentation, rapid sand filtration, postchlorination, and pH adjustment. Raw-water storage at the filter plant is 20 million gallons. Ground-level storage capacity for treated water is 21 million gallons (2 reservoirs of 10 million gallons each and a clear well with a capacity of 1 million gallons).

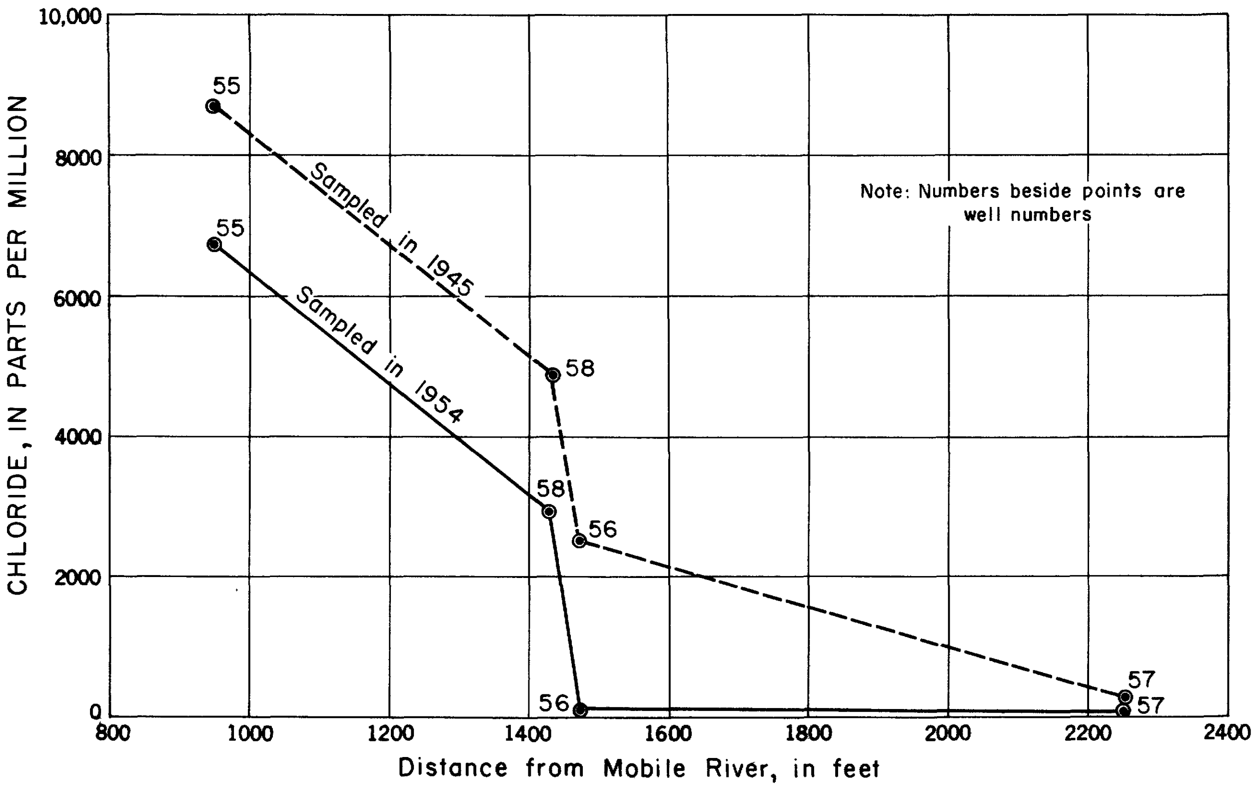

Figure 22.—Chloride content of shallow ground water in 4 wells west of the Mobile River, 1945 and 1954.

Elevated storage is negligible. The treated-water storage reservoirs are approximately 200 feet above the city, and the water flows into the distribution system by gravity. Pressures of about 50 pounds per square inch are maintained without additional pumping. Average daily use for selected years during the period 1930–54 are shown in figure 23. Figure 24 shows the **purchases of raw water from the industrial supply for** the period from July 1953 to June 1954, and it indicates how the annual use varies within the year.

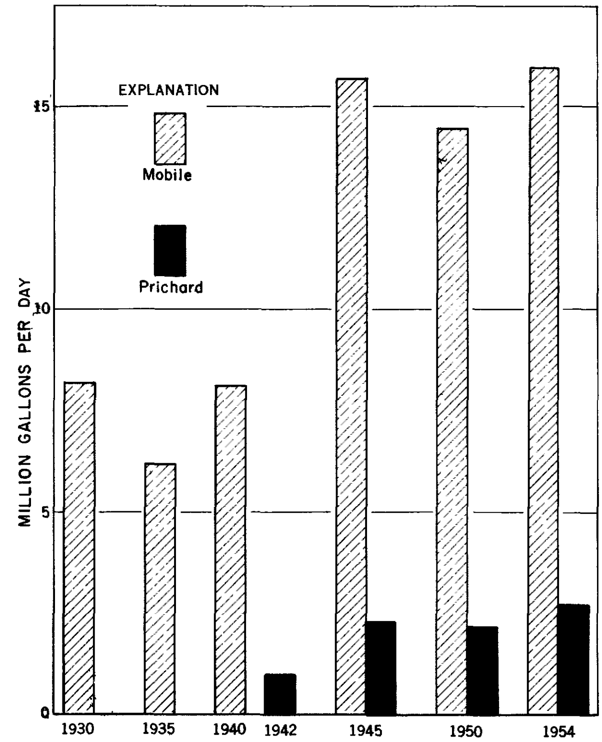

Figure 23.—Average annual use of water by the Mobile Water Service System and Prichard Water System.

Mobile Industrial Supply System

The Mobile Industrial Supply System is operated by the Water Works Board, which was formed to develop the Big Creek source. In addition to supplying some of the larger industrial users in the area, it also supplies the Water Service System with raw water. Water is pumped from Big Creek Reservoir on Big Creek, about 18 miles west of the center of the city. Usable capacity of this impoundment is 45,336 acre-feet or 14,800 million gallons. Pumping and transmission-line capacity from the reservoir is 70 mgd. A 50-million-gallon reservoir adjacent to the municipal filter plant provides additional storage for industrial use. Water in this reservoir is not now available to the filter plant for domestic use, but plans are being prepared to make 40 million gallons available to the filter plant intakes.

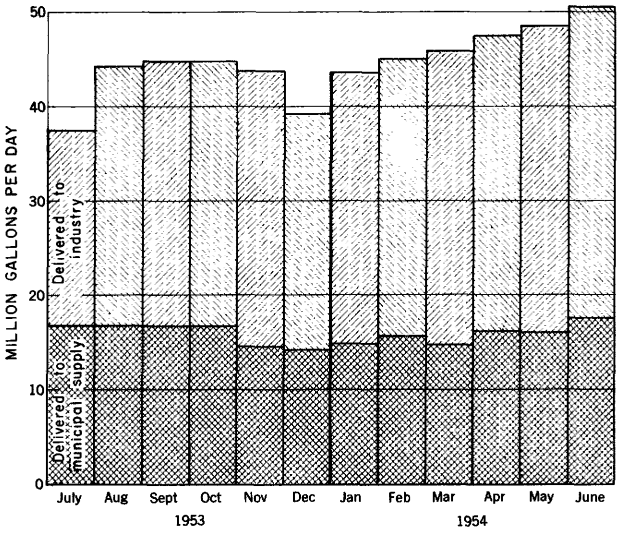

Figure 24.—Average monthly use of water by the Mobile Industrial Supply System.

The industrial water is not treated before delivery to the consumer. Figure 24 shows the average daily pumpage and use by month for the period from July 1953 to June 1954.

Big Creek Reservoir was designed to insure a safe yield of 100 mgd, of which 30 mgd is reserved for domestic use, leaving 70 mgd available for industrial use.

The dependable yield of Big Creek Reservoir was appraised on the basis of current records. Streamflow data for Big Creek near Mobile were adjusted to a base period (1939–54) by a method of correlating them with records of Escambia Creek near Flomaton and the Escatawpa River near Wilmer. These data indicate that the most severe drought of the 15-year base period occurred during the summer and fall of 1954. Computations show that during this time a release of 100 mgd would have drawn down the reservoir by about 84 percent of its usable capacity before the drought eased. A release of 110 mgd would have required the entire usable capacity of the reservoir.

Water obtained from the Big Creek Reservoir is of excellent quality, as indicated by the analyses of raw and treated water shown in table 8.

Prichard Water Works

The municipally owned Prichard Water Works serves 35,000 people in the town of Prichard and the neighboring towns of Chickasaw and Whistler. The raw water is pumped from Eightmile Creek, about $1\frac{1}{2}$ miles west of Chickasaw. There is no impoundment on the stream. Safe yield for the stream without impoundment is

Table 8.—Chemical character of the Mobile water supply, Big Creek Reservoir

[Chemical constituents are in parts per million]

	February 15, 1954 (Raw water)	February 15, 1954 (Finished water)
Silica (SiO_2)	3.5	1.5
Aluminum (Al)	.04	.22
Iron (Fe)	.09	.00
Total Iron	1.6	.00
Manganese (Mn)	....	....
Calcium (Ca)	.5	9.2
Magnesium (Mg)	.4	.6
Sodium (Na)	2.0	1.7
Potassium (K)	.5	.6
Carbonate (CO_3)	0	0
Bicarbonate (HCO_3)	4	15
Sulfate (SO_4)	1.2	9.2
Chloride (Cl)	2.8	7.0
Fluoride (F)	.0	.0
Nitrate (NO_3)	.7	.4
Dissolved solids	22	56
Hardness as $CaCO_3$		
Total	3	25
Noncarbonate	0	13
Sediment	2.5	2.4
Color	15	4
pH	5.6	7.3
Specific conductance (micromhos at 25°C)	22.5	71.8
Turbidity	6	4
Temperature (°F)	57	61

Regular determinations at Mobile Water Works, 1953

	Alkalinity as $CaCO_3$ (parts per million)			pH			Hardness as $CaCO_3$ (parts per million)			Temperature (°F)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	4.0	8	1	6.5	7.0	6.1	7	12	4	70	89	50
Finished water	14	20	8	9.2	9.9	8.2	29.5	48	18			

estimated to be 15 mgd. This estimate is based on measurements made on the stream at Bear Fork Road about 1½ miles upstream and data gathered on other streams in the area. Raw-water pumping and transmission-line capacity is 4 mgd. There is 0.5 million gallons of storage capacity for raw water at the treatment plant. The plant has a rated capacity of 4 mgd, with an overload capacity of 4.5 mgd. Treatment consists of prechlorination, coagulation with alum and lime, sedimentation, rapid sand filtration, postchlorination, and pH adjustment. Treated water storage is 0.5 million gallons in the clear well and 1.73 million gallons in elevated tanks. The service pumping capacity is 4 mgd. The average daily pumpage for the first half of 1954 was 2.73 mgd, with a maximum daily rate of 3.9 mgd. Average output for selected years during the period 1942 to 1954 is shown in figure 23.

Water from Eightmile Creek is typical of water from the smaller surface streams in the Mobile area: low in mineral content and of generally excellent quality. Analyses of the treated and untreated water sampled in 1951 and 1954 show little change in chemical quality, even though the samples were not collected in the same month of each year. These analyses and a summary of the daily records made at the treatment plant for 1953 are shown in table 9.

Table 9.—Chemical character of the Prichard water supply, Eightmile Creek

[Chemical constituents are in parts per million]

	Oct. 24, 1951 (raw water)	Oct. 24, 1951 (finished water)	Feb. 15, 1954 (raw water)	Feb. 15, 1954 (finished water)
Silica (SiO_2)	4.5	4.5	4.4	5.7
Alumium (Al)	....	....	.13	.13
Iron (Fe)	.15	.02	.09	.00
Total Iron	....	....	.41	.00
Manganese (Mn)	.00	.00	....	....
Calcium (Ca)	1.1	12	.7	7.8
Magnesium (Mg)	1.1	.8	.2	.6
Sodium (Na)	2.1	1.9	2.5	2.3
Potassium (K)	1.2	.5	.3	.2
Carbonate (CO_3)	0	4	0	0
Bicarbonate (HCO_3)	8	13	5	13
Sulfate (SO_4)	1.2	12	1.5	9.2
Chloride (Cl)	3.5	6.8	3.8	5.0
Fluoride (F)	.1	.0	.1	.0
Nitrate (NO_3)	.7	.7	.2	.5
Dissolved solids	32	50	16	46
Hardness as $CaCO_3$				
Total	7	33	3	22
Noncarbonate	1	16	0	11
Sediment	....	....	7	2.0
Color	60	4	5	1
pH	6.1	9.2	6.9	7.5
Specific conductance (micromhos at 25°C)	22.9	78.3	20.6	63.9
Turbidity	6	1	3	2
Temperature (°F)	71	71	61	59

Regular determinations at Prichard Water Works, 1953

	Alkalinity as $CaCO_3$ (parts per million)			pH			Temperature (°F)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	......	4	1	......	6.1	5.3	......	78	74
Finished water	......	16	10	......	8.5	8.0	......		

Other Public Supplies

Brookley Field, an Air Force base just south of Mobile, obtains its water supply from 5 wells, of which 3 are in the alluvium and 2 are in the deposits of Miocene(?) age. The depths of these wells range from 108 to 179 feet, and discharges range from 720 to 1,200 gpm. Specific capacities of the wells range from 31 to 59 gpm per foot of drawdown. Average consumption is about 1.3 mgd. The water is reported to be of good quality and low in chloride content. It is chlorinated before use.

A sixth well at Brookley Field is reported to obtain water from the deposits of Miocene age at a depth of 675 feet and to flow about 350 gpm. Water from this well contains chloride in excess of 600 ppm and is undesirable for domestic use. The flow from the well is not being used.

PRESENT WATER USE

In 1954 water was withdrawn in the Mobile area at an average rate of about 360 mgd. (See fig. 25.)

Private Industrial Supplies

Many industries and commercial enterprises in the area have developed private water supplies for their

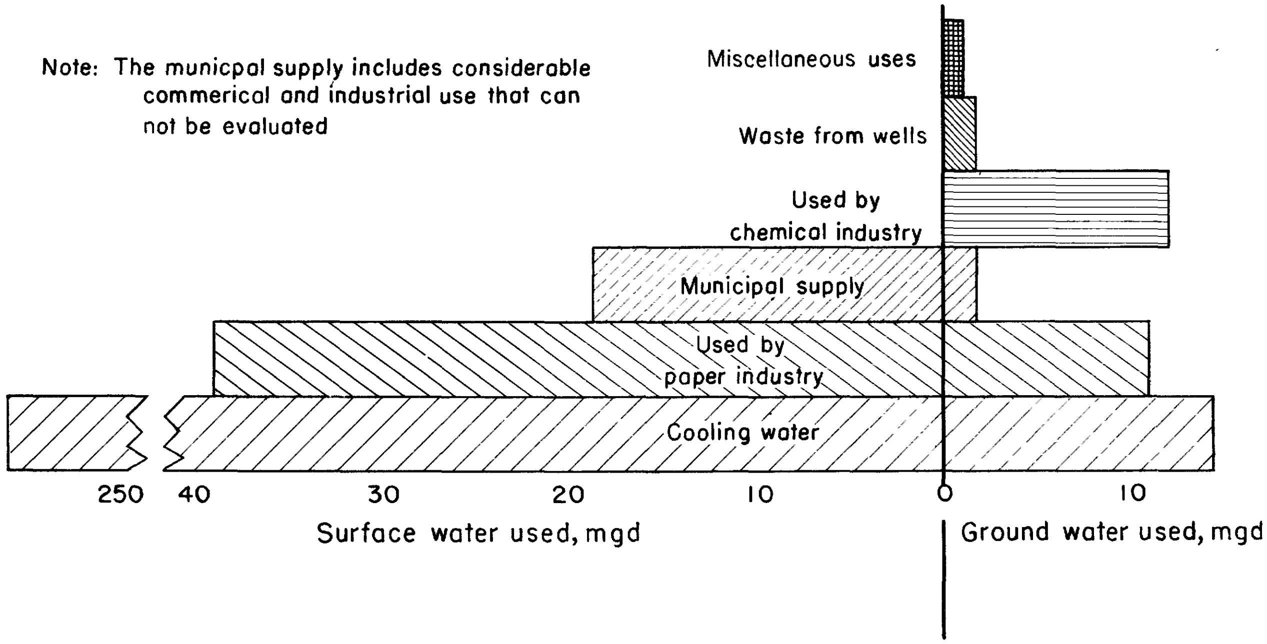

Figure 25.—Water used, in millions of gallons per day, in the Mobile area, 1954.

own use. Factors governing the development of a private supply include the availability of water from a public supply, relative cost of private and public supplies, and the particular need of the user in relation to the chemical quality and temperature of the water. Where a public supply is not available and rather large amounts of water are required, industry generally has developed surface water sources. Where water of relatively constant chemical quality or temperature is desired or where comparably small amounts are needed which do not justify expensive treatment, ground-water sources have been developed.

The recent expansion of the Mobile public supply systems has increased the supply of water available in the immediate area of the city. Some of the major industrial users in the area served by this supply have discontinued or reduced the use of their privately developed surface supplies and are purchasing water from the public supply.

Major industrial water users in the Mobile area who have developed private supplies include the paper industry, chemical industry, and steam powerplants. Estimates of the amounts of water used by these groups from their private supplies are given in the sections below.

Paper Industry

One of the major uses of industrial water in the Mobile area is in the manufacture of paper. During the first half of 1954 paper manufacturers were using water at the rate of about 21 mgd from their private supplies, of which about 11 mgd was pumped from wells and about 10 mgd was pumped from local streams. In addition, the industry purchased about 29 mgd from the public industrial supply. Pumpage from local streams was reduced sharply during 1952 when the public supply became available.

Chemical Industry

The chemical industry has expanded rapidly in the last few years. The newer plants are well north of the metropolitan area and along the west bank of Mobile and Tombigbee Rivers. This area is not served by public water supplies, and so the plants have developed private systems. Because water of uniform chemical quality or temperature is often desired, greatest attention has been given to ground-water resources. It is estimated that the industry is using water from wells at the rate of 12 mgd.

Power Generation

A considerable amount of water is used for cooling in the generation of electricity by steam power. The steam-electric plants in the area report a use of 256 mgd of water from the Mobile River. This water is returned to the river unchanged, except that it is approximately 15°F warmer after use. In addition, another 0.5 mgd is pumped from wells for other uses at the power plants.

Other Industrial Supplies

Available information indicates that other industries in the area use about 16 mgd from private wells. These supplies are developed by cement plants, gypsum plants, iceplants, bottling companies, packing companies, and others. A large amount of water used during the summer for air conditioning is included in the above estimate; however, accurate measure of water used for air conditioning can not be made, and so the estimated figure for use could contain a rather large error.

Irrigation

Use of water in irrigation is not a significant factor in the area covered by this report. Irrigation is practiced to some extent in the southern part of Mobile County and to a greater extent in parts of Baldwin County, across Mobile Bay to the east.

Rural

The rural district close to the city is quite thickly populated, but in the area up the river the population is much less dense. About 15,000 people live in rural areas that are not served by public water supplies or by the private supplies at the industrial developments. Most of these people obtain their water from wells or springs. Assuming a per capita use of 30 gpd, the estimated rural use is 0.5 mgd.

POTENTIAL WATER SUPPLIES

Although the quality of surface waters and most ground waters in the Mobile area available for future development is generally good, experience in other highly industrialized areas has shown that waste disposal accompanying such development often leads to contamination of surface waters unless a carefully controlled disposal program is carried out. In such areas many problems arise concerning water pollution and trade wastes, methods of analysis to determine the extent and nature of the pollution, and the nature of treatment of such wastes to make them acceptable for discharge to rivers. Some knowledge of the quality of water presently available will materially assist in the determination of the extent and nature of many pollution problems in years to come, especially if the quality of surface and ground waters is analyzed periodically.

As the domestic and industrial use of waters increases, ground water sources may become depleted or inadequate for reasons of quality or quantity, and the use of surface supplies must be increased. During the period 1941–45, for example, heavy withdrawals concentrated in the vicinity of Dauphin and St. Joseph Streets in downtown Mobile resulted in increasing chloride concentrations so much that some 20 wells in the area had to be abandoned or drilled deeper. It is essential, therefore, that data be made available on supplementary water supplies, including information on the seasonal variations of surface water supplies in the whole area.

Public Supplies

The public industrial supply in the immediate metropolitan area is capable of increasing its deliveries by about 20 mgd without overloading its facilities. The domestic supplies of Mobile and Prichard are now operating at close to the capacities of their treatment plants. If treatment, transmission, and pumping capacities were increased, the public water supplies, domestic and industrial, could increase their deliveries by about 60 mgd without exceeding the safe yield of their present sources.

Industries in the metropolitan area have largely discontinued use of private supplies of surface water that have previously yielded approximately 25 mgd and instead they are purchasing water from the industrial supply. Resumption of use of these sources would, of course, increase the overall supply by that amount. The Mobile Water System discontinued use of Threemile Creek and Clear Creek when the Big Creek supply became available. Approximately 12 mgd of additional water would be available if needs again required diversion from those streams.

Surface Water

The potential sources of surface water supplies can be separated into three general groups: (1) the Mobile and Tombigbee Rivers; (2) the smaller streams that can supply additional water to the present public supply systems; and (3) other small streams that could serve industry that builds beyond the public supply systems.

Mobile and Tombigbee Rivers

Industries located along the west bank of the Mobile River and upstream along the west bank of the Tombigbee River have used those streams for the disposal of their wastes. Some industries use them as sources of cooling water. Other industries that build here will probably make similar use of these streams.

The Mobile River has an average flow of about 60,000 cfs, or 39,000 mgd, and is by far the largest present and potential source of water in the area. Salinity in the lower reaches during low-water periods restrict the use of this water somewhat; however, the water farther upstream is of good quality. The amount of water available along the shoreline varies with the location because of the many interconnecting channels. At low and medium stages the entire flow of the Mobile River is confined to one channel for a short distance, from the confluence of the Alabama and the Tombigbee Rivers to the division between the Tensaw and lower Mobile Rivers. Streamflow in this reach is represented by the data shown for the Mobile River near Mount Vernon. An estimate of the flow available in the lower Mobile River below the division with the Tensaw River can be deduced from figure 8.

The duration of flow in the lower Mobile River was estimated from the data in figure 5 and figure 8. The resulting curve is shown in figure 26. The flow in the lower Mobile River down to the division with the Spanish River, just a few miles north of the city, is practically the same as shown by the curve because the volume of diversion or inflow is negligible. However, the effect of tide increases progressively in a downstream direction. Flows at different points along this reach are comparable if average flows for weekly or monthly periods are used.

The flow of the Tombigbee River from the Jackson bridge down to the mouth of the Alabama River cutoff is almost the same as at the gaging station at Leroy. No information is available on the amount of water that flows into the Tombigbee from the cutoff; therefore, little is known about the flow of the Tombigbee

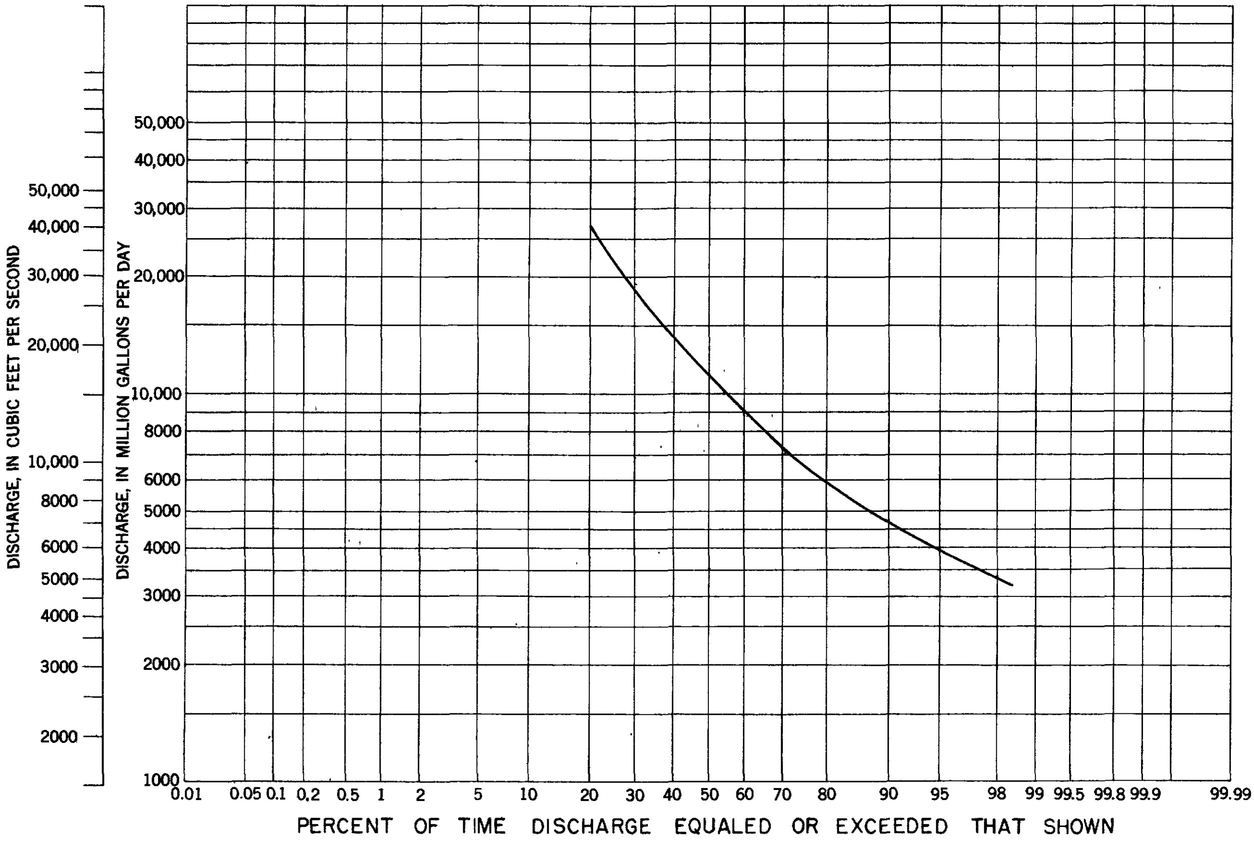

Figure 26.—Approximate duration curve of daily flow, lower Mobile River, computed for the period 1930–54.

River below the mouth of the cutoff except that it is probably greater than it is above the cutoff. The whole reach of river from Jackson bridge to the confluence is affected by tide during low flows, and considerable variation of flow can be expected during a tidal cycle.

Escatawpa River

The Escatawpa River appears to be a leading potential source of additional water for the Mobile public system when the demand of that system exceeds the supply available at the Big Creek Reservoir and the transfer of water from it to Big Creek Reservoir seems feasible. Data on the duration of flow in this stream are shown in table 2.

Additional information, presented in figure 27, gives the longest periods of consecutive days for which the daily streamflow was less than the indicated amount. Figure 28 shows the amount of storage required to assure various flows. Data in these figures are given as flow per square mile of drainage area so that the data may be readily used to compute the approximate flow at sites other than the gaging station. The computed flow is correct only if the entire drainage area is contributing to the flow at the gaging station at a uniform rate. This is a valid assumption if the difference is small between the gaged area and the area at which the discharge is to be computed. The greater the difference between the gaged area and the area at which the discharge is to be computed, the greater the probable error in the computed discharge.

For example, if information were desired at a point on the stream where the drainage area is 400 square miles, figure 27 would show that the flow at that place has been below 24 mgd (0.06 mgd per square mile) for 13 consecutive days; from figure 28 it can be estimated that 132,000 acre-feet of storage (330 x 400) would be required to assure a flow of 240 mgd (0.6 mgd per square mile).

Chickasaw Creek

Chickasaw Creek can be considered a potential source of supply for additional water for the cities of Prichard, Whistler, and Chickasaw or for industries that may build in the area. Data on duration of flow of this stream are given in table 2. Insufficient basic data are available to present storage curves, but it is apparent from table 2 that the stream is capable of supplying a substantial amount of water.

Other Small Streams

Many small streams flow into the Mobile and lower Tombigbee Rivers from the west. Of these only three are considered to be potential sources of moderate quantities of water for an industry that may build along

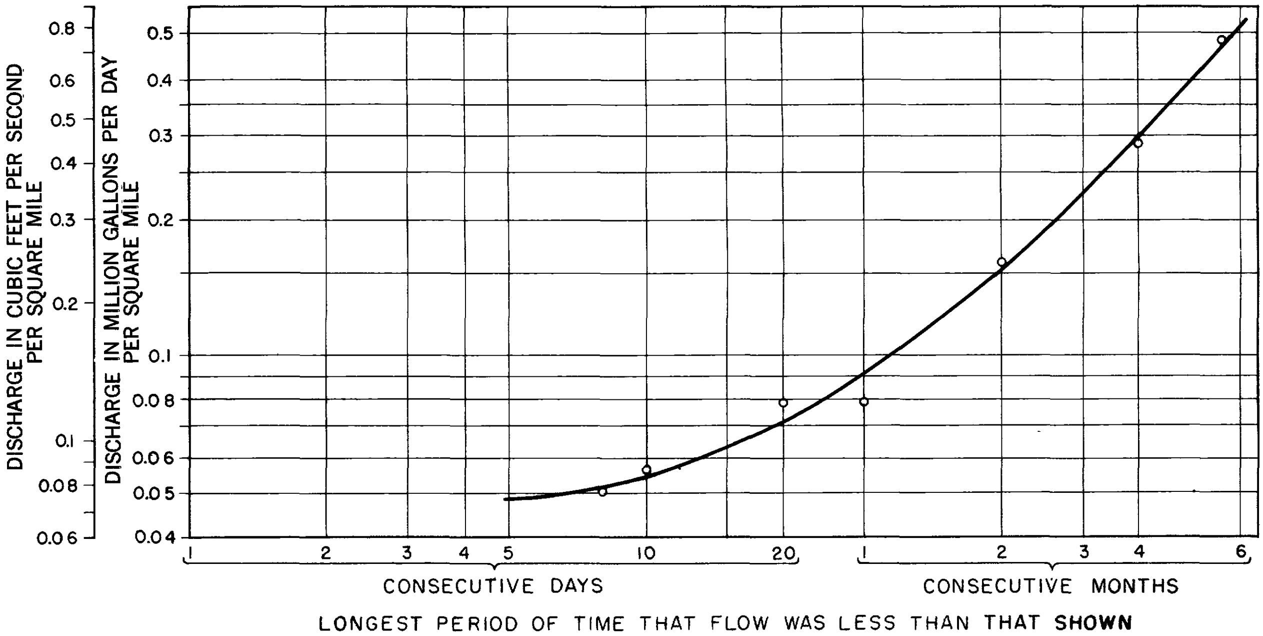

Figure 27.—Maximum period of deficient flow, Escatawpa River near Wilmer, from August 1945 to December 1954.

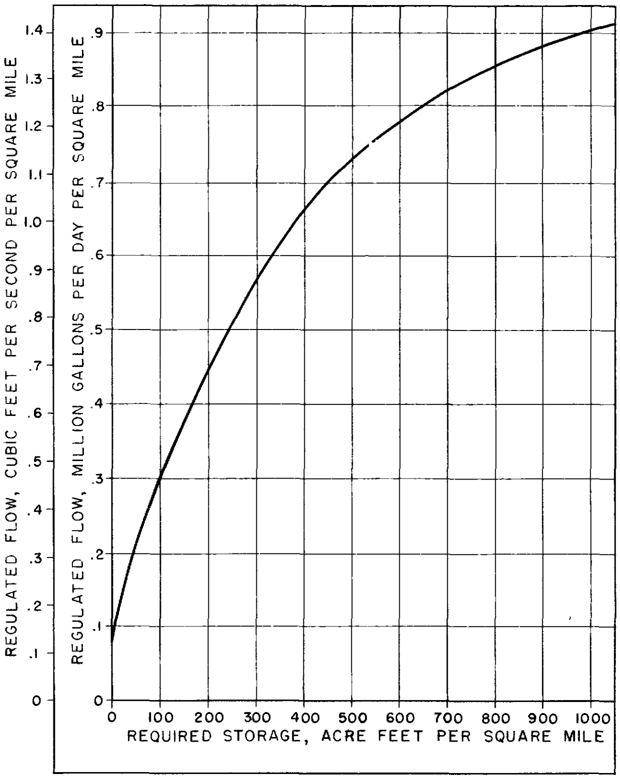

Figure 28.—Storage at point on Escatawpa River near Wilmer that would be required to produce given flows.

the west riverbank. These three are Basset Creek at the extreme northern end of the area, Bayou Sara just north of the metropolitan area, and Cedar Creek which is about half way between them. Flow-duration data for these streams are presented in table 3.

Other small streams may be considered to be potential sources of supplies if a modest amount of water is desired or if an impoundment is used.

Quality

Analyses presented in tables 4, 6, 8, and 9 indicate that surface waters of good to excellent quality are available in the Mobile area for further industrial use. Water from the streams is quite low in mineral content and varies little throughout the year, regardless of stream discharge. Some industrial and other uses may require treatment of the water for removal of iron, color, and sediment. Sediment may increase to significant amounts during periods of high discharge. It is believed, also, that the effects of impoundment upon chemical quality should receive adequate study before the construction of reservoirs.

Ground Water

Quantity

Ground water, in general, is abundant in the area. Except in downtown Mobile, a considerable amount of additional development is possible.

Along the west side of the Mobile River and in Mobile, small-capacity wells generally can be developed in the alluvium. If large developments are contemplated, however, exploratory drilling and a testing program should be undertaken as an aid in determining the character, extent, and saturated thickness of the water-bearing material.

Sands of Miocene age below the alluvium include several aquifers in which wells of large yield can be developed. The data are inconclusive as to the extent and possible yield from these aquifers north of Mobile, as most of the development has been confined to the shallow aquifer in the alluvium or sand beds in the upper part of the Miocene deposits. Well 22 (pl. 1) at Citronelle, obtaining water from sands in the Miocene between 639 and 727 feet, is reported to pump 500 gpm. The water is of good chemical quality. This is the only well in the immediate vicinity of Citronelle that is known to tap an aquifer below 400 feet, but it is reasonable to assume that similar aquifers occur in adjacent areas and wells could be located through test drilling.

Heavy pumping in a concentrated area in downtown Mobile resulted in encroachment of salt water from the Mobile River in former years. The same problem will recur if pumping from closely spaced wells is increased again.

The data available are inadequate for evaluating satisfactorily the maximum amount of ground water that can be obtained. However, the withdrawal from the ground-water reservoirs in 1954, totaling about 42 mgd, is believed to be much less than the amount safely available in the area.

Quality

The quality of ground water in the Mobile area varies. In the metropolitan area the water from the alluvium contains small to large amounts of sodium chloride and the water is soft to very hard. In the area north of Mobile water from the alluvium is of good quality; it is low in chloride, hardness, and dissolved solids. In some places, however, these waters may contain moderate to excessive amounts of iron.

In the downtown area of Mobile the water from the Miocene deposits to a depth of about 200 feet is generally of fair chemical quality; it is low in hardness and dissolved solids and contains low to moderate amounts of sodium chloride. Below a depth of about 200 feet, the water is generally hard, high in dissolved solids, and it contains excessive amounts of sodium chloride. North of Mobile in the vicinity of Citronelle the water from sands of Miocene age is of good quality in a well 735 feet deep; the water is low in iron, hardness, sodium chloride, and dissolved solids.

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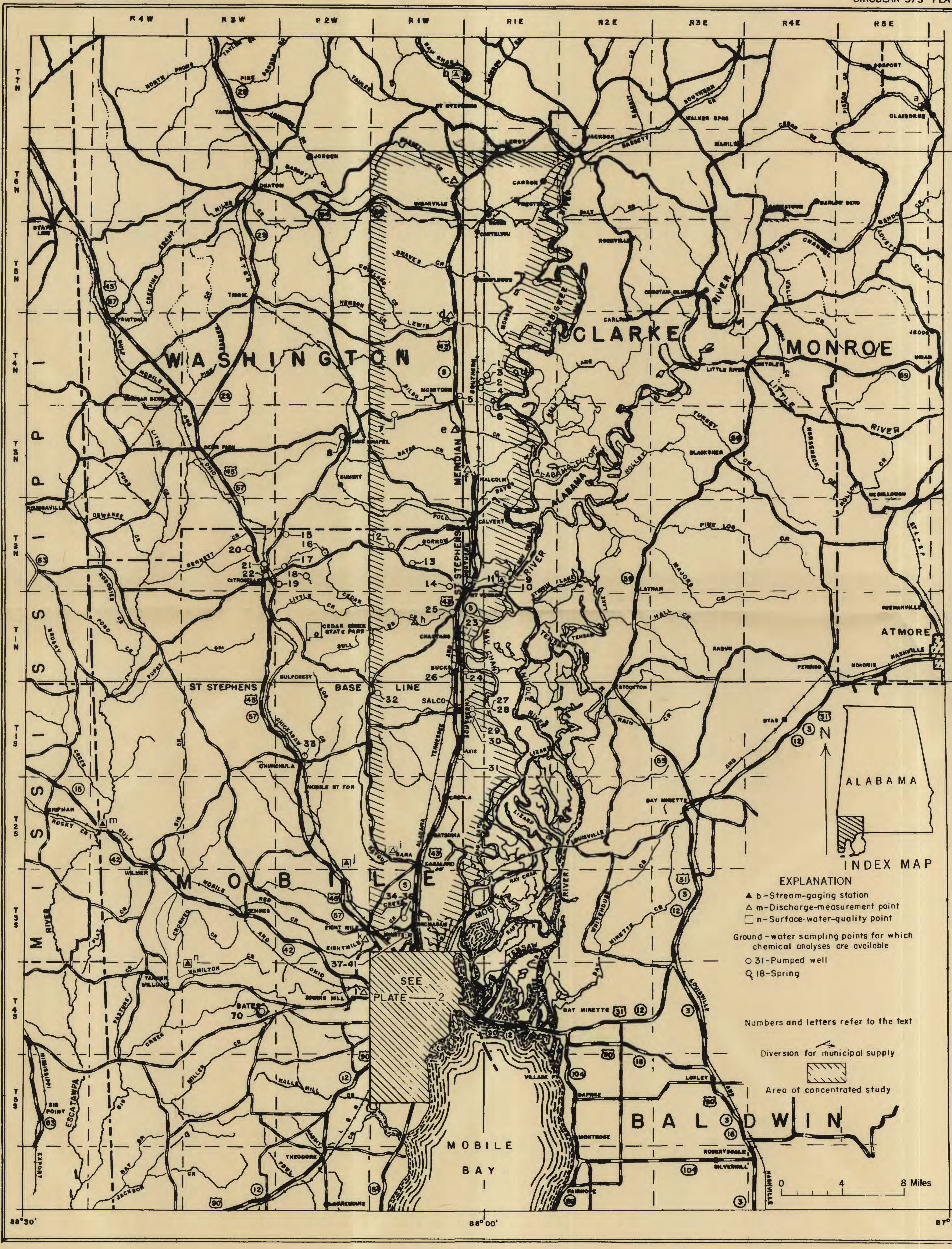
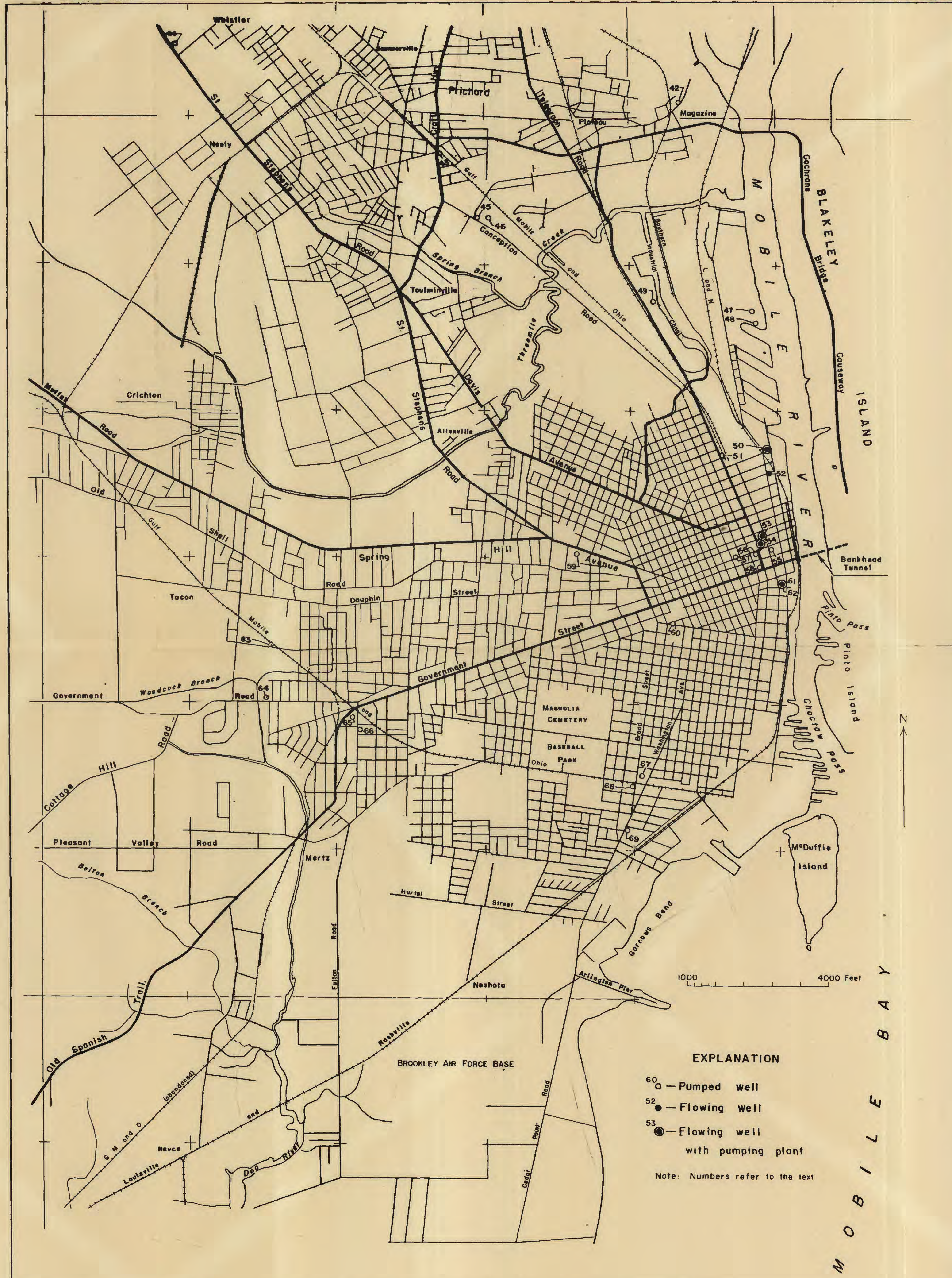


MAP OF MOBILE AREA SHOWING WHERE WATER-RESOURCES DATA HAVE BEEN COLLECTED



MAP OF CITY OF MOBILE AND VICINITY SHOWING WHERE GROUND-WATER DATA HAVE BEEN COLLECTED