Public Water Supplies of the 100 Largest Cities in the United States, 1962

CHARLES N. DURFOR and EDITH BECKER

Geological Survey Water-Supply Paper 1812

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has cataloged this publication as follows:

Durfor, Charles Norman, 1923–

Public water supplies of the 100 largest cities in the United States, 1962, by Charles N. Durfor and Edith Becker. [Washington, U.S. Govt. Print. Off., 1964]

ix, 364 p., illus., maps, diagrs., tables. 24 cm. ([U.S.] Geological Survey. Water-Supply Paper 1812)
Bibliography: p. 81–83.

1. Water-supply—U.S. 2. Water, Underground—U.S. I. Becker, Edith, 1930—, joint author. II. Title. (Series)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price $2.00 (paper cover)

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Mobile	2
Montgomery	3
Arizona:	
Phoenix	4
Tucson	5
California:	
Fresno	6
Long Beach	7
Los Angeles	8
Oakland	9
Sacramento	10
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San Francisco	12
San Jose	13
Colorado:	
Denver	14
Connecticut:	
Bridgeport	15
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New Haven	17
District of Columbia:	
Washington	18
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Jacksonville	19
Miami	20
St. Petersburg	21
Tampa	22
Georgia:	
Atlanta	23
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Honolulu	25
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North Carolina:	
Charlotte	65
Greensboro	66
Ohio:	
Akron	67
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Cleveland	69
Columbus	70
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Youngstown	73
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PUBLIC WATER SUPPLIES OF THE 100 LARGEST CITIES IN THE UNITED STATES, 1962

By CHARLES N. DURFOR and EDITH BECKER

ABSTRACT

The public water supplies of the 100 largest cities in the United States (1960 U.S. Census) serve 9,650 million gallons of water per day (mgd) to 60 million people, which is 34 percent of the Nation's total population and 48 percent of the Nation's urban population. The amount of water used to satisfy the domestic needs as well as the needs of commerce and industry ranges from 13 mgd, which serves a population of 124,000, to 1,200 mgd, which serves a city of 8 million people.

The water for the public supplies of these largest cities comes from ground water—wells and infiltration galleries—and from surface water—streams, reservoirs, and lakes. Twenty of the cities use ground water exclusively for public supplies, and 14 use a combination of ground and surface waters. Sixty-six cities use surface water solely; of these cities 37 depend solely upon reservoir water, and 20 depend solely upon natural streamflow. Water from the Great Lakes furnishes part or all of the water supply for 10 of these largest cities.

Hardness of water, measured in parts per million (ppm), is an important factor in the usability of water supplies. Twenty-seven cities, serving a population of 8 million, have a raw-water hardness exceeding 180 ppm ("very hard"), but only 13 cities, serving a population of 3.7 million, have a "very hard" treated-water supply; and although 22 cities, serving about 10 million people, have a raw-water hardness ranging from 121 to 180 ppm ("hard"), only 16 cities, serving a population of 11 million, have a "hard" treated-water supply. Only 16 cities, serving a population of 16 million people, have a raw-water hardness ranging from 61 to 120 ppm ("moderately hard"), whereas 41 cities, serving a population of 22 million, have a treated-water supply having a hardness within this desirable range. A few cities that have a "soft" raw water add lime to control corrosion and consequently increase their water hardness to more than 61 ppm. Thirty cities, serving a population of about 23 million, have a treated-water supply with a hardness of less than 61 ppm.

The dissolved-solids content in raw-water supplies of 27 cities, which serve a total population of slightly more than 21 million people, is 100 ppm or less. Thirty-eight cities serving a total population of 23 million people have raw-water supplies with a dissolved-solids content between 101 and 250 ppm, whereas 48 cities, serving a population of 28 million—about half the population of these

cities—furnish water having this range of dissolved solids. Twenty-nine cities serving a total population of 11 million people have raw-water supplies that contain between 251 to 500 ppm of dissolved solids. Because some of these cities treat their water supply, 22 cities serving 8 million people furnish water having a dissolved-solids content between 251 and 500 ppm. Only six cities, serving a population of about 1½ million people, have raw-water supplies containing more than 500 ppm of dissolved solids; four of these cities soften the water and consequently reduce the dissolved-solids content. Thus, about 1 million people in three cities receive water containing more than 500 ppm of dissolved solids.

Chemical analyses of treated-water supplies indicate that more than 90 percent of the supplies contain less than (a) 500 ppm of dissolved solids, (b) 100 ppm of sulfate, (c) 50 ppm each of calcium, sodium, and chloride, (d) 30 ppm of silica, (e) 20 ppm of magnesium, (f) 5 ppm each of potassium and nitrate, and (g) 1 ppm of fluoride.

Spectrographic analyses, reported in micrograms per liter (μg per l), show that 87 percent of the treated-water supplies contain less than 500 μg per l of aluminum and more than 90 percent of the supplies contain less than (a) 500 μg per l of strontium, (b) 150 μg per l of iron, (c) 50 μg per l of lithium, (d) 10 μg per l each of molybdenum, nickel, lead, and vanadium, and (e) 5 μg per l each of chromium, rubidium, and titanium.

Radiochemical analyses of treated-water supplies reveal that the maximum beta activity of these supplies is 130 picocuries per liter (pc per l) and the maximum activity due to radium content is 2.5 pc per l, both of which are well under the recommended maximum limits for drinking water.

The report is divided into two sections. The first describes the uses of water in large cities, the raw-water supplies available for public supplies, the major and minor constituents and the properties of water, the methods of analyses, the treatment of water, the effects of chemical treatment on constituents and properties of water, and the costs of water treatment. The second is a city-by-city inventory that gives (a) the population of the city, (b) the adjacent communities supplied by the city water system, (c) the total population served, (d) the sources of water supply (including auxiliary and emergency supplies), (e) the average amount of water used daily, (f) the lowest 30-day mean discharge of streams used for public supply during recent years, (g) the treatment of water, (h) the rated capacity of each water-treatment plant, and (i) the storage capacity for raw and finished water. For 58 of the cities, the sources of water, the location of water-treatment plants, and the areas served by the city system are shown on maps. Chemical, spectrographic, and radiochemical analyses of treated water and chemical and spectrographic analyses for many of the raw-water supplies are presented in tabular form.

INTRODUCTION

Water is essential to man and industry. Unless adequate amounts of water of acceptable chemical quality are available, man and industry will move to a better water supply. Water of acceptable chemical quality is defined as water that requires no treatment before use or water from which dissolved minerals can be removed by economically feasible water-treatment methods.

Information concerning the public water supplies—especially the chemical character of raw- and treated-water supplies—is important to operators of waterworks, industries planning to use the water, industries planning to sell chemicals and equipment pertaining to water, water-treatment consultants, public-health officials, and students interested in water supply.

For more than 40 years the U.S. Geological Survey has been studying the quality of public water supplies. Collins (1923) reported on the public water supply of 307 places, which represented 36 percent of the Nation's total population; Collins, Lamar, and Lohr (1932) gave data for 670 places, which represented 46 percent of the total population; and Love and Lohr (1954) reported on 1,315 locations, which represented 58 percent of the total population. The present study was limited to the 100 largest cities in the United States as determined by the 1960 U.S. Census (U.S. Bureau of Census, 1961) in order to permit the inclusion of comprehensive spectrographic and radiochemical analyses of public water supplies. About 60 million people, which is 34 percent of the Nation's total population and 48 percent of the Nation's urban population, are supplied from the water systems of these cities.

During these 40 years many changes have taken place in the public water supplies of the Nation. In 1922 only 2 cities (serving a population of less than 700,000) of these 100 largest cities softened their water supply. Today almost 11 million people in 28 of these cities receive softened water. Even in the last decade significant changes have occurred in the treatment of municipal water supplies. In 1952, only 10 of these 100 largest cities were fluoridating their water supplies, but today more than 21 million people in 34 of these cities receive fluoridated water. In the last four decades many cities also changed their sources of raw water. Generally a new source of water supply had a lower dissolved-solids content and a lower hardness. These changes in water treatment and in the quality of the raw-water source have influenced the quality of the water served to the customer.

The 100 largest cities in this report—hereafter also referred to as "these largest cities"—are listed alphabetically by State in table 1. Each city has been assigned a number that identifies the city in many of the illustrations.

The first section of this report briefly describes uses of water in large cities, the types of raw-water sources available for public supplies, the major constituents in water, some properties of water, many minor elements in water, the methods of analyses, the treatment of public water supplies, the effects of water treatment on constituents in and properties of water, and the cost of water-treatment chemicals.

The second section is a descriptive inventory, city by city, of (a) the suburban towns supplied by the city system, (b) the population of the city, (c) the total population served, (d) the sources of supply, (e) the auxiliary and emergency sources of supply, (f) the average daily water use, (g) where available, the lowest 30-day mean discharge of streams used for public water supply, (h) the water treatment, (i) the rated capacity of each treatment plant, and (j) the raw-water and finished-water storage capacity. For 58 cities the sources of water, the location of treatment plants, and the areas served by the municipal system are shown on maps. Chemical, spectrographic, and radiochemical analyses of all treated-water supplies and chemical and spectrographic analyses of many of the raw-water supplies are presented in tabular form.

USE OF WATER IN LARGE CITIES

In these largest cities, municipal water systems supply water for for homes, commercial establishments, industry, irrigation, and public needs such as fire fighting, street flushing, and operation of municipal offices and activities.

More water is used in daily activities than one might realize. As an example, a family of five camped for a weekend near the Atlantic Ocean. Facilities were primitive, and modern plumbing was lacking; nevertheless the family used 10 gallons of water for drinking, cooking, and washing—even though the children washed only when ordered to do so!

At their home, which is in a large eastern city, this same family has modern conveniences: automatic clothes- and dish-washing machines, garbage disposal, shower and tub, and flush toilet. During 1962, the family used an average of 275 gallons of water each day, or 55 gallons per member. No record was kept of the amounts of water used for the various purposes, but the city of Akron, Ohio (Akron Bureau of Water Supply), estimated the use of water in the average home in Akron to be as illustrated in figure 1.

The amount of water used in homes varies from region to region and from season to season. A survey of middle-income homes throughout the United States indicated that smaller amounts of water are used per person in the humid East than in other parts of the country (K. A. MacKichan, written commun., 1960); the amount used by each member of the family ranges from 27 to 75 gallons per day in the East to more than 200 gallons per day in the West. In most areas, the amount of water used during the summer far exceeds the amount used during the winter. In Jacksonville, Fla., for

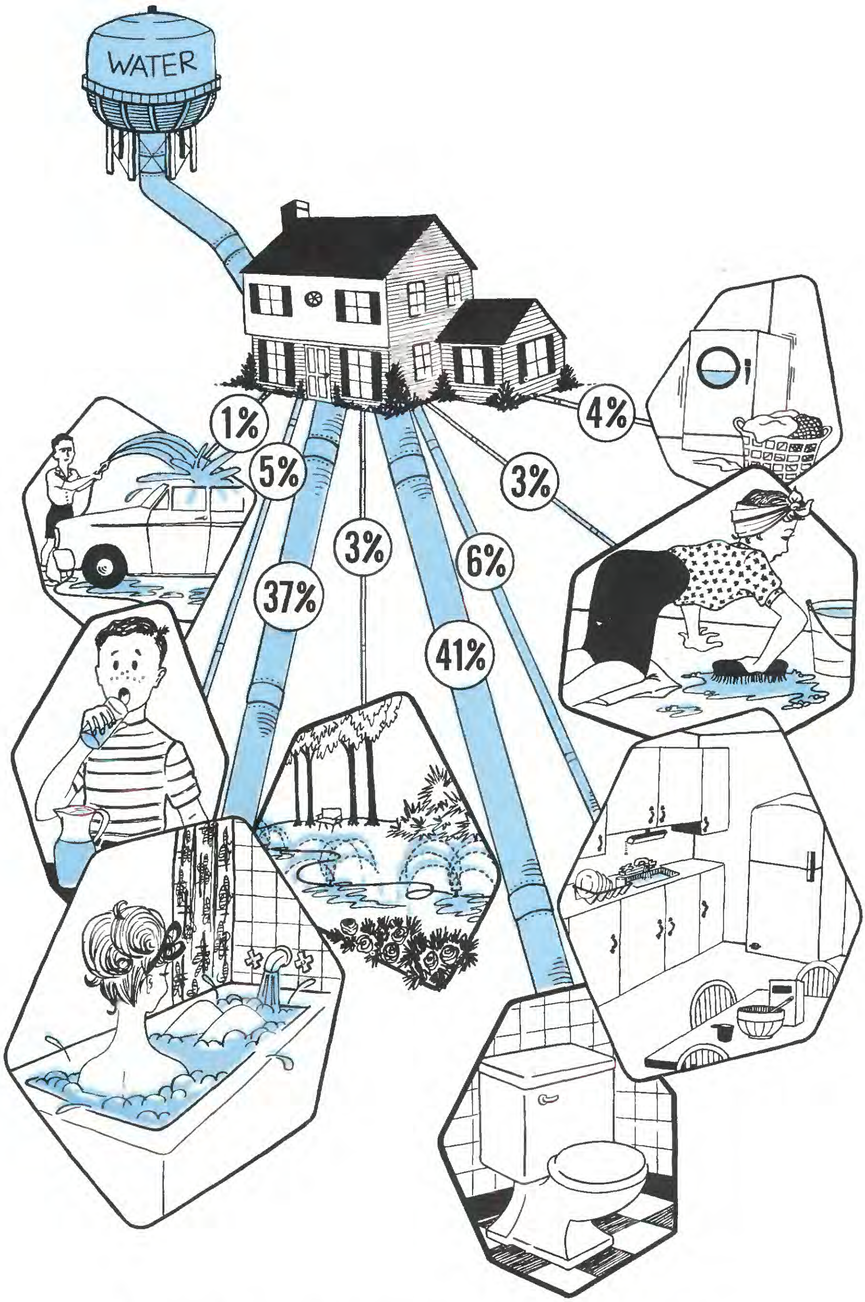


FIGURE 1.—Use of water in an average home in Akron, Ohio.

example, the water pumped on January 31, 1960, was only about one-third the amount pumped on May 21, 1960.

During the past 20 years, many water-using devices that improve man's comfort have had unprecedented popularity. For example, in Baltimore, Md., the amount of water used by commercial establishments for air conditioning and refrigeration alone increased 40 percent during the 5-year period 1948–52 (Requardt, Shaw, and Wolman, 1953). The amount of water used in the home also has increased substantially because of more widespread use of garbage-disposal equipment, shower baths, automatic dish- and clothes-washing machines, hot-water heaters, and sanitary plumbing.

In large cities many commercial firms and small industries that do not require large amounts of water obtain their water from the municipal water supply, if the quality of water furnished by the city is satisfactory. Although most commercial establishments do not use large amounts of water, the aggregate use of water by all commercial establishments in a large city can be a significant part of the total water demand on the municipal supply. In recent years, some commercial establishments—for example, self-service laundries—have significantly increased in size and number and so has their demand for water.

Industry also must have water to sustain itself and to expand. Maps showing concentrations of industries indicate that most industries are on streams and lakes near large cities. For example, the paper industry, which uses 5 to 40 gallons of water per pound of paper produced, is located principally in the water-rich areas of the East and the Northwest and along the Great Lakes (Mussey, 1955, p. 1–2). Many industrial establishments obtain part of their water supply from municipal water systems. In 1962, these largest cities sold an average of 27 percent of their public water supply to industry; one city sold 63 percent of its public supply to industry.

In a few cities, the amount of water used for irrigation is a significant part of the municipal water demand. For example, although water is used for irrigation only intermittently in Los Angeles, Calif., the water used for this purpose in a recent year (1960) was about equal to the entire public water demand during that year for Mobile, Ala., a city having a population of more than 200,000 people. In Houston, Tex., the city sells large amounts of untreated San Jacinto River water to rice growers.

Municipal water-supply systems in the United States during 1960 supplied an average of about 150 gallons of water to each person each day. In these largest cities, the water requirements were higher than the national average. In Chicago, Ill., enough water was furnished each day to supply each Chicagoan with about 255 gallons During the same period, Springfield, Mass., furnished each inhabitant about 181 gallons (the suburbs of Springfield, which are less industrialized, required only about 68 gallons of water per person).

As a result of increases in population, domestic water demand, and industrial water demand, most cities have expanded their water

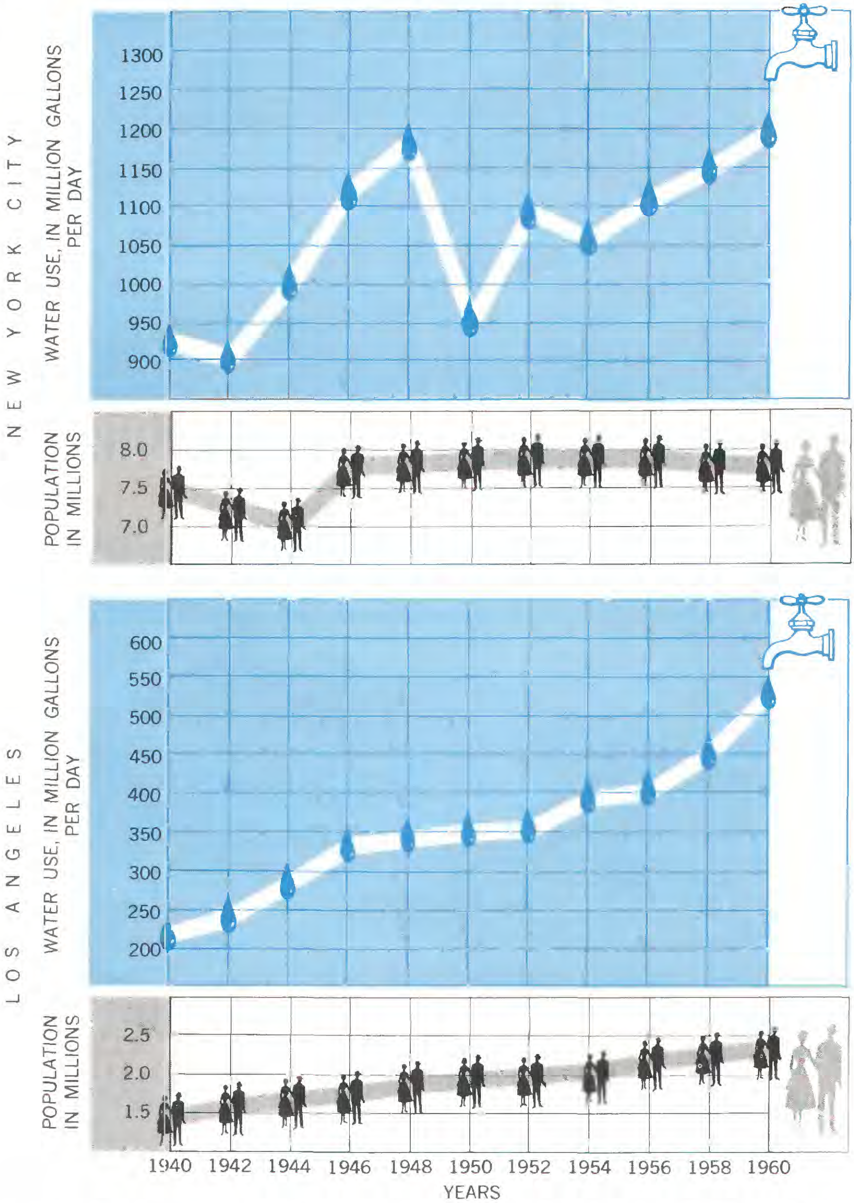


FIGURE 2.—Increase in water use and population Los Angeles, Calif., and New York City, N.Y., 1940–60.

systems. Fifty-one of these largest cities were planning in 1962 to spend a total of more than $313 million on waterworks construction (Dowling, 1962). New York City supplied 30 percent more water in 1960 than in 1940; Los Angeles, 110 percent; and Tucson with its increased population and pleasant winter climate had to supply almost 600 percent more water in 1960 than in 1940. Figure 2 illustrates the population changes and water demands of two of the largest cities in this country during the period 1940–60. It is interesting to note that in Los Angeles the water demand has steadily increased in direct proportion to the increase in population, whereas in New York City the amount of water supplied has increased 30 percent although the population served has increased less than 5 percent. The sharp dip in the water use in New York City in 1949 and 1950 was due to water rationing caused by a severe drought in the watersheds from which New York City obtained its water supply. Additional water is now being diverted from the East Branch of the Delaware River to supplement the supply.

SOURCES OF WATER SUPPLIES

These largest cities obtain their water supplies from two types of water resources: (a) ground water—wells and infiltration galleries—and (b) surface water—streams, lakes, and reservoirs. Most cities obtain their water from one type of source; a few cities always use multiple sources, whereas some cities use multiple sources only part of the year. For example, in El Paso, Tex., ground water is used most of the year, but during the summer, when demand is high, the Rio Grande is used to satisfy about 25 percent of the demand. The opposite is true for Bridgeport, Conn., which normally uses surface water but also uses ground water during periods of peak demand. Many municipal systems are connected with other municipal or industrial water supplies or can obtain water from other water sources during emergencies. The types of water sources used by these largest cities are shown in figure 3. The primary and auxiliary sources of water supply are given in the descriptive material for each of the 100 largest cities. The raw- and finished-water storage capacities for the individual cities also are given in the description.

GROUND-WATER SUPPLIES

Rain that falls on soil is pulled down into the ground by gravity and by capillary action. If the ground material is tightly compacted and has only minute pore spaces and cracks, water infiltrates slowly;

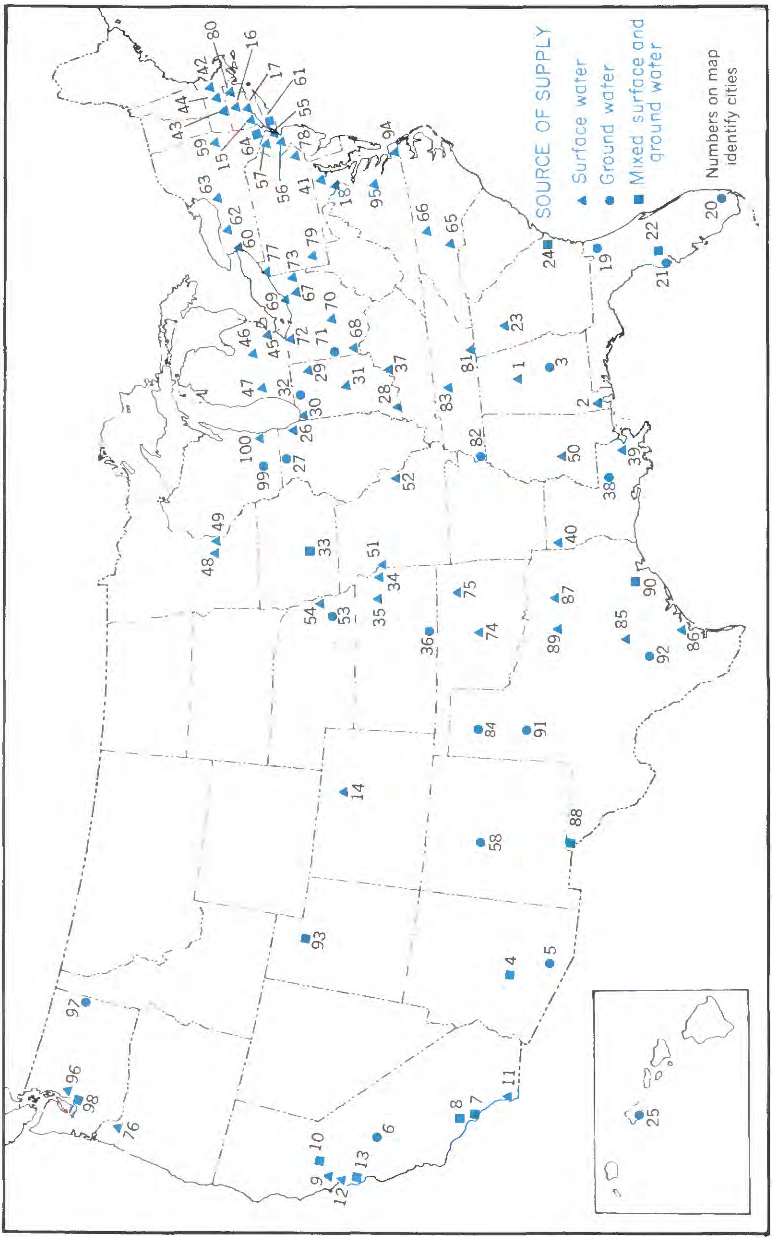


FIGURE 3.—Sources of water for public water supplies of the 100 largest cities in the United States, 1962. See table 1 for identification of cities.

if the ground material contains large pore spaces and cracks and the rocks have large holes, the water infiltrates rapidly, and large amounts of water accumulate. Once in the ground, the water moves downwards or sideways until it meets an impermeable material. Here the water collects, filling all available pore spaces, cracks, and holes, and forms a ground-water reservoir or aquifer.

According to Meinzer (1923, p. 148),

> Among all kinds of rocks the best water bearers are deposits of gravel. Next to gravel come sand, sandstone, limestone, and basalt. Among the many kinds of rock material that do not yield water freely but are nevertheless drawn upon where first-class aquifers are lacking are the fine-grained and poorly assorted unconsolidated deposits and the hard rocks with only tight joints. The most completely unproductive of all materials are the true clays and fine silts, whose original interstices are too minute to yield water and which are too soft to have joints or other secondary openings.

The rock formations of the area also determine the chemical composition of the dissolved solids in ground water. Some rocks, such as granite, are nearly insoluble in water and have little influence upon the water in contact with them. Other rocks, such as limestone and dolomite, are highly soluble; water that has been in contact with such rocks may contain large amounts of dissolved minerals.

Ground water is in contact with rocks for a longer time than is surface water and thus contains more dissolved minerals than adjacent surface water. The presence of carbon dioxide underground generally causes more calcium carbonate to be dissolved in ground water than in adjacent surface water, which is constantly exposed to air. The underground conditions also favor dissolution of iron and manganese from the surrounding rock. The filtering action of soils and rocks produces clear, colorless water, but upon exposure to air the calcium carbonate in the ground water may form a white precipitate, and the iron and manganese may form a rusty-colored precipitate.

The chemical composition of most ground water generally does not vary greatly with time. Thus, a single chemical analysis of ground water from a specific location will probably be representative of the year-round chemical quality. However, excessive withdrawals or pollution can radically change the chemical quality.

Of these largest cities, 20 cities use ground water exclusively for public water supply, and 14 cities use both ground and surface water. Ground water is obtained from gravel deposits (4 cities), sandstone or sands and gravel (13 cities), limestone (5 cities), alluvium and valley fill (7 cities), and volcanic rock (1 city, Honolulu). In addition, a few cities obtain ground water from water-bearing formations that are a composite of some of these rock types or from formations that include clay, till, or glacial drift. Some cities obtain ground water from more than one water-bearing formation.

SURFACE-WATER SUPPLIES

FACTORS AFFECTING STREAMFLOW

Most of the rain that falls during intense rainstorms flows overland into streams; only a small part soaks into the ground and becomes ground water. The amount of water flowing in streams varies with the amount of precipitation, the season of the year, and ground-water inflow.

In the northern part of this country, the soil freezes during the winter, and most precipitation as rain flows overland to streams. Precipitation as snow lies on the ground until melted. If the snow melts gradually, most of the water infiltrates into the ground; if the snow melts rapidly, a large part of the water flows overland to streams. Early spring rains melt the remaining snow, and the melt water and rain flow overland to streams. In parts of the West, many communities depend upon snowmelt to furnish a large part of the public water supply for the year. During the summer, the lack of rain and the use of water for crop irrigation decrease the amount of water in streams. With the onset of cooler weather and fall rains, streamflow again increases.

During and for a short period after rainstorms, the amount of water in streams increases. Gradually the level of water in the stream decreases. If no rain falls for a long time, the stream may dry up. Streams that dry up—ephemeral streams—are common in the arid parts of the Western United States. Streams that do not dry up after extended periods of no rain—perennial streams—receive water from underground storage.

The movement of water between perennial streams and ground-water reservoirs is governed by the relative heights of each. When the streams are in flood, the water level is higher than the water table near the stream, and water moves into the ground. As the stream level decreases, the amount of water moving to the zone of saturation in the ground decreases until the water level of each is about equal. After the level of water in the stream becomes lower than the level of water in the zone of saturation in the ground, ground water moves toward the stream. When flow in a stream is supported principally by ground water, it has reached minimum or base flow.

MINERAL CONTENT OF STREAMS

The amount of dissolved solids in a stream is ever changing. As the stream flows toward its mouth, many sources contribute dissolved and suspended matter to the stream. Forest areas may contribute dark-colored surface runoff containing nitrogenous wastes from the decomposition of organic matter. Cultivated farmlands can contribute muddy runoff containing phosphate, potassium, and nitrate from fertilizers. Along various reaches of the stream, ground-water inflow may increase the dissolved solids in the stream, and industries may contribute waste waters containing appreciable amounts of dissolved chemicals. Thus, it is not surprising that the raw water obtained by Minneapolis, Minn., from the upper reaches of the Mississippi River contains about one-half the amount of dissolved solids as the raw water used by New Orleans, La., near the mouth of the river.

The dissolved-solids content of streams is at a minimum when streams are in flood. As the streamflow decreases, the concentration of dissolved solids generally increases. When the flow of water in a perennial stream is maintained by ground water, the chemical composition of the stream is influenced strongly by the composition of the ground water, and the dissolved-solids content is generally at a maximum.

IMPOUNDMENT OF STREAMS

Cities drawing water from uncontaminated mountain streams obtain water that is clean, low in dissolved solids, and free from disagreeable taste, odor, and color. But the volume of water in most mountain streams is small and undependable. Many cities impound water during periods of increased streamflow to provide water for extended periods when the consumption exceeds the streamflow. Where the drainage area of a stream is small and the impoundment of a single stream yields insufficient water, some municipal water-supply systems include a series of impoundment reservoirs. "So intricate is New Haven's system that water drawn from a tap in the city may be coming from one of the Maltsby Lakes in the morning, from Lake Whitney in the afternoon, and from Lake Gaillard in the evening" (New Haven Water Co., 1955).

Water is impounded in storage reservoirs during periods of high streamflow when the dissolved-solids content of streams is at a minimum. The dissolved-solids content of water in most reservoirs is fairly constant. Reservoirs act as huge settling basins for suspended matter, and they are especially effective in reducing turbidity caused by intense summer rains of short duration (Churchill, 1957).

Temperature changes cause stratification of water in reservoirs and lakes. In the fall when the density of the surface layer exceeds that of the bottom layer, the lake water "turns over." That is, the bottom layer moves upward and displaces the surface layer, bringing to the surface high concentrations of manganese and the foul tastes and odors of putrification. For example, manganese is present in the discharge from a reservoir on the Chattahochee River near Atlanta, Ga., during late summer and early fall (Ingols and Wilroy, 1962), and Baltimore, Md., has a long history of manganese in fall turnover of impounded water.

Sixty-six of the 100 largest cities use water from streams, lakes, or reservoirs; of these cities, 37 depend solely upon reservoirs, and 20 depend solely upon natural streamflow. Cities that do not have raw-water storage reservoirs and thus obtain their water supply directly from streams are generally on large rivers: four cities are on the Missouri River, three are on the Ohio River, and three are on the Mississippi River; most of the remaining 10 cities withdraw water from streams that can furnish in excess of 450 mgd (million gallons per day). Many of the cities on smaller rivers have additional sources of supplies—or have cast an eye on more desirable sites for future water-resources development.

THE GREAT LAKES

The Great Lakes constitute the largest body of fresh water in the world. The storage capacity of Lake Erie—the shallowest of the Great Lakes—is more than 10 times as great as Lake Mead, the largest artificial lake in the world. The combined overflow from the Great Lakes is equivalent to the flow of the fourth largest river in the United States.

The mineral content of the Great Lakes is relatively constant from month to month and changes only slightly from year to year. Near Erie, Pa., the dissolved-solids content of Lake Erie has increased only about 6 percent during the past 30 years (Pennsylvania Department of Commerce, 1958). The average dissolved-solids content of the lakes increases slightly in downstream order—from Lake Superior to Lake Ontario.

The large volume of water in the lakes helps maintain fairly uniform water temperatures: summer temperatures offshore are 5° to 10° cooler than the temperature of the contributing streams (73°F is the expected high average temperature for Lake Erie).

Generally the turbidity in the Great Lakes is low. Verduin (1953) estimated that the turbidity in western Lake Erie is uniformly about 11 ppm (parts per million). During high winds, storms, and periods of inversion of lake-water temperature, the silt on the lakebeds is disturbed and the turbidity increases.

Ten cities draw their water supply from the Great Lakes: Chicago, Ill., Gary, Ind., Grand Rapids, Mich., and Milwaukee, Wis., obtain their water from Lake Michigan; Buffalo, N.Y., Cleveland, Ohio, Toledo, Ohio, and Erie, Pa., obtain water from Lake Erie; and

Rochester, N.Y., withdraws about 21 percent of its water from Lake Ontario. Detroit, Mich., obtains its water from the Detroit River which, with the St. Clair River, carries the overflow from Lake Huron into Lake Erie.

CONSTITUENTS AND PROPERTIES OF WATER

After a long, hard hike through the woods, a sip of cool spring water tastes wonderful; at such a time, it is difficult to think about the chemicals in water. One is tempted to say that this spring water is ideal—after all, it is clear, cool, and sparkling, and it tastes good. But is it ideal water?

This same water may contain minute amounts of chemicals that can cause bodily harm if the water is ingested over a long period of time. It may contain chemical constituents that will consume large amounts of soap and detergents, or it may contain constituents that will stain porcelain fixtures and laundry. It may contain constituents that will form scale, which will gradually choke pipes, or it may lack these same constituents, and then it will corrode pipes. Does this mean we should keep away from water? No! What we are saying is that all natural water contains chemical constituents—from A (aluminum) to Z (zinc)—and that the amounts of these constituents vary from too much for one purpose to too little for another purpose; as a result, water generally has to be treated before it can be used.

MAJOR CHEMICAL CONSTITUENTS

The chemical constituents most commonly found in water are silica, iron, manganese, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, and dissolved solids (dissolved solids is the residue after evaporating a water sample at 180°C). Aluminum, boron, and strontium are present in appreciable amounts in some areas; these constituents will be discussed on page 32.

Table 2 shows the major sources of each of these constituents and also the maximum concentrations of these constituents in surface and ground water, ocean water, and natural brines. In unpolluted surface and ground water, the occurrence and amount of these constituents are regulated to a large extent by the geologic environment. In Pennsylvania, for example, the headwaters of a certain stream originating in an anthracite coal field are laden with sulfate; the pH is less than 4.0. When the stream leaves the anthracite field it contains no bicarbonate; it then flows through an area underlain with limestone, and here the sulfate content decreases, the bicarbonate content increases, and pH increases to more than 4.5. Near its mouth this stream passes through a limestone quarry; here the stream picks up more bicarbonate and carbonate, and the pH becomes greater than 9.0.

Most natural water contains calcium and magnesium; these elements are known as the alkaline earths and are the chief cations found in many waters. (An ion is an element, or a group of elements combined to act as a single constituent, that has an electrical charge; an ion with a negative charge is an anion; an ion with a positive charge is a cation.) It is not uncommon for natural water to contain several times as much calcium as magnesium.

Sodium and potassium are common alkali metals found in water; generally, they are present in much smaller quantities than the alkaline earths. In southern Louisiana and Texas, calcium and magnesium in ground water are exchanged with sodium and potassium in the soil, and the resultant water is enriched in sodium and potassium and contains negligible amounts of calcium and magnesium. Streams receiving waste water from irrigation and streams in arid areas, in tidal areas, and in areas underlain by sodium chloride beds also contain considerably more alkali metals than alkaline earths.

Carbonate and bicarbonate are found in most natural water because of the abundant deposits of readily soluble limestone (composed principally of calcium carbonate) and dolomite (composed principally of magnesium and calcium carbonates). In the presence of carbon dioxide, the dissolving of carbonate rocks by water forms anions of bicarbonates and carbonates in water. Figure 4, a photograph taken at a roadcut in Oklahoma, illustrates the effect of water moving through a crack in a limestone deposit. Seemingly, water moved down the vertical crack in the limestone, dissolved the limestone, and enlarged the crack, a condition that permitted more water to enter. In time, the enlarged crack became filled with dirt. Many ground-water environments are favorable to the dissolving of limestone rocks and so large amounts of bicarbonate are present in the water. In different environments, water saturated with calcium carbonate may reprecipitate calcium carbonate.

Sulfate is present in natural water but is commonly not found in as large an amount as is bicarbonate; however, water draining mining areas, gypsum beds, and arid lands frequently contains more sulfate than bicarbonate.

Chloride and nitrate are commonly found in all water, generally in amounts less than 10 ppm.

TABLE 2.—*Major chemical constituents in water—their sources, concentrations, and effects upon usability*

[Concentrations are in parts per million. Table prepared with the assistance of B. P. Robinson]

Constituent	Major sources	Concentration in natural water	Effect upon usability of water	Concentration in public water supplies of the 100 cities: Untreated water Max.	Untreated water Min.	Treated water Max.	Treated water Min.	Drinking water should contain less than concentration shown if more suitable supplies are or can be made available [1]
Silica (SiO_2)	Feldspars, ferromagnesium and clay minerals, amorphous silica chert, opal.	Ranges generally from 1.0 to 30 ppm, although as much as 100 ppm is fairly common; as much as 4,000 ppm is found in brines.	In the presence of calcium and magnesium, silica forms a scale in boilers and on steam turbines that retards heat; the scale is difficult to remove. Silica may be added to soft water to inhibit corrosion of iron pipes.	72	0.0	72	0.0	
Iron (Fe)	1. *Natural sources:* Igneous rocks: Amphiboles, ferromagnesian micas, ferrous sulfide (FeS), ferric sulfide or iron pyrite (FeS_2), magnetite (Fe_3O_4). Sandstone rocks: Oxides, carbonates, and sulfides of iron clay minerals. 2. *Manmade sources:* Well casing, piping, pump parts, storage tanks, and other objects of cast iron and steel which may be in contact with the water. Industrial wastes.	Generally less than 0.50 ppm in fully aerated water. Ground water having a pH less than 8.0 may contain 10 ppm; rarely as much as 50 ppm may occur. Acid water from thermal springs, mine wastes, and industrial wastes may contain more than 6,000 ppm.	More than 0.1 ppm precipitates after exposure to air; causes turbidity, stains plumbing fixtures, laundry and cooking utensils, and imparts objectionable tastes and colors to foods and drinks. More than 0.2 ppm is objectionable for most industrial uses.	1.90	0.00	1.30	0.00	0.3
Manganese (Mn)	Manganese in natural water probably comes most often from soils and sediments. Metamorphic and sedimentary rocks and mica biotite and amphibole hornblende minerals contain large amounts of manganese.	Generally 0.20 ppm or less. Ground water and acid mine water may contain more than 10 ppm. Reservoir water that has "turned over" may contain more than 150 ppm.	More than 0.2 ppm precipitates upon oxidation; causes undesirable tastes, deposits on foods during cooking, stains plumbing fixtures and laundry, and fosters growths in reservoirs, filters, and distribution systems. Most industrial users object to water containing more than 0.2 ppm.	0.60	0.00	2.5	0.00	0.05

Calcium (Ca)	Amphiboles, feldspars, gypsum, pyroxenes, aragonite, calcite, dolomite, clay minerals.	As much as 600 ppm in some western streams; brines may contain as much as 75,000 ppm.	Calcium and magnesium combine with bicarbonate, carbonate, sulfate, and silica to form heat-retarding, pipe-clogging scale in boilers and in other heat-exchange equipment. Calcium and magnesium combine with ions of fatty acid in soaps to form soap suds; the more calcium and magnesium, the more soap required to form suds. A high concentration of magnesium has a laxative effect, especially on new users of the supply.	145	0.0	145	0.0	
Magnesium (Mg)	Amphiboles, olivine, pyroxenes, dolomite, magnesite, clay minerals.	As much as several hundred parts per million in some western streams; ocean water contains more than 1,000 ppm, and brines may contain as much as 57,000 ppm.		120	0.0	120	0.0	
Sodium (Na)	Feldspars (albite); clay minerals; evaporites, such as halite (NaCl) and mirabilite ($Na_2SO_4 \cdot 10H_2O$); industrial wastes.	As much as 1,000 ppm in some western streams; about 10,000 ppm in sea water; about 25,000 ppm in brines.	More than 50 ppm sodium and potassium in the presence of suspended matter causes foaming, which accelerates scale formation and corrosion in boilers. Sodium and potassium carbonate in recirculating cooling water can cause deterioration of wood in cooling towers. More than 65 ppm of sodium can cause problems in ice manufacture.	177	1.1	198	1.1	
Potassium (K)	Feldspars (orthoclase and microcline), feldspathoids, some micas, clay minerals.	Generally less than about 10 ppm; as much as 100 ppm in hot springs; as much as 25,000 ppm in brines.		30	0.2	30	0.0	
Carbonate (CO_3)	Limestone, dolomite.	Commonly 0 ppm in surface water; commonly less than 10 ppm in ground water. Water high in sodium may contain as much as 50 ppm of carbonate.	Upon heating, bicarbonate is changed into steam, carbon dioxide, and carbonate. The carbonate combines with alkaline earths—principally calcium and magnesium—to form a crustlike scale of calcium carbonate that retards flow of heat through pipe walls and restricts flow of fluids in pipes. Water containing large amounts of bicarbonate and alkalinity are undesirable in many industries.	21	0	26	0	
Bicarbonate (HCO_3)		Commonly less than 500 ppm; may exceed 1,000 ppm in water highly charged with carbon dioxide.		380	5	380	0	
Sulfate (SO_4)	Oxidation of sulfide ores; gypsum; anhydrite; industrial wastes.	Commonly less than 1,000 ppm except in streams and wells influenced by acid mine drainage. As much as 200,000 ppm in some brines.	Sulfate combines with calcium to form an adherent, heat-retarding scale. More than 250 ppm is objectionable in water in some industries. Water containing about 500 ppm of sulfate tastes bitter; water containing about 1,000 ppm may be cathartic.	572	0.0	572	0.0	250

See footnote at end of table.

TABLE 2.—*Major chemical constituents in water—their sources, concentrations, and effects upon usability*—Continued

[Concentrations are in parts per million. Table prepared with the assistance of B. P. Robinson]

Constituent	Major sources	Concentration in natural water	Effect upon usability of water	Concentration in public water supplies of the 100 cities: Untreated water, Max.	Untreated water, Min.	Treated water, Max.	Treated water, Min.	Drinking water should contain less than concentration shown if more suitable supplies are or can be made available [1]
Chloride (Cl)	Chief source is sedimentary rock (evaporites); minor sources are igneous rocks. Ocean tides force salty water upstream in tidal estuaries.	Commonly less than 10 ppm in humid regions; tidal streams contain increasing amounts of chloride (as much as 19,000 ppm) as the bay or ocean is approached. About 19,300 ppm in sea water; and as much as 200,000 ppm in brines.	Chloride in excess of 100 ppm imparts a salty taste. Concentrations greatly in excess of 100 ppm may cause physiological damage. Food processing industries usually require less than 250 ppm. Some industries—textile processing, paper manufacturing, and synthetic rubber manufacturing—desire less than 100 ppm.	540	0.5	540	0.0	250
Fluoride (F)	Amphiboles (hornblende), apatite, fluorite, mica.	Concentrations generally do not exceed 10 ppm in ground water or 1.0 ppm in surface water. Concentrations may be as much as 1,600 ppm in brines.	Fluoride concentration between 0.6 and 1.7 ppm in drinking water has a beneficial effect on the structure and resistance to decay of children's teeth. Fluoride in excess of 1.5 ppm in some areas causes "mottled enamel" in children's teeth. Fluoride in excess of 6.0 ppm causes pronounced mottling and disfiguration of teeth.	7.0	0.0	7.0	0.0	The recommended control limits depend upon annual averages of maximum daily air temperature and range from 0.6 to 0.8 ppm at 79.3° to 90.5° F and 0.9 to 1.7 ppm at 50.0° to 53.7° F.
Nitrate (NO_3)	Atmosphere; legumes, plant debris, animal excrement, nitrogenous fertilizer in soil and sewage.	In surface water not subjected to pollution, concentration of nitrate may be as much as 5.0 ppm but is commonly less than 1.0 ppm. In ground water the concentration of nitrate may be as much as 1,000 ppm.	Water containing large amounts of nitrate (more than 100 ppm) is bitter tasting and may cause physiological distress. Water from shallow wells containing more than 45 ppm has been reported to cause methemoglobinemia in infants. Small amounts of nitrate help reduce cracking of high-pressure boiler steel.	23	0.0	23	0.0	45 (In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.)

Dissolved solids	The mineral constituents dissolved in water constitute the dissolved solids.	Surface water commonly contains less than 3,000 ppm; streams draining salt beds in arid regions may contain in excess of 15,000 ppm. Ground water commonly contains less than 5,000 ppm; some brines contain as much as 300,000 ppm.	More than 500 ppm is undesirable for drinking and many industrial uses. Less than 300 ppm is desirable for dyeing of textiles and the manufacture of plastics, pulp paper, rayon. Dissolved solids cause foaming in steam boilers; the maximum permissible content decreases with increases in operating pressure.	1, 580	10	1, 580	22	500

[1] U.S. Public Health Service (1962b).

FIGURE 4.—Solution cavity in limestone. The effect of water moving through a limestone deposit is shown. The water moved down the vertical crack, dissolved the limestone, and enlarged the crack, a condition that permitted more water to enter.

For more than 60 years the dental defect that appears as a dark stain on tooth enamel and that is known as mottled enamel—locally called "Texas teeth" or "Colorado stain"—has been under investigation. It was reasoned that this defect was caused by some trace element in water. Later, fluorine was proved to be the cause (McNeil, 1957). Still later, fluoride concentrations of about 0.6 to 1.7 ppm in water were found to reduce the incidence of dental caries, and concentrations greater than 1.7 ppm were found to protect the teeth from cavities but to cause an undesirable black stain (U.S. Public Health Service, 1962b). For further information on the physiological effects of fluoride, the reader is referred to a selection of papers on the subject prepared by the U.S. Public Health Service (1962a).

Water boiled in a dish leaves a crust of salt composed principally of silica, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, nitrate, and some water bound in the residue. Upon heating this residue to 180° C, two changes occur:

most of the water of crystallization is expelled, and most bicarbonate is converted to carbonate. The residue dried at 180° C (called residue on evaporation) approximates the quantity of anhydrous chemicals in solution and is used as an indication of the dissolved-solids content in the water.

In many locations, efforts are made to obtain an adequate public supply of water containing small amounts of dissolved solids; the cost of treating water generally increases with increased amounts of dissolved solids. However, a person accustomed to drinking water containing a moderate amount of dissolved solids may complain about the "flat taste" of drinking water that has less than 100 ppm of dissolved solids. The amount of dissolved solids in the untreated water used for public supply ranges from less than 100 ppm along the Appalachian Mountains and in the far West to more than 500 ppm in the arid Southwest. (See fig. 5.)

Many of the largest cities obtain their water supplies from more than one source. For these cities, the dissolved-solid contents were weighted in proportion to the population served by each water source (fig. 5). The dissolved-solids content of each source was multiplied by the population served by that source. The products of the dissolved solids and population for each source were added. The resultant sum of the products was divided by the population served by all sources in the city to obtain a population-weighted average dissolved-solids content.

Many of the calculations of the population-weighted dissolved-solids content are based upon yearly averages supplied by officials of city waterworks. Other calculations of population-weighted dissolved-solids content are based on samples collected so as to represent an average value. The dissolved-solids content for a few cities was not calculated because of a lack of data.

The presence of specific amounts of certain constituents can have an adverse effect upon the usability of water. A few of the known tolerances of specific chemicals that affect the usability of water are listed in table 2. Some constituents, such as iron and manganese, are detrimental, even in small quantities. Fortunately, most water used by industry—more than 95 percent—is used for cooling, for which the main prerequisites are that the water be free of sediment, debris, and algae that could clog pipes. For a more comprehensive report on "quality tolerance of water for industrial uses," the reader is referred to Moore (1940).

Since about 1914, criteria have been promulgated to govern the quality of drinking water used on interstate carriers. The drinking-water standards established by the U.S. Public Health Service have gained wide acceptance and are now used by many water authorities

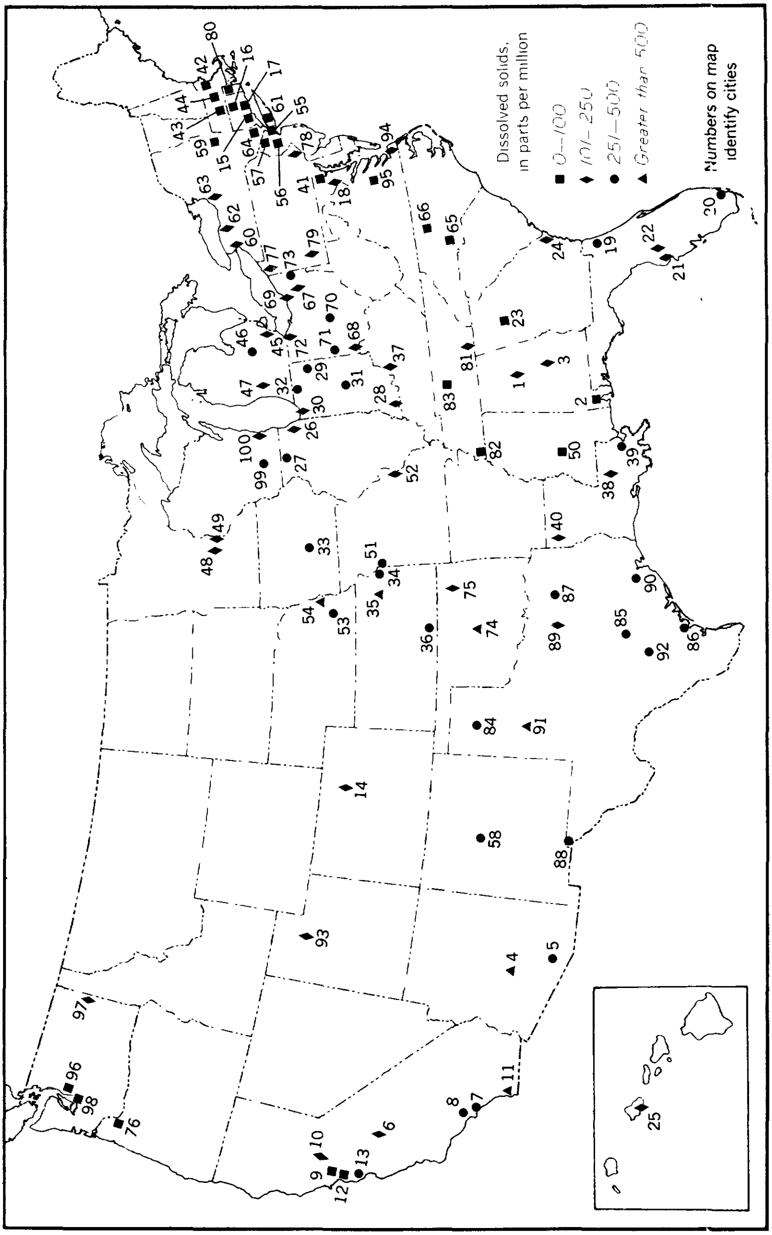


FIGURE 5.—Dissolved solids in untreated public water supplies of the 100 largest cities in the United States, 1962. (Average weighted by population served.) See table 1 for identification of cities.

as a guide in determining local drinking-water standards. These standards provide two types of chemical limits: maximum permissible limits for chemicals having known or suspected adverse physiological effects and recommended permissible limits for chemicals that are generally nontoxic but have adverse qualities pertaining to color, staining, taste, and odor. The concentrations shown in table 2 are the maximum concentrations that should be found in a public water supply where "in the judgment of the certifying authority, other more suitable supplies are or can be made available" (U.S. Public Health Service, 1962b).

MAJOR PROPERTIES

The properties of water that influence the use of water and the degree of water treatment are hardness, specific conductance, pH, color, turbidity, and temperature. The description and causes of these properties, their concentrations in natural water, the effect of concentrations upon usability of water, and concentrations in the public water supplies of the 100 largest cities are summarized in table 3.

HARDNESS

In one part of the country, a newcomer may be provoked into exclaiming about the hardness of the water because of his difficulty in working up a lather with soap and water. In another part of the country, a newcomer may remark about the softness of the water because soap suds are so easily formed. Hardness of water is a property of water that is a measure of the amount of soap required to form a lather. Not too many years ago the hardness of water was measured in the laboratory by determining the amount of soap solution that must be added to water to form suds.

Before soap can form a lather, part of the soap molecule must react with the calcium and magnesium in the water to form an insoluble curd. The smaller the amounts of calcium and magnesium, the easier soap suds are formed; conversely, the greater the amounts of calcium and magnesium, the more soap curds are formed and the more soap is consumed.

In 1856, Thomas Clark, of England, defined hardness as follows: "Each degree of hardness is as much as a grain of chalk or the calcium in a grain of chalk would produce in a gallon of water, by whatever means dissolved" (Baker, 1948). In this report hardness is expressed as the amount of calcium carbonate in a million parts of water chemically equal to the amount that could be formed from the calcium and magnesium in solution. Aluminum, iron, manganese, and other

TABLE 3.—*Properties of water—their description, concentrations, and effects upon usability of water*

Property and unit of measurement	Description and causes	Concentration or value in natural water	Effect upon usability of water	Concentration or value in public water supplies of the 100 largest cities			
				Untreated water		Treated water	
				Max.	Min.	Max.	Min.
Hardness (parts per million)	Hardness is expressed as the quantity of calcium carbonate equivalent to the calcium and magnesium present. It is caused principally by calcium and magnesium ions, but other alkaline earths (barium and strontium) and free acid and heavy-metal ions contribute to hardness.	In most surface water the hardness is less than 1,000 ppm; in ground water, the hardness is generally less than 2,000 ppm. In arid regions the hardness of surface and ground waters may be higher.	Water low in hardness causes corrosion of metallic surfaces. Hard water consumes excessive amounts of soap and synthetic detergents in homes, laundries, and textile industries; it forms insoluble scum and curds and causes problems in the processing of foods, beverages, and rubber. Hardness of water is classified as follows: *Hardness range (ppm)* — *Description* 0–60 — Soft. 61–120 — Moderately hard. 121–180 — Hard. More than 180 — Very hard.	738	0	738	0
Specific conductance (micromhos)	Specific conductance is a measure of the electrical conductivity of water: it varies with the amount of dissolved solids and is used to approximate the dissolved-solids content.	In the eastern and far northwestern parts of the United States most water has a specific conductance of less than 1,000 micromhos. In arid regions of western United States water with a specific conductance of more than 1,000 micromhos is not uncommon. Ocean water has a specific conductance of more than 50,000 micromhos.	------------	1,660	8	1,660	18
pH (pH units)	pH values range from 0 to 14. Water with a pH of 7.0 is neutral. Water having a pH less than 7.0 is acid, and water having a pH greater than 7.0 is alkaline.	pH of ground water commonly ranges from 6.0 to 9.0. In surface water it commonly ranges from 6.0 to 8.0. Water influenced by acid mine drainage may have a pH about 2.0.	For most domestic and industrial uses, water having a pH between 6.0 and 10 generally causes no great problems. Water having a pH below the range may be corrosive.	9.8	6.0	10.5	5.0

Color (color units)	Decaying vegetation; peat, lignite, and other plant remains; and industrial wastes cause color in water.	Ground water generally has little or no color. Surface-water swamps, where vegetation is abundant, may have color amounting to several hundred units on the cobalt-platinum scale.	Color due to suspended matter is generally removed during flocculation and filtration. Highly colored water is aesthetically objectionable for drinking water and is objectionable for many industrial processes, such as dyeing, brewing, and ice making.	115	0	24	0
Turbidity (parts per million)	Silts and clays from soil erosion, thermal turnover of lakes, and industrial wastes cause water to be turbid. Streams and lakes become turbid after intense rainstorms.	Ground water generally has little or no turbidity. In surface water the concentration may temporarily exceed 2,500 ppm.	Turbid water is aesthetically objectionable. Sediments causing turbidity may settle out and form films. Turbid water is objectionable for many industrial processes; turbidity is generally removed by sedimentation, clarification, or filtration.	2,170	0	13	0
Temperature (degrees Fahrenheit)	Surface-water temperatures approximate mean monthly air temperatures and ground-water temperatures approximate mean annual air temperatures. Shallow water is more sensitive to changes in air temperatures. Warmed industrial outflows raise stream temperature.	During winter, shallow streams and lakes may freeze. Temperatures of most streams are consistently less than 100°F. Thermal pollution has raised temperatures in some streams to more than 130°F.	Warm drinking water is objectionable. At times, warm water is advantageous for some water-treatment and industrial processes. However, for industrial cooling water, generally the higher the water temperature, the larger the amount of water required.				

metals in water also consume soap and thus contribute to the hardness of water; however, the amounts in which they are present in the water are generally small, and their effect upon hardness is insignificant.

In 1933 when soap—not detergent—was a household name, it was firmly established that the amount and cost of soap used in the home increased with increases in the hardness of water. In recent years, with the advent of synthetic detergents, less concern has been expressed over the hardness of water. Today, synthetic detergents outsell soaps 10 to 1 (Soap and Detergent Assoc., 1962), and some people think that synthetic detergents are as effective in hard water as in soft water. However, most synthetic detergents contain about 30–50 percent sequestering ingredients that react with calcium and magnesium, the hardness components of water. "In hard water these ingredients are decreased in effective concentration for their cleaning purpose" (DeBoer and Larson, 1961). A recent study indicated that three times the amount of synthetic detergents was required for 400 ppm hardness water than for 0 ppm hardness (Aultman, 1957).

Sixteen cities, serving more than 15 million people, have "moderately hard" (61–120 ppm) raw water and do not soften their supply; laundries and other industries consider it advantageous to remove some of the hardness. Many municipalities try to reduce the hardness of their water supply to 85–100 ppm.

Twenty-two cities, serving almost 16 million people, have "hard" (121–180 ppm) raw water for their public supply. Homes using hard water have more problems with soap curds than homes that use softer water. Many industries require that "hard" water be treated to lower the hardness. About one-half of the 22 cities, serving about 6 million people, lower the hardness by some type of water softening.

Twenty-seven cities, supplying more than 8 million people, have "very hard" (more than 180 ppm) raw water; only 15 of these cities, serving more than 5 million people, lower the hardness.

The anions in water—principally bicarbonate and carbonate—determine the proportions of "carbonate" and "noncarbonate" hardness that constitute the hardness of water. Carbonate hardness is the amount of hardness chemically equivalent to the amount of bicarbonate and carbonate in solution. Carbonate hardness is approximately equal to the amount of hardness that is removed from water by boiling. Carbonate hardness of water results in the deposition of a calcium and magnesium carbonate scale, especially at temperatures above boiling point; this scale impedes the transfer of heat and constricts the effective pipe diameter, which reduces the flow of water.

Noncarbonate hardness is the difference between the hardness calculated from the total amount of calcium and magnesium in solution and the carbonate hardness. If the carbonate hardness (expressed as calcium carbonate) equals the amount of calcium and magnesium hardness (also expressed as calcium carbonate), there is no noncarbonate hardness. Noncarbonate hardness is about equal to the amount of hardness remaining after water is boiled. The scale formed at high temperatures by the evaporation of water containing noncarbonate hardness is tough, heat resistant, and difficult to remove.

Soft water and hard water are common terms, but there is no clear line of demarcation. Water that seems hard to an easterner may seem soft to many westerners. The hardness-of-water classification used in this report is as follows:

Hardness range (parts per million of calcium carbonate)	*Hardness description*
0–60	Soft.
61–120	Moderately hard.
121–180	Hard.
More than 180	Very hard.

Figure 6 shows the hardness of untreated water sources for these largest cities. For cities that obtain their water from more than one source, the hardness is weighted according to the population served from each source. Many of the hardness calculations are based on yearly averages; others are based on samples collected to represent an average hardness of water. Some cities are not included here because of the lack of data.

For ordinary household uses and for many industrial purposes, "soft" water (hardness 0–60 ppm) requires no softening. However, softening is required by a few industries and the operation of some steam boilers at pressures in excess of 200 pounds per square inch. Twenty-nine cities, serving more than 21 million people, have "soft" raw water and do not soften their supply. Water having a low hardness may become corrosive; therefore, some of these cities add lime to raise the pH and thus slightly increase the hardness.

SPECIFIC CONDUCTANCE

Specific conductance is a convenient rapid determination used to estimate the amount of dissolved solids in water. It is a measure of the ability of water to transmit a small electrical current. The more dissolved solids in water that can transmit electricity, the greater the specific conductance of the water. Commonly, the dissolved solids (in parts per million) is about 65 percent of the specific conductance (in micromhos). This relationship is not constant from stream to stream or from well to well, and it may even vary in the same sources with changes in the composition of the water.

For highly mineralized water and highly colored water, the dissolved solids is more than 65 percent of the conductivity; for water con-

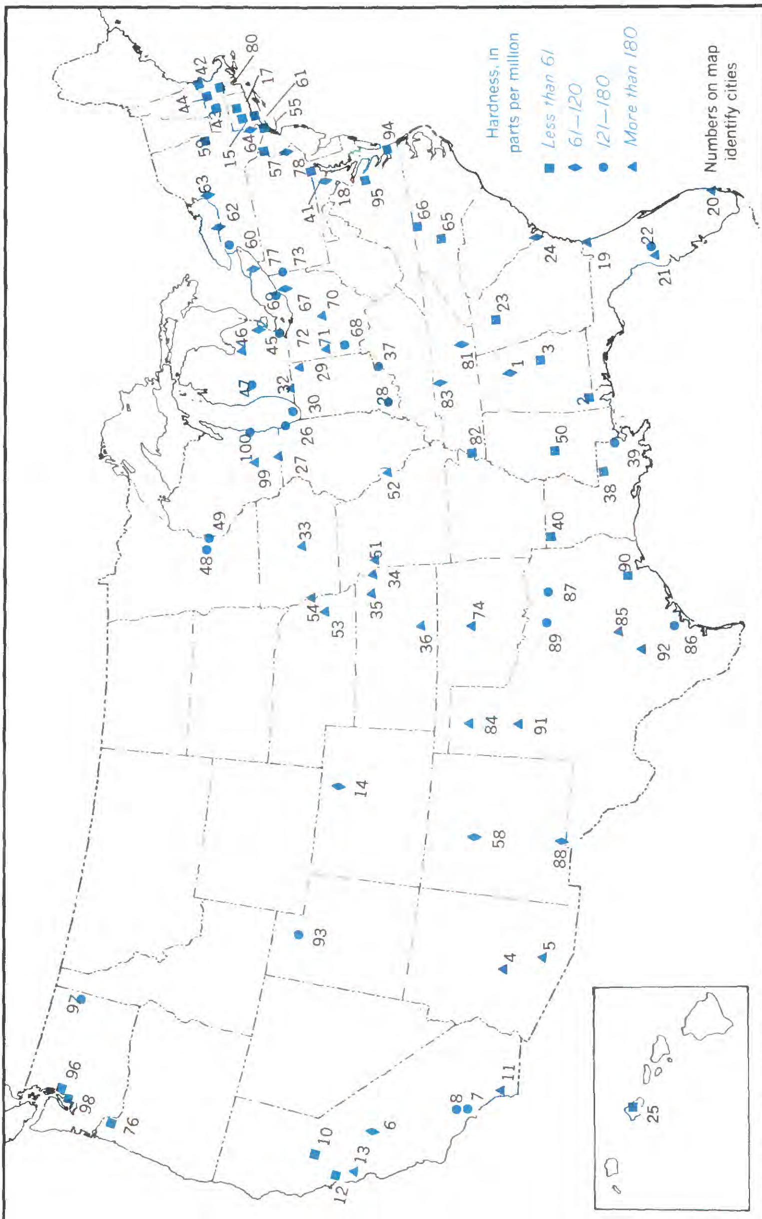


FIGURE 6.—Hardness of untreated public water supplies of the 100 largest cities in the United States, 1962. Several cities are not shown because of insufficient data. (Average weighted by population served.) See table 1 for identification of cities.

taining large amounts of acid, caustic soda, or sodium chloride, the dissolved solids is less than 65 percent of the conductivity.

pH

Water that is neither acidic nor basic (alkaline) is called a neutral water and has a pH of 7.0. The pH of water solutions can range from 0 to 14 and can be increased or lowered by the introduction of chemicals. Strong acids—such as sulfuric, hydrochloric, or nitric acid—added to a neutral water can reduce the pH to as low as 0. Weak acids, like carbonic acid, added to water also lower the pH, although not as effectively as strong acids. Conversely, strong bases—like sodium hydroxide (caustic soda)—can increase the pH of water to as much as 14; weak bases do not increase the pH of water as effectively as strong bases. Salts formed by the reaction of strong acids and strong bases generally have little effect upon the pH of neutral water. Salts of a strong acid and of a weak base—such as iron sulfate—when added to a neutral water lower the pH, and salts of a weak acid and a strong base—such as sodium carbonate—increase the pH of a neutral water.

Geologic terrane and environment influence the pH of streams, lakes, and underground water. Most rocks in contact with water are not very soluble, and most streams and underground water have only small amounts of dissolved solids. In these dilute solutions, the introduction or the loss of small amounts of chemicals can radically alter the pH. For example, when well water having a pH less than 5.0 and containing a large amount of carbon dioxide is aerated to expel the carbon dioxide, the pH can be raised to more than 8.0. The lower the concentration of dissolved solids in water, the more sensitive the pH of water is to additions or losses of chemicals.

The pH of a water has a strong influence on its usability. A low pH or a high pH can make water extremely corrosive to pipes and equipment. The pH affects the solubility of some compounds in water and thus determines whether a sample of well water will remain clear and colorless or whether it will become clouded or colored by precipitates such as iron oxide or calcium carbonate. In water-treatment plants, pH partly determines the amount of chemicals required to clarify and soften water.

In general, most natural waters have a pH between 5.0 and 8.0. A small percentage of waters have a pH less than 5.0. Acid mine drainage containing sulfuric acid may reduce the pH of streams to less than 2.0, and some waters in contact with extremely basic rocks can have a pH in excess of 9.0.

The average pH of the raw-water resources used by 98 of the 100 municipalities is shown in figure 7. Two cities are not shown on the

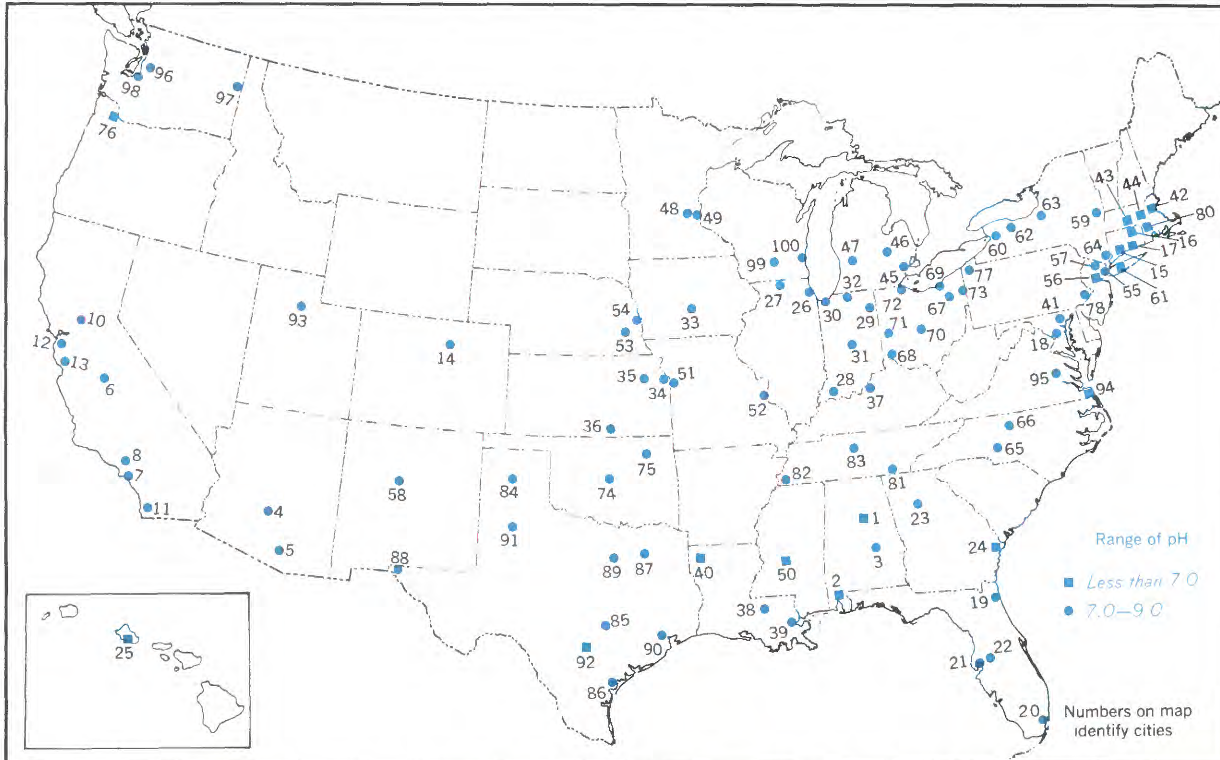


FIGURE 7.—pH of untreated public water supplies of the 100 largest cities in the United States, 1962. Two cities are not shown because of insufficient data. (Average weighted by population served.) See table 1 for identification of cities.

map because of lack of data. The water supplies have been grouped into those having a pH of less than 7.0 and those having a pH between 7.0 and 9.0. These data are based on calculations submitted by officials of city waterworks or on water samples that are representative of the pH for the water supply.

The water used by these largest cities is obtained from the best water resources available to the municipal water departments. As shown in figure 7, 18 of these cities, serving a total population of more than 16 million people, obtain raw water that has an average pH of less than 7.0; the pH of all raw-water supplies in these cities was between 5.8 and 7.0. Eighty cities, serving a total population of more than 42 million people, obtain raw water that has an average pH between 7.0 and 9.0.

COLOR

The color of streams and lakes is caused principally by suspended sediment and by matter dissolved in water. Immediately after a rain, streams are muddy owing to the sediment in suspension. As the floodwaters recede, the muddiness of water disappears, and the water becomes clear. Most color due to suspended matter disappears with the settling out of the suspended matter. All color determinations in the laboratory are made on the water sample after the sediment has been allowed to settle. Because of the filtering action of soils and rocks, very little ground water has any noticeable color.

Surface water containing living and decaying plants and trees has a dingy tinge. During the summer when streamflow is low, the color of the water becomes accentuated because plant growth is accelerated and the decomposition of decaying vegetable litter proceeds at a rapid pace. Industrial waste water containing iron, copper, manganese, chromium, and other metals also may impart color. Colored water is objectionable for domestic use and in many industries, especially in food and beverage processing, paper manufacturing, and dyeing industries.

TURBIDITY

Turbidity of water is caused principally by fine sediments such as clay and silt and by minute organisms and plants that are held in suspension and do not rapidly settle out. In lakes and streams the turbidity increases during the active growing period and, like color, also increases rapidly after rains and decreases as floodwaters recede. The heavier the suspended sediment particles, the quicker turbidity decreases. Turbidity, like color, is objectionable and undesirable in the home and in many industries.

TEMPERATURE

Because 95 percent of the water used by industry is for cooling, temperature is an important property of water. A consistently low water temperature is desirable. Many industrial water users prefer ground water because its temperature generally does not change more than 3°–4° F per year, and it generally approximates the mean annual air temperature. Ground-water temperature tends to increase with depth; below 60 feet, ground-water temperature increases only about 1° F for each 60–100 feet increase in depth.

The temperatures of streams and lakes are more sensitive to changes in air temperature. The mean monthly temperature of surface water approximates the mean monthly air temperature, except during freezing weather. The mean daily temperature of surface water increases at a slower rate in the spring months and decreases at a slower rate in the autumn than does the mean daily air temperature. The shallower the water depth, the more sensitive the water temperature is to changes in air temperature. Figure 8 is a general map of stream temperatures compiled from 467 maximum monthly mean temperature readings (U.S. Geological Survey, 1962).

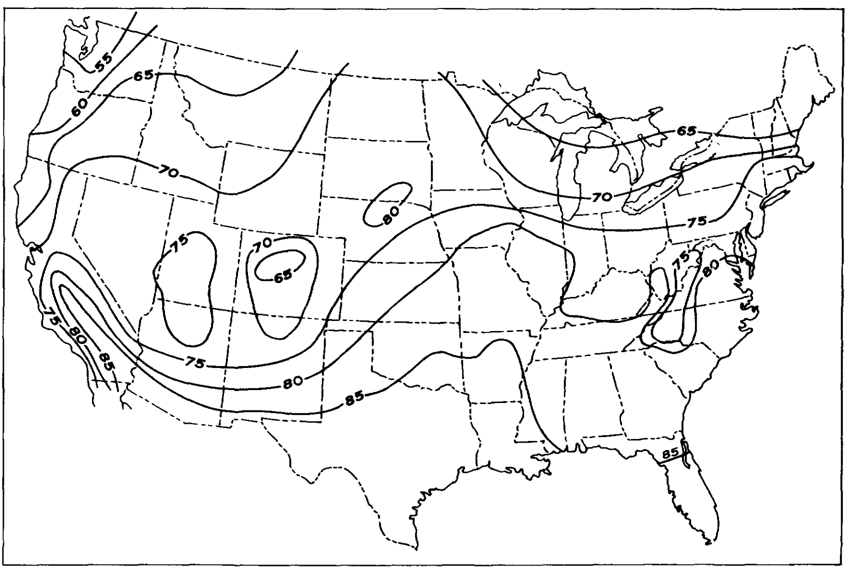


FIGURE 8.—Stream temperatures, in degrees Fahrenheit, during the summer.

MINOR CHEMICAL CONSTITUENTS

In addition to the major dissolved constituents in water, many minor constituents (usually called trace elements if they are present in concentration of less than 1 ppm) are also present. The sum of all these minor constituents commonly makes up less than 1 percent of all the dissolved constituents in water. The concentration of trace elements, as determined by spectrographic analyses (see p. 41), is expressed in micrograms per liter (μg per l) which is 1 millionth of a gram of substance dissolved in a liter of solution. One thousand micrograms per liter is equal to 1 part per million. In this study only six metals—aluminum, iron, manganese, barium, strontium, and boron—have ranges of concentrations in untreated waters that exceed 100 μg per l; all other minor elements have a maximum individual concentration of less than 100 μg per l and a medium individual value of 10μg per l or less.

Some sources of trace elements in water, concentrations found in natural water and in treated public water supplies of these largest cities, and the maximum amounts recommended for drinking water are summarized in table 4.

Data on the distribution of trace elements in natural water, with the exception of strontium, radium, and uranium, are meager. Previously, the concentration of the trace elements, such as those listed in table 4, was measured only when the presence of an element was suspected because of pollution. With the advent of improved techniques for measuring the minute amounts of trace elements, data on the distribution of these trace elements are increasing. Durum and Haffty (1963) found that concentrations of trace elements in Atlantic Coast streams when compared with the median concentrations in streams throughout the continent indicate the Atlantic Coast streams to be enriched in concentrations of silver, chromium, manganese, molybdenum, nickel, strontium, and titanium and to be slightly deficient in barium and lithium. By the same standards, minor-element concentrations in Gulf Coast streams exceed continental concentrations of aluminum, barium, copper, iron, lithium, rubidium, and titanium and are deficient in chromium, lead, and strontium. Pacific Coast streams are slightly enriched in lead and molybdenum and are deficient in barium, chromium, rubidium, and titanium.

Naturally occurring strontium in excess of 1,500 μg per l is present in streams in parts of northern and western Texas and southern New Mexico and Arizona. Concentrations of between 500 and 1,500 μg per l occur in streams in the Southeastern United States, most of the Great Plains region, the Western mountain and plateau region, and California. Concentrations of less than 500 μg per l occur in streams in the Pacific Northwest, Northeastern United States, and the Central Lowlands (Skougstad and Horr, 1960). Apparently, the concentration of strontium is higher in water draining calcareous soils (soils containing calcium carbonate) than in water draining noncalcareous

TABLE 4.—*Minor constituents in water—their common sources, concentrations found, and recommended maximum concentrations in drinking water*

[For further information, the reader is referred to Rankama and Sahama, 1950]

Constituent	Some common sources	Concentration in natural water	Concentration in treated water of public supplies of 100 largest cities (µg per l, unless otherwise indicated)		Drinking water should contain less than concentration shown if more suitable supplies are or can be made available [1] (ppm, unless otherwise indicated)	Concentration in drinking water more than that shown constitute grounds for rejection of the supply [1] (ppm)
			Maximum	Minimum		
Aluminum	Feldspars, micas, and clay minerals; also present as the result of alum treatment in water supplies.	Generally less than 1 ppm; as much as 7,500 ppm in acid lakes.	1,500	3.3		
Barium	Feldspars, mica, biotite, barite, witherite.	Generally less 0.5 ppm. Sea water, about 0.05 ppm; brine, as much as 5,000 ppm.	380	1.7		1.0
Boron	Amphiboles, biotite, colemanite, and tourmaline; detergents; industrial wastes.	Generally less than a few tenths parts per million. Sea water, about 4.6 ppm; mineral springs, may exceed 500 ppm; brine, may exceed 9,000 ppm.	590	2.5		
Chromium	Chromite; industrial pollution.	Generally less than 0.1 ppm. Industrial pollution, as much as 40 ppm.	35	Not detectable.		0.05 (hexavalent)
Copper	Native copper, chalcocite, bornite, chalcopyrite, cuprite, many other minerals containing copper. Copper and brass pipes; algae-controlling copper salts; industrial wastes.	Generally less than a few tenths parts per million. Sea water, 0.001-0.01 ppm; industrial pollution (mine water) as much as several thousand parts per million.	250	Less than 0.61.	1.0	
Lead	Galena, aragonite, feldspars. Dissolution of lead pipes; industrial and mining wastes.	Generally less than 0.5 ppm in streams and in ground water. Sea water, 0.004 ppm; industrial pollution, several hundred parts per million.	62	Not detectable.		
Lithium	Mica, amphiboles, pyroxenes.	Generally less than 1 ppm. Sea water, 0.1 ppm; brine, as much as 80 ppm.	170	Not detectable.		
Nickel	Pentlandite, niccolite, chloanthite, garnierite, millerite, olivine, hypersthene.	Generally less than 0.1 ppm.	34	Not detectable.		

Phosphorus	Apatite; organic wastes; fertilizers; detergents.	Generally less than a few parts per million. Sea water, 0.003–0.3 ppm; industrial pollution, 10 ppm.	370	Not detectable.		
Radium	Most igneous rocks, sandstones, shales.	Uncontaminated water generally contains less than 10 pc per l.	2.5 pc per l	Less than 0.1 pc per l	3 picocuries of Ra^{226}	
Rubidium	Greisen, lepidolite (concealed in many potassium minerals), potassium feldspar, potassium mica.	Generally less than 0.1 ppm.	67	Not detectable.		
Strontium	Feldspars, apatite, pyroxenes, amphiboles, celestite, strontianite, aragonite, fossils.	Generally less than 5.0 ppm in freshwater streams; as much as 30 ppm in ground water. Sea water, about 13 ppm; brine, as much as 3,500 ppm.	1,200	2.2		
Titanium	Ilmenite, rutile, sphene, phlogopites, amphiboles, biotite, pyroxene.	Generally less than 0.1 ppm.	49	Not detectable.		
Uranium	Uraninite, carnotite; most igneous rocks, sandstones, and shales.	Uncontaminated water generally contains less than 44 micrograms per liter.	250	Less than 0.1		
Zinc	Sphalerite; mine waste waters; industrial wastes.	Generally in trace amounts. Sea water, 0.005 ppm; industrial pollution, as much as several thousand parts per million.	610	Not detectable.		

1 U.S. Public Health Service (1962b).

soils (Alexander, Nusbaum, and MacDonald, 1954). Information on the distribution of strontium has been made available as a result of the recent interest in strontium 89 and strontium 90, which were released by nuclear tests.

The beneficial and the detrimental effects of some trace elements on humans have been known for many years. Supplementary iron has been used in medicine since about 1000 B.C. (Strain, 1961). The effects of arsenic were carefully described by medieval chemists more than 400 years ago. For some trace metals—such as antimony, arsenic, bismuth, barium, beryllium, cadmium, chromium, copper, iron, lead, selenium, silver, strontium, and zinc—the amounts causing a beneficial or a detrimental effect have been approximately determined. The effective dosage varies with age, weight, tolerance, retention of the element, presence of other trace elements, and sensitivity of the individual. If an effective dosage (in milligrams) is known and an average amount of water taken over a 24-hour period is assumed, then a safe concentration can be recommended.

The presence of trace elements in process water used by industry can be harmful. Unfortunately, the effects of these trace elements in water are being learned slowly and, in some instances, at great expense. One paper manufacturer found that the use of alum—a chemical commonly used in the clarification of water—tends to precipitate barium. One plant has spent as much as $30,000 per year for treatment of its water to hold the barium in solution (G. E. Ferguson, written commun., 1961).

Some trace elements and properties are determined by radiochemical analysis. (See p. 44.) Concentrations of uranium are expressed in micrograms per liter. Radioactivity due to radium and beta activity are expressed in picocuries per liter (pc per l). A curie is approximately the amount of radioactivity in 1 gram of radium—to be more precise, a curie is the amount of radioactivity giving 3.7×10^{10} (37 billion) disintegrations per minute (Stearns, 1961). A picocurie is 1 million-millionth of a curie, or 3.7×10^{-2} (0.037) disintegrations per minute. The amount of activity due to radium in most natural water ranges from 0.1 to about 10 picocuries.

Radium is a common source of radioactivity in water, and it has the lowest maximum permissible concentration of any radioactive element in water. From a health standpoint, less radium can be tolerated in drinking water than any other element emitting radiation. The amount of radium in water is commonly measured by determining the alpha-emitting activity of the element radium.

In the last two decades the location of deposits of radium and uranium have been of national concern. In the present study and in an earlier study (Hursh, 1954), radium was detected in most large municipal water supplies. Scott and Barker (1962) found the largest amounts of uranium in natural water in the west-central United States.

Beta particles, or electrons, are almost weightless and have a negative charge. Beta activity is caused by the emission of beta particles from unstable elements, principally strontium in water, that tend to decay into other elements. Several beta emitters occur in nature, and many have been created artifically. Products of fission—the breaking up of an atom with the release of huge amounts of energy—from atomic power installations or from atomic weapons consist largely of beta emitters (Barker, 1959).

ANALYSES OF WATER

The analyses of the water supplies of these largest cities are of interest to operators of waterworks, industrial water users, geochemists, city officials, water-treatment consultants, and many others. Because of the widespread interest in the quality of these water supplies, each treated-water supply was sampled and analyzed chemically, radiochemically, and spectrographically. In addition, most raw-water supplies were chemically analyzed, and many raw-water supplies were also analyzed spectrographically.

The samples of water for many chemical and all radiochemical and spectrographic analyses were collected and analyzed by personnel of the Water Resources Division, U.S. Geological Survey. For many years the quality of water in streams, lakes, and ground-water supplies have been analyzed in laboratories of the Water Resources Division. Many of the chemical analyses of streams and lakes are published in an annual series of water-supply papers entitled "Quality of Surface Waters of the United States."

Many municipal water authorities cooperated in this project by furnishing yearly average, maximum, and minimum comprehensive chemical analyses, which have been incorporated into the tables of chemical analyses in the second section of this report. The analyses furnished by these waterworks officials are clearly indicated in the tables. In addition, many cities determined, at regular intervals, the pH, hardness, and alkalinity of raw and treated water; these data have been summarized in separate tables.

Many tests are made in the analyses of water used in the home, in industry, and for irrigation. (See fig. 9.) Some tests—such as pH, hardness, bicarbonate, color, turbidity, and temperature—are performed routinely in many municipal water laboratories; other determinations—such as for boron, chromium, iron, manganese, chloride, and nitrate—may be performed only at infrequent intervals or when a specific constituent is suspected of having a concentration that may cause problems. Few laboratories routinely perform all the tests listed on the pictograph (fig. 9).

The tests are made for many reasons. Water to be used in the home is tested at the treatment plant to ensure that the water is acceptable for drinking and that it does not contain concentrations in excess of the values recommended in table 2. In addition, the waterworks operator analyzes raw water to estimate the quantity of chemicals that will be needed to obtain the desired treated-water quality, and he analyzes treated water to ensure that the desired water quality has been obtained; the operator does not want to waste chemicals in treatment, nor does he want to overtreat the water.

Many of the tests made on water to be used in industry are similar to the tests made on water to be used in the home. The presence of iron and manganese in excessive amounts causes staining problems in the industrial-dyeing establishments just as it does in the home laundry, and excess amounts of iron are as undesirable in large food-processing plants as they are in domestic supplies. The presence in water of certain constituents and properties causes added problems in some industries. For example, water having a hardness of 30 ppm could disrupt the manufacture of synthetic rubber, and water having a high chloride content has stopped the manufacture of high-grade toilet tissue. Other industrial processes are sensitive to specific constituents, and industrial water users must be on their guard against undesirable concentrations of these constituents.

Although the number of tests performed on water used for agriculture is fewer than the number of tests made on water to be used in the home or industrially, these tests are just as important. Water that contains excessive amounts of sodium can cause a sealing of certain soils and thus prevent water from penetrating the soil down to the plant roots. Some plants need specific concentrations of some elements; boron, for example, is essential to plant growth, but it is toxic at concentrations only slightly above the optimum (U.S. Salinity Laboratory Staff, 1954). High concentrations of other constituents—such as magnesium, sulfate, and chloride—can cause plant growth problems.

CHEMICAL ANALYSES

In this study the chemical analyses basically consisted of the determination of silica (SiO_2), iron (Fe), manganese (Mn), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), bicarbonate

(HCO_3), carbonate (CO_3), sulfate (SO_4), chloride (Cl), fluoride (F), nitrate (NO_3), dissolved solids, hardness, specific conductance, pH, color, turbidity, and temperature.

Tests	Water use		
	Home	Industry	Agriculture
Silica		✓	
Iron	✓	✓	
Manganese	✓	✓	
Aluminum		✓	
Boron			✓
Chromium	✓		
Calcium	✓	✓	✓
Magnesium	✓	✓	✓
Sodium	✓	✓	✓
Potassium	✓	✓	✓
Bicarbonate	✓	✓	✓
Carbonate	✓	✓	✓
Sulfate	✓	✓	✓
Chloride	✓	✓	✓
Fluoride	✓		
Nitrate	✓	✓	✓
Phosphate		✓	
Dissolved solids	✓	✓	✓
Hardness	✓	✓	✓
Specific conductance	✓	✓	✓
pH	✓	✓	✓
Color	✓	✓	
Turbidity	✓	✓	
Temperature	✓	✓	✓

FIGURE 9.—Tests commonly made in water analyses.

735–717 O—64——4

The values of most constituents obtained by chemical analysis represent the amount of the constituents in solution at the time of the analysis. For some constituents and properties, these values may be slightly higher or lower than the values that might have been found if the analysis had been done directly at the sampling site.

Most of the principal methods used in the chemical analysis of water samples in this study are illustrated in figure 10 and briefly described in the following paragraphs. For a more thorough description of the methods used, the reader is referred to "Methods for Collection and Analysis of Water Samples," by Rainwater and Thatcher (1960).

Generally, pH is measured by immersing a set of electrodes in a water sample; the potential produced is measured by a pH meter.

Silica, iron, nitrate, manganese, fluoride, magnesium, and sulfate are determined by adding a known amount of color-causing reagent to water and measuring the intensity of the resultant color in a spectrophotometer. The intensity of the color produced is approximately proportional to the concentration of the constituent being determined.

Hardness, chloride, calcium, carbonate, and bicarbonate are determined by adding a measured amount of standardized reagent to a known volume of water until a color change or pH change signals that the reaction is complete.

Sodium and potassium are measured in a flame photometer. In this determination, the solution to be analyzed is vaporized in a flame, and the resultant color intensity of the flame is measured.

All these methods mentioned require that the concentration of the constituent being analyzed be fairly low; most of the waters used for public supply fall in this category. However, if the concentration of the constituent is large, the constituent may be measured gravimetrically. In this method, the substance to be analyzed is precipitated; the precipitate is filtered, washed, and weighed. This method may be used to determine silica, calcium, magnesium, sodium, potassium, sulfate, and chloride.

Dissolved solids are usually measured by evaporating a known volume of water sample, drying the residue at 180° C, and then weighing the residue.

Color of water is measured by visually comparing the color of the sample against a set of color standards. Turbidity, likewise, is measured by visually comparing the turbidity of the sample against a set of turbidity standards.

Specific conductance is determined by dipping a cell into a water sample and measuring the electrical conductivity of the water sample. The conductance of the water is calibrated in micromhos (one-millionth of a mho).

SPECTROGRAPHIC ANALYSES

Spectrographic analysis is a rather recent and exciting technique used in the analysis of water. More than 60 elements in water can be analyzed by this method from a small amount (about 60 milligrams) of the residue formed from the evaporation of a water sample. This method is extremely sensitive; for example, as little as 0.23 micrograms of silver per liter was detected in one of the water supplies. The minimum percentages of some trace elements that can be detected are listed in table 5.

TABLE 5.—*Spectrographic detection limits for elements*

[The concentration of an element in micrograms per liter is obtained by multiplying the percent of the element in the residue by the acidulated dissolved solids of the water]

Element	*Percent of residue*	*Element*	*Percent of residue*
Aluminum (Al)	0.0001	Manganese (Mn)	0.001
Arsenic (As)	.1	Molybdenum (Mo)	.0003
Boron (B)	.001	Nickel (Ni)	.001
Barium (Ba)	.001	Phosphorus (P)	.1
Beryllium (Be)	.0001	Rubidium (Rb)	.001
Cesium (Cs)	.003	Silver (Ag)	.0001
Chromium (Cr)	.0001	Strontium (Sr)	.001
Cobalt (Co)	.001	Tin (Sn)	.001
Copper (Cu)	.0001	Titanium (Ti)	.0003
Iron (Fe)	.001	Vanadium (V)	.003
Lead (Pb)	.001	Zinc (Zn)	.1
Lithium (Li)	.0001		

Spectrographic analysis is based on the measurement of light emitted by individual elements in a sample that has been volatilized and ignited by an electric arc. A small amount of an element is put into a flame that melts, volatilizes, and ignites the element and produces a light that is characteristic of the element. For example, a small piece of sodium put into a flame turns the flame yellow; the introduction of a piece of lithium into a flame turns the flame bright red. The ignition of a sample—at about 4,000° C—containing more than one element produces a light that is a combination of the lights emitted by the individual elements. To measure the individual elements, the light from ignition of the sample is dispersed through a prism to obtain a series of bright lines, each of which is characteristic of an element. The intensity of each spectral line is proportional to the concentration of the element causing the spectral line.

The techniques used in the spectrographic analyses of water samples in this study were reported by Haffty (1960). In most spectrographic analyses the concentration of elements was calculated by multiplying the percentage of each element in the acidified residue by the dissolved-

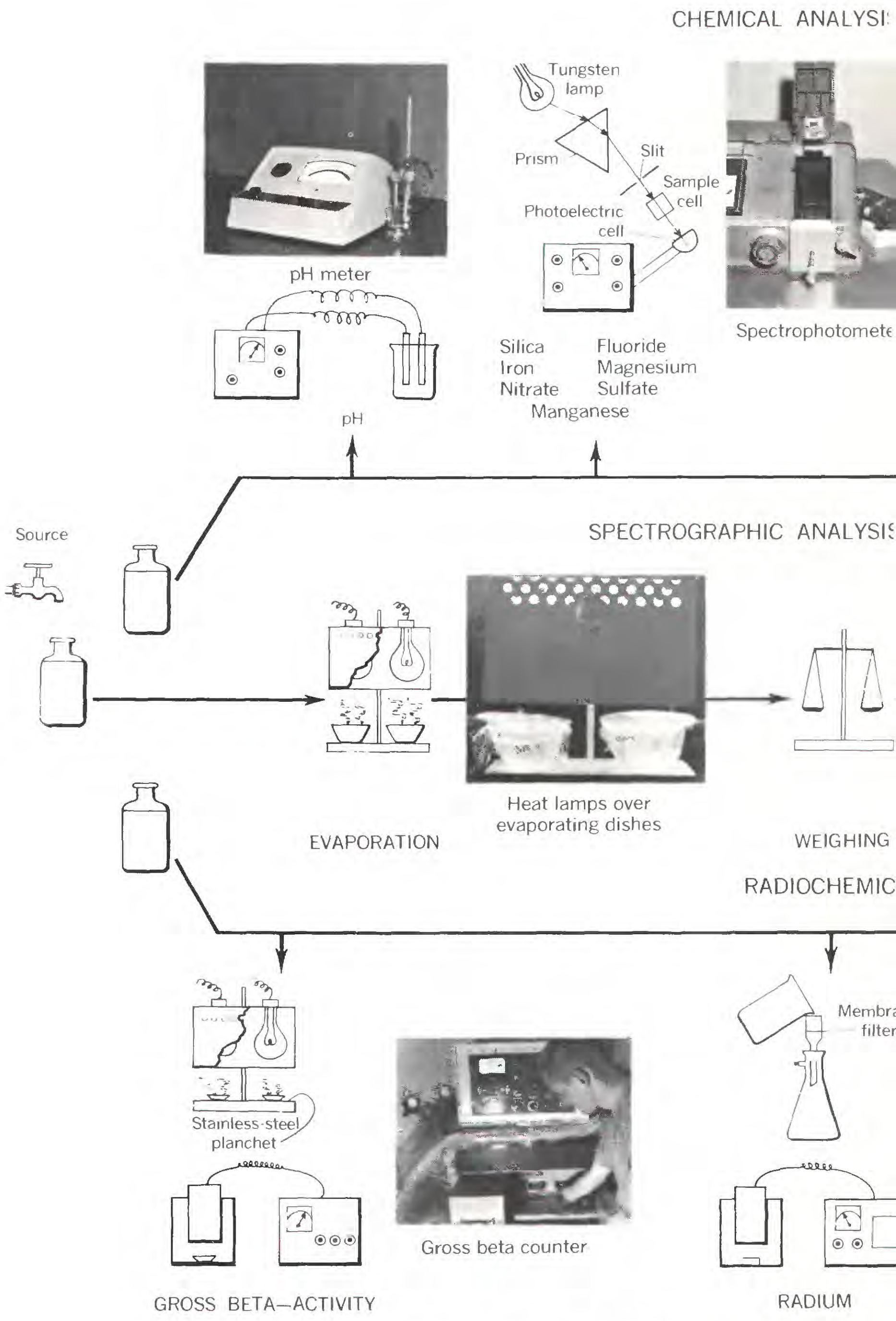
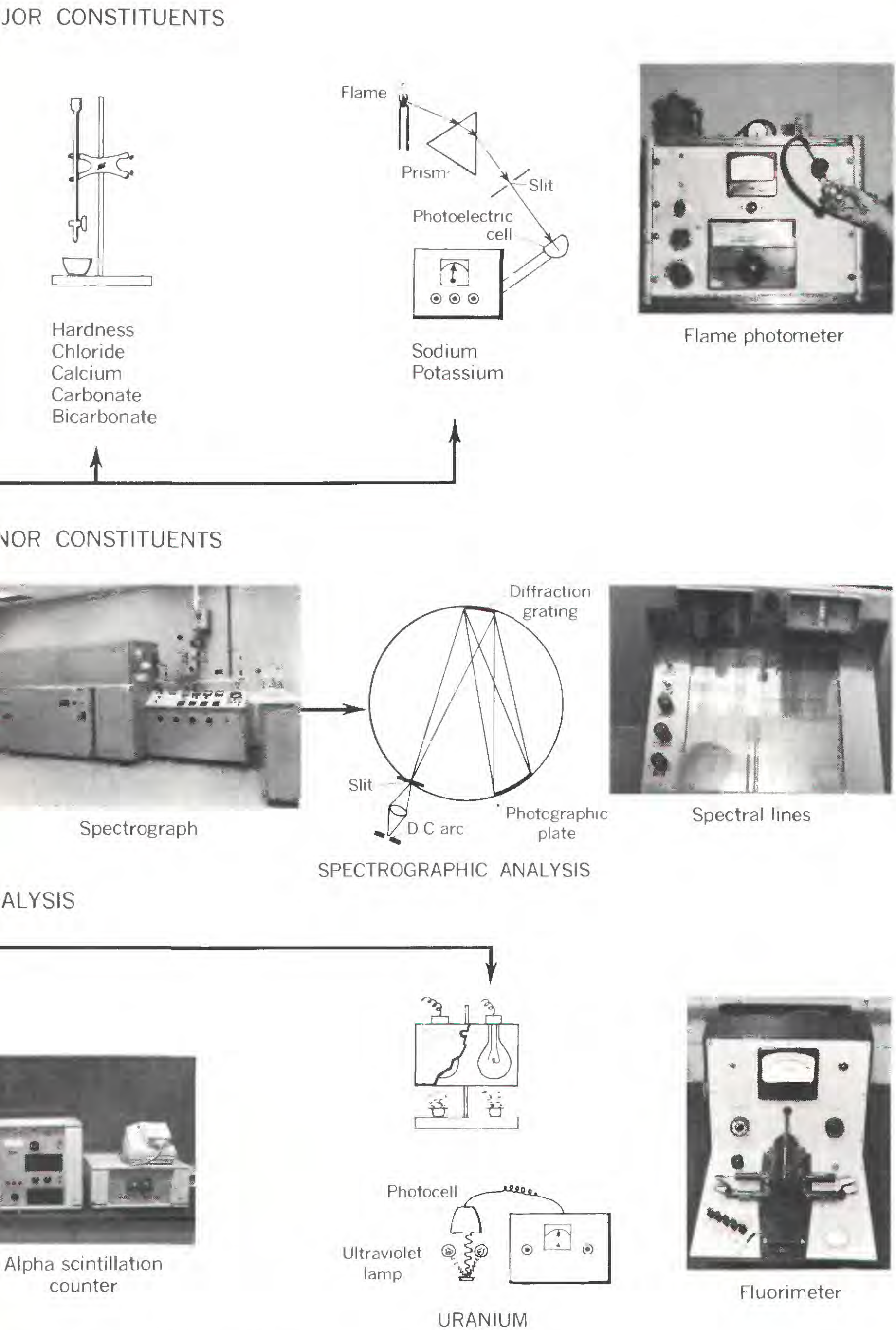


FIGURE 10.—Methods of chemical, spectrograph



d radiochemical analyses of water.

solids content of an acidulated water sample. In a few analyses, where insufficient water was available, the concentration was calculated by multiplying the percentage of each element in the acidulated residue by the dissolved-solids content determined in the routine chemical analysis; these analyses are footnoted in the tables of spectrographic analyses.

Most public water supplies contained the following minor constituents: aluminum, barium, boron, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, rubidium, silver, strontium, and titanium. In addition, beryllium, bismuth, gallium, phosphorus, scandium, tin, vanadium, ytterbium, yttrium, and zinc were detected in some raw and treated water supplies. Elements looked for but not found were antimony, arsenic, cadmium, cerium, cesium, dysprosium, erbium, europium, gadolinium, germanium, gold, hafnium, holmium, indium, iridium, lanthanum, lutetium, mercury, neodymium, niobium, osmium, palladium, platinum, praseodymium, rhenium, ruthenium, samarium, tantalum, tellurium, thallium, thorium, thulium, tungsten, and zirconium.

A few elements—notably iron and manganese—were analyzed both chemically and spectrographically. Where the values of the constituents obtained by chemical analysis differ from the values of the constituent obtained by spectrographic analysis, the spectrographic values are generally higher. This fact is understandable. The acidification of the spectrographic sample at the time of collection prevented the precipitation of the metals; thus, slightly more metal may have remained in solution in the acidified spectrographic sample than remained in solution in the chemical analysis of the sample, which is not acidified.

RADIOCHEMICAL ANALYSES

Three radiochemical determinations were made on the water samples collected in this study: (a) determination of the activity due to the emission of beta particles, (b) determination of the activity due to the emission of alpha particles from radium, and (c) determination of the concentration of uranium. Each of these methods can be used to detect extremely small concentrations. In the analyses of the waters used for public supplies, the minimum activity of beta particles detected was less than 1.1 pc per l, the minimum activity of alpha particles emitted by radium was less than 0.1 pc per l, and the minimum concentration of uranium was less than 0.1 μg per l.

The beta activity of water samples was determined by evaporating a water sample to dryness in a platinium dish, transferring the residue to a small stainless-steel disk called a planchet, and measuring with a suitable beta counter the beta activity emitted.

The radium content of the water sample was determined by adding sufficient barium and sulfate to precipitate barium sulfate and then boiling the solution. Radium in the water sample is coprecipitated with the barium sulfate. The precipitate is collected on a membrane filter. After more than 12 days, the alpha activity of radium is measured with an alpha scintillation counter and compared with standards.

Uranium was determined by evaporating a sample of water to dryness and fusing the residue with an alkaline salt containing fluoride. The cooled residue was then exposed to ultraviolet light, and the resulting fluorescence was measured with a fluorimeter and compared with that of standards.

For a more detailed explanation of these radiochemical methods of analyses the reader is referred to a paper entitled "Determination of Radioactive Materials in Water" (Barker, 1959).

WATER TREATMENT

Constituents and properties of public water supplies commonly are kept within prescribed limits. Although an excessive amount of some constituents could be harmful, a deficiency of some constituents also is undesirable. Over the years, the minimum and maximum concentrations of many constituents that affect the uses of water have been determined. As one might expect, some constituents are harmful in drinking water but are not detrimental for many industrial uses. Many efforts have been made to establish what an "ideal water" contains with respect to dissolved constituents. Table 6 lists the characteristics and concentrations of an ideal water quality as visualized by a task group of the American Water Works Association. The task group readily admits that "few, if any, waters can fully meet such a definition of the ideal" (Bean, 1962).

Most cities in this study treat their raw-water supply to improve the quality. The treatments of the municipal water supplies for these cities have been summarized in table 7. In addition, the treatment given to each water supply is given in the section describing the operating characteristics of each municipal water supply. In order to understand the necessarily brief description of the treatment given for each city, we shall take a quick look at common municipal treatments of water.

TABLE 6.—*Characteristics of water of ideal quality, as suggested by the American Water Works Association*

[Data after Bean (1962, p. 1316)]

Physical characteristics		*Maximum concentration in ideal water*
Turbidity	ppm	<0.1
Color (true)	color units	3
Odor		(1)
Taste		None.
Chemical constituents [parts per million]		
Toxic:		
Lead (Pb)		0.03
Barium (Ba)		.5
Fluoride (F)[2]:		
50.0–53.7°F		1.2
53.8–58.3°F		1.1
58.4–63.8°F		1.0
63.9–70.6°F		.9
70.7–79.2°F		.8
79.3–90.5°F		.7
Arsenic (As)		.01
Cyanide (CN)		.01
Silver (Ag)		.02
Selenium (Se)		.01
Cadmium (Cd)		.01
Chromium (Cr, hexavalent)		.01
Nontoxic:		
Aluminum (Al)		.05
Iron (Fe)		.05
Manganese (Mn)		.01
Copper (Cu)		.2
Zinc (Zn)		1.0
Nitrate (NO_3)		22
Corrosion and scaling characteristics [parts per million]		
Hardness (as $CaCO_3$)		80.0
Alkalinity (as $CaCO_3$)		(3)
Radiological activity [picocuries per liter]		
Gross beta		100
Radium (Ra^{226})		3
Strontium (Sr^{90})		5

[1] No change on carbon contact.

[2] Temperature in the 5-year average of maximum daily air temperature.

[3] Not more than 1 ppm change in alkalinity in distribution system; not more than 1 ppm change in alkalinity after 12 hours at 130° F in a closed plastic bottle, followed by filtration.

TABLE 7.—*Sources and treatments of public water supplies of the 100 largest cities in the United States, 1962*

Source and treatment	Number of cities	Population served	
		Thousands	Percent of population of 100 largest cities
Surface water:			
Chlorination	66	39, 939	65. 9
Sedimentation and coagulation	54	27, 772	45. 8
Rapid sand filtration	51	26, 511	43. 8
Slow sand filtration	7	2, 536	4. 2
Pressure filtration	2	356	. 6
Iron removal	4	1, 475	2. 4
Softening:			
With lime[1]	10	4, 649	7. 7
With lime-soda ash	9	3, 359	6. 0
Ground water:			
No treatment	1	150	. 2
Chlorination	19	5, 565	9. 2
Sedimentation and coagulation	7	2, 147	3. 5
Rapid sand filtration	7	2, 970	4. 9
Iron and manganese removal	5	1, 474	2. 4
Softening:			
With lime	3	1, 055	1. 7
With lime-soda ash	1	320	. 5
Mixed surface and ground water:			
No treatment	1	72	. 1
Chlorination	13	14, 015	23. 1
Sedimentation and coagulation	7	8, 770	14. 5
Rapid sand filtration	8	1, 921	3. 2
Slow sand filtration	1	33	. 1
Iron and manganese removal	1	500	. 8
Softening:			
With lime	2	340	. 6
With lime-soda ash	1	259	. 4
By cation exchange	2	698	1. 2

[1] At least one city supplements lime softening with soda ash during critical periods.

Municipal water-treatment plants are designed to be able to produce treated water of the desired quality from the worst local raw-water supplies. For example, many treatment plants are designed to handle water from streams that may at times carry large amounts of silt and floating trash and to soften the hardest water that can be obtained from the watershed. The maximum amount of water that a treatment plant is designed to treat is called the rated capacity of the plant; the rated capacities of the treatment plants in these largest cities are given in the descriptive material for the individual city. During times of high water demand, raw water generally has a low turbidity and thus does not need to stay the full time in the sedimentation and clarification basins. Thus, treatment plants can treat more water than the rated capacity. Few treatment plants operate at rated capacity for extended periods of time.

For ease in understanding water treatment, a drawing showing the principal steps involved in the treatment of a hypothetical "very hard" surface water laden with silt is shown in figure 11. To further illustrate the processes involved, photographs of various actual treatment plants are included. Few municipal supplies employ all the processes. Some cities may use only a few of the processes, whereas other cities use parts of this basic treatment plan, repeat some processes, and may add a few that are not shown. Ground-water supplies generally do not require clarification, but many of the other processes illustrated are used in treating ground-water supplies.

SCREENING

Water is pumped or flows by gravity from a stream into a sedimentation basin. To prevent tree limbs and other floating and submerged trash from entering intake pipes, the water passes through a crib, which consists of iron grates extending above and below the water surface.

PRECHLORINATION

Chlorine added after screening or at any phase before filtration is called prechlorination. The amount of chlorine to be added is determined from laboratory tests. Chlorine gas is not applied directly to the water being treated; instead, regulated amounts of chlorine are applied to a small stream of water, which is then mixed into the water to be treated. Chlorine added at this phase controls the growth of plants and microscopic organisms that could impart undesirable tastes and odors to the water. The plants and organisms might also be deposited on the filter beds, coat the particles of sand, and thus reduce the efficiency of the filter bed. Tastes, odors, and bacteria also may be controlled at this point by "breakpoint chlorination." In this method the amount of chlorine added to water is sufficient to ensure that there is chlorine gas in excess of the amount required to oxidize organic matter, sulfides, unoxidized iron and manganese, and any other oxidizable matter in the water.

SEDIMENTATION

Chlorinated water now flows into a sedimentation basin, where the destruction of organic material by chlorine continues to improve the taste and odor of water. The basin is designed so that the water will move slowly and give the coarse particles of suspended matter time to settle to the floor of the basin. The size of the basin and the detention time of the water in the basin depends upon the amount of water being treated and the coarseness of the sediments. Coarse sediments may settle in hours, whereas fine sediments could require days and even weeks to settle completely. Under normal operating conditions, sedimentation basins remove a large percentage of suspended matter from water and thus prevent suspended matter from being carried along onto the filter beds. Sedimentation at this stage also is called "presedimentation" and "plain sedimentation." Natural lakes and large artificial reservoirs act as huge sedimentation basins and have the added advantage of seldom requiring cleaning. (Small artificial sedimentation basins require periodic or continuous cleaning to remove the deposited suspended matter.)

CHEMICAL TREATMENT

After sedimentation, chemicals are added for coagulation, softening, and removal of tastes and odors. In these largest cities, the three principal chemicals added are alum, lime, and carbon. Alum is added for coagulation, lime is added for softening and corrosion control, and carbon is added for the removal of undesirable tastes and odors. Many of the chemicals added have beneficial secondary effects. Lime added primarily for softening also accelerates coagulation and improves water color. Alum added primarily for coagulation improves color and assists in the settling of sludge from lime softening. At some municipal water-treatment plants, chlorine or other disinfectants may be added in the chemical-treatment building; the addition of these disinfectants is discussed on pages 48 and 58.

COAGULATION

To remove the sediments, turbidity, color, and organic matter that were not removed in the sedimentation basin, coagulation chemicals are added in the chemical-treatment building. These coagulation chemicals when added to water form clumps that resemble cotton candy; these clumps are called flocs, and suspended sediment and bacteria adhere to them. The large flocs slowly settle and drag down the suspended matter. Without these coagulation chemicals and the resultant flocs, the suspended matter could coat the sand grains of the filters, and fine particles and some color could pass through the filter and appear in the water served to the consumer.

The amount of the coagulation chemicals and the efficacy of coagulation is influenced by water temperature, pH, water color, turbidity, mineral content of the water, mixing time, violence of agitation, the presence of nuclei for the sediment to adhere to, and the type and dosage of chemicals (Am. Water Works Assoc., 1950). Coagulation

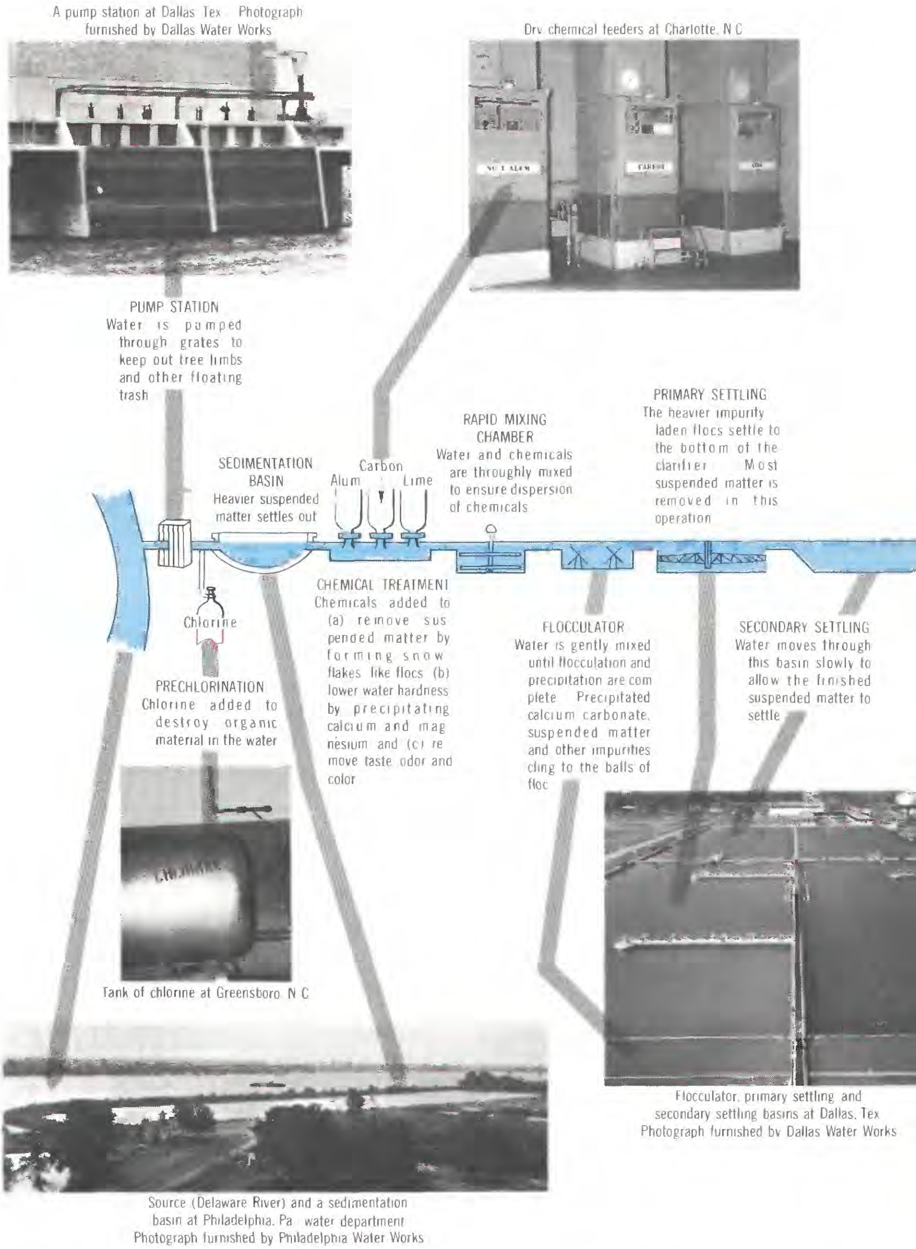
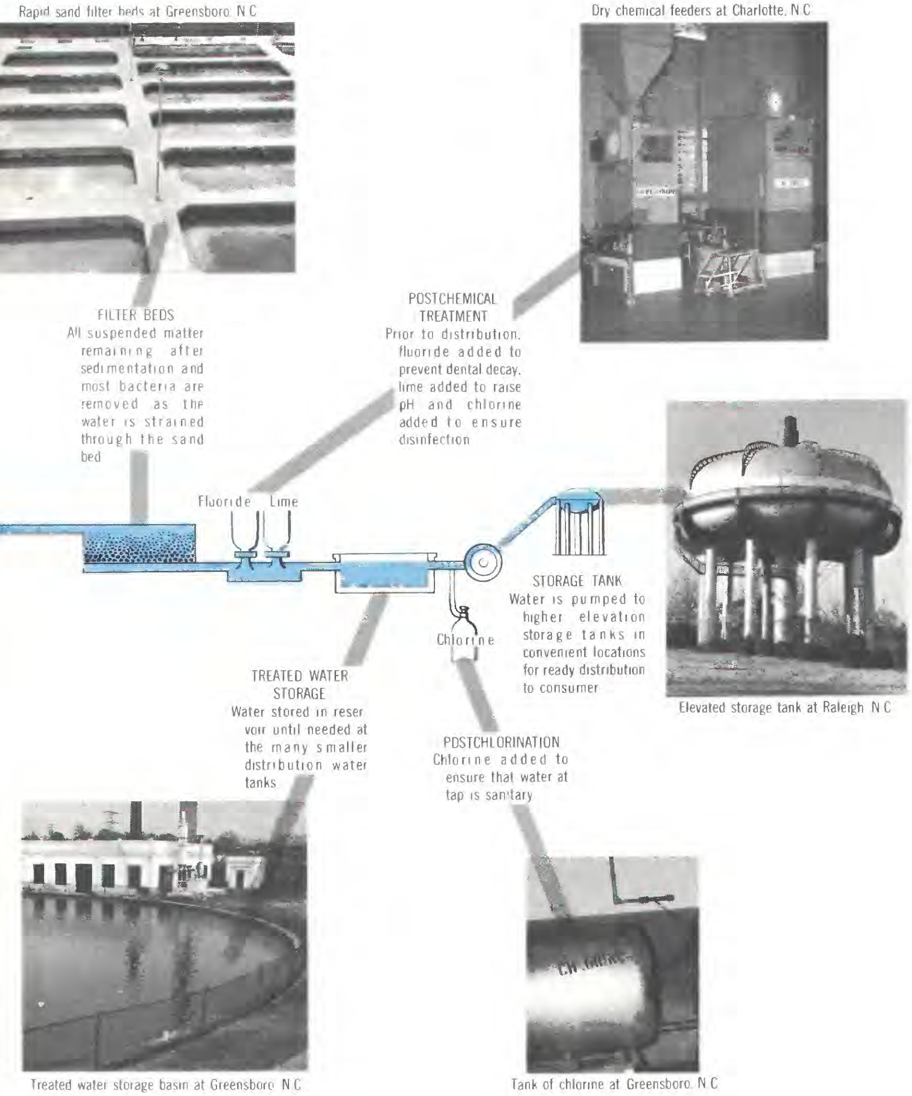


FIGURE 11.—Flowsheet and pictures illustrating the treatment of a hypothetical "very ha
various processes. Most of the cities nan



lic water supply. Photographs of actual municipal water treatment plants illustrate the
his figure do not have "very hard" water.

chemicals are usually added under the supervision of the laboratory personnel of the waterworks plant. The dosage of chemicals required to obtain optimum coagulation is commonly determined by measuring the amount required to obtain a good floc in a jar containing a sample of water being treated.

A recent technique for adding coagulating chemicals takes advantage of the fact that coagulation chemicals dissolved in water have a positive charge and suspended matter in water has a negative charge. The coagulation chemical is added until the water sample is neither negative because of an excess of suspended sediment nor positive because of an excess of coagulation chemicals.

The most commonly used coagulation chemical is aluminum sulfate—more commonly know as alum. Of the 68 cities in this study that used coagulation chemicals, 52 used alum. Aluminum sulfate reacts with bicarbonate and carbonate ions in water and lowers the pH of the water being treated. Alum forms the best flocs in the pH range of 5.5 to 6.8 (Nordell, 1961). If water contains large amounts of bicarbonate and carbonate, sulfuric acid may be added to lower the pH. After coagulation, lime or soda ash may be added to raise the pH to more than 9.0 to prevent corrosion in distribution pipes.

Iron compounds are less commonly used for coagulation. Ferric sulfate—commercially known as Ferrisul or Ferrifloc—was used in eight cities, and ferrous sulfate—commonly known as copperas—was used in seven cities. Iron salts used for coagulation also react with bicarbonate and carbonate ions in water and lower the pH of the water. For effective coagulation, the ferrous iron is oxidized to ferric iron by chlorine or the dissolved oxygen in the water; iron salts mixed with chlorine are effective in removing color. When iron salts are used for coagulation and to remove color, the optimum pH range of the water is 3.5 to 5.0 (Nordell, 1961). Waters coagulated with iron salts at this low pH are treated after coagulation with lime or soda ash to raise the pH and to prevent corrosion. Effective coagulation with iron salts also occurs at a pH greater than 9.0; iron compounds mixed with lime are especially effective in clarifying turbid waters.

Activated silica and clays are used as coagulation aids, especially during cold weather, because they improve coagulation by further promoting the formation of rapidly settling flocs. About 10 percent of the cities in this study use coagulation aids in addition to the coagulation chemicals.

Some municipal water systems do not add coagulation chemicals but recirculate a part of the sludge from previous coagulation and softening operations. The recirculated sludge serves as a nucleus for the fine sediments and bacteria to adhere to. The recirculated sludge and the adhering sediments then settle out of the water.

SOFTENING

Water hardness is caused principally by the presence of calcium and magnesium in water. To lower the hardness of water—called softening—the amounts of these constituents must be reduced or the constituents removed altogether. In municipal supplies, water is softened principally by (a) the addition of lime—called lime softening—and (b) the addition of lime and soda ash—called lime-soda softening. In these softening processes, calcium and magnesium in water are converted from a soluble form into bulky precipitates of calcium carbonate and magnesium hydroxide. Softening processes produce considerable volumes of sludge, which can carry down suspended sediment, turbidity particles, bacteria, and minute particles of organic matter. Softening chemicals added with coagulation chemicals increase the efficacy of coagulation chemicals. Most cities that employ these methods of chemical softening have a subsequent filtration operation to remove the softening sludge.

Lime softening.—Lime softening is used in 15 of 28 cities that reduce the hardness of raw water. If hardness is caused by calcium bicarbonate, lime is added to reduce the amount of calcium; if hardness is caused also by magnesium bicarbonate, additional lime is added to remove a part of the magnesium content. About twice the amount of lime must be used to lower magnesium bicarbonate hardness as is needed to lower calcium bicarbonate hardness. Most calcium is removed (precipitated) from the solution before magnesium is removed.

Lime in excess of the amount used to cause the precipitation of calcium and magnesium is removed in a subsequent operation to prevent the deposition of calcium carbonate on filters and to prevent the deposition of calcium carbonate scale in distribution pipes.

Lime-soda softening.—The lime-soda method of softening is used in 11 cities to reduce carbonate and noncarbonate hardness. As soda ash (sodium carbonate) is more expensive than lime, the accepted procedure is to add an excess of lime to remove the maximum amount of calcium and magnesium possible (carbonate hardness) and then to add enough soda ash to lower the hardness to the desired level. Excess softening chemicals are removed in subsequent operations.

Cation exchange.—In at least one city, the calcium and magnesium in water are taken out of solution by cation exchange and replaced by sodium. This process is usually carried out after filtration to prevent contamination and coating of ion-exchange resins. In the cation-exchange process, water passes through a bed of material that has the property of replacing calcium and magnesium ions in water with sodium ions. By ion exchange, water hardness can be reduced to zero; however, this water is extremely corrosive and expensive. Before 1940, the materials used in the beds were natural minerals called zeolites; today, most ion-exchange beds are composed of synthetic resins. On all but 14 days of the period July 1, 1960, to June 30, 1961, cation-exchange softening was the only process used by the Metropolitan Water District of Southern California, which supplies softened water to Los Angeles and Long Beach. The average hardness of the Colorado River was reduced from 323 ppm to a hardness of 200 ppm in the treated water (Metropolitan Water District of Southern California, 1961). Infrequently, the Metropolitan Water District of Southern California uses lime to partially soften water before cation exchange to prevent clogging of ion-exchange resins; the resultant lime sludge forms a nucleus for coagulation and clarification. After water passes through an ion-exchange softener, the bed material becomes reduced in sodium ions and must be regenerated by washing the bed with a solution of sodium chloride (common table salt).

REMOVAL OF TASTES AND ODORS

Good drinking water is free of undesirable tastes and odors. Undesirable tastes and odors generally come from two major sources: (a) decaying vegetation, live and dead algae, and bacterial slimes and (b) sewage and industrial pollution. The oxidation and precipitation of iron and manganese also cause unwanted colors and tastes.

The removal of unwanted tastes and odors is a continuing process throughout water treatment. In many reservoirs and lakes, plants and shrubs are removed before water is stored and copper sulfate is broadcast periodically during growing seasons to reduce the amount of algae. In sedimentation basins and large bodies of water, natural sedimentation effects the removal of earthy materials that impart undesirable tastes, odors, and colors. If a strong disinfectant, such as chlorine, is also used in these basins, then algae and bacteria are killed and deposited with the earthy materials. Aeration and strong oxidizing chemicals cause iron and manganese oxides to precipitate from water. Alum and other coagulation chemicals clarify water by creating flocs, which serve as nuclei for bacteria, suspended matter, algae, and other taste- and odor-causing materials to cling to and thus settle out. Some bleaching clays are effective in removing colors, in addition to acting as coagulation aids. The large volumes of sludge from lime softening act as nuclei for the attraction and removal of many causes of tastes and odors; lime also acts as a disinfectant to remove undesirable taste- and odor-causing bacteria.

Activated carbon is an effective chemical added primarily to absorb taste, odor, and color from water supplies. Carbon—in a slurry or in dry form—is added with coagulation and softening chemicals.

After absorbing undesirable tastes, odors, and colors, carbon becomes a part of the coagulation floc and settles.

CLARIFICATION

Rapid mix.—After coagulation, softening, and taste- and odor-removing chemicals are added, the water is thoroughly agitated to ensure that the chemicals are thoroughly dispersed. In many cities the chemicals are mixed in the water by large rotating blades, as shown in figure 11. At some locations, air is introduced into water to assist the mixing. The air also causes the oxidation of iron and manganese and expels undesirable gases such as carbon dioxide and foul-smelling hydrogen sulfide. The water is thoroughly agitated for only a short period of time.

Flocculators.—After the chemicals are thoroughly dispersed in the water being treated, the water is continuously and gently, but thoroughly, mixed. Flocs are formed that attract most of the suspended sediments and other coagulable materials present in the water. In the foreground of the photograph of figure 11 some of the flocs can be seen as they are being gently rolled to the surface.

Primary settling.—After flocs have reached optimum size, the floc-laden water flows to a primary settling basin, as shown in figure 11. Here the flocs have an opportunity to settle and entrap most of the undesirable sediments that were not removed in the sedimentation basin. The deposited sludge is swept to a central point for disposal. Some plants reuse a part of the sludge to accelerate coagulation, some plants reclaim the lime in the sludge, and other plants dispose of all the sludge.

Stabilization.—Water softened by lime and lime-soda processes is saturated with calcium carbonate before any calcium carbonate precipitate is formed. After the water has been softened to the desired hardness, water must be stabilized to prevent any further deposition of softening sludge. Stabilization, which is achieved by adding sulfuric acid or by injecting carbon dioxide gas (recarbonation) to convert the calcium carbonate in water into very soluble calcium bicarbonate, neutralizes the excess lime in water and lowers the pH. To prevent clogging of filter beds, some plants stabilize the water, and other plants stabilize after filtration to obtain a lower hardness water. Stabilization after filtration allows the filter bed to become coated with calcium carbonate precipitates and requires more frequent washing of the filter bed.

In some municipal water-treatment systems, phosphate compounds (Calgon is popular) are added to calcium carbonate saturated water to prevent the precipitation of calcium carbonate scale. The phosphate

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compounds also prevent the precipitation of iron oxides and reduce corrosion.

Secondary settling.—After most of the sludge has been deposited in the primary settling basin, the water flows to the secondary settling basin. Here much of the remaining suspended matter settles, and the water is discharged to the filters for final purification.

FILTRATION

In these largest cities three types of filters are used: rapid sand filter, slow sand filter, and pressure filter.

Rapid sand filters are large concrete boxes, commonly covering an area of 1,000 square feet or less, in which perforated pipe systems—called underdrains—are laid on the floor of the box. Overlying the filter underdrains is a layer of gravel, which gradually decreases in size from coarse gravel near the drains to a fine gravel on the top of the layer. Overlying the gravel layer is a layer of several feet of fine sand. Water flows onto the top of the filter and then, by gravity, flows through the sand layer, down through the gravel layer, and into the filter underdrains. In some cities the sand layer has been replaced by a lighter weight layer of anthracite coal (anthrafilt). It takes about 2 hours for water to seep down through the rapid sand filters.

As water flows through the rapid sand filter, residual suspended matter is deposited on the sand grains and thus helps to filter the solid materials in water. After water passes through the filter for a time, the sand becomes dirty and the pores between the sand grains become clogged. As a result, flow of water through the sand filter is retarded. To free the rapid sand filters of this suspended matter, water is forced up through the filter bed and the deposited dirt and silt is flushed to waste. The time interval between filter-bed washing varies with the composition of water, the water treatment, and the water temperature. Providence, R.I., washes its filter beds after about 80 hours of operation (Providence Water Supply Board, 1961); Dallas, Tex., after about 60 hours (Dallas Water Council, 1960); and Toledo, Ohio, after about 34 hours (Toledo Div. Water, 1962). Of the 70 municipalities that use filtration as part of the water treatment, 64 cities use the rapid sand filtration method.

A few municipal filtration plants use pressure filters instead of the more common gravity sand filter. The rapid sand filter and the pressure filter are similar in construction except that the pressure filter is enclosed in a steel shell for operating at pressures other than atmospheric.

Slow sand filtration is used to filter all or part of the water supplies of eight of the largest cities. Slow sand filters are constructed so that a layer of fine sand is supported by a layer of gravel; the gravel layer is supported by a filter underdrain. These slow sand filters commonly cover an area of about 1 acre. Water flows through the slow sand filters at about one-fiftieth of the rate at which it flows through the rapid sand filters. As water flows down by gravity through a freshly cleaned sand-filter bed, a slimy coat deposits on the sand grains. This slimy growth of suspended sediment and bacteria, called schmutzdecke, takes several days to develop and is primarily responsible for the removal of bacteria from water.

Slow sand filters are effective for the filtration of raw water that has—without any previous clarification of the water—low turbidity, low color, and low bacteria count. To prevent clogging of sand grains in slow sand filters, turbid water requires coagulation and clarification before filtration. The schmutzdecke on the sand grains of the slow sand filter is especially effective in removing tastes and odors. These filters are operated for months before they are cleaned but require many days to clean.

REMOVAL OF IRON AND MANGANESE

Iron and manganese in surface water seldom cause treatment problems, and the small amounts of these elements are generally removed during clarification, softening, and filtration. However, these elements in ground water can cause water-treatment problems. Because of the presence of carbon dioxide and the absence of oxygen, most ground-water supplies contain considerably more iron and manganese than do adjacent streams. Most ground water is clear and colorless as it emerges from the well. On exposure to air, carbon dioxide gas is dispersed, and the iron and manganese in clear well (ground) water becomes oxidized to form unsightly precipitates that give water a rusty appearance.

Iron and manganese are removed from water principally by oxidizing these metals to their insoluble oxides by injecting air into water, cascading the water over a bed of coarse coke or similar material, or spraying the water into the air. The precipitated iron and manganese oxides settle out in sedimentation basins and are caught on the filter beds. (Water that is saturated with air is extremely corrosive; the air must be expelled by deaeration or by the addition of chemicals before the water is distributed to the consumer.) When necessary, manganese may be oxidized with permanganate; however, the resultant precipitate tends to clog filters (Bogren, 1962). The water is then settled and filtered to remove the fine insoluble precipitates.

POSTCHEMICAL TREATMENT

If the water is to be fluoridated, the fluoride is added generally after filtration, because the fluoride can be removed by lime-softening and alum-coagulation processes. The fluoride is added in the form of sodium fluoride, sodium silicofluoride, or fluosilicic acid; the amount added to the water depends on the amount already present and the desired concentration in the treated water. The optimum concentration recommended for drinking water (table 2) ranges from 0.6 to 1.7 ppm, depending on the local 5-year average air temperature. The number of communities in the United States that added fluoride to their water increased from 6 to more than 2,000 between 1945 and 1962. In 1962, about 51 million people in the United States and Puerto Rico were using fluoridated water supplies (Am. Water Works Assoc., 1964). In these 100 largest cities, 34 cities serving more than 21 million people were using fluoridated water.

Lime-softening water that has not been stabilized before filtration is now stabilized with carbon dioxide, sulfuric acid, or a phosphate compound to prevent a heavy deposition of calcium carbonate scale in the distribution system. Lime is added to water having a low pH or a low hardness so that the pH will be increased and a slight scale of calcium carbonate will be deposited to control corrosion.

Except for final chlorination, the clarified, softened, and post-treated water is now ready for distribution to the consumer. This water is stored in clear wells or finished water reservoirs until needed in the various sections of the city. As required, treated water is pumped from reservoirs at treatment plants to small elevated storage tanks, distributed throughout the city. These tanks are sufficiently large to keep the various sections of town supplied with water and to prevent unduly large demand surges for water.

POSTCHLORINATION

While in storage, prior to distribution, the water is given a final treatment with chlorine. The addition of chlorine at this stage of the treatment, or at any time after filtration, is called postchlorination. The amount of chlorine added to water depends on the amount of organic matter and the amount of chemicals in water that will react with chlorine; after clarification and filtration, little organic matter is present in water. Sufficient chlorine must be added to water to ensure that bacterial growth is suppressed from the time that water leaves the treatment plant until water flows from the tap in the home. Water that may be in transit for a long time before being used is commonly treated with more chlorine than is water in transit for a short period of time. In some cities, water is rechlorinated at pumping stations in the distribution system.

For many years the principal disinfectant used in water treatment has been chlorine. In many municipal water-treatment plants, chlorine gas is added to a water solution that is then mixed with the water to be treated. In some treatment plants the chlorine may be added as a dry powder called hypochlorite, which when dissolved in water releases chlorine gas. In about 30 percent of these largest cities, ammonia is used with chlorine to form chloramine compounds, which are effective in maintaining a satisfactory residual of chlorine in distribution systems. Chloramines do not produce the undesirable tastes and odors associated with chlorinated waters that contain minute amounts of phenol compounds. Ozone, a form of oxygen, is also used for disinfection in a few cities.

EFFECT OF WATER TREATMENT UPON WATER QUALITY

Softening, adjusting pH, and coagulation change the chemical composition of water. The obvious changes in water quality are the lowering of the concentrations of calcium and magnesium to obtain less hard water, the resultant lowering of the dissolved-solids contents, and the changes in pH. In addition, iron and manganese concentrations in treated water are lower than in raw water. Most other constituents and properties of water are not altered significantly. The major changes that occur during lime softening, lime-soda softening, and cation exchange are illustrated in figure 12.

Softening with lime removes carbonate hardness. If the hardness is caused primarily by calcium, lime removes about equivalent amounts of calcium and bicarbonate from water; small amounts of magnesium in water settle out with the sludge of calcium carbonate (see fig. 12). If a significant part of the carbonate hardness is caused by magnesium, additional lime increases the amount of magnesium carried down with the softening sludge. Lime softening also causes the coprecipitation of iron, manganese, strontium, and possibly other trace elements.

Chemical analyses of water before and after lime-soda softening at one of these largest cities is illustrated in figure 12. The addition of lime and soda decreased the calcium, magnesium, and bicarbonate contents but increased the sodium content. During the lime-soda treatment illustrated in figure 12, the amount of soda ash (sodium carbonate) added was not sufficient to give the treated water a significantly higher dissolved-solids content than the raw water.

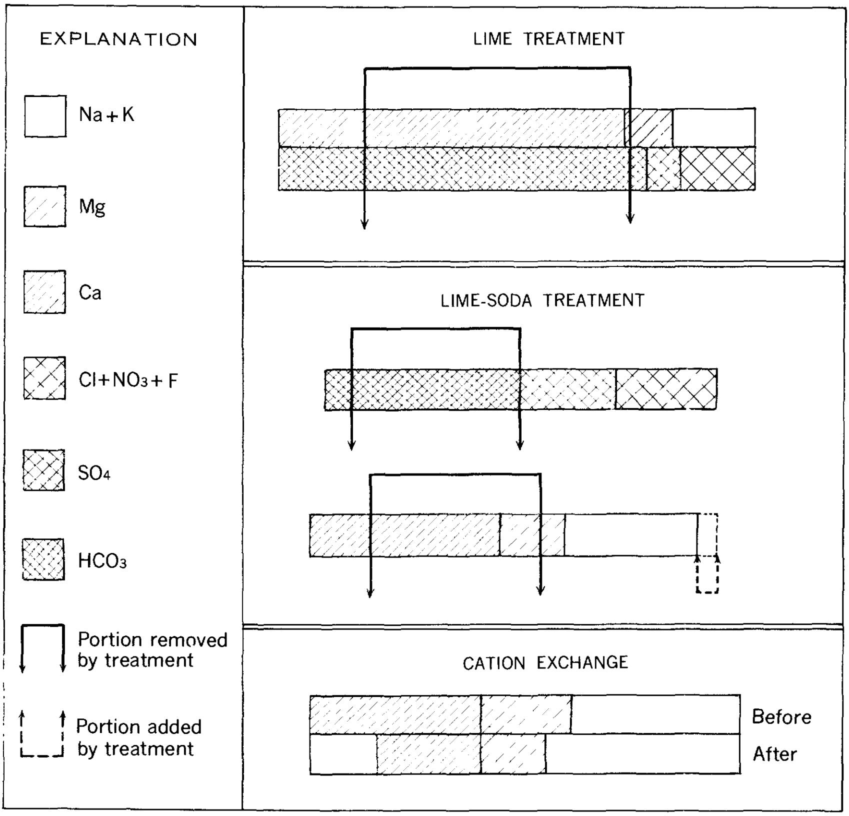


FIGURE 12.—Effect of water softening upon the chemical composition of water being treated.

As indicated in figure 12, cation exchange softens water by replacing a part of the calcium with nonhardness-causing sodium and also by replacing a part of the magnesium with sodium. In this process, the bicarbonate, sulfate, chloride, and nitrate concentrations remain unchanged. During cation softening, the dissolved-solids content generally increases, although the hardness is lowered.

In the coagulation process to remove turbidity and suspended solids, the coagulants aluminum sulfate and iron sulfate lower the concentration of bicarbonate and carbonate in water and increase the concentration of sulfate. Because aluminum and iron sulfate are acidic, the pH of the water during this treatment is reduced, unless it is adjusted upward by the addition of lime. Although the aluminum coagulants may contain 0.3 percent iron as an impurity, this iron is subsequently removed during coagulation.

In chlorination, chlorine reacts with water to release oxygen, which acts as a disinfectant, and to form hydrochloric acid, which lowers the pH of the water. The soluble chloride remains in solution and slightly increases the dissolved-solids content.

In the adjustment of the pH of water for the control of corrosion, the pH is raised generally by the addition of lime, which also increases the water hardness and generally increases the strontium content slightly. In some treatment plants soda ash (sodium carbonate) is used to raise the pH without increasing the hardness of the water.

Radioactivity is eliminated during many phases of water treatment. Ion exchange by some silts, natural sedimentation, and coagulation followed by clarification remove large amounts of radioactive materials from turbid waters. Sedimentation and coagulation followed by clarification can remove between 45 and 85 percent of radioactive fission products; subsequent filtration removes additional amounts of radioactive materials. Softening by the lime-soda method also accelerates the removal of the radioactive materials in the raw water. Complete ion exchange of water removes 99.99 percent of the radioactive materials (Bevis, 1960).

Recent spectrographic analyses indicate that of the impurities in water-treatment chemicals only aluminum, iron, and strontium alter the concentration of trace elements in the water being treated.

QUALITY OF THE WATER SERVED TO THE CONSUMER

Let us now take a brief look at the finished product. Although it is difficult to establish any regional patterns of water hardness of treated-water supplies of these cities, the "soft" water supplies (hardness less than 61 ppm) are located along the Atlantic coast, in coastal Oregon and Washington, and along the Gulf Coast westward to Houston, Tex., where natural cation exchange (softening) occurs. The hardest water supplies are generally in the far southwest and in the East North Central States (Ohio, Indiana, Illinois, Michigan, and Wisconsin).

A comparison of the hardness of the treated-water supplies (fig. 13) with the hardness of the raw-water supplies (fig. 6) of these largest cities reveals some interesting changes in the hardness of water supplies as a result of municipal softening practices. (The hardness values in figure 13 were calculated by the same method used to calculate the population-weighted hardness of the raw-water supplies, figure 6.) Although 27 cities have a raw-water hardness exceeding 180 ppm ("very hard"), only 13 cities have a "very hard" treated-water supply; and although 22 cities have a raw-water hardness

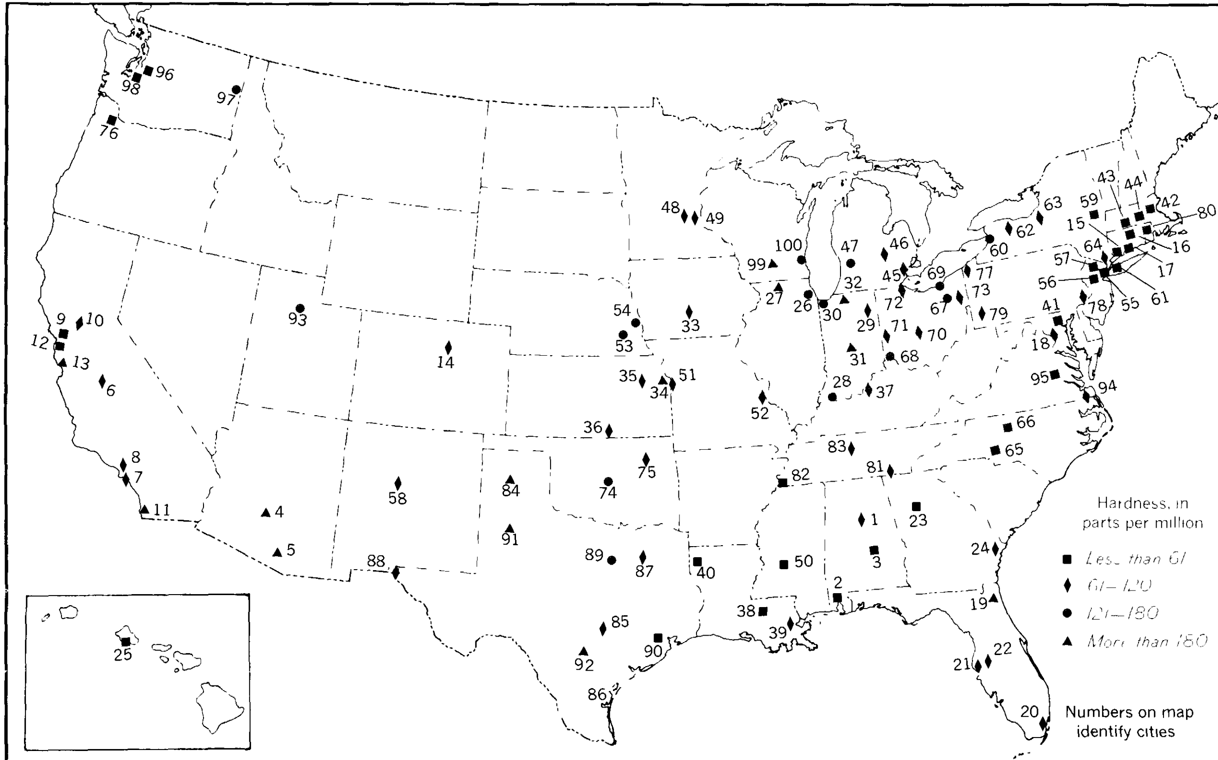


FIGURE 13.—Hardness of treated public water supplies of the 100 largest cities in the United States, 1962. (Average weighted by population served.) See table 1 for identification of cities.

ranging from 121 to 180 ppm ("hard"), only 16 cities have a "hard" treated water supply. Only 16 cities have a raw-water hardness ranging from 61 to 120 ppm ("moderately hard"), whereas 41 cities have a treated-water hardness of this desirable range. A few cities that have "soft" raw water add lime to reduce corrosion and thus increase the water hardness to more than 61 ppm. Thirty public supplies have a treated-water hardness of less than 61 ppm.

The pH of the treated-water supplies of these largest cities is shown in figure 14. Most cities having a treated-water supply whose pH is less than 7.0 are in the northeastern part of the country. In most of these cities chlorination is the only treatment given to the water served to the consumer. Almost three-quarters of the cities have treated water with a pH ranging from 7.0 to 9.0. Of the 17 cities that have a treated-water supply with a pH greater than 9.0, only 3 cities do not soften their water supply.

The dissolved-solids content of the water served to consumers in these largest cities in the United States is shown in figure 15. Only 3 cities in the southwestern part of the country serving a population of about 1 million have treated-water supplies that contain more than 500 ppm of dissolved solids, which is the maximum limit recommended by the U.S. Public Health Service for dissolved solids if other water sources are available. The treated-water supplies having the lowest dissolved-solids content are generally found in cities east of the Appalachian Mountains. Except for these general statements about the extreme ranges of dissolved solids, no statements can be made about any geographical distribution pattern of dissolved-solids content of treated-water supplies because of the diverse treatment of water supplies. For example, although Kansas City, Kans., and Kansas City, Mo., obtain raw-water supplies containing about the same amount of dissolved solids, the different water-treatment practices of the individual cities result in the quality of the treated-water supplies being different. Kansas City, Kans., does not soften its water, whereas Kansas City, Mo., lowers the hardness to about 85 ppm.

A comparison of the dissolved-solids content of the raw-water supplies (fig. 5) with the dissolved-solids content of treated-water supplies (fig. 15) indicates that many cities have lowered their dissolved-solids content. Three of the six cities that have raw-water supplies that contain more than 500 ppm have treated-water supplies that contain between 251 and 500 ppm; 22 cities have treated-water supplies that contain between 251 and 500 ppm of dissolved solids, whereas 29 cities have a raw-water supply that contains this range of dissolved solids. Although only 38 cities have a raw-water supply

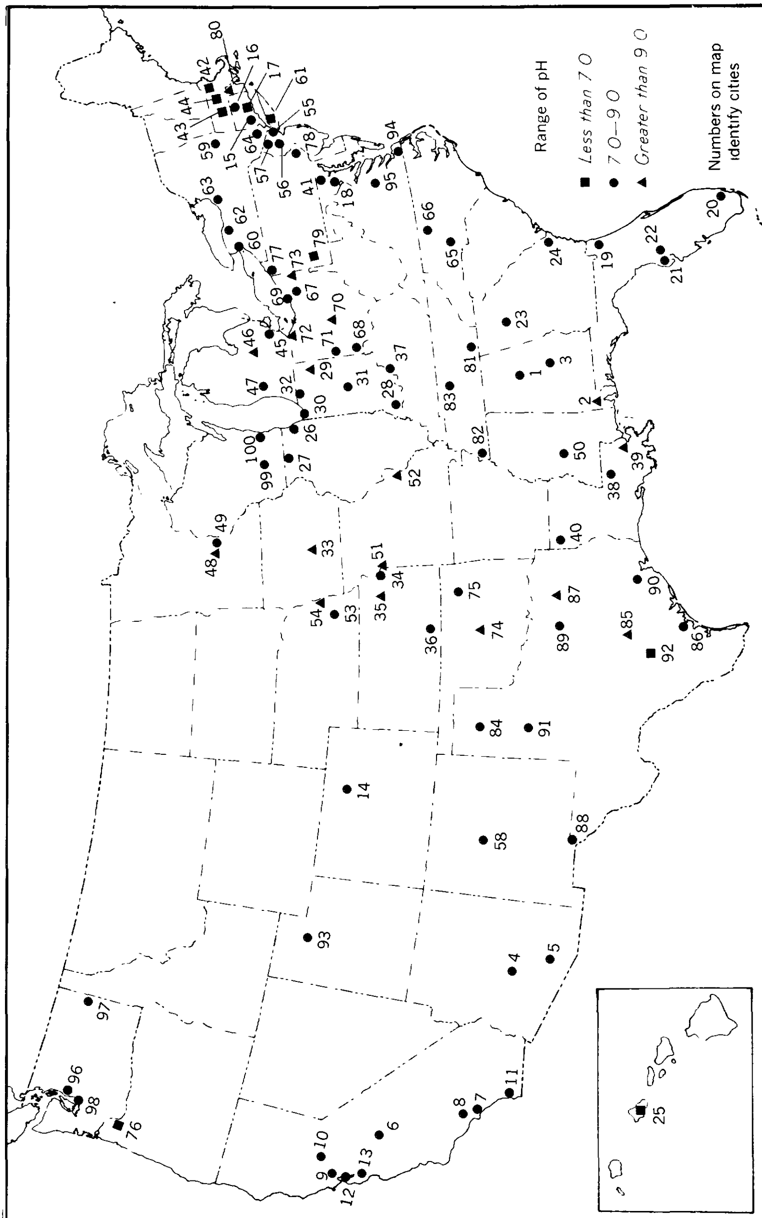


FIGURE 14.—pH of treated public water supplies of the 100 largest cities in the United States, 1962. (Average weighted by population served.) See table 1 for identification of cities.

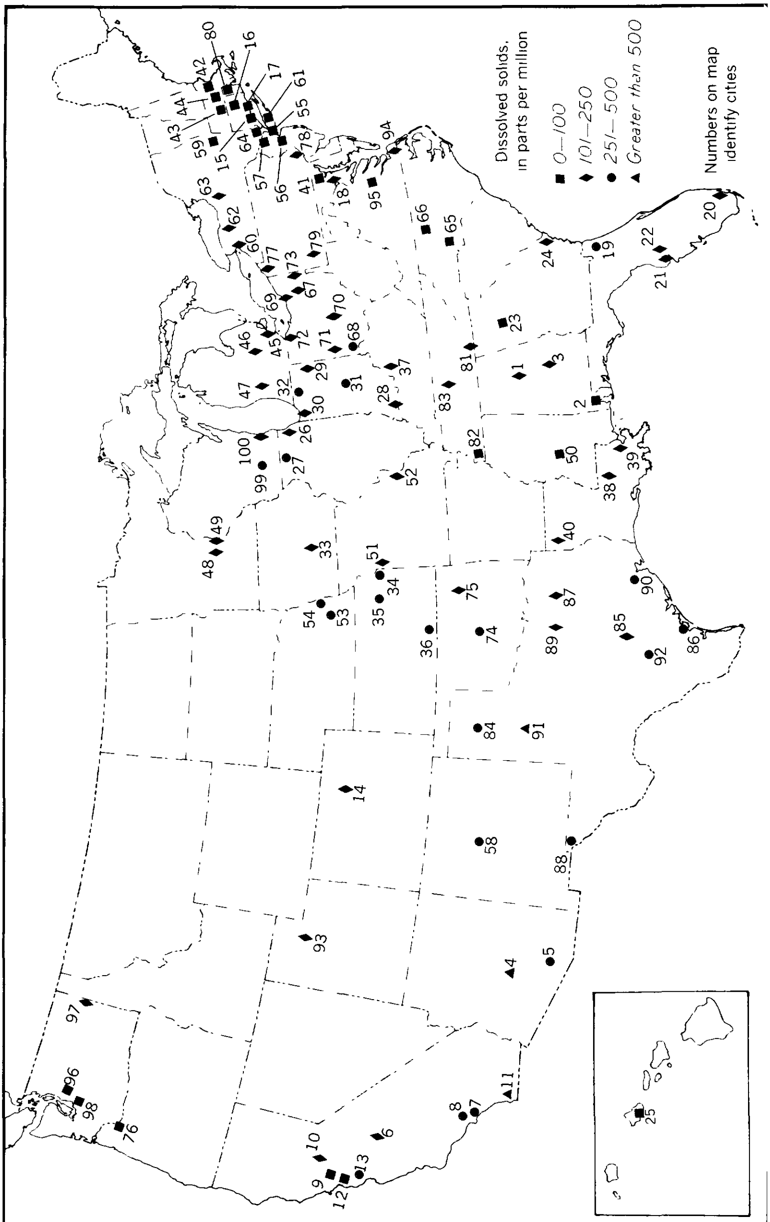
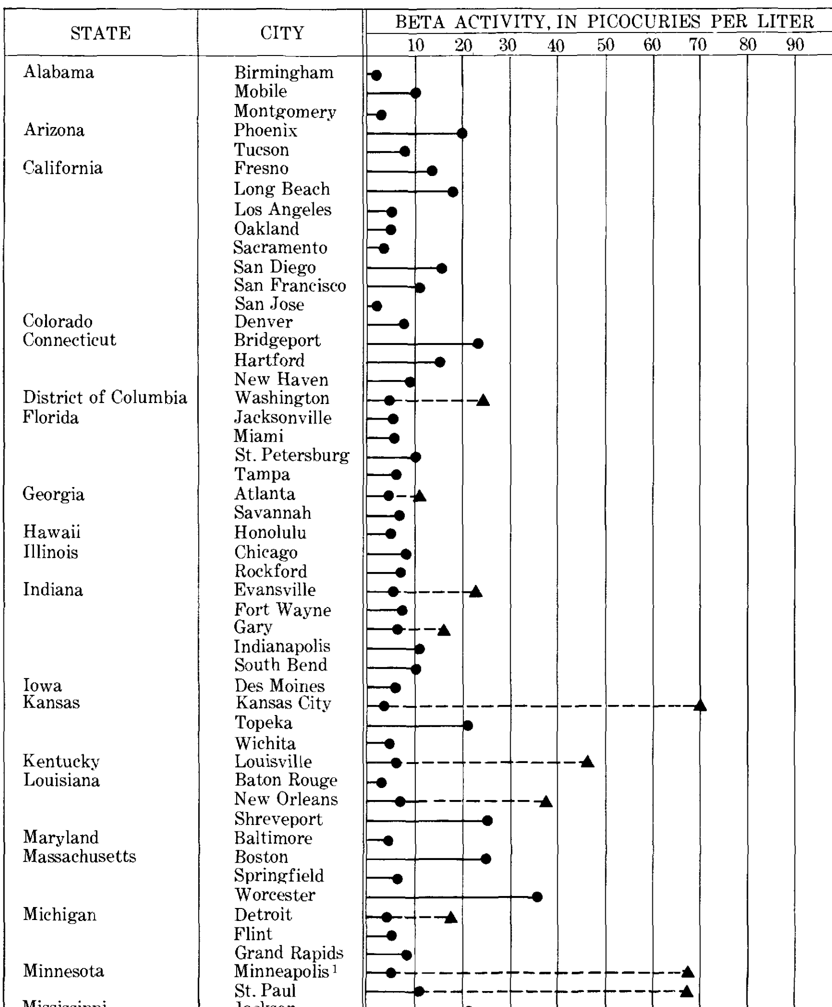


FIGURE 15.—Dissolved solids in treated public water supplies of the 100 largest cities in the United States, 1962. (Average weighted by population served.) See table 1 for identification of cities.

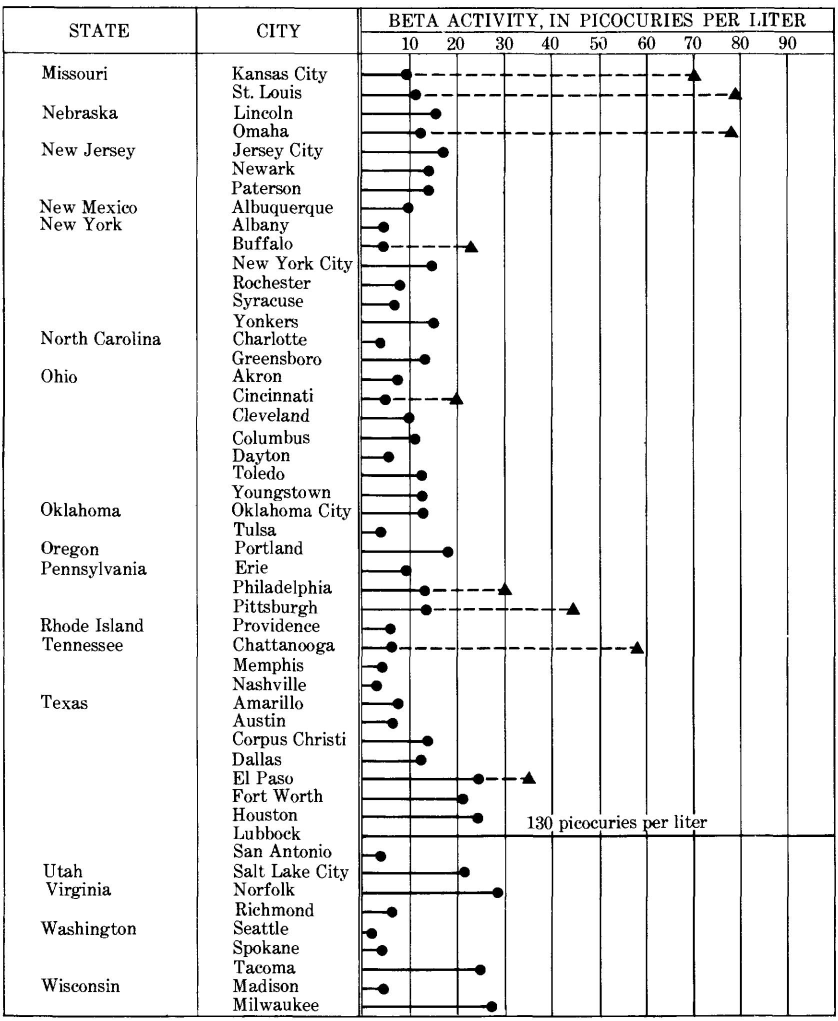
containing from 101 to 250 ppm of dissolved solids, 48—almost half of the cities—supply treated water having a dissolved-solids content of between 101 to 250 ppm. All 27 cities that have a treated-water supply that contains less than 100 ppm also have a raw-water supply with less than 100 ppm of dissolved solids; many of these supplies had some treatment chemicals added to the water, but seemingly not enough chemicals were added to increase appreciably the dissolved-solids content.



[1]Mississippi River (90 percent of supply).

FIGURE 16.—Beta activity of dissolved solids in untreated and treated public water supplies of the 100 largest cities in the United States, 1962.

The maximum beta activity of the dissolved solids in the raw-water supplies of 17 of these largest cities during the period of July 1, 1961, to July 30, 1962, is given in figure 16. Also shown are the beta activities of the dissolved solids of the treated-water supplies. As indicated on the illustration, the beta activity of the treated water is considerably less than that of the raw water. The beta activity of most treated-water supplies is well under the recommended maximum tolerance of 1,000 pc per l.



——● Beta activity in treated water supply. Source: Geological Survey analysis.

– – –▲ Maximum beta activity in raw water, July 1, 1961, to June 30, 1962. Source: U.S. Public Health Service, 1962.

FIGURE 16.—Continued

The concentrations of constituents in treated-water supplies of these 100 largest cities as determined by chemical, spectrographic, and radiochemical analyses are summarized in table 8.

TABLE 8.—*Summary of chemical, spectrographic, and radiochemical analyses of treated-water supplies of the 100 largest cities in the United States, 1962*

[ND, not detected]

Constituent or property	Water supplies having less than stated concentration		Constituent or property	Water supplies having less than stated concentration	
	Concentration	Percent of water supplies		Concentration	Percent of water supplies
Chemical analyses [parts per million]			**Spectrographic analyses** [micrograms per liter]		
Silica (SiO_2)	30	94	Silver (Ag)	0.50	95
Iron (Fe)	.25	98	Aluminum (Al)	500	87
Manganese (Mn)	.10	95	Boron (B)	100	94
Calcium (Ca)	50	93	Barium (Ba)	100	94
Magnesium (Mg)	20	96	Chromium (Cr)	5.0	95
Sodium (Na)	50	93	Copper (Cu)	100	94
Potassium (K)	5.0	93	Iron (Fe)	150	94
Bicarbonate (HCO_3)	150	91	Lithium (Li)	50	96
Carbonate (CO_3)	1.0	86	Manganese (Mn)	100	97
Sulfate (SO_4)	100	93	Molybdenum (Mo)	10	96
Chloride (Cl)	50	93	Nickel (Ni)	10	95
Fluoride (F)	1.0	92	Phosphorus (P)	ND	92
Nitrate (NO_3)	5.0	93	Lead (Pb)	10	95
Dissolved solids	500	97	Rubidium (Rb)	5.0	91
Do	250	86	Strontium (Sr)	500	96
Hardness as $CaCO_3$	200	94	Titanium (Ti)	5.0	96
Noncarbonate hardness as $CaCO_3$	75	94	Vanadium (V)	10	91
Specific conductance (micromhos at 25° C)	500	93	**Radiochemical analyses**		
pH ... pH units	9.0	90	Beta activity picocuries per liter	20	92
Color ... color units	10	96	Radium (Ra) ... do	.2	91
Turbidity	3	94	Uranium (U) micrograms per liter	2.0	93

COST OF CHEMICALS USED IN WATER TREATMENT

The cost of chemicals used in treating public water supplies varies with the treatment and the chemical and physical characteristics of the water being treated. Some public supplies are not treated, some are only chlorinated, some require clarification in addition to chlorination, and some are softened. In addition, some supplies require such further treatment as taste and odor control and removal of iron and manganese. The cost of treating water by the same process varies from city to city because of differences in composition of the raw water. Even in the same city, the treatment varies seasonally as the composition of raw water changes.

Although disinfection by chlorination is a relatively simple process, the cost of chlorine added per million gallons of water ranges from less than 25 cents to more than $3.50. The cost varies with the characteristics of the water: the higher the dissolved-solids content, hardness, turbidity, and color, the higher the cost of chlorination. Many cities chlorinate public water supplies for less than $1.50 per million gallons of water.

Lime is widely used for raising the pH and for softening water. Water that does not require softening commonly has the pH adjusted to prevent corrosion. The amount and cost of lime added for pH adjustment depends on the pH and dissolved-solids content of the raw water and on the desired pH of the treated water. The cost of adding lime in lime softening and lime-soda softening processes depends to a large extent on the hardness of the raw water and the desired hardness of the treated water. Dayton, Ohio, lowers the average hardness from 356 ppm in the raw water to 103 ppm in the treated water—a decrease of 253 ppm. A second city, Toledo, Ohio, lowers the average hardness from 124 ppm in the raw water to 70 ppm in the treated water—a decrease of 54 ppm. Dayton uses about five times as much lime as does Toledo.

The amount, type, and cost of coagulation chemicals used depend on the type and amount of turbidity and suspended sediment in the raw water. As the amount of turbidity and suspended sediment in the raw-water supply increases, the amount and cost of coagulation chemicals used increase. At Philadelphia, Pa., where the average of the turbidities of the raw-water supplies is about 75 ppm, about 182 pounds of coagulation chemicals is added to a million gallons of water at a cost of about $4.25 per million gallons of treated water. At Washington, D.C., "the additional cost of alum and lime for treating high range turbidities of from 200 to 600 units compared to low range turbidities of 5 to 10 units would cost about $1.28 per million gallons" (Smith, J. C., written communication, 1962).

Carbon—used for taste and odor control—is a chemical whose amounts and costs for treatment range from less than 5 cents to more than $2.00 per million gallons of water processed; many cities apply carbon at a cost of less than $1.00 per million gallons.

Fluoridation chemicals are added to obtain a fluoride content of about 1 ppm in the treated water. The amount of treatment chemicals added depends on the amount of natural fluoride in the water. Generally the cost of the fluoride chemicals added to a million gallons of water is about $1.00.

In many cities the total cost of chemicals added to the water during treatment is less than $20 per million gallons of water and is only a small part of the cost of providing a desirable water supply.

INDUSTRIAL WATER USE

Many municipal water systems furnish significant amounts of water to industrial establishments, and a few cities have separate water-supply systems for industrial use. A brief discussion is given below of the amounts and quality of water used by industry and the treatment given to industrially used water. For more detailed information on industrial water supplies and treatment, the reader is referred to publications dealing with industrial water supplies, such as those prepared by Betz Laboratories (1962), Nordell (1961), and Powell (1954).

Water is used in industry for three principal purposes: cooling water; boiler water, which is water used for the generation of steam in boilers; and process water, which is water that comes into contact with the product being manufactured.

Cooling water.—The minimum quality requirement of once-through cooling water (water not recirculated) is that the water be free of sediment, debris, and algae that could clog pipes. Most once-through cooling waters receive a minimum of treatment: chlorination to suppress algae growth, and clarification of surface waters.

The quality requirements for recirculated cooling water are more critical. (See table 9.) The general path of recirculated cooling water is as follows: cooled water flows through heat exchangers and is warmed by the product being cooled; this warmed water is then passed through a cooling tower or pond, where it is cooled by heat exchange with air and by evaporation of a water spray. In this process the water becomes saturated with oxygen from air, which could accelerate metal corrosion. The dissolved oxygen is removed by deaeration or controlled by the addition of chemical inhibitors such as chromate and phosphate.

Cooling water may deposit scale or attack iron pipes after the water has been recirculated several times. To reduce corrosiveness and to prevent the formation of scale, a fraction of the recirculated cooling water is discarded to waste and replaced by water that has a lower dissolved-solids content or is softer.

TABLE 9.—*Water-quality tolerances of cooling water suggested by the American Water Works Association*

[Data modified from American Water Works Assoc. (1950)]

Constituent or property	*Limiting values (ppm)*
Hardness as $CaCO_3$	50
Iron (Fe)	.5
Manganese (Mn)	.5
Iron plus manganese	.5
Turbidity	50
Corrosiveness	None.

Boiler water.—Because of the rigid water-quality requirements for water used in boilers, only small amounts of chemicals can be tolerated. Table 10 gives the suggested water-quality tolerance for boiler water—that is, for the water inside the boiler. At the high temperatures of steam boilers, corrosion and scale formation are accelerated. Water containing appreciable amounts of calcium bicarbonate or appreciable amounts of calcium sulfate deposits a heat-retarding adherent scale that becomes baked on the metal surface and is difficult to remove. In the presence of calcium, silica acts as a cementing agent and forms a low-heat-conducting hard glassy scale. Silica also deposits on turbines of steam-generating equipment and causes operating difficulties. The higher the pressure of the boiler, the lower the dissolved-solids content that can be tolerated. (See table 10.) Silica and the hardness-causing elements that are responsible for scale formation are removed by methods such as hot lime, hot phosphate, lime-phosphate, and ion-exchange softening techniques.

TABLE 10.—*Water-quality tolerances of boiler water, in parts per million*

[From Betz Laboratories (1962, p. 174)]

Operating pressure (psi)	Total dissolved solids	Total alkalinity	Suspended dissolved solids
0–300	3, 500	700	300
301–450	3, 000	600	250
451–600	2, 500	500	150
601–750	2, 000	400	100
751–900	1, 500	300	60
901–1,000	1, 250	250	40
1,001–1,500	1, 000	200	20
1,501–2,000	750	150	10
2,001 and higher	500	100	5

Boiler water having a low pH, a small amount of calcium and magnesium, and a large amount of sulfate and chloride can be corrosive. The more sulfate and chloride in water and the higher the operating pressure, the greater the danger of corrosion. These troublesome chemical constituents may be removed by ion exchange. The presence of dissolved gases, especially oxygen, also accelerates corrosion. To reduce corrosion by oxygen and other undesirable gases, water may be passed through degasifiers, or chemical inhibitors such as chromate or phosphate may be added. Lime may be added to raise the pH and thus prevent corrosion. In addition, the following may be added directly to water in the boiler: nitrates and tannins, to prevent a special type of boiler fracture known as "caustic embrittlement"; antifoam agents, to prevent foaming; and phosphate, to prevent scale formation.

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Process water.—The amount of process water used in an industrial establishment depends upon the product being produced. In the refining of petroleum, the amount of water that comes into contact with the product is small, whereas in the manufacture of synthetic rubber, more than 60 percent of the water used is process water. In a similar manner the quality requirements for process water vary widely. In the processing of many food products, water that is satisfactory for drinking is satisfactory for process use, whereas water used in the manufacture of synthetic rubber must have a hardness of less than 30 ppm (Durfor, 1963). A few of the maximum limits for chemical constituents in water to be used in industry are shown in table 2. For the requirements of specific industries the reader is referred to Nordell (1961).

SUMMARY

About 60 million people—34 percent of the total population of the United States and 48 percent of the urban population—are served by the water-supply systems of the 100 largest cities. The amount of water used to furnish the domestic needs as well as the needs of commerce, industry, and other demands on the municipal systems of these largest cities ranges from about 13 mgd, which serves a population of 124,000 in Greensboro, N.C., to about 1,200 mgd, which serves a population of more than 8 million in New York City. The total amount of water used by the 100 largest cities is about 9,650 mgd. Many of these cities are expanding their water-supply systems to provide for anticipated increases in demands for water.

For these largest cities, the population served, the average amount of water used, the sources of raw-water supply, the raw- and finished-water storage capacities, the types of treatment, and the rated capacities of the treatment plants are given in the descriptions of the individual cities. For easy reference, table 11 summarizes these data and lists the illustrations that show the raw-water sources, the location of treatment plants, and the water-service areas.

The water used by these largest cities comes from ground water—wells and infiltration galleries—and surface water—streams, reservoirs, and lakes. Twenty cities use only ground water for public supplies. Fourteen cities utilize both ground and surface water; some use predominantly ground water, and others use mostly surface water. Sixty-six cities use water from streams, lakes, or reservoirs; of these cities, 37 depend solely upon impounded waters, and 20 depend solely upon natural streamflow. Many of the cities that depend solely upon natural streamflow obtain water from rivers that have a discharge in excess of 450 mgd. Water from the Great Lakes furnishes part or all the water supply for 10 of these largest cities.

Because ground water is in contact with surrounding rock formations for longer periods of time than is water in streams, most ground water (during a large part of the year) contains more dissolved solids than does the nearby surface water. The chemical quality of most ground-water supplies is stable, and ground-water temperatures approximate mean annual air temperatures. In streams the chemical quality varies seasonally. The maximum concentrations of dissolved solids occur generally during base flow, when the flow of the stream is maintained by ground water; minimum concentrations of dissolved solids occur when the discharge of the stream is at a maximum and the effect of the ground-water inflow is subdued. Because streams are generally impounded during flood period, the mineral content of water in reservoirs is generally less than that of the unimpounded streams. The mineral content of water in the Great Lakes increases slightly downstream—from Lake Superior to Lake Ontario—but varies little seasonally.

Chemical, spectrographic, and radiochemical analyses were made of water supplies; the available analyses for each of the 100 largest cities are indicated in table 11. Table 12 summarizes the maximum, median, and minimum values of constituents and properties of water served to customers in these largest cities.

In order to furnish water that is safe, clear, and not too hard, most cities treat the water before it is pumped to the home. About 98 percent of the population served by these supplies receive water that is chlorinated. To reduce turbidity in surface-water supplies, many cities clarify the water. About 56 percent of the population in these 100 cities receive filtered water. The most common treatment is rapid sand filtration; some cities employ slow sand filtration, and a smaller number use pressure filtration. Because of the natural filtering action of soils, few ground-water supplies require filtration except where used in conjunction with the removal of sludge from softening processes. Twenty-eight cities serving less than 20 percent of the total population of the 100 cities employ softening processes. Of the 28 cities, 15 cities employ lime softening to reduce the hardness of water. To remove troublesome amounts of iron or manganese less than 10 cities require special processes. To reduce incidence of dental caries in these cities, 34 cities serving more than 21 million people fluoridate thin water.

The quality of the public water supplies of the 100 largest cities in the United States is summarized in table 13.

TABLE 11.—*Summary of data on public water supplies of the 100 largest cities in the United States, 1962*

State and city	Popu-latiou served (thou-sands)	Water used (mgd)	Source		Illustra-tion No.	Storage capacity (million gallons)		Treatment				Rated capacity of treat-ment plants (mgd)	Analyses reporied				
			Surface water	Ground water		Raw	Treated	Clari-fication	Soften-ing	Chlori-nation	Fluori-dation		Chemical Raw	Chemical Treated	Spectrographic Raw	Spectrographic Treated	Radio-chemi-cal Treated
Alabama:																	
Birmingham	441	53.8	X		17	5,682	4.5	X		X		73	X	X	X	X	X
Mobile	211	20.0	X			50	26.2	X		X	X	40	X	X		X	X
Montgomery	148	16.0		X		14.5	8.0	X		X			X	X	X	X	X
Arizona:																	
Phoenix	487	92.7	X	X		0	100	X		X		120	X	X	X	X	X
Tucson	232	39.0		X			33.3			X				X		X	X
California:																	
Fresno	150	53.4		X		1.5							X		X		(1)
Long Beach	344	46.6	X	X	18, 19	28	120	X	X	X		40	X	X		X	X
Los Angeles	2,458	466	X	X	19	132,000			X	X			X	X		X	X
Oakland	1,000	143.4	X		20	101,000	664	X		X		261		X		X	X
Sacramento	181	47.5	X	X	20	0	14.5	X		X		64	X	X	X	X	X
San Diego	600	72.9	X		19	141,000	141	X	X	X		135	X	X		X	X
San Francisco	1,600	166	X		20	180,000	404			X	X		X	X		X	X
San Jose	358	46.7	X	X	20	2,290	102	X						X		X	X
Colorado:																	
Denver	620	131	X		21	87,000	49.0	X		X		325	X	X	X	X	X
Connecticut:																	
Bridgeport	320	49.0	X		22	24,000	4.7			X		193	X	X		X	X
Hartford	355	42.5	X		23	42,700	15.8	X		X	X	56		X		X	X
New Haven	320	44.0	X		24	22,300	16.7	X		X		12		X		X	X
District of Columbia:																	
Washington	1,100	167	X		25	560	184	X		X	X	229	X	X	X	X	X
Florida:																	
Jacksonville	247	36.7		X			22.5			X			X	X	X	X	X
Miami	550	102		X	26	0	12.0	X	X	X	X	145	X	X	X	X	X
St. Petersburg	250	13.1		X			17.5	X	X	X		23	X	X	X	X	X
Tampa	290	29.6	X	X		2,500	24.6	X	X	X		60	X	X		X	X
Georgia:																	
Atlanta	600	68.2	X		27	500	30.5	X		X		92	X	X	X	X	X
Savannah	170	55.0	X	X			17.0	X		X		50	X	X	X	X	X
Hawaii:																	
Honolulu	405	62.5		X	28		32.2			X			X		X		(1)
Illinois:																	
Chicago	4,423	1,030	X		29		76.9	X		X	X	330	X	X	X	X	X
Rockford	132	19.8		X		0	20.0			X				X		X	X

Indiana:																	
Evansville	160	21.0	×			0	30.0	×		×		36		×		×	×
Fort Wayne	168	20.8	×			710	22.0	×	×	×	×	48	×	×	×	×	×
Gary	225	23.5	×				14.0	×		×	×	52		×		×	×
Indianapolis	500	68.0	×		30	14,000	30.0	×		×	×	72		×		×	×
South Bend	133	20.0		×		6.0	10.5			×				×		×	×
Iowa:																	
Des Moines	259	25.3	×	×	31	1,570	22.7	×	×	×	×	96	×	×		×	×
Kansas:																	
Kansas City	200	29.3	×		32		18.2	×		×		60	×	×		×	×
Topeka	131	12.4	×		33	0	56.0	×	×	×	×	40	×	×		×	×
Wichita	255	25.0		×	34		19.5	×	×	×		120	×	×		×	×
Kentucky:																	
Louisville	550	83.8	×			168	60.0	×	×	×	×	160	×	×	×	×	×
Louisiana:																	
Baton Rouge	152	14.8		×			6.1			×		18		×		×	×
New Orleans	628	105	×			0	42.0	×	×	×		240	×	×	×	×	×
Shreveport	164	20.1	×				15.0	×		×		54	×	×	×	×	×
Maryland:																	
Baltimore	1,387	211	×		35	86,000	775	×		×	×	360	×	×	×	×	×
Massachusetts:																	
Boston	2,000	215	×		36	486,000	2,960			×		425	×	×		×	×
Springfield	236	31.5	×		37	26,900	70.0	×		×		55		×		×	×
Worcester	187	23.5	×		38	7,760	3.8			×		42		×		×	×
Michigan:																	
Detroit	3,078	483	×				240	×		×		964	×	×	×	×	×
Flint	196	32.0	×			6,400	25.0	×	×	×		56	×	×	×	×	×
Grand Rapids	200	34.0	×				52.8	×		×	×	66	×	×	×	×	×
Minnesota:																	
Minneapolis	582	58.7	×		39		118.0	×	×	×	×	278	×	×	×	×	×
St. Paul	334	42.6	×		40	6,750	1.2	×	×	×	×	100	×	×	×	×	×
Mississippi:																	
Jackson	150	15.0	×				3.0	×		×		37		×		×	×
Missouri:																	
Kansas City	750	88.0	×		32		72.0	×	×	×		210	×	×	×	×	×
St. Louis	760	181	×		41	35	201.0	×	×	×	×	360	×	×		×	×
Nebraska:																	
Lincoln	128	23.6		×	42	0	46.5	×		×		60	×	×		×	×
Omaha	327	64.5	×		43	86	56.0	×	×	×		140	×	×		×	×
New Jersey:																	
Jersey City	350	61.0	×		44	10,800	100			×		100		×		×	×
Newark	750	55.7	×		44	40,800	701.0			×		296	×	×		×	×
Paterson	550	80.8	×		44	28,000	263	×		×		95	×	×		×	×
New Mexico:																	
Albuquerque	201	30.0		×			80			×				×		×	×
New York:																	
Albany	142	24.5	×			12,800	210	×		×		32	×	×	×	×	×
Buffalo	593	145	×				30.0	×		×	×	160	×	×	×	×	×
New York City	8,350	1,190	×	×	45, 46	507,000	3,370	×		×				×		×	×
Rochester	292	62.9	×				231	×		×	×	72	×	×		×	×
Syracuse	235	42.3	×				235			×		58	×	×		×	×
Yonkers	191	12.0	×	×	46	1,000	2.0	×		×		16		×		×	×

See footnote at end of table.

TABLE 11.—*Summary of data on public water supplies of the 100 largest cities in the United States, 1962*—Continued

State and city	Population served (thousands)	Water used (mgd)	Source		Illustration No.	Storage capacity (million gallons)		Treatment				Rated capacity of treatment plants (mgd)	Analyses reported				
			Surface water	Ground water		Raw	Treated	Clarification	Softening	Chlorination	Fluoridation		Chemical		Spectrographic		Radiochemical
													Raw	Treated	Raw	Treated	Treated
North Carolina:																	
Charlotte	213	22.1	X		47	100	21.3	X		X	X	36	X	X	X	X	X
Greensboro	124	13.0	X		48	3,020	21.7	X		X		20	X	X		X	X
Ohio:																	
Akron	315	41.1	X		49	10,100	48.0	X		X		60		X		X	X
Cincinnati	750	97.0	X		50	330	131	X		X		200	X	X		X	X
Cleveland	1,675	319	X		51	80	293	X		X	X	515		X		X	X
Columbus	594	71.3	X		52	26,000	49.0	X	X	X		110	X	X		X	X
Dayton	320	46.6		X			64.9	X	X	X		96	X	X		X	X
Toledo	400	65.5	X		53		35.0	X	X	X	X	120	X	X		X	X
Youngstown	250	22.2	X		54	11,000	35.0	X	X	X		64		X		X	X
Oklahoma:																	
Oklahoma City	340	31.1	X			99,400	46.0	X	X	X	X	61	X	X	X	X	X
Tulsa	292	42.5	X			36,200	55.0	X		X	X	120		X	X	X	X
Oregon:																	
Portland	542	69.0	X			20,000	208.0			X		225		X		X	X
Pennsylvania:																	
Erie	160	38.0	X				44.6	X		X		67		X		X	X
Philadelphia	2,003	510	X		55		747	X		X	X	653	X	X		X	X
Pittsburgh	1,210	137	X			110	531	X	X	X	X	215		X		X	X
Rhode Island:																	
Providence	383	45.2	X		56	39,700	54.4	X		X	X	105	X	X		X	X
Tennessee:																	
Chattanooga	231	38.0	X			0	13.0	X		X	X	52	X	X	X	X	X
Memphis	600	68.8		X	57	2.0	75.0	X		X		105	X	X		X	X
Nashville	350	37.8	X				60.0	X		X	X	40	X	X	X	X	X
Texas:																	
Amarillo	150	21.6		X		2.0	28.5			X		57	X	X		X	X
Austin	206	29.7	X			741,000	44.0	X	X	X		63	X	X		X	X
Corpus Christi	212	48.1	X		58	98,400	44.0	X	X	X	X	81	X	X		X	X
Dallas	800	89.8	X		59	566,000	161	X	X	X		312	X	X		X	X
El Paso	280	45.0	X	X	60		92.6	X	X	X		110	X	X		X	X
Fort Worth	360	47.0	X		61	188,000	60.0	X		X		129	X	X		X	X
Houston	770	108	X	X	62	52,000	60.0	X		X		188	X	X	X	X	X
Lubbock	133	18.0		X			39.0			X		47	X	X	X	X	X
San Antonio	603	81.7		X	63		49.3			X		398	X	X		X	X

Utah:																	
Salt Lake City	272	59.3	×	×	64	51,300	94.4	×	----	×	----	178	×	×	×	×	×
Virginia:																	
Norfolk	375	41.9	×	----	65	8,900	20.0	×	----	×	×	64	×	×	----	×	×
Richmond	303	31.1	×	----	66	170	58.0	×	----	×	×	66	×	×	----	×	×
Washington:																	
Seattle	735	103	×	----	67	4,760	385.0	----	----	×	----	279	×	×	×	×	×
Spokane	183	68.0	----	×	----	----	89.9	----	----	×	----	----		×		×	×
Tacoma	165	48.2	×	×	----	----	313	----	----	×	----	72	----	×	----	×	×
Wisconsin:																	
Madison	135	17.0	----	×	----	3.3	9.4	----	----	×	×	15	----	×	----	×	×
Milwaukee	867	143	×	----	----	----	99.0	×	----	×	×	200	×	×	×	×	×

[1] Most water receives no treatment, and radiochemical analyses were made on raw water.

TABLE 12.—*Maximum, median, and minimum values of constituents and properties of finished water in public water supplies of the 100 largest cities in the United States, 1962*

[<, less than; ND, not detected]

Constituent or property	Maximum	Median	Minimum
Chemical analyses [parts per million]			
Silica (SiO_2)	72	7.1	0.0
Iron (Fe)	1.30	.02	.00
Manganese (Mn)	2.50	.00	.00
Calcium (Ca)	145	26	.0
Magnesium (Mg)	120	6.25	.0
Sodium (Na)	198	12	1.1
Potassium (K)	30	1.6	.0
Bicarbonate (HCO_3)	380	46	0
Carbonate (CO_3)	26	0	0
Sulfate (SO_4)	572	26	.0
Chloride (Cl)	540	13	.0
Fluoride (F)	7.0	.4	.0
Nitrate (NO_3)	23	.7	.0
Dissolved solids	1,580	186	22
Hardness as $CaCO_3$	738	90	0
Noncarbonate hardness as $CaCO_3$	446	34	0
Specific conductance ... micromhos at 25° C	1,660	308	18
pH ... pH units	10.5	7.5	5.0
Color ... color units	24	2	0
Turbidity	13	0	0
Spectrographic analyses [micrograms per liter]			
Silver (Ag)	7.0	0.23	ND
Aluminum (Al)	1,500	54	3.3
Boron (B)	590	31	2.5
Barium (Ba)	380	43	1.7
Chromium (Cr)	35	.43	ND
Copper (Cu)	250	8.3	<.61
Iron (Fe)	1,700	43	1.9
Lithium (Li)	170	2.0	ND
Manganese (Mn)	1,100	5.0	ND
Molybdenum (Mo)	68	1.4	ND
Nickel (Ni)	34	<2.7	ND
Lead (Pb)	62	3.7	ND
Rubidium (Rb)	67	1.05	ND
Strontium (Sr)	1,200	110	2.2
Titanium (Ti)	49	<1.5	ND
Vanadium (V)	70	<4.3	ND
Radiochemical analyses			
Beta activity ... picocuries per liter	130	7.2	<1.1
Radium (Ra) ... do	2.5	<.1	<.1
Uranium (U) ... micrograms per liter	250	.15	<.1

TABLE 13.—*Summary of quality of public water supplies of the 100 largest cities in the United States, 1962*

	Raw-water supplies [1]		Treated-water supplies	
	Population served (millions)	Number of cities	Population served (millions)	Number of cities
Hardness (ppm):				
Less than 61	21	29	23	30
61–120	15	16	22	41
121–180	16	22	11	16
More than 180	8	27	3.7	13
Dissolved solids (ppm):				
Less than 100	21	27	21	27
101–250	23	38	28	48
251–500	11	29	8	22
More than 500	1.5	6	1	3
pH:				
Less than 7.0	16	18	14	9
7.0–9.0	42	80	38	74
More than 9.0			7	17

[1] A few cities are not included because data are lacking.

FOR FURTHER INFORMATION

Further information on quality of water may be obtained from the U.S. Geological Survey Water Resources Division offices listed below.

State	*Office*
Alabama	P.O. Box V University, Alabama 35486
Alaska	P. O. Box 36 (Wright Building) Palmer, Alaska 99645
Arizona	P.O. Box 4070 Tucson, Arizona 85717
Arkansas	Federal Office Building, Room 2301 700 West Capitol Avenue Little Rock, Arkansas 72201
California	Federal Building and U.S. Court House, Room 8042 650 Capitol Avenue Sacramento, California 95814
Colorado	*See* Utah.
Connecticut	*See* New York.
Delaware	*See* Maryland.
District of Columbia	Old Post Office Building, Room 117 Washington, D.C. 20242
Florida	Federal Building, Room 244 Ocala, Florida 32670
Georgia	*See* Florida.
Hawaii	Office of the Branch Chief—Pacific Area 345 Middlefield Road Menlo Park, California 94025

State	Office
Idaho	*See* Oregon.
Illinois	*See* Ohio.
Indiana	*See* Ohio.
Iowa	*See* Nebraska.
Kansas	*See* Nebraska.
Kentucky	*See* Ohio.
Louisiana	Prudential Building, Room 201 6554 Florida Boulevard Baton Rouge, Louisiana 70806
Maine	*See* New York.
Maryland	Abbey Building, Room 3 3 North Perry Street Rockville, Maryland 20850
Massachusetts	*See* New York.
Michigan	*See* Ohio.
Minnesota	*See* Nebraska.
Mississippi	*See* Louisiana.
Missouri	*See* Arkansas.
Montana	*See* Wyoming.
Nebraska	Nebraska Hall, Room 125 901 North 17th Street Lincoln, Nebraska 68508
Nevada	222 East Washington Street Carson City, Nevada 89701
New Hampshire	*See* New York.
New Jersey	*See* Pennsylvania.
New Mexico	P.O. Box 4217 (Geology Building, University of New Mexico) Albuquerque, New Mexico 87106
New York	P.O. Box 948 (Federal Building, Room 341) Albany, New York 12201
North Carolina	P.O. Box 2857 (Federal Building) Raleigh, North Carolina 27602
North Dakota	*See* Nebraska.
Ohio	2822 East Main Street Columbus, Ohio 43209
Oklahoma	P.O. Box 4355 (2300 S. Eastern) Oklahoma City, Oklahoma 73109
Oregon	P.O. Box 3202 (Old Post Office Building, Room 416) Portland, Oregon 97208
Pennsylvania	U.S. Custom House, Room 1302 2d and Chestnut Streets Philadelphia, Pennsylvania 19106
Puerto Rico	12 Arroyo Street Hato Rey, Puerto Rico 00918
Rhode Island	*See* New York.
South Carolina	*See* North Carolina.
South Dakota	*See* Nebraska.

State	*Office*
Tennessee	823 Edney Building Chattanooga, Tennessee 37402
Texas	Vaughn Building 807 Brazos Street Austin, Texas 78701
Utah	Federal Building, Room 8428 125 South State Street Salt Lake City, Utah 84111
Vermont	*See* New York.
Virginia	*See* North Carolina.
Washington	Room 300, 1305 Tacoma Avenue, South Tacoma, Washington 98402
West Virginia	*See* Maryland.
Wisconsin	*See* Ohio.
Wyoming	1214 Big Horn Avenue Worland, Wyoming 82401

REFERENCES CITED

Akron Bureau of Water Supply, [no date], Akron City Water Works: Akron, Ohio, 6 p.

Alexander, G. V., Nusbaum, R. E., and MacDonald, N. S., 1954, Strontium and calcium in municipal water supplies: Am. Water Works Assoc. Jour., v. 46, no. 7, p. 643–654.

American Water Works Association, 1950, Water quality and treatment, 2d ed.: New York, Am. Water Works Assoc., 451 p.

——— 1964, Status of fluoridation in the United States and Canada, 1962: Am. Water Works Assoc. Jour., v. 56, no. 1, p. 111–120.

Aultman, W. W., 1957, Softening of municipal water supplies: Water and Sewage Works, v. 104, no. 8, p. 327–334.

Baker, M. N., 1948, The quest for pure water: New York, Am. Water Works Assoc., Inc., 527 p.

Barker, F. B., 1959, Determination of radioactive materials in water: Am. Soc. Testing Materials, Spec. Tech. Pub. 276, p. 278–288.

Bean, E. L., 1962, Progress report on water quality criteria: Am. Water Works Assoc. Jour., v. 54, no. 11, p. 1313–1331.

Betz Laboratories, Inc., 1962, Betz handbook of industrial water conditioning, 6th ed.: Philadelphia, Pa., Betz Laboratories, 425 p.

Bevis, H. A., 1960, Significance of radioactivity in water supply and treatment: Am. Water Works Assoc. Jour., v. 52, no. 7, p. 841–846.

Bogren, G. G., 1962, Removal of iron and manganese from ground waters: New England Water Works Assoc. Jour., v. 76, no. 1, p. 70–76.

Chicago Department of Water and Sewers, Bureau of Water, 1961, Chicago water system; a description—the system and its sanitary protection: Chicago, Ill., 29 p.

Churchill, M. A., 1957, Effects of storage impoundments on water quality: Am. Soc. Civil Engr. Proc., Sanitary Engr. Div. Jour., v. 83, no. SA1 (paper 1171), 48 p., 24 figs.

Collins, W. D., 1923, The industrial utility of public water supplies in the United States: U.S. Geol. Survey Water-Supply Paper 496.

Collins, W. D., Lamar, W. L., and Lohr, E. W., 1934, The industrial utility of public water supplies in the United States, 1932: U.S. Geol. Survey Water-Supply Paper 658.

Dallas Water Council, 1960, Water supply, city of Dallas—a report to the consumer: Dallas, Tex., 21 p.

DeBoer, L. M., and Larson, T. E., 1961, Water hardness and domestic use of detergents: Am. Water Works Assoc. Jour., v. 53, no. 7, p. 809–822, 8 figs., 6 tables.

Dowling, R. T., 1962, Water works construction will top 338 million in 105 communities: Water Works Engineering, v. 115, no. 6, p. 469–471.

Durfor, C. N., 1963, Water requirements of the styrene, butadiene, and synthetic rubber industries: U.S. Geol. Survey Water-Supply Paper 1330–F.

Durum, W. H., and Haffty, Joseph, 1961, Occurrence of minor elements in water: U.S. Geol. Survey Circ. 445.

——— 1963, Implications of the minor elements content of some major streams of the world: Geochim. et Cosmochim. Acta, v. 27, p. 1–11.

Haffty, Joseph, 1960, Residue method for common minor elements: U.S. Geol. Survey Water-Supply Paper 1540–A.

Honolulu Board of Water Supply, 1963, Oahu water plan: Honolulu, Hawaii, 68 p.

Hursh, J. B., 1954, Radium in public supplies: Am. Water Works Assoc. Jour., v. 46, no. 1, p. 46–54.

Ingols, R. S., and Wilroy, R. D., 1962, Observations on manganese in Georgia waters: Am. Water Works Assoc. Jour., v. 54, no. 2, p. 203–207.

Lamar, William, 1953, Chemical and physical quality examination, Chap. 4 *of* Ohio Department of Natural Resources, Division of Water, Lake Erie pollution survey—final report: p. 81–123.

Lohr, E. W., and Love, S. K., 1954, The industrial utility of public water supplies in the United States, 1952, pt. 1, States east of the Mississippi River; pt. 2, States west of the Mississippi River: U.S. Geol. Survey Water-Supply Papers 1299 (pt. 1) and 1300 (pt. 2).

MacKichan, K. A., and Kammerer, J. C., 1961, Estimated use of water in the United States, 1960: U.S. Geol. Survey Circ. 456.

McNeil, D. R., 1957, The fight for fluoridation: New York, Oxford Univ. Press, 241 p.

Meinzer, O. E., 1923, The occurrence of ground water in the United States: U.S. Geol. Survey Water-Supply Paper 489.

Metropolitan Water District of Southern California, 1961, Report of the fiscal year July 1, 1960, to June 30, 1961: Los Angeles, Calif., Metropolitan Water District Southern California 23d Ann. Rept.

Moore, E. W., 1940, Progress report of the committee on quality tolerances of water for industrial uses: New England Water Works Assoc. Jour., v. 54, p. 263.

Mussey, O. D., 1955, Water requirements of the pulp and paper industry: U.S. Geol. Survey Water-Supply Paper 1330–A.

New Haven Water Company, 1955, Water—lifestream of a community: New Haven, Conn., 31 p.

Nordell, Eskel, 1961, Water treatment for industrial and other uses, 2d ed.: New York, Reinhold Publishing Corp., 598 p.

Pennsylvania Department of Commerce, Bureau of Industrial Development, 1958, Industrial water supplies in Pennsylvania: Plant Location Factors Rept. 3, 88 p.

Phoenix Water and Sewers Department, [1961], Annual report for fiscal year July 1, 1960–June 30, 1961: Phoenix, Ariz., 30 p.

Powell, S. T., 1954, Water conditioning for industry: New York, McGraw-Hill Book Co., Inc., 548 p.

Providence Water Supply Board, 1961, Annual report of the Water Supply Board of the City of Providence for the year ending September 30, 1961: Providence, R.I., 103 p.

Rainwater, F. H., and Thatcher, L. L., 1960, Methods for collection and analysis of water samples: U.S. Geol. Survey Water-Supply Paper 1454, 301 p., 17 figs., 3 tables.

Rankama, Kalervo, and Sahama, Th. G., 1950, Geochemistry: Chicago Univ., Press, 912 p.

Requardt, G. J., Shaw, H. B., and Wolman, Abel, 1953, Report to the City of Baltimore on future sources of water supply and appurtenant problems: Baltimore, Md.

Scott, R. C., and Barker, F. B., 1962, Data on uranium and radium in ground water in the United States, 1954 to 1957: U.S. Geol. Survey Prof. Paper 426, 115 p., 2 pls., 7 figs., 2 tables.

Skougstadt, M. W., and Horr, C. A., 1960, Occurrence of strontium in natural water: U.S. Geol. Survey Circ. 420.

Soap and Detergent Association, 1962, Synthetic detergents in perspective—their relationship to sewage disposal and safe water supplies: New York, Soap and Detergent Assoc., 39 p.

Stearns, R. L., 1961, Glossary of terms frequently used in nuclear physics: New York, Am. Inst. Physics, 40 p.

Strain, W. H., 1961, Effects of some minor elements on animals and people: Rochester, N.Y., Rochester Univ. School of Medicine and Dentistry, 44 p. [Presented at Am. Assoc. Adv. Science symposium "Geochemical Evolution—the First Five Billion Years," Denver, Colo., December 29, 1961.]

Streeter, H. W., 1953, Bacterial and sanitary analyses, Chap. 3 *of* Ohio Department of Natural Resources, Division of Water, Lake Erie pollution survey—final report: p. 29–80.

Toledo Division of Water, 1962, Annual report—1961: Toledo, Ohio, 70 p.

U.S. Bureau of the Census, 1961, Statistical abstract of the United States, 1961: 1037 p.

U.S. Corps of Engineers, 1952, Variations in Great Lakes levels: Detroit, Mich., U.S. Corps of Engineers, Great Lakes Div., 33 p.

U.S. Geological Survey, 1962, Water for recreation values and opportunities: Outdoor Recreation Resources Review Comm. Study Report 10.

U.S. Public Health Service, 1962, Radiological health data: v. 3, nos. 1–12.

——— 1962a, Fluoride drinking waters: U.S. Public Health Service Pub. 825, 636 p.

——— 1962b, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.

——— 1962c, Municipal water facilities, communities of 25,000 populations and over, United States and possessions—as of January 1, 1962: U.S. Public Health Service Pub. 661.

U.S. Salinity Laboratory Staff, 1954, Diagnoses and improvement of saline and alkali soils: U.S. Dept. Agriculture, Agriculture Handb. 60 p.

Verduin, J., 1953, The suspended silt in western Lake Erie during the spring of 1951, *in* Chap. 5 *of* Ohio Department of Natural Resources, Division of Water, Lake Erie pollution survey—final report: p. 130–133.

INVENTORY OF MUNICIPAL SUPPLIES

Description of Facilities
Analyses of Raw and Treated Water
Maps of Water Resources

ALABAMA

Birmingham *Mobile* *Montgomery*

BIRMINGHAM

(See fig. 17.)

Ownership: Municipal.

Other areas served: Bay View, Bessemer and its suburban area, Edgewater, Fairfield, Fultondale, Graysville, Homewood, Mountain Brook, Tarrant City, and outlying communities.

Population served: Birmingham, 340,887; total, about 441,000.

Sources and percentages of supply:

Domestic supply: Cahaba River and Lake Purdy, a storage reservoir on Little Cahaba River, 90 percent; and Inland Lake, owned by the Birmingham Industrial Water System, from which raw water is purchased, 10 percent.

Industrial supply: Blackburn Fork of the Black Warrior River impounded in Inland Lake, which has a 21-billion-gal capacity.

Lowest mean discharge: Cahaba River at Centerville, Ala., for 30-day period in climatic water years (April 1–March 31) 1950–59: 80.1 mgd.

Average amount of water used daily in system during 1962: 53.8 mgd (U.S. Public Health Service, 1962c).

Treatment:

Shades Mountain filter plant (Cahaba River and Lake Purdy): Plain sedimentation, prechlorination, coagulation with alum, sedimentation, rapid sand filtration, postchlorination, and addition of hydrated lime for adjustment of pH to between 7.5 and 8.0.

Putnam Station filter plant, formerly Birmingham Station plant (Inland Lake): Coagulation with alum, addition of lime for adjustment of pH to 8.4, sedimentation, rapid sand filtration, and postchlorination.

Industrial supply from Inland Lake: Chlorination and addition of soda ash.

Rated capacity of treatment plants: Shades Mountain filter plant, 55 mgd; Putnam Station filter plant, 18 mgd.

Raw-water storage: 5,682 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 106.

Finished-water storage: 4.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

735-717 O—64——7

Analytical data—Birmingham

	Inland Lake	Putnam Station filter plant[1]	Cahaba River	Shades Mountain filter plant
Percent of supply	10	10	90	90
Date of collection	8-29-61	8-29-61	8-29-61	8-29-61
Type of water: R, raw; F, finished	R	F	R	F

Chemical analyses
[In parts per million]

	Inland Lake	Putnam Station filter plant[1]	Cahaba River	Shades Mountain filter plant
Silica (SiO_2)	3.7	3.3	5.7	5.7
Iron (Fe)	.16	.08	.03	.07
Calcium (Ca)	2.0	8.8	26	29
Magnesium (Mg)	.5	.7	4.9	5.5
Sodium (Na)	2.1	1.8	10	9.9
Potassium (K)	.9	.9	1.7	1.7
Bicarbonate (HCO_3)	9	20	87	90
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	.8	9.0	31	37
Chloride (Cl)	2.9	2.6	2.0	3.2
Fluoride (F)	.0	.0	.1	.1
Nitrate (NO_3)	.4	.6	.3	.4
Dissolved solids (residue at 180° C)	29	43	195	147
Hardness as $CaCO_3$	7	25	85	95
Noncarbonate hardness as $CaCO_3$	0	9	14	21
Specific conductance (micromhos at 25° C)	33	68	220	238
pH	6.8	6.8	7.0	7.5
Color	10	0	0	0

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Inland Lake	Putnam Station filter plant[1]	Cahaba River	Shades Mountain filter plant
Beta activity	------	1.8	------	2.6
Radium (Ra)	------	<.1	------	<.1
Uranium (U)	------	<.1	------	.2

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

	Inland Lake	Putnam Station filter plant[1]	Cahaba River	Shades Mountain filter plant
Silver (Ag)	------	0.35	ND	<0.22
Aluminum (Al)	------	86	43	830
Boron (B)	------	7.3	30	45
Barium (Ba)	------	10	50	58
Beryllium (Be)	------	ND	ND	ND
Cobalt (Co)	------	ND	ND	ND
Chromium (Cr)	------	.09	2.0	2.7
Copper (Cu)	------	.67	3.0	2.0
Iron (Fe)	------	17	37	79
Lithium (Li)	------	------	2.4	2.5
Manganese (Mn)	------	1.0	15	56
Molybdenum (Mo)	------	ND	1.3	1.3
Nickel (Ni)	------	<.4	<1.9	3.4
Phosphorus (P)	------	ND	ND	ND
Lead (Pb)	------	.4	50	2.2
Rubidium (Rb)	------	------	6.0	6.3
Tin (Sn)	------	ND	ND	ND
Strontium (Sr)	------	2.2	60	70
Titanium (Ti)	------	<.4	<1.9	<2.2
Vanadium (V)	------	ND	ND	ND
Zinc (Zn)	------	43	ND	ND

[1] Spectrographic concentrations are based on nonacidified residue on evaporation.

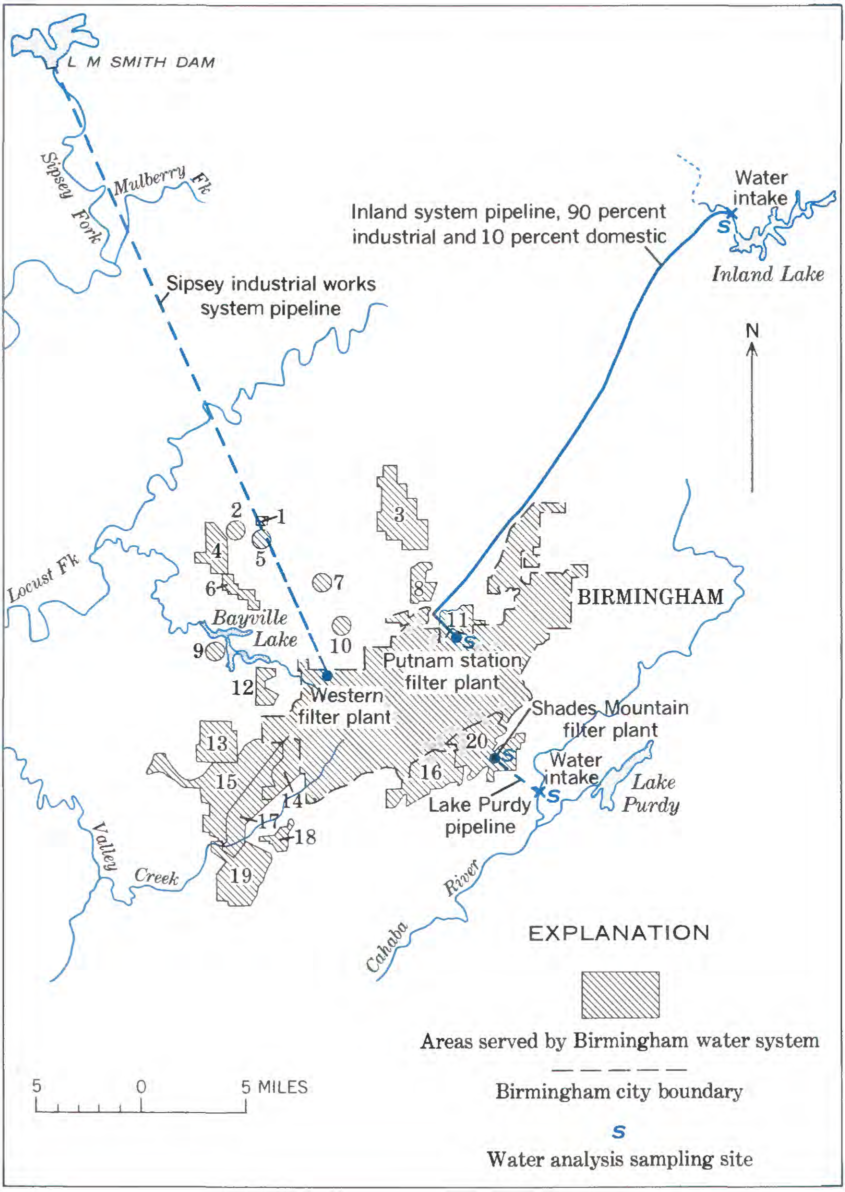

FIGURE 17.—Water supplies and areas served by Birmingham, Ala., water system. (Approved by local municipal water officials, April 1963.) Areas served outside city: 1, Cardiff; 2, Alden; 3, Gardendale; 4, Graysville; 5, Blossburg; 6, Adamsville; 7, Republic; 8, Fultondale; 9, Bay View & Mulga; 10, Hillview; 11, Tarrant City; 12, Edgewater; 13, Pleasant Grove; 14, Fairfield; 15, Dolomite Div.; 16, Homewood; 17, Woodard; 18, Lipscomb; 19, Bessemer; 20, Mountain Brook.

MOBILE

Ownership: Municipal.

Other areas served: Two suburban areas.

Population served: Mobile, 210,000 (1962); total, about 211,000.

Source of supply: Big Creek (impounded).

Auxiliary and emergency supplies: Twenty million gallons in a municipal-owned reservoir that is used by industrial plants.

Average amount of water used daily in system during 1962: 20 mgd (U.S. Public Health Service, 1962c).

Treatment: Mobile treatment plant—prechlorination, coagulation with alum and lime, sedimentation, rapid sand filtration, postchlorination, fluoridation, and pH adjustment.

Rated capacity of treatment plant: Mobile treatment plant, 40 mgd.

Raw-water storage: Two reservoirs, 20 and 30 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.5.

Finished-water storage: Elevated tanks, 1.2 million gal; ground reservoirs, 25 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.3.

Regular determinations at Mobile treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	2.7	8	2	5.6	7.6	5.0	6	8	4	50	111	32
Finished water	13	18	10	9.2	9.5	8.7	35	40	30	1.9	6	1

Analytical data—Mobile

	Big Creek	Treatment plant	
Percent of supply	100	100	100
Date of collection	4-5-62	4-5-62	4-27-62
Type of water: R, raw; F, finished	R	F	F
Chemical analyses [In parts per million]			
Silica (SiO_2)	3.2	3.2	3.1
Iron (Fe)	.03	.00	.03
Calcium (Ca)	.0	11	10
Magnesium (Mg)	.6	.4	.3
Sodium (Na)	2.1	2.8	2.8
Potassium (K)	.3	.4	.4
Bicarbonate (HCO_3)	4	14	14
Carbonate (CO_3)	0	16	0
Sulfate (SO_4)	.6	16	7.8
Chloride (Cl)	2.3	3.0	7.1
Fluoride (F)	.0	1.1	1.1
Nitrate (NO_3)	.2	.2	.2
Dissolved solids (residue at 180° C)	34	83	62
Hardness as $CaCO_3$	2	30	26
Noncarbonate hardness as $CaCO_3$	0	18	12
Specific conductance (micromhos at 25°C)	18	94	79
pH	5.8	6.5	6.7
Color	40	20	10
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]			
Beta activity			11
Radium (Ra)			<.1
Uranium (U)			.1
Spectrographic analyses [In micrograms per liter. ND, looked for but not found]			
Silver (Ag)			0.09
Boron (B)			29
Barium (Ba)			25
Beryllium (Be)			ND
Cobalt (Co)			ND
Chromium (Cr)			1.9
Copper (Cu)			.62
Iron (Fe)			57
Lithium (Li)			.23
Manganese (Mn)			17
Molybdenum (Mo)			ND
Nickel (Ni)			1.1
Phosphorus (P)			ND
Lead (Pb)			1.0
Rubidium (Rb)			.8
Tin (Sn)			ND
Strontium (Sr)			14
Titanium (Ti)			2.1
Vanadium (V)			1.7
Zinc (Zn)			ND

MONTGOMERY

Ownership: Municipal.

Population served: Montgomery, 133,874; about 14,000 outside the city limits; total, 148,000.

Sources and percentages of supply: Court Street pumping plant: 18 wells, 39 percent; Day Street pumping plant: 31 wells, 61 percent. Well depths range from 72 to 740 feet. The depth of most wells is between 400 and 600 feet. Individual well yield ranges from 100 to 750 gpm.

Average amount of water used daily in system during 1962: 16 mgd (U.S. Public Health Service, 1962c).

Treatment:

Day Street pumping plant: Chlorination, aeration, addition of soda ash and Calgon, settling.

Court Street pumping plant: Chlorination.

Raw-water storage: 14.5 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: Two million gallons in each of four reservoirs.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Average determinations of finished water on February 18, 1960:

Plant	Alkalinity as $CaCO_3$ (ppm)	pH	Hardness as $CaCO_3$ (ppm)
Day Street	112	8.8	52
Court Street	141	7.5	26

Analytical data—Montgomery

	18 wells at Court Street plant	Court Street treatment plant	31 wells at Day Street plant	Day Street treatment plant
Percent of supply	39	39	61	61
Date of collection	8-29-61	8-29-61	8-29-61	8-29-61
Type of water: R, raw; F, finished	R	F	R	F

Chemical analyses
[In parts per million]

	18 wells at Court Street plant	Court Street treatment plant	31 wells at Day Street plant	Day Street treatment plant
Silica (SiO_2)	12	12	17	17
Iron (Fe)	.08	.01	.05	.05
Calcium (Ca)	3.5	3.3	16	16
Magnesium (Mg)	.3	.2	1.0	1.0
Sodium (Na)	51	55	51	53
Potassium (K)	1.3	1.1	1.6	1.4
Bicarbonate (HCO_3)	118	126	149	158
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	9.2	12	9.6	12
Chloride (Cl)	8.8	9.7	13	12
Fluoride (F)	.4	.4	.4	.7
Nitrate (NO_3)	1.9	2.3	2.5	2.0
Dissolved solids (residue at 180° C)	154	167	203	212
Hardness as $CaCO_3$	10	9	44	44
Noncarbonate hardness as $CaCO_3$	0	0	0	0
Specific conductance (micromhos at 25°C)	243	255	305	317
pH	7.2	7.2	7.3	7.5
Color	0	0	0	0

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	18 wells at Court Street plant	Court Street treatment plant	31 wells at Day Street plant	Day Street treatment plant
Beta activity	------	2.7	------	2.9
Radium (Ra)	------	.1	------	.1
Uranium (U)	------	<.1	------	<.1

Spectrographic analyses
[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND, looked for but not found]

	18 wells at Court Street plant	Court Street treatment plant	31 wells at Day Street plant	Day Street treatment plant
Silver (Ag)	ND	------	------	<0.31
Aluminum (Al)	83	------	------	31
Boron (B)	110	------	------	140
Barium (Ba)	67	------	------	71
Beryllium (Be)	ND	------	------	ND
Cobalt (Co)	ND	------	------	ND
Chromium (Cr)	ND	------	------	ND
Copper (Cu)	4.3	------	------	17
Iron (Fe)	45	------	------	68
Lithium (Li)	.12	------	------	2.5
Manganese (Mn)	48	------	------	100
Molybdenum (Mo)	ND	------	------	ND
Nickel (Ni)	ND	------	------	ND
Phosphorus (P)	ND	------	------	370
Lead (Pb)	ND	------	------	ND
Rubidium (Rb)	3.3	------	------	<3.1
Tin (Sn)	ND	------	------	ND
Strontium (Sr)	93	------	------	340
Titanium (Ti)	<2.4	------	------	<3.1
Vanadium (V)	ND	------	------	ND
Zinc (Zn)	ND	------	------	ND
Gallium (Ga)	<.X	------	------	ND

PHOENIX

Ownership: Municipal.
Other areas served: Scottsdale and suburban areas of Phoenix.
Population served: Phoenix, 434,277; total, 487,300.
Sources and percentages of supply: Verde River infiltration gallery, near Fort McDowell, 3 percent; Verde wells, 17 percent; Verde River (Verde River filter plant), 12 percent; Verde and Salt Rivers (Squaw Peak filter plant), 30 percent; Scottsdale wells, 15 percent; wells acquired from private water companies, 23 percent.
Auxiliary and emergency supplies: Wells in downtown Phoenix.
Average amount of water used daily in system during 1962: 92.7 mgd (Phoenix Water and Sewers Department, 1961).
Treatment:
  Squaw Peak filter plant (Verde and Salt Rivers): Presedimentation; coagulation with alum, lime, and activated carbon; sedimentation; rapid sand filtration; chlorination.
  Verde River filter plant (Verde River): Addition of lime, coagulation with alum and ferric sulfate, addition of activated carbon, sedimentation, rapid sand filtration, stabilization with carbon dioxide, and chlorination.
  Ground water: Chlorination.
Rated capacity of treatment plants: Squaw Peak filter plant, 90 mgd; Verde River filter plant, 30 mgd.
Raw-water storage: None.
Finished-water storage: Squaw Peak plant, 40 million gal; 64th Street and Thomas Road, 60 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.1.
Remarks: The total amount of water that can be produced from all sources is 235 mgd. Storage for the water supply is provided by five major storage reservoirs having a combined capacity of 100 million gal. Engineering studies have determined that production capacity will be increased by an additional 121 mgd by 1964 and by an additional 140 mgd by 1970.
Regular determination at filter plants:

Plant	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Squaw Peak: Finished water	122	-----	-----	7.7	-----	-----	205	-----	----
Verde River: Raw water	-----	202	132	-----	8.2	7.5	-----	240	136

Analytical data—Phoenix

	Verde River	Verde River filter plant	Squaw Peak filter plant	Verde well field	Scottsdale well 36	Well 105[1]
Percent of supply	12	12	30	17	15	----------
Depth of well (feet)	----------	----------	----------	----------	1,000	466
Diameter of well (inches)	----------	----------	----------	----------	20	16
Date drilled	----------	----------	----------	----------	1958	1954
Date of collection	7-27-61	7-27-61	7-27-61	1-11-62	1-11-62	8-15-60
Type of water: R, raw; F, finished	R	F	F	F	F	F

Chemical analyses

[In parts per million]

	Verde River	Verde River filter plant	Squaw Peak filter plant	Verde well field	Scottsdale well 36	Well 105[1]
Silica (SiO_2)	14	13	13	22	26	----------
Iron (Fe)	.02	.02	.02	.00	.00	0.00
Calcium (Ca)	50	53	46	61	98	125
Magnesium (Mg)	14	15	15	26	42	43
Sodium (Na)	131	131	138	41	96	----------
Potassium (K)	4.8	4.9	4.8	3.2	4.0	----------
Bicarbonate (HCO_3)	176	164	142	286	209	220
Carbonate (CO_3)	0	0	0	0	0	----------
Sulfate (SO_4)	51	63	57	71	130	97
Chloride (Cl)	196	198	212	27	218	540
Fluoride (F)	.4	.3	.3	.3	.3	.4
Nitrate (NO_3)	2.7	3.1	3.6	2.6	11	23
Phosphate (PO_4)	----------	----------	----------	----------	----------	.01
Nitrite (NO_2)	----------	----------	----------	----------	----------	.012
Dissolved solids (residue at 180° C)	560	567	563	386	756	1,580
Hardness as $CaCO_3$	184	192	176	258	418	492
Noncarbonate hardness as $CaCO_3$	40	58	60	24	246	----------
Specific conductance (micromhos at 25° C)	1,000	1,020	1,020	640	1,270	----------
pH	7.8	7.3	7.2	7.8	7.7	7.8
Color	3	2	2	0	0	----------
Temperature ° F	74	74	82	68	84	78

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Verde River	Verde River filter plant	Squaw Peak filter plant	Verde well field	Scottsdale well 36	Well 105[1]
Beta activity	----------	7.0	11	5.7	21	----------
Radium (Ra)	----------	<.1	<.1	.2	.4	----------
Uranium (U)	----------	1.4	1.3	2.6	5.5	----------

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Verde River	Verde River filter plant	Squaw Peak filter plant	Verde well field	Scottsdale well 36	Well 105[1]
Silver (Ag)	<0.8	<0.8	<0.8	<0.53	<0.92	----------
Aluminum (Al)	130	250	260	31	20	----------
Boron (B)	45	29	31	210	520	----------
Barium (Ba)	99	79	81	58	100	----------
Beryllium (Be)	ND	ND	ND	ND	ND	----------
Cobalt (Co)	ND	ND	ND	ND	ND	----------
Chromium (Cr)	ND	ND	3.3	<.53	7.1	----------
Copper (Cu)	2.7	1.6	4.7	1.9	2.1	----------
Iron (Fe)	26	13	20	37	43	----------
Lithium (Li)	91	81	82	16	43	----------
Manganese (Mn)	27	ND	ND	<5.3	ND	----------
Molybdenum (Mo)	<2	<2	<2.4	4.2	ND	----------
Nickel (Ni)	<8	<8	<8	<5.3	ND	----------
Phosphorus (P)	ND	ND	ND	ND	ND	----------
Lead (Pb)	ND	ND	ND	12	ND	----------
Rubidium (Rb)	12	14	15	ND	<9.2	----------
Tin (Sn)	ND	ND	ND	ND	ND	----------
Strontium (Sr)	320	320	450	580	680	----------
Titanium (Ti)	<8	ND	<8	1.6	ND	----------
Vanadium (V)	ND	ND	ND	<16	<28	----------
Zinc (Zn)	ND	ND	ND	ND	ND	----------

[1] Analyzed by the city of Phoenix.

TUCSON

Ownership: Municipal.

Other areas served: South Tucson, Rillito, and suburban areas around Tucson.

Population served: Tucson, 212,892; total, 231,836.

Source of supply: Water supply comes from about 200 wells, from 130 to 1,000 feet deep, located in three general groups:

Upper Santa Cruz wells: Nine wells located in Upper Santa Cruz basin, south and east from the Municipal Airport along and near the Nogales highway. Water from these wells is pumped to the surface and flows by gravity to the east-side distribution system and to storage in the 22d Street reservoir.

North-side wells, or "Mesa Wells": Water for the eastern and extreme northern parts of the city is furnished by about 150 wells that are in a 2-mile-wide southeast-trending area in the northeast part of the city.

South-side wells: The supply for the west part of the city—roughly the area within the city limits and South Tucson west of Tyndall Avenue—comes from 21 wells along the east side of the Santa Cruz River.

Average amount of water used daily in system during 1962: 39 mgd (U.S. Public Health Service, 1962c).

Treatment: Chlorination at all times, ammoniation at times.

Finished-water storage: Ground reservoirs, 31.1 million gal; elevated storage, 2.2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—Tucson

	Composite of south-side wells	Composite of north-side wells	Composite of Upper Santa Cruz wells
Percent of supply	33	33	33
Date of collection	1-10-62	1-10-62	1-10-62
Type of water: F, finished	F	F	F
Chemical analyses [In parts per million]			
Silica (SiO_2)	35	29	34
Iron (Fe)	.00	.00	.00
Calcium (Ca)	63	42	80
Magnesium (Mg)	10	3.4	11
Sodium (Na)	67	34	33
Potassium (K)	2.4	1.8	2.7
Bicarbonate (HCO_3)	242	158	226
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	115	39	91
Chloride (Cl)	16	14	17
Fluoride (F)	1.0	.2	.3
Nitrate (NO_3)	3.6	7.9	16
Dissolved solids (residue at 180° C)	433	252	412
Hardness as $CaCO_3$	198	119	244
Noncarbonate hardness as $CaCO_3$	0	0	59
Specific conductance (micromhos at 25° C)	654	381	603
pH	7.6	7.8	7.4
Color	0	0	0
Temperature °F	72	70	76
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]			
Beta activity	7.7	<1.1	5.3
Radium (Ra)	<.1	<.1	.1
Uranium (U)	6.2	1.6	7.3
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]			
Silver (Ag)	ND	<0.35	<0.54
Aluminum (Al)	35	19	17
Boron (B)	110	66	64
Barium (Ba)	91	130	130
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	.79	<.35	1.3
Copper (Cu)	2.2	2.8	1.4
Iron (Fe)	36	83	64
Lithium (Li)	35	9.0	7.0
Manganese (Mn)	ND	<3.5	<5.4
Molybdenum (Mo)	14	1.8	<1.6
Nickel (Ni)	ND	<3.5	ND
Phosphorus (P)	ND	ND	ND
Lead (Pb)	9.1	5.9	8.0
Rubidium (Rb)	ND	ND	ND
Tin (Sn)	ND	ND	ND
Strontium (Sr)	850	550	400
Titanium (Ti)	<1.7	<1.0	ND
Vanadium (V)	<17	<10	<16
Zinc (Zn)	ND	ND	ND

CALIFORNIA

Fresno
Long Beach
Los Angeles
Oakland
Sacramento
San Diego
San Francisco
San Jose

FRESNO

Ownership: Municipal.
Population served: Fresno, 136,000; total, 149,600.
Source of supply: Fifty-eight wells. The depths of most of the wells are between 200 and 300 feet. The yield of the wells is reported to range from 2,000 to 2,425 gpm and to average 2,200 gpm.
Average amount of water used daily in system during 1962: 53.4 mgd (U.S. Public Health Service, 1962c).
Treatment: None.
Water storage: 1.5 million gal in two tanks.
Days of water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—Fresno

	Composite of wells	Well 32 [1]	Well 3 [1]	Well 27 [1]
Percent of supply	100			
Depth of well (feet)		182	123	130
Diameter of well (inches)		20	18	18
Date drilled		1941	1923	
Date of collection	7-19-61			
Type of water: R, raw	R	R	R	R

Chemical analyses

[In parts per million]

	Composite of wells	Well 32 [1]	Well 3 [1]	Well 27 [1]
Silica (SiO_2)	68	58	62	68
Iron (Fe)	.00	.01	.01	.00
Calcium (Ca)	15	25	3[illegible]	38
Magnesium (Mg)	11	14	17	19
Sodium (Na)	17	22	22	24
Potassium (K)	4.4	4.3	4.5	4.7
Bicarbonate (HCO_3)	118	174	183	212
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	6.0	3.3	6.2	15
Chloride (Cl)	5.8	18	2[illegible]	29
Fluoride (F)	.1	.1	.1	.1
Nitrate (NO_3)	13	5.4	6.0	5.8
Dissolved solids (residue at 180° C)	221	267	300	340
Hardness as $CaCO_3$	82	120	143	175
Noncarbonate hardness as $CaCO_3$	0			
Specific conductance (micromhos at 25° C)	249			
pH	7.5	7.6	7.7	7.8
Color	3			

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Composite of wells	Well 32 [1]	Well 3 [1]	Well 27 [1]
Beta activity	12			
Radium (Ra)	<.1			
Uranium (U)	.5			

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Composite of wells	Well 32 [1]	Well 3 [1]	Well 27 [1]
Silver (Ag)	ND			
Aluminum (Al)	6.2			
Boron (B)	17			
Barium (Ba)	34			
Beryllium (Be)	ND			
Cobalt (Co)	ND			
Chromium (Cr)	.60			
Copper (Cu)	1.0			
Iron (Fe)	4.8			
Lithium (Li)	.62			
Manganese (Mn)	ND			
Molybdenum (Mo)	<.9			
Nickel (Ni)	ND			
Phosphorus (P)	ND			
Lead (Pb)	5.7			
Rubidium (Rb)	2.8			
Tin (Sn)	ND			
Strontium (Sr)	19			
Titanium (Ti)	ND			
Vanadium (V)	12			
Zinc (Zn)	ND			

[1] Analyzed by the Twining Laboratories.

LONG BEACH

(See figs. 18 and 19.)

Ownership: Municipal.
Population served: 344,168.
Sources and percentages of supply: Thirty-five wells, 60 percent of present supply; ground water supplies will be reduced by 25 percent in the near future when ground waters of the Central Basin are adjudicated; they will then constitute 45 percent of the supply. Metropolitan Water District (see following discussion) treated water, 40 percent of present supply. This will increase to 55 percent when the well source decreases.
Average amount of water used daily in system during 1962: 46.6 mgd (U.S. Public Health Service, 1962c).
Treatment:
  Long Beach treatment plant: Well water—prechlorination; coagulation with ferric chloride; addition of diatomaceous earth, caustic soda and Calgon; sedimentation; rapid sand filtration; and postchlorination.
  Metropolitan Water District of Southern California: See following description.
Rated capacity of treatment plant: Long Beach treatment plant, 40 mgd.
Raw-water storage: 28 million gal.
Finished-water storage: Clear wells, 3.8 million gal; other, 116 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.6.

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Ownership: Metropolitan Water District of Southern California, which is composed of 13 cities, 11 municipal water districts, and the San Diego County Water Authority:
  The cities are: Anaheim, Beverly Hills, Burbank, Compton, Fullerton, Glendale, Long Beach, Los Angeles, Pasadena, San Marino, Santa Ana, Santa Monica, and Torrance.
  The municipal water districts and their component cities are:
    Central Basin: Artesia, Bell, Bellflower, Commerce, Cudahay, Dairy Valley, Downey, Huntington Park, Lakewood, Lynwood, Maywood, Mirada Hills, Montebello, Norwalk, Paramount, Pico Rivera, Santa Fe Springs, Signal Hill, South Gate, Vernon, and Whittier.
    Orange County: Buena Park, Cypress, Dairyland, Fountain Valley, Garden Grove, Huntington Beach, La Habra, Los Alamitos, Orange, Placentia, Seal Beach, Stanton, Tustin, Westminster, and San Juan Capistrano.
    West Basin: Culver City, El Segundo, Gardena, Hawthorne, Hermosa Beach, Inglewood, Lawndale, Manhattan Beach, Palos Verdes Estates, Redondo Beach, Rolling Hills, and Rolling Hills Estates.
    Pomona Valley: Claremont, Glendora, Industry, La Verne, Pomona, San Dimas, and Walnut.
    Coastal: Brea, Costa Mesa, Laguna Beach, Newport Beach, and San Clemente.
    Chino Basin: Chino, Fontana, Montclair, Ontario, and Upland.
    Calleguas: Oxnard.

Ownership—Continued

The municipal water districts and their component cities are—Continued

Eastern: Hemet, Perris, and San Jacinto.

Western: Corona, Elsinore, and Riverside.

Foothill.

Virgenes.

The San Diego County Water Authority is composed of the following constituent cities and districts:

Cities: Escondido, National City, Oceanside, and San Diego.

Municipal water districts: Buena Colorado, Carlsbad, Poway, Rainbow, Rincon del Diablo, Rio San Diego, and Valley Center.

Irrigation districts: Helix, San Dieguito, Santa Fe, and South Bay.

Cities within districts: Carlsbad, Chula Vista, El Cajon, and La Mesa.

Population served: 7,739,000 (estimated for 1961).

Source of supply: Colorado River impounded in Lake Havasu. The main aqueduct line is designed to deliver 1,082 mgd (1,212,000 acre-ft annually) from Lake Havasu on the Colorado River to the terminal reservoir, Lake Mathews, near Riverside, Calif. A portion of the water from Lake Mathews is delivered to the F. E. Weymouth softening and filtration plant at La Verne, Calif. East of Lake Mathews two San Diego aqueducts deliver Colorado River water to the San Diego County Water Authority.

Treatment: F. E. Weymouth softening and filtration plant—prechlorination, softening by ion exchange, preliminary partial lime softening and coagulation with alum and activated silica when necessary, rapid sand filtration, and pH adjustment with lime.

Rated capacity of treatment plants: F. E. Weymouth softening and filtration plant, 400 mgd.

Finished-water storage: Palos Verdes Reservoir, 358 million gal.

Remarks: Plans call for a water treatment plant north of Yorba Linda to have an initial capacity of 200 mgd with provision for expansion to 400 mgd.

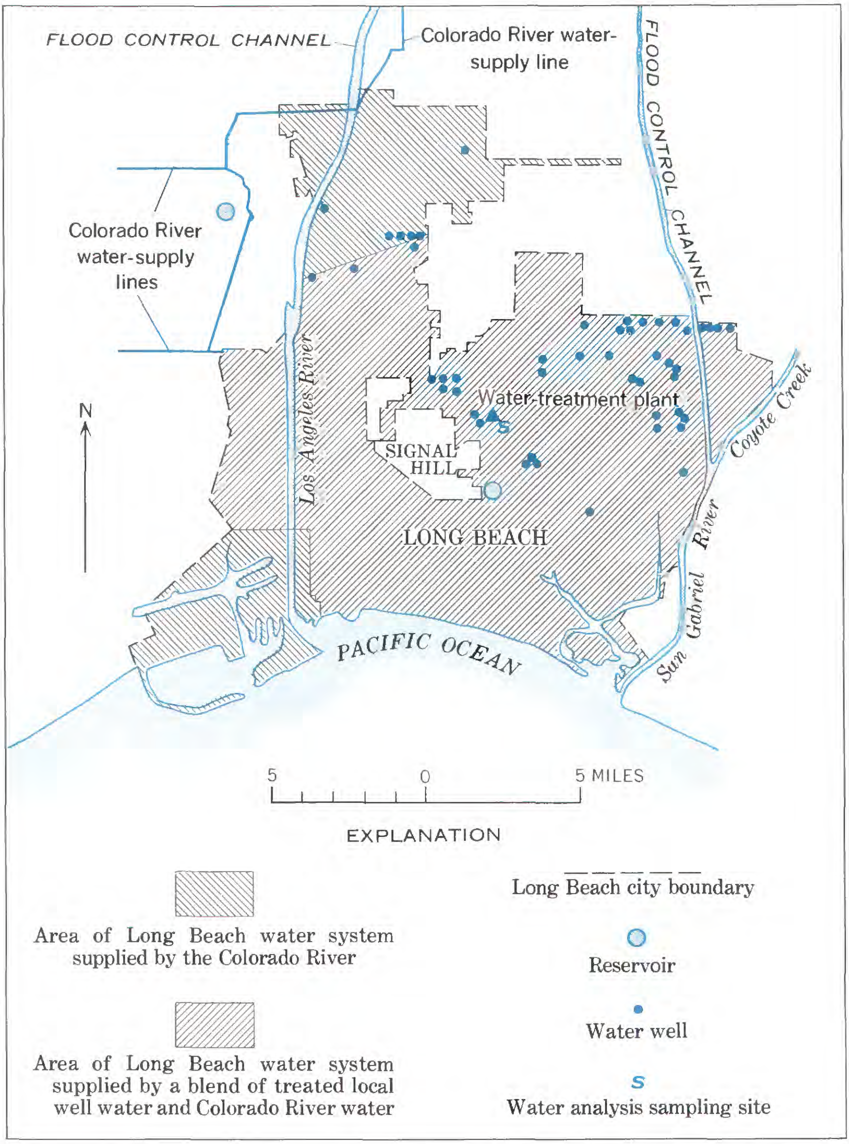

FIGURE 18.—Water supplies and areas served by Long Beach, Calif., water system. (Approved by local municipal water officials, October 1963.)

735-717 O—64——8

Analytical data—Long Beach

	Long Beach well water	Long Beach treatment plant		LaVerne treatment plant	
Percent of supply			60	40	
Date of collection	(1)	(1)	1-23-62	1-24-62	(2)
Type of water: R, raw; F, finished	R	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	20	20	20	9.8	8.7
Iron (Fe)	.04	.03	.00	.00	
Calcium (Ca)	13	24	20	34	52
Magnesium (Mg)	1.0	2.3	1.0	11	17
Sodium (Na)	71	63	74	198	151
Potassium (K)	1.0	1.2	1.0	4.4	4
Bicarbonate (HCO_3)	182	173	188	150	139
Carbonate (CO_3)	5	6	0	0	1
Sulfate (SO_4)	13	15	13	286	285
Chloride (Cl)	20	27	34	92	88
Fluoride (F)	.4	.4	.5	.3	.4
Nitrate (NO_3)			.1	1.3	1.2
Dissolved solids (residue at 180° C)	229	248	250	722	678
Hardness as $CaCO_3$	37	66	54	130	200
Noncarbonate hardness as $CaCO_3$	0	0	0	7	84
Specific conductance (micromhos at 25° C)			415	1,150	1,095
pH	8.7	8.6	8.0	8.2	8.3
Color	76	7	7	3	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity			3.9	18	
Radium (Ra)			.1	.3	
Uranium (U)			<.1	8.6	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)			<0.40	ND	
Aluminum (Al)			95	220	
Boron (B)			130	57	
Barium (Ba)			33	73	
Beryllium (Be)			ND	ND	
Cobalt (Co)			ND	ND	
Chromium (Cr)			<.40	<.89	
Copper (Cu)			190	21	
Iron (Fe)			33	88	
Lithium (Li)			6.0	53	
Manganese (Mn)			12	<8.9	
Molybdenum (Mo)			5.6	6.7	
Nickel (Ni)			4.0	9.8	
Phosphorus (P)			ND	ND	
Lead (Pb)			5.6	<8.9	
Rubidium (Rb)			4.0	ND	
Tin (Sn)			ND	ND	
Strontium (Sr)			150	670	
Titanium (Ti)			9.1	<2.7	
Vanadium (V)			12	<17	
Zinc (Zn)			ND	ND	

[1] Average analyses by the city of Long Beach, July 1, 1960, to June 30, 1961.
[2] Average analyses by the Metropolitan Water District of Southern California, July 1, 1960, to June 30, 1961.

LOS ANGELES

(See fig. 19.)

Ownership: Municipal.

Population served: Total, 2,458,000 (includes 26,000 in Los Angeles County).

Sources and percentages of supply: Owens Valley Aqueduct sources, 59.7 percent; Los Angeles River Conduit, 11.3 percent; Metropolitan Water District, 20.1 percent (see description under "Long Beach"); miscellaneous local wells, 8.9 percent.

Average amount of water used daily in system during 1962: 466 mgd (U.S. Public Health Service, 1962c).

Treatment: Municipal water system—chlorination of reservoirs and distribution system.

Water storage, in million gallons: Impounding reservoirs, 114,043; flow regulation reservoirs, 244; central and western distribution reservoirs and tanks, 6,613; San Fernando Valley distribution reservoirs and tanks, 11,546; and harbor distribution reservoirs and tanks, 14.

Days of water storage (storage, in million gal/average daily water used, in mgd): 283.

Analytical data—Los Angeles

	Colorado River[1]	San Fernando Reservoir	Weymouth treatment plant
Percent of supply	20	60	20
Date of collection	(2)	7-25-61	(2)
Type of water: R, raw; F, finished	R	F	F

Chemical analyses

[In parts per million]

	Colorado River[1]	San Fernando Reservoir	Weymouth treatment plant
Silica (SiO_2)	8.7	31	8.7
Iron (Fe)		.01	
Calcium (Ca)	84	24	52
Magnesium (Mg)	28	5.1	17
Sodium (Na)	92	32	151
Potassium (K)	4	3.5	4
Bicarbonate (HCO_3)	140	133	139
Carbonate (CO_3)	1	0	1
Sulfate (SO_4)	285	23	285
Chloride (Cl)	83	16	88
Fluoride (F)	.4	.5	.4
Nitrate (NO_3)	1.4	.2	1.2
Dissolved solids (residue at 180° C)	657	212	678
Hardness as $CaCO_3$	323	81	200
Noncarbonate hardness as $CaCO_3$	206	0	84
Specific conductance (micromhos at 25° C)	1,040	307	1,095
pH	8.4	8.1	8.3
Color		3	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Colorado River[1]	San Fernando Reservoir	Weymouth treatment plant
Beta activity		5.2	
Radium (Ra)		<.1	
Uranium (U)		4.8	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Colorado River[1]	San Fernando Reservoir	Weymouth treatment plant
Silver (Ag)		<0.3	
Aluminum (Al)		66	
Boron (B)		420	
Barium (Ba)		30	
Beryllium (Be)		ND	
Cobalt (Co)		ND	
Chromium (Cr)		.77	
Copper (Cu)		130	
Iron (Fe)		30	
Lithium (Li)		95	
Manganese (Mn)		24	
Molybdenum (Mo)		16	
Nickel (Ni)		4.8	
Phosphorus (P)		ND	
Lead (Pb)		4.5	
Rubidium (Rb)		9.5	
Tin (Sn)		ND	
Strontium (Sr)		150	
Titanium (Ti)		<3	
Vanadium (V)		13	
Zinc (Zn)		ND	

[1] Analyzed by the Metropolitan Water District of Southern California.
[2] Average analysis, July 1, 1960, to June 30, 1961.

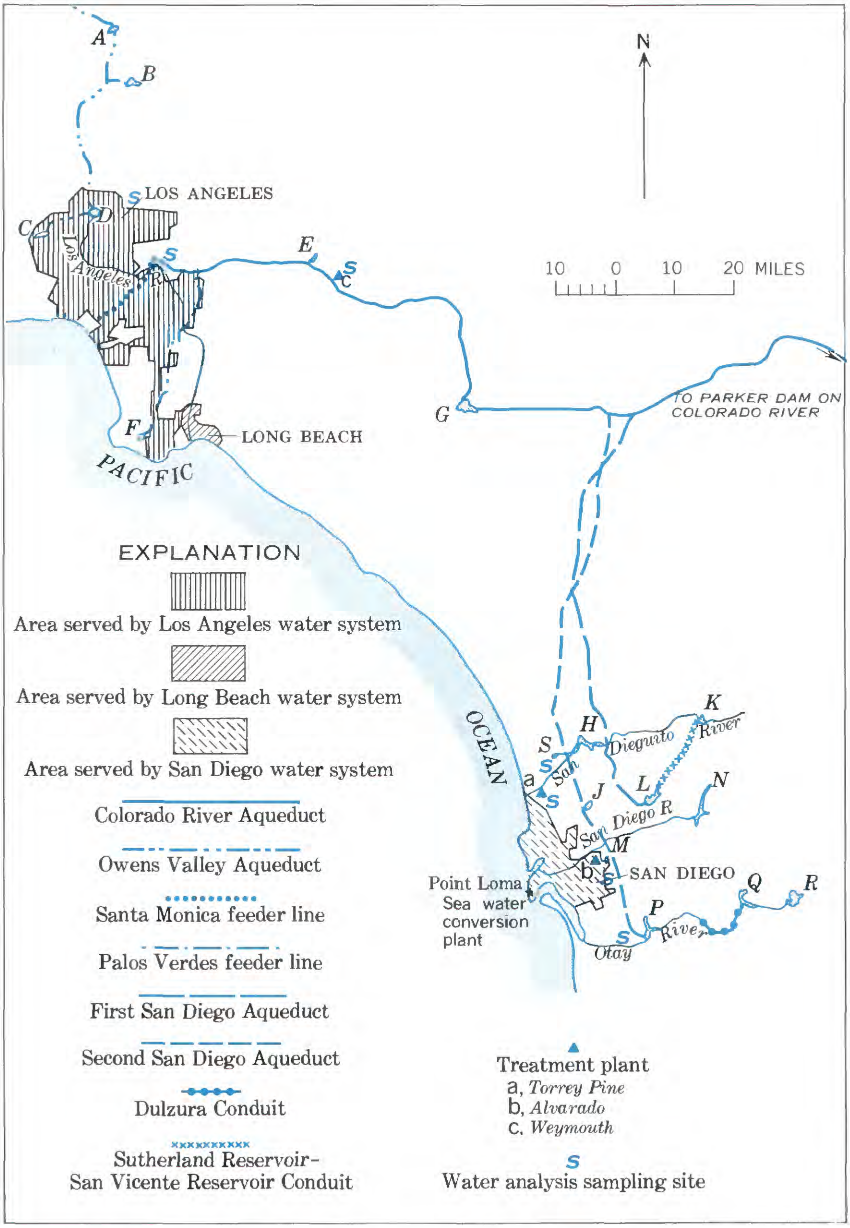

FIGURE 19.—Water supplies and areas served by Long Beach, Los Angeles, and San Diego, Calif., water systems. (Approved by local municipal water officials, April 1963.) List of reservoirs: *A*, Fairmont; *B*, Bouquet; *C*, Chatsworth; *D*, San Fernando; *E*, Morris; *F*, Palo Verdes; *G*, Lake Mathews; *H*, Lake Hodges; *J*, Miramar; *K*, Sutherland; *L*, San Vicente; *M*, Murray; *N*, El Capitan; *P*, Lower Otay; *Q*, Barrett; *R*, Morena; *S*, San Dieguito.

OAKLAND

(See fig. 20.)

Ownership: East Bay Municipal Utility District.

Other areas served: Albany, Alameda, Berkeley, El Cerrito, Emeryville, Hercules, Piedmont, Pleasant Hills, Richmond, San Leandro, San Pablo, Walnut Creek, and unincorporated areas of Alamo, Ashland, Castro Valley, Chabot, Cherryland, Colonial Acres, Danville, El Sobrante, Fairview, Kensington, Lafayette, Orinda, Rodeo, Rollingwood, San Lorenzo, San Ramon, Saranap, Tara Hills, C & H Refinery (Crockett), and Union Oil Co. (Oleum).

Population served: Oakland, 367,548; total 1,000,000.

Sources and percentages of supply: Mokelumne River (impounded), 99 percent; local supplies, 1 percent.

Average amount of water used daily in system during 1962: 143.4 mgd (U.S. Public Health Service, 1962c).

Treatment:

Orinda filter plant: Rapid sand filtration and chlorination.

Lafayette filter plant: Prechlorination, rapid sand filtration, and postchlorination.

San Pablo and Upper San Leandro filter plants: Aeration, prechlorination, addition of alum for coagulation, sedimentation, addition of lime for pH adjustment, rapid sand filtration, and postchlorination.

Chabot filter plant: Prechlorination, addition of alum for coagulation, sedimentation, addition of lime for pH adjustment, rapid sand filtration, and postchlorination.

Rated capacity of treatment plants: Orinda filter plant, 105 mgd; San Pablo filter plant, 54 mgd; Lafayette filter plant, 42 mgd; Upper San Leandro filter plant, 52 mgd; Chabot filter plant, 8 mgd.

Raw-water storage, in million gallons: Reservoirs: Pardee, San Pablo, Upper San Leandro, Chabot, and Lafayette, 100,722. The storage capacities of the terminal reservoirs are as follows: San Pablo, 14; Upper San Leandro, 13.5; Chabot, 3.4; Lafayette, 1.4.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.3 years.

Finished-water storage: One hundred and twenty-four distribution reservoirs, 664 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 4.6.

Remarks: Pardee Reservoir, having a storage capacity of 68,400 million gal, is about 94 miles northeast of the East Bay area. Water is released through an outlet tower into the twin Mokelumne Aqueducts, which together are capable of delivering almost 100 mgd by gravity flow. By operating pumping plants, the daily flow can be increased to more than 210 mgd. A third aqueduct scheduled for completion in December 1962 will increase the capacity to 338 mgd. Most of this water is treated at the Orinda filter plant and transmitted into distribution mains; the remaining amounts are stored in the four terminal reservoirs.

Although much of the water is served by gravity, the district requires 89 pumping plants and 124 distribution reservoirs to serve those living at the higher altitudes.

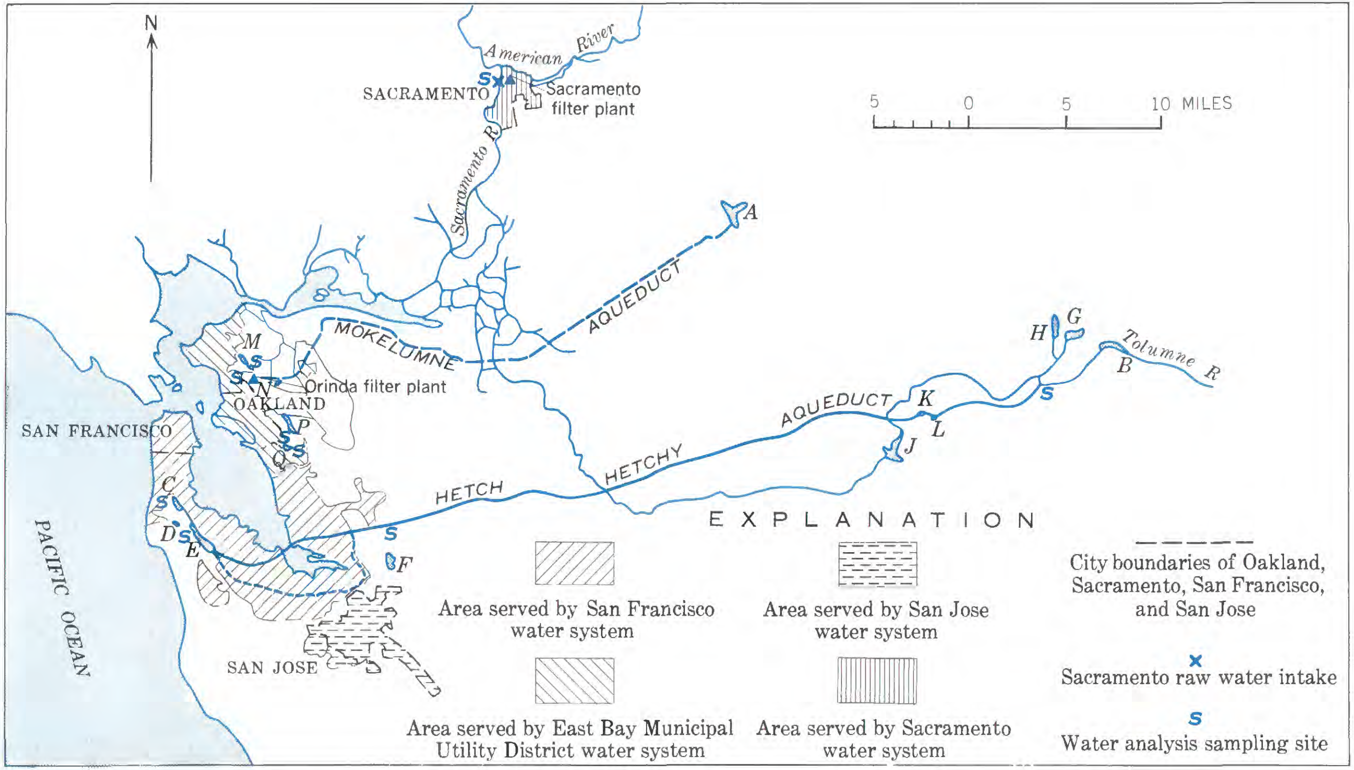

FIGURE 20.—Water supplies and areas served by Oakland, Sacramento, San Francisco, and San Jose, Calif., water systems. (Approved by local municipal water officials, April 1963.) List of reservoirs: *A*, Pardee; *B*, Hetch Hetchy; *C*, San Andreas; *D*, Pilarcitos; *E*, Crystal Springs; *F*, Calaveras; *G*, Lake Eleanor; *H*, Cherry Lake; *J*, Don Pedro; *K*, Moccasin; *L*, Priest: Reservoirs and filter plants: *M*, San Pablo; *N*, Lafayette; *P*, Upper San Leandro; *Q*, Chabot.

Analytical data—Oakland

	Orinda filter plant	San Pablo filter plant [1]	Upper San Leandro filter plant [1]	Chabot filter plant [1]
Percent of supply	99			
Date of collection	1-30-62	(2)	(2)	(2)
Type of water: F, finished	F	F	F	F

Chemical analyses
[In parts per million]

	Orinda filter plant	San Pablo filter plant	Upper San Leandro filter plant	Chabot filter plant
Silica (SiO_2)	9.8	4.7	5.4	1.8
Iron (Fe)	.00	.02	.02	.04
Manganese (Mn)		.00	.00	.00
Calcium (Ca)	8.0	17	23	47
Magnesium (Mg)	.7	3.6	6.1	20
Sodium (Na)	2.5	8.0	6.7	23
Potassium (K)	.5	1.0	1.3	2.4
Aluminum (Al)		.4	.0	.8
Boron (B)		.07	.03	.04
Bicarbonate (HCO_3)	19	56	78	200
Carbonate (CO_3)	3	1	1	2
Sulfate (SO_4)	.0	13	22	58
Chloride (Cl)	5.2	8.0	20	7.0
Fluoride (F)	.2	.1	.2	.3
Nitrate (NO_3)	.2			
Phosphate (PO_4)		.0	.0	.0
Dissolved solids (residue at 180° C)	40	91	113	284
Hardness as $CaCO_3$	23	57	82	199
Noncarbonate hardness as $CaCO_3$	3	9	17	32
Specific conductance (micromhos at 25° C)	61	152	201	472
pH	9.0	8.6	8.2	8.2
Color	2			

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Orinda filter plant	San Pablo filter plant	Upper San Leandro filter plant	Chabot filter plant
Beta activity	4.1			
Radium (Ra)	<.1			
Uranium (U)	<.1			

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

	Orinda filter plant	San Pablo filter plant	Upper San Leandro filter plant	Chabot filter plant
Silver (Ag)	<0.06			
Aluminum (Al)	25			
Boron (B)	25			
Barium (Ba)	17			
Beryllium (Be)	ND			
Cobalt (Co)	ND			
Chromium (Cr)	.20			
Copper (Cu)	2.1			
Iron (Fe)	25			
Lithium (Li)	2.1			
Manganese (Mn)	1.8			
Molybdenum (Mo)	.26			
Nickel (Ni)	1.0			
Phosphorus (P)	ND			
Lead (Pb)	2.7			
Rubidium (Rb)	1.8			
Tin (Sn)	ND			
Strontium (Sr)	27			
Titanium (Ti)	.4			
Vanadium (V)	1.8			
Zinc (Zn)	ND			

[1] Analyzed by the East Bay Municipal Utility District.
[2] Average analyses for the year 1961.

SACRAMENTO

(See fig. 20.)

Ownership: Municipal.

Population served: Total, about 181,000.

Sources and percentages of supply: Sacramento River, 85 percent of supp Because the intake of the water treatment plant is just below the confluence the American River with the Sacramento River, the water delivered to the pla contains a large fraction of American River water. Seventy-eight wells which 55 were operated in 1960, 15 percent.

Lowest mean discharge: Sacramento River at Sacramento, Calif., for 30-d period in climatic water years (April 1–March 31) 1950–59: 4,090 mgd.

Average amount of water used daily in system during 1962: 47.5 mgd (U Public Health Service, 1962c).

Treatment: Sacramento filter plant—prechlorination, coagulation with alu sedimentation, rapid sand filtration, adjustment of pH with lime, and po chlorination.

Rated capacity of treatment plant: Sacramento filter plant, 64 mgd.

Raw-water storage: None.

Finished-water storage: 14.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water us in mgd): Less than 1.

Regular determinations at Sacramento filter plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	M
Raw water	59	78.	26	7.4	7.8	6.6	53	74	26	40	360	
Finished water	57	84	13	------	------	------	63	84	32	0	0	

Analytical data—Sacramento

	Sacramento River	Filter plant
Percent of supply	85	85
Date of collection	7-26-61	7-26-61
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	21	21
Iron (Fe)	.01	.00
Calcium (Ca)	10	17
Magnesium (Mg)	6.6	7.2
Sodium (Na)	10	12
Potassium (K)	.8	1.0
Bicarbonate (HCO_3)	69	79
Carbonate (CO_3)	0	0
Sulfate (SO_4)	7	18
Chloride (Cl)	8.0	9.5
Fluoride (F)	.1	.0
Nitrate (NO_3)	.9	.2
Dissolved solids (residue at 180° C)	110	136
Hardness as $CaCO_3$	52	72
Noncarbonate hardness as $CaCO_3$	0	7
Specific conductance (micromhos at 25° C)	149	200
pH	7.4	7.9
Color	3	2
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity	----------	3.1
Radium (Ra)	----------	<.1
Uranium (U)	----------	<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	<0.1	<0.2
Aluminum (Al)	15	34
Boron (B)	32	54
Barium (Ba)	15	29
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	.15	.33
Copper (Cu)	4.4	8.3
Iron (Fe)	29	21
Lithium (Li)	.51	.72
Manganese (Mn)	6.6	1.8
Molybdenum (Mo)	ND	<.5
Nickel (Ni)	<1	<2
Phosphorus (P)	ND	ND
Lead (Pb)	1.6	2.1
Rubidium (Rb)	1.5	1.6
Tin (Sn)	ND	ND
Strontium (Sr)	9.3	29
Titanium (Ti)	<1	ND
Vanadium (V)	<4	4.7
Zinc (Zn)	ND	ND

SAN DIEGO

(See fig. 19.)

Ownership: Municipal.

Other areas served: San Dieguito Irrigation District, Santa Fe Irrigation District, Del Mar, and part of Coronado.

Population served: San Diego, 588,000 (1961); total, about 600,000.

Sources and percentages of supply: San Diego River system, 47 percent; Cottonwood-Otay River system, 43 percent; San Dieguito River system, 10 percent. The percentages of supply shown are the "normal" percentages. Considerable quantities of Colorado River water have been used for the past several dry years. For the year ending December 1961, about 92 to 94 percent of the city supply was from the Colorado River. Colorado River water is received through the Colorado River aqueduct and the San Diego aqueducts of the Metropolitan Water District of Southern California (see description under "Long Beach") and the San Diego County Water Authority (see "Long Beach").

The San Diego River system includes water from the San Diego River and tributaries and is stored in El Capitan, San Vicente, and Murray Reservoirs. Water from the upper San Dieguito River is stored in Sutherland Reservoir and diverted to the San Diego River system. Colorado River water is received at San Vicente Reservoir. Water from the San Diego River system is treated at the Alvarado plant.

The Cottonwood-Otay River system includes water from Buckman and La Posta Creeks (tributaries of Cottonwood Creek), stored in the Morena Reservoir; Cottonwood and Pine Valley Creeks, stored in Barrett Reservoir; and Dulzura Creek, stored in Lower Otay Reservoir. All Cottonwood-Otay water eventually reaches Lower Otay Reservoir. Colorado River water also reaches Lower Otay Reservoir from the San Diego aqueduct. Water from this system is treated at the Lower Otay plant.

Water from the San Dieguito River system is stored in Lake Hodges and San Dieguito Reservoir. Colorado River water from the second San Diego aqueduct also enters this system. Water from this system is treated at the Torrey Pines plant.

Miramar Reservoir stores Colorado River water; the water is treated at the Miramar Plant and enters the main distribution system in San Diego.

Point Loma sea-water conversion plant produces 1 mgd of fresh water; this water is passed through a limestone bed and then mixed with three volumes of treated water from the Alvarado plant before entering the distribution system.

Average amount of water used daily in system during 1962: 72.9 mgd (U.S. Public Health Service, 1962c).

Treatment:

Alvarado treatment plant (San Diego River system): Prechlorination, coagulation with ferric sulfate, partial softening with lime, settling, addition of polyphosphate, and rapid sand filtration.

Lower Otay treatment plant (Cottonwood-Otay system): Pressure filtration and chlorination.

Torrey Pines treatment plant (San Dieguito River system): Pressure filtration and chlorination.

Miramar treatment plant (Miramar Reservoir): Pressure filtration and chlorination.

Rated capacity of treatment plants: Alvarado treatment plant, 66 mgd; Lower Otay treatment plant, 16 mgd; Torrey Pines treatment plant, [illegible] mgd; Miramar treatment plant, 50 mgd.

Raw-water storage: 141,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 5.3 years.

Finished-water storage: 141 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.9.

Analytical data—San Diego

	Lake Hodges Reservoir [1]	Alvarado treatment plant	Torrey Pines treatment plant [1]	Lower Otay Reservoir [1]
Percent of supply	10	47	10	4
Date of collection		1-24-62		
Type of water: R, raw; F, finished	R	F	F	R
Chemical analyses [In parts per million]				
Silica (SiO_2)	11	12	11	12
Iron (Fe)	.17	.00	.01	.04
Manganese (Mn)	.23		.02	.03
Calcium (Ca)	87	66	89	27
Magnesium (Mg)	29	29	28	21
Sodium (Na)	99	99	107	90
Potassium (K)	5.6	4.7	5.8	6.3
Bicarbonate (HCO_3)	155	68	152	148
Carbonate (CO_3)	0	6	0	21
Sulfate (SO_4)	282	290	294	43
Chloride (Cl)	97	92	105	109
Fluoride (F)	.4	.5	.5	.5
Nitrate (NO_3)	1.0	1.1	.4	.4
Dissolved solids (residue at 180° C)	761	666	776	461
Hardness as $CaCO_3$	334	282	338	155
Noncarbonate hardness as $CaCO_3$	207	216	213	0
Specific conductance (micromhos at 25° C)		1,000		
pH	7.9	8.7	8.2	9.1
Color		2		
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter]				
Beta activity		16		
Radium (Ra)		.2		
Uranium (U)		6.9		
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]				
Silver (Ag)		<0.78		
Aluminum (Al)		39		
Boron (B)		93		
Barium (Ba)		130		
Beryllium (Be)		ND		
Cobalt (Co)		ND		
Chromium (Cr)		ND		
Copper (Cu)		14		
Iron (Fe)		49		
Lithium (Li)		33		
Manganese (Mn)		ND		
Molybdenum (Mo)		8.6		
Nickel (Ni)		<7.8		
Phosphorus (P)		ND		
Lead (Pb)		11		
Rubidium (Rb)		ND		
Tin (Sn)		ND		
Strontium (Sr)		1,100		
Titanium (Ti)		<2.3		
Vanadium (V)		<23		
Zinc (Zn)		ND		

[1] Analyzed by city of San Diego.

SAN FRANCISCO

(See fig. 20.)

Ownership: Municipal.

Other areas served: Belmont, Belmont Water District, Burlingame, Moffett Field, Redwood City, San Carlos, San Mateo, Sunol, Pacifica, Foster City, Brisbane, Hillsborough, San Francisco International Airport, Milpitas, and Alviso; part of the supply for Alameda County Water District, Atherton, Daly City, Menlo Park, Millbrae, Palo Alto, South San Francisco, San Bruno, Half Moon Bay, Hayward, Sunnyvale, Mountain View, and Stanford University.

Population served: San Francisco, 742,855; total, about 1,600,000.

Sources and percentages of supply: Hetch Hetchy system, 72 percent of supply; Alameda system, 18 percent of supply; Peninsula system, 10 percent of supply.

The Hetch Hetchy system includes the Tuolumne River impounded in Hetch Hetchy Reservoir, Priest Reservoir, and Moccasin Reservoir. These waters enter the transvalley aqueduct leading to San Francisco approximately 155 miles to the west. The present aqueduct has a capacity of 160 million gal, but approval has been given for the construction of a third pipeline.

The Alameda system lies on the east side of San Francisco Bay within the drainage area of Alameda Creek. The chief source is Calaveras Reservoir, which impounds Calaveras Creek and Arroyo Hondo and water diverted from upper Alameda Creek through a tunnel. Water from Calaveras Reservoir flows by gravity to enter the Hetch Hetchy aqueduct. During dry years water is also obtained from Sunol filter galleries on Alameda Creek. When these sources are used, the water is pumped into the Hetch Hetchy aqueduct near the Bay Crossing Division.

The Peninsula system includes chiefly three reservoirs: Crystal Springs, Pilarcitos, and San Andreas. These reservoirs catch and store the local runoff. Also Crystal Springs is the terminal reservoir for the Hetch Hetchy aqueduct, which carries water from all the Alameda and Hetch Hetchy sources. Water from Pilarcitos Reservoir is released to San Andreas Reservoir. Water from Crystal Springs and San Andreas Reservoirs is supplied to several distribution reservoirs throughout the city. Crystal Springs lines supply downtown, commercial, and waterfront areas of the city and peninsula communities as far south as San Carlos. San Andreas lines furnish water to residential areas of San Francisco. Bay Crossing lines (Hetch Hetchy aqueduct) supply peninsula communities south of San Carlos and some communities in Alameda County.

Auxiliary and emergency supplies: Sunset well system and Lake Merced, within San Francisco.

Average amount of water used daily in system during 1962: 166 mgd (U.S. Public Health Service, 1962c).

Treatment: Chlorination, addition of copper sulfate for algae control in open reservoirs. Lime treatment of Hetch Hetchy water. Aeration of water from Calaveras Reservoir. Fluoridation of Crystal Springs and San Andreas Reservoirs.

Raw-water storage, in millions of gallons:

Hetch Hetchy system: Hetch Hetchy Reservoir, 117,300; Priest Reservoir, 770; Moccasin, 114.

Alameda system: Calaveras Reservoir, 31,500.

Peninsula system: Crystal Springs Reservoir, 22,580; San Andreas Reservoir, 6,180; and Pilarcitos Reservoir, 1,010.

Storage reservoirs, total capacity: Approximately 179,550.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 3 years.

Finished-water storage, in million gallons: Distribution reservoirs total capacity, 403; elevated tanks, total capacity, 1.3.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.4.

Analytical data—San Francisco

	Calaveras Reservoir [1]	Crystal Springs Reservoir	San Andreas Reservoir	Hetch Hetchy Reservoir [1]	Hetch Hetchy treatment plant [1]
Percent of supply	18	8	2	72	72
Date of collection	7-11-61	1-31-62	1-31-62	7-8-61	7-11-61
Type of water: R, raw; F, finished	F	F	F	R	F
Chemical analyses [In parts per million]					
Silica (SiO_2)	7.6	3.9	9.6	2.4	2.7
Iron (Fe)	.00	.00	.01	.02	.03
Manganese (Mn)	.00			.00	.00
Calcium (Ca)	28	7.6	9.2	.7	3.2
Magnesium (Mg)	10	1.2	2.2	.3	.6
Sodium (Na)	12	3.3	4.9	1.1	2.9
Potassium (K)	1.4	.4	.4	.2	.4
Bicarbonate (HCO_3)	125	22	31	4.2	11
Carbonate (CO_3)	2	0	0	0	0
Sulfate (SO_4)	21	3.0	4.0	.7	1.5
Chloride (Cl)	7.7	6.5	8.5	1.0	3.6
Fluoride (F)	.1	.2	.9	.0	.0
Nitrate (NO_3)	.0	.1	.0	.0	.0
Dissolved solids (residue at 180° C)	154	40	53	10	27
Hardness as $CaCO_3$	111	24	32	3	10
Noncarbonate hardness as $CaCO_3$	5	6	7	0	1
Specific conductance (micromhos at 25° C)	260	66	89	8	34
pH	8.9	7.3	7.2	7.4	9.1
Color	1	2	3	1	1
Turbidity	1			0	1
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]					
Beta activity		6.8	11		
Radium (Ra)		<.1	.1		
Uranium (U)		.2	.3		
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]					
Silver (Ag)		<0.06	<0.08		
Aluminum (Al)		46	89		
Boron (B)		63	41		
Barium (Ba)		19	22		
Beryllium (Be)		ND	ND		
Cobalt (Co)		ND	ND		
Chromium (Cr)		.39	1.5		
Copper (Cu)		31	7.3		
Iron (Fe)		97	110		
Lithium (Li)		.63	1.5		
Manganese (Mn)		17	15		
Molybdenum (Mo)		.57	.63		
Nickel (Ni)		3.3	4.1		
Phosphorus (P)		ND	ND		
Lead (Pb)		3.2	4.7		
Rubidium (Rb)		<.6	<.8		
Tin (Sn)		ND	ND		
Strontium (Sr)		43	68		
Titanium (Ti)		.6	2.7		
Vanadium (V)		<1.7	<2.4		
Zinc (Zn)		ND	ND		

[1] Analyzed by the city of San Francisco.

SAN JOSE

(See fig. 20.)

Ownership: San Jose Water Works (private).
Other areas served: Los Gatos and surrounding area.
Population served: San Jose, 204,196; total, 358,000.
Sources and percentages of supply: One hundred nineteen wells ranging in depth from 185 to 1,535 feet, 80 percent of supply. Los Gatos, Saratoga, and Alamitos Creeks supply about 20 percent of supply. These percentages vary during wet and dry years.
Average amount of water used daily in system during 1962: 46.7 mgd (U.S. Public Health Service, 1962c).
Treatment: Well water is not treated. Surface water is filtered through diatomaceous earth.
Raw-water storage: Stream storage in five reservoirs, 2,290 million gal.
Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 49.
Finished-water storage: 102 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.2.

Analytical data, composite of wells

[Percent of supply: 80. Date of collection: 7-20-61. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	31	Fluoride (F)	0.0
Iron (Fe)	.00	Nitrate (NO_3)	6.7
Calcium (Ca)	51	Dissolved solids (residue at 180°C)	335
Magnesium (Mg)	18	Hardness as $CaCO_3$	203
Sodium (Na)	29	Noncarbonate hardness as $CaCO_3$	9
Potassium (K)	1.2		
Bicarbonate (HCO_3)	237	Specific conductance (micromhos at 25° C)	533
Carbonate (CO_3)	0		
Sulfate (SO_4)	23	pH	7.8
Chloride (Cl)	32	Color	3

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	1.9	Uranium (U)	0.5
Radium (Ra)	<0.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.32	Molybdenum (Mo)	ND
Aluminum (Al)	49	Nickel (Ni)	ND
Boron (B)	52	Phosphorus (P)	ND
Barium (Ba)	84	Lead (Pb)	11
Beryllium (Be)	ND	Rubidium (Rb)	ND
Cobalt (CO)	ND	Tin (Sn)	ND
Chromium (Cr)	1.0	Strontium (Sr)	98
Copper (Cu)	3.0	Titanium (Ti)	ND
Iron (Fe)	5.2	Vanadium (V)	ND
Lithium (Li)	2.1	Zinc (Zn)	ND
Manganese (Mn)	<3.2		

COLORADO

Denver

DENVER

(See fig. 21.)

Ownership: Municipal.

Other areas served: Suburban areas, except Englewood.

Population served: Denver, 496,105; total, about 620,000.

Sources and percentages of supply: South Platte River and tributaries (impounded), 45 percent; Fraser River and tributaries (impounded), 47 percent; other, 3 percent.

South Platte River is impounded in Antero Reservoir, Eleven Mile Canyon Reservoir, Lake Cheesman, and Marston Lake. Bear Creek is diverted near Morrison into Harriman Lake and Soda Lakes and thence to Marston Lake. Western Slope diversion water (Fraser River) is brought from beyond the Continental Divide via the Moffat Tunnel (about 25 miles northwest of the city) to South Boulder Creek to Gross Reservoir and from there to Ralston Reservoir. Water from Ralston Reservoir is brought by conduit to the Moffat filter plant, 3.5 miles west of the city.

Average amount of water used daily in system during 1962: 131 mgd (U.S. Public Health Service, 1962c).

Treatment:

Kassler slow-sand-filter plant: (a) South Platte River: settling, slow sand filtration, disinfection with chloramine, and addition of copper sulfate for control of algae in Platte Canon Reservoir. (b) Infiltration galleries: chlorination.

Marston Lake, north-side filter plant (South Platte River and Bear Creek): Settling, aeration, coagulation with aluminum sulfate, filtration with anthrafilt (coal), addition of activated carbon, disinfection with chloramine, addition of copper sulfate for control of algae in Marston Lake, microstraining, and disinfection with chloramine.

Marston Lake, south-side filter plant (South Platte River and Bear Creek): Settling, coagulation with aluminum sulfate, filtration with rapid sand filters, addition of activated carbon, disinfection with chloramine, addition of copper sulfate for control of algae in Marston Lake, microstraining, and disinfection with chloramine.

Moffatt filter plant (South Boulder Creek and Ralston Creek): Settling; coagulation with aluminum sulfate, sodium aluminate, and lime; filtration with rapid sand filter; treatment with activated carbon; and disinfection with chloramine.

Rated capacity of treatment plants: Kassler slow-sand-filter plant, 50 mgd; Marston Lake, north-side filter plant, 100 mgd; Marston Lake, south-side filter plant, 25 mgd; Moffat filter plant, 150 mgd.

Raw-water storage, in million gallons:

Storage reservoirs: Antero, 5,111; Eleven Mile, 31,861; Cheesman, 25,763; Soda Lakes, 227; and Gross, 14,033.

Operating reservoirs: Platte Canon, 295; Marston Lake, 5,817; Ralston Lake, 3,673; and Long Lake, 439.

Total raw-water storage: 87,219.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.8.

Finished-water storage: Marston Lake, north side, 33 million gal; Moffat, 16 million gal.

Days of finished-water storage (storage, in million gal/average daily water used in mgd): Less than 1.

Regular determinations at filter plants, 1960:

Plant	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Kassler:												
Raw water	60	112	34	7.8	8.4	7.4	101	120	84	12	36	6
Finished water	64	106	38	7.8	8.3	7.2	106	139	76	1.0	1.0	1.0
Marston Lake, north side:												
Raw water	77	118	60	8.1	8.5	7.6	115	134	81	3.0	5.0	3.0
Finished water	77	122	60	7.7	8.0	7.4	114	129	91	1.0	1.0	1.0
Marston Lake, south side:												
Raw water	80	170	60	7.9	8.7	7.3	113	140	95	3.5	7.8	3.0
Finished water	73	140	52	7.5	8.2	7.2	107	122	91	1.4	3.0	1.0
Moffat:												
Raw water	23	32.0	18.0	7.7	8.1	7.3	32	42	21	15	73	5.0
Finished water	24	43.0	18.0	7.6	7.8	7.4	41	51	35	.5	.7	.3

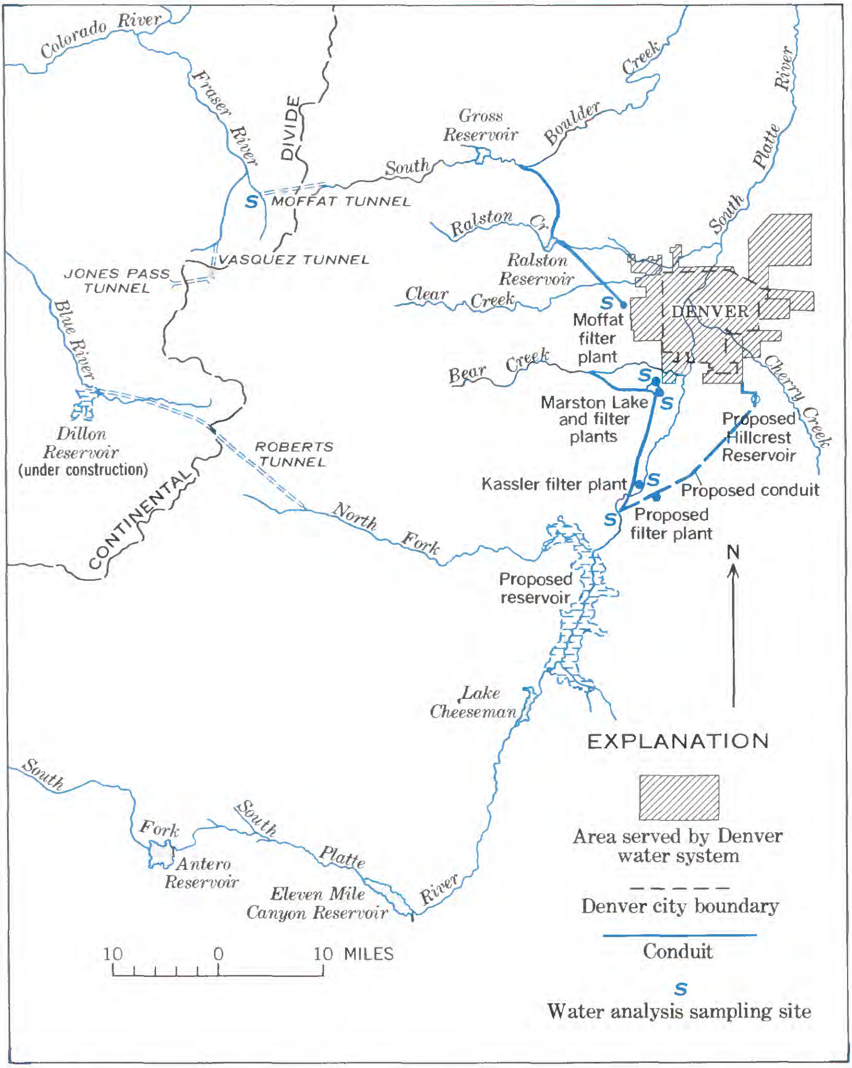

FIGURE 21.—Water supplies and areas served by Denver, Colo., water system. (Approved by local municipal water officials, June 1963.)

Analytical data—Denver

	Fraser River and Williams Fork	Moffat filter plant	South Platte River and Bear Creek	Marston Lake north-side filter plant	South Platte River	Kassler filter plant	Marston Lake south-side filter plant
Percent of supply	47	46	38	31	15	15	8
Date of collection	8-28-61	8-26-61	8-28-61	8-28-61	8-29-61	8-29-61	8-29-61
Type of water: R, raw; F, finished	R	F	R	F	R	F	F

Chemical analyses

[In parts per million]

	Fraser River and Williams Fork	Moffat filter plant	South Platte River and Bear Creek	Marston Lake north-side filter plant	South Platte River	Kassler filter plant	Marston Lake south-side filter plant
Silica (SiO_2)	8.2	7.5	6.8	6.2	7.8	8.0	9.0
Iron (Fe)	.06	.00	.08	.03	.21	.10	.00
Manganese (Mn)	.00	.00	.00	.00	.00	.00	.00
Aluminum (Al)							6.1
Lithium (Li)							.05
Calcium (Ca)	6.8	10	27	26	31	31	26
Magnesium (Mg)	1.9	2.2	8.0	8.3	12	11	9.2
Sodium (Na)	2.0	2.7	24	24	34	31	27
Potassium (K)	.2	.4	1.8	1.8	2.0	2.0	1.8
Bicarbonate (HCO_3)	24	28	86	80	104	100	72
Carbonate (CO_3)	0	0	0	0	0	0	0
Sulfate (SO_4)	9.0	19	38	38	47	51	43
Chloride (Cl)	1.0	.0	33	32	49	44	34
Fluoride (F)	.3	.8	1.0	.9	.9	.9	.8
Nitrate (NO_3)	.5	.4	.5	.7	.2	.7	.6
Phosphate (PO_4)							.00
Dissolved solids (residue at 180° C)	40	39	172	175	232	216	186
Hardness as $CaCO_3$	25	34	100	99	127	123	103
Noncarbonate hardness as $CaCO_3$	5	11	30	33	41	41	44
Specific conductance (micromhos at 25° C)	58	86	332	335	448	423	335
pH	7.6	7.2	7.5	7.4	7.0	7.4	8.0
Color	0	0	0	0	0	0	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Fraser River and Williams Fork	Moffat filter plant	South Platte River and Bear Creek	Marston Lake north-side filter plant	South Platte River	Kassler filter plant	Marston Lake south-side filter plant
Beta activity		3.3		4.8		6.8	
Radium (Ra)		<.1		<.1		.9	
Uranium (U)		.2		1.7		2.8	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Fraser River and Williams Fork	Moffat filter plant	South Platte River and Bear Creek	Marston Lake north-side filter plant	South Platte River	Kassler filter plant	Marston Lake south-side filter plant
Silver (Ag)	ND	ND	<0.26	<0.26	ND	ND	
Aluminum (Al)	23	15	190	320	86	62	
Boron (B)	3.8	5.7	21	42	100	30	
Barium (Ba)	6.2	12	58	74	72	110	
Beryllium (Be)	ND	ND	ND	ND	ND	ND	
Cobalt (Co)	ND	ND	<2.6	ND	ND	ND	
Chromium (Cr)	<.07	ND	1.0	ND	ND	.65	
Copper (Cu)	16	14	31	90	1.7	15	
Iron (Fe)	39	1.9	29	32	58	29	
Lithium (Li)	.24	.53	4.2	5.3	5.8	7.2	
Manganese (Mn)	5.5	3.7	15	7.1	7.2	<3.4	
Molybdenum (Mo)	<.20	<.25	3.4	2.4	1.2	1.5	
Nickel (Ni)	.7	ND	3.9	3.2	ND	5.5	
Phosphorus (P)	ND	ND	ND	ND	ND	ND	
Lead (Pb)	ND	ND	<2.6	2.9	<3.6	5.5	
Rubidium (Rb)	1.1	.9	ND	ND	ND	ND	
Tin (Sn)	ND	ND	ND	ND	ND	ND	
Strontium (Sr)	4.1	6.2	290	230	240	380	
Titanium (Ti)	1.0	ND	<2.6	<2.6	<3.6	<3.4	
Vanadium (V)	ND	ND	ND	ND	ND	ND	
Zinc (Zn)	ND	ND	ND	ND	ND	ND	

CONNECTICUT

Bridgeport *Hartford* *New Haven*

BRIDGEPORT

(See fig. 22.)

Ownership: Bridgeport Hydraulic Co.

Other areas served (wholly or in part): Easton, Fairfield, Monroe, Shelton, Stratford, Trumbull, and Westport.

Population served: Bridgeport, 156,748; total, 320,000.

Sources and percentages of supply: Saugatuck River impounded in Saugatuck Reservoir, and Aspetuck River impounded in Aspetuck Reservoir. Water from these reservoirs is diverted into Hemlocks Reservoir, 51 percent. Water from the Housatonic well field and water from Means Brook are impounded in Means Brook Reservoir; Far Mill River, impounded in Far Mill River Reservoir. Water from these reservoirs is diverted to Trap Falls Reservoir, 26 percent. Mill River impounded in Easton Reservoir, 21 percent and in Shelton Reservoir, 2 percent.

Auxiliary and emergency supplies: Westport well fields are activated during periods of peak loads. Shelton Reservoir is used when needed.

Average amount of water used daily in system during 1962: 49 mgd (U.S. Public Health Service, 1962c).

Treatment:

Hemlocks and Trap Falls treatment plants: Chlorination, pH adjustment with lime, and addition of Calgon.

Easton treatment plant: Chlorination and pH adjustment with lime.

Shelton and Huntington treatment plants: Chlorination, pH adjustment with caustic soda, and addition of Calgon.

Rated capacity of treatment plants: Hemlocks treatment plant, 100 mgd; Trap Falls treatment plant, 50 mgd; Easton treatment plant, 32 mgd; Shelton treatment plant, 1.6 mgd; Westport treatment plant, 9 mgd.

Raw-water storage: 24,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.3 years.

Finished-water storage: Tanks: North Avenue, 1.5 million gal; Tashua, 3.0 million gal; Nichols Tank, 0.2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—Bridgeport

	Easton Reservoir	Easton treatment plant	Hemlocks Reservoir	Hemlocks treatment plant	Trap Falls Reservoir	Trap Falls treatment plant
Percent of supply	21	21	51	51	26	26
Date of collection	6-1-62	5-15-62	6-1-62	6-1-62	6-1-62	5-15-62
Type of water: R, raw; F, finished	R	F	R	F	R	F
Chemical analyses [In parts per million]						
Silica (SiO_2)	6.5	10	4.0	5.0	7.7	7.7
Iron (Fe)	.09	.07	.06	.07	[1].12	[1].19
Manganese (Mn)	.01	.02	.01	.01	[1].03	[1].02
Aluminum (Al)	------	.1	.1	------	------	0.1
Calcium (Ca)	7.0	11	6.4	10	7.3	10
Magnesium (Mg)	1.1	.7	1.6	1.4	1.6	1.5
Sodium (Na)	3.6	3.7	3.6	3.6	3.8	4.1
Potassium (K)	1.2	1.3	1.0	1.0	1.0	1.0
Bicarbonate (HCO_3)	11	14	16	18	12	10
Carbonate (CO_3)	0	0	0	0	0	0
Sulfate (SO_4)	13	14	13	13	14	16
Chloride (Cl)	5.9	9.0	5.5	8.0	6.4	11
Fluoride (F)	.1	.1	.1	.1	.1	.1
Nitrate (NO_3)	.8	.7	.4	.5	1.0	1.2
Phosphate (PO_4)	------	.06	.01	------	------	.40
Dissolved solids (residue at 180° C)	51	60	47	57	57	68
Hardness as $CaCO_3$	22	31	27	31	25	31
Noncarbonate hardness as $CaCO_3$	13	19	14	16	15	23
Specific conductance (micromhos at 25° C)	73	86	78	88	79	91
pH	6.6	6.7	6.9	7.2	6.6	6.7
Color	9	5	6	4	12	6
Turbidity	1	2	.2	3	2	2
Temperature °F	50	55	57	60	62	56
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]						
Beta activity	------	14	------	14	------	22
Radium (Ra)	------	<.1	------	<.1	------	<.1
Uranium (U)	------	<.1	------	<.1	------	<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]						
Silver (Ag)	------	0.10	------	0.19	------	<0.06
Aluminum (Al)	------	38	------	34	------	30
Boron (B)	------	16	------	8.7	------	7.1
Barium (Ba)	------	21	------	23	------	12
Beryllium (Be)	------	ND	------	ND	------	ND
Cobalt (Co)	------	ND	------	ND	------	ND
Chromium (Cr)	------	<.08	------	.08	------	<.06
Copper (Cu)	------	50	------	60	------	20
Iron (Fe)	------	79	------	94	------	38
Lithium (Li)	------	.48	------	.47	------	.22
Manganese (Mn)	------	23	------	21	------	16
Molybdenum (Mo)	------	.27	------	ND	------	ND
Nickel (Ni)	------	1.4	------	1.3	------	<.6
Phosphorus (P)	------	ND	------	170	------	89
Lead (Pb)	------	3.8	------	6.1	------	2.2
Rubidium (Rb)	------	2.9	------	2.5	------	.9
Tin (Sn)	------	ND	------	ND	------	ND
Strontium (Sr)	------	27	------	39	------	3.8
Titanium (Ti)	------	.6	------	1.7	------	.3
Vanadium (V)	------	ND	------	<2.0	------	ND
Zinc (Zn)	------	ND	------	ND	------	ND

[1] In solution when collected.

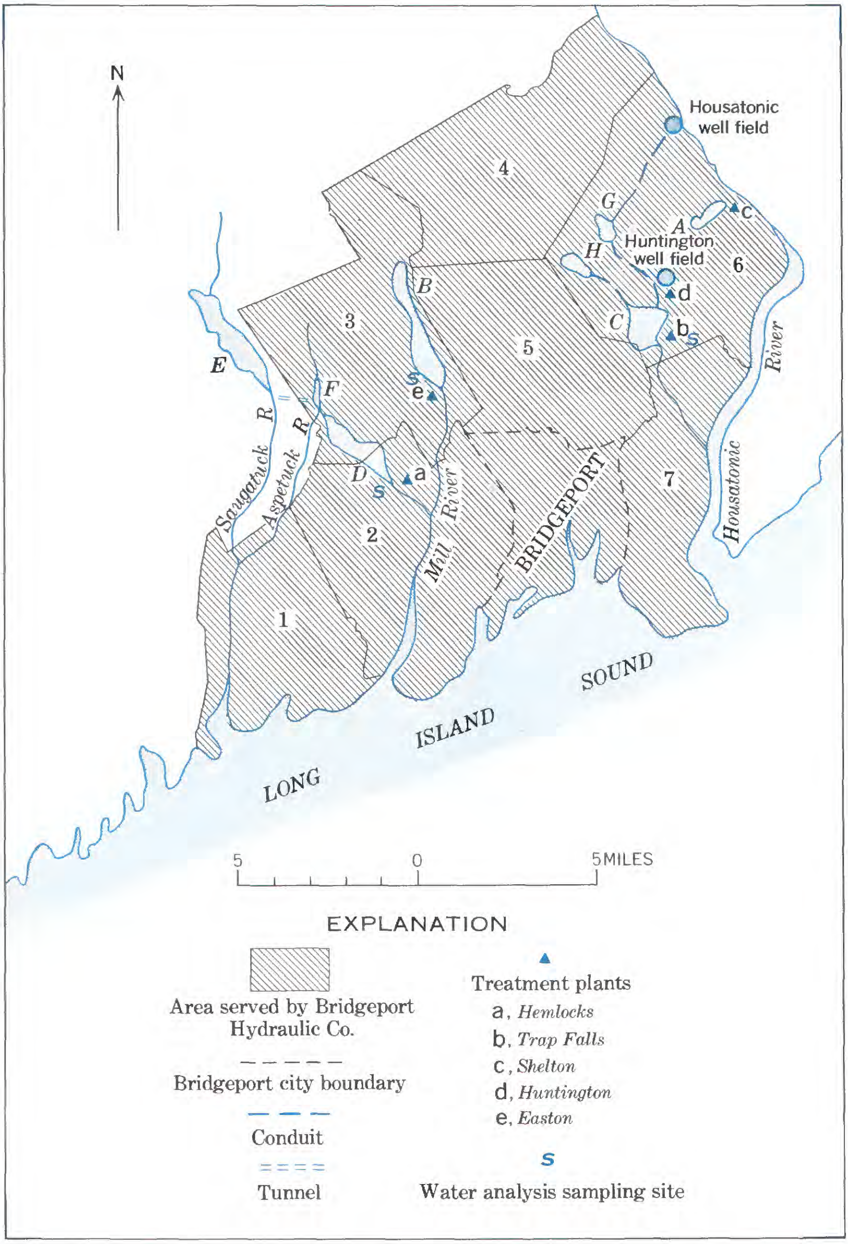

FIGURE 22.—Water supplies and areas served by Bridgeport, Conn., Hydraulic Co. (Approved by local municipal water officials, April 1963.) List of areas served: 1, Westport; 2, Fairfield; 3, Easton; 4, Monroe; 5, Trumbull; 6, Shelton; 7, Stratford. List of reservoirs: *A*, Shelton; *B*, Easton; *C*, Trap Falls; *D*, Hemlocks; *E*, Saugatuck; *F*, Aspetuck; *G*, Means Brook; *H*, Far Mill River.

HARTFORD

(See fig. 23.)

Ownership: Metropolitan District of Hartford County.

Other areas served: (Member towns) Newington, Bloomfield, East Hartford, Rocky Hill, Wethersfield, Windsor, and (nonmember towns) Glastonbury and West Hartford.

Population served: Hartford, 162,178; total, 355,000.

Sources and percentages of supply: East Branch Farmington River impounded in Barkhamsted Reservoir; Nepaug River impounded in Nepaug Reservoir; Cold Brook Reservoir.

Auxiliary and emergency supplies: West Hartford Systems (series of small reservoirs) used when reservoirs are overflowing and when needed to supplement regular system.

Average amount of water used daily in system during 1962: 42.5 mgd (U.S. Public Health Service, 1962c).

Treatment:

West Hartford filter plant: Aeration, slow sand filtration, chlorination, fluoridation, and corrosion control.

Cold Brook plant: Chlorination, corrosion control, and fluoridation.

Rated capacity of treatment plants: West Hartford filter plant, 55 mgd; Cold Brook plant, 1.5 mgd.

Raw-water storage, in million gallons: Barkhamsted Reservoir, 31,700; Nepaug Reservoir, 9,700; West Hartford Reservoir, 1,300.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.8 years.

Finished-water storage: 15.8 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at West Hartford filter plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	------	------	------	6.8	6.9	6.7	------	------	------	1.7	2.4	1.2
Finished water	11	12	9	7.2	7.5	7.0	20	23	16	.7	.9	.5

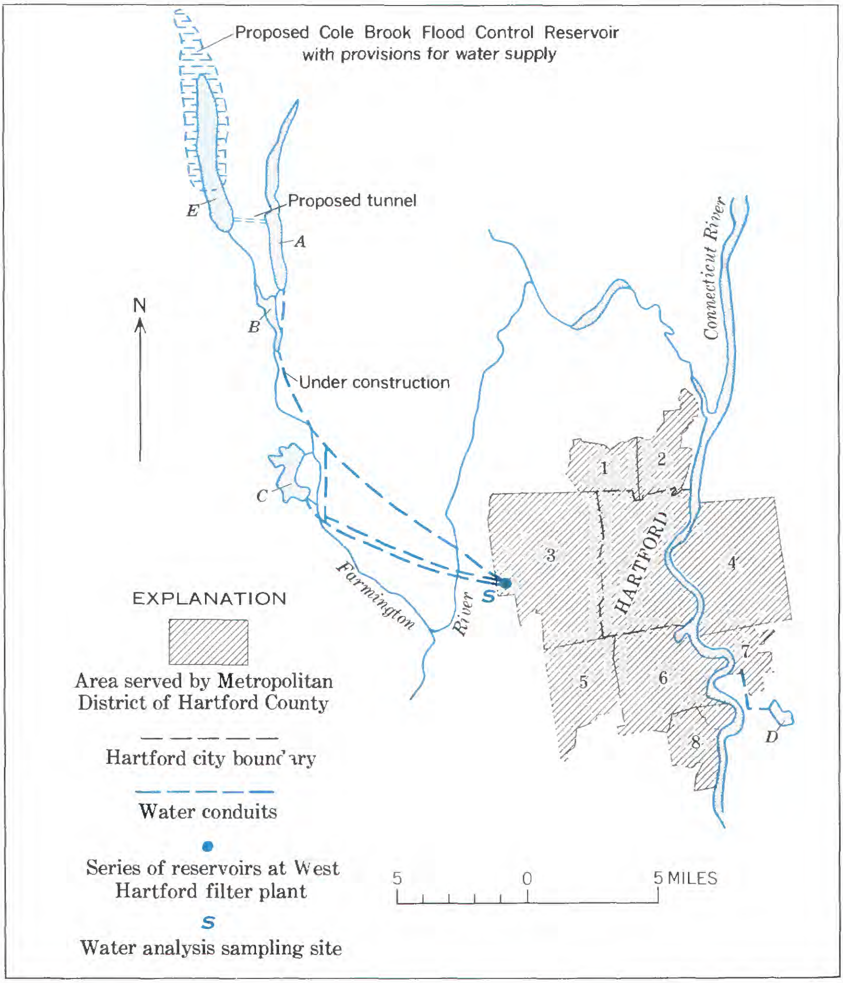

FIGURE 23.—Water supplies and areas served by Metropolitan District of Hartford County, Conn., water system. (Approved by local municipal water officials, March 1963.) List of areas: 1, Bloomfield; 2, Windsor; 3, West Hartford; 4, East Hartford; 5, Newington; 6, Wethersfield; 7, Glastonbury; 8, Rocky Hill. List of reservoirs: *A*, Barkhamsted; *B*, compensating; *C*, Nepaug; *D*, Cold Brook; *E*, West Branch.

Analytical data—Hartford

	West Hartford filter plant	
Percent of supply	97	
Date of collection	4-16-62	(1)
Type of water: F, finished	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	5.6	4.6
Iron [2] (Fe)	.05	
Manganese [2] (Mn)	.00	.00
Calcium (Ca)	8.0	8.2
Magnesium (Mg)	1.8	1.3
Sodium (Na)	2.8	5.6 (Na + K)
Potassium (K)	.6	
Bicarbonate (HCO_3)	18	22
Carbonate (CO_3)	0	
Sulfate (SO_4)	11	8.4
Chloride (Cl)	3.9	5.2
Fluoride (F)	1.0	1.0
Nitrate (NO_3)	.1	.2
Dissolved solids (residue at 180° C)	46	
Hardness as $CaCO_3$	28	20
Noncarbonate hardness as $CaCO_3$	13	
Specific conductance (micromhos at 25° C)	75	57
pH	7.0	7.2
Color	3	5
Turbidity	3	1
Temperature °F	44	

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	14	
Radium (Ra)	<.1	
Uranium (U)	<.1	

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	0.29	
Aluminum (Al)	20	
Boron (B)	56	
Barium (Ba)	17	
Beryllium (Be)	ND	
Cobalt (Co)	ND	
Chromium (Cr)	<.06	
Copper (Cu)	7.2	
Iron (Fe)	34	
Lithium (Li)	.21	
Manganese (Mn)	1.9	
Molybdenum (Mo)	ND	
Nickel (Ni)	1.0	
Phosphorus (P)	230	
Lead (Pb)	1.7	
Rubidium (Rb)	.7	
Tin (Sn)	ND	
Strontium (Sr)	13	
Titanium (Ti)	.8	
Vanadium (V)	ND	
Zinc (Zn)	ND	

[1] Analyses by Metropolitan District, of sample composited for several months during 1961.
[2] In solution when collected.

NEW HAVEN

(See fig. 24.)

Ownership: New Haven Water Co.

Other areas served: Bethany, Branford, Cheshire, East Haven, Hamden, North Branford, North Haven, Orange, West Haven, and Woodbridge; the company sells water to Milford City.

Population served: New Haven, 152,048; total, 320,000.

Sources and percentages of supply: Lake Gaillard, 41 percent; Lake Whitney, 13 percent; Lake Saltonstall, 12 percent; Lakes Dawson, Glen, Chamberlain, and Watrous (Woodbridge System), 12 percent; Lake Wintergreen, 9 percent; Lake Bethany, 4 percent; Beaver Brook Lake, 4 percent; and Maltby Lakes, 2 percent.

Auxiliary and emergency supplies: Hammonassett Lake, Branford Lake, Cheshire and Mount Carmel well fields.

Average amount of water used daily in system during 1962: 44 mgd (U.S. Public Health Service, 1962c).

Treatment:

Whitney filter plant: Slow sand filtration and chlorination.

All other sources: Chlorination; Calgon added at times to some supplies.

Rated capacity of treatment plant: Whitney filter plant, 12 mgd.

Raw-water storage, in million gallons: Lake Whitney, 258; Lake Wintergreen, 100; Prospect Lake, 26; Lake Gaillard and Menunkatuc, 15,845; Maltby Lakes, 276; Woodbridge System (Lakes Dawson, Glen, Chamberlain, Watrous, and Bethany), 2,790; Lake Saltonstall, 1,600; Beaver Brook Reservoir, 18; and Hammonassett Reservoir, 1,400.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.2 years.

Finished-water storage: 16.7 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—New Haven

	Whitney filter plant	Lake Gaillard	Lake Saltonstall	Woodbridge system	Lake Wintergreen	Lake Bethany	Beaver Brook Lake	Maltby Lakes
Percent of supply	13	41	12	12	9	4	4	2
Date of collection	5-14-62	5-14-62	5-14-62	5-14-62	5-14-62	5-14-62	5-14-62	5-14-62
Type of water: F, finished	F	F	F	F	F	F	F	F

Chemical analyses

[In parts per million]

	Whitney filter plant	Lake Gaillard	Lake Saltonstall	Woodbridge system	Lake Wintergreen	Lake Bethany	Beaver Brook Lake	Maltby Lakes
Silica (SiO_2)	7.0	4.4	3.2	5.9	4.4	7.0	4.8	5.4
Iron[1] (Fe)	.08	.08	.08	.23	.11	.10	.07	.13
Manganese[1] (Mn)	.01	.00	.03	.03	.04	.01	.01	.00
Calcium (Ca)	23	8.0	21	7.2	6.2	6.2	18	13
Magnesium (Mg)	2.8	2.6	6.4	1.4	1.6	1.6	5.8	2.1
Sodium (Na)	5.9	3.0	6.4	3.7	2.7	3.4	11	5.3
Potassium (K)	.6	.6	1.0	.7	.4	.6	2.4	.6
Bicarbonate (HCO_3)	60	20	70	11	5	7	28	28
Carbonate (CO_3)	0	0	0	0	0	0	0	0
Sulfate (SO_4)	18	13	21	13	18	13	34	18
Chloride (Cl)	9.5	5.3	10	7.2	3.4	7.3	23	8.5
Fluoride (F)	.1	.1	.0	.1	.1	.1	.1	.1
Nitrate (NO_3)	3.4	.8	1.1	.8	.3	.5	6.4	1.5
Dissolved solids (residue at 180° C)	107	56	112	58	51	54	133	78
Hardness as $CaCO_3$	69	31	79	24	22	22	69	41
Noncarbonate hardness as $CaCO_3$	20	14	22	15	18	17	46	18
Specific conductance (micromhos at 25°C)	174	85	188	76	68	73	209	123
pH	7.0	6.8	7.5	6.3	6.0	6.2	6.7	6.9
Color	2	3	2	6	5	8	2	6
Turbidity	1	1	2	1	1	2	2	1
Temperature °F	58	55	--	55	55	54	59	59

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Whitney filter plant	Lake Gaillard	Lake Saltonstall	Woodbridge system	Lake Wintergreen	Lake Bethany	Beaver Brook Lake	Maltby Lakes
Beta activity	5.8	9.4	--	--	--	--	--	--
Radium (Ra)	<.1	<.1	--	--	--	--	--	--
Uranium (U)	.2	.2	--	--	--	--	--	--

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Whitney filter plant	Lake Gaillard	Lake Saltonstall	Woodbridge system	Lake Wintergreen	Lake Bethany	Beaver Brook Lake	Maltby Lakes
Silver (Ag)	<0.14	0.30	--	--	--	--	--	--
Aluminum (Al)	21	9.5	--	--	--	--	--	--
Boron (B)	73	28	--	--	--	--	--	--
Barium (Ba)	51	12	--	--	--	--	--	--
Beryllium (Be)	ND	ND	--	--	--	--	--	--
Cobalt (Co)	ND	ND	--	--	--	--	--	--
Chromium (Cr)	.70	<.06	--	--	--	--	--	--
Copper (Cu)	40	14	--	--	--	--	--	--
Iron (Fe)	26	28	--	--	--	--	--	--
Lithium (Li)	.28	.10	--	--	--	--	--	--
Manganese (Mn)	1.9	16	--	--	--	--	--	--
Molybdenum (Mo)	ND	ND	--	--	--	--	--	--
Nickel (Ni)	1.9	.7	--	--	--	--	--	--
Phosphorus (P)	ND	ND	--	--	--	--	--	--
Lead (Pb)	1.9	1.5	--	--	--	--	--	--
Rubidium (Rb)	ND	<.6	--	--	--	--	--	--
Tin (Sn)	ND	ND	--	--	--	--	--	--
Strontium (Sr)	43	8.2	--	--	--	--	--	--
Titanium (Ti)	.5	.6	--	--	--	--	--	--
Vanadium (V)	<4.1	ND	--	--	--	--	--	--
Zinc (Zn)	ND	ND	--	--	--	--	--	--

[1] In solution when collected.

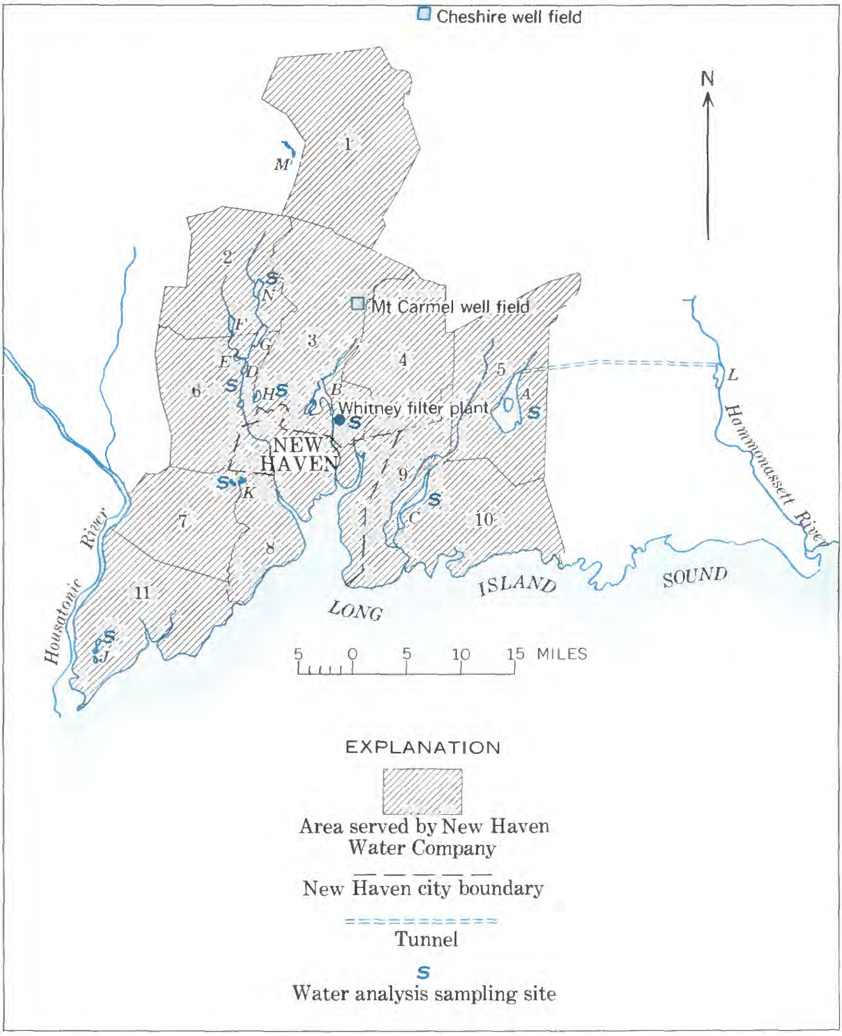

FIGURE 24.—Water supplies and areas served by New Haven, Conn., Water Co. (Approved by local municipal water officials, April 1963.) List of areas served: 1, Cheshire; 2, Bethany; 3, Hamden; 4, North Haven; 5, North Branford; 6, Woodbridge; 7, Orange; 8, West Haven; 9, East Haven; 10, Branford; 11, Milford. List of lakes: *A*, Lake Gaillard; *B*, Lake Whitney; *C*, Lake Saltonstall; *D*, Lake Dawson; *E*, Lake Glen; *F*, Lake Chamberlain; *G*, Lake Watrous; *H*, Lake Wintergreen; *J*, Beaver Brook Lake; *K*, Maltby Lakes; *L*, Hammonassett Reservoir; *M*, Prospect Lake; *N*, Lake Bethany.

DISTRICT OF COLUMBIA

WASHINGTON, D.C.

(See fig. 25.)

Ownership: Department of the Army and the District of Columbia. The water system of the District has two components: the supply division and the distribution system. The supply division comprises the collection and purification systems; it is under the control of the Department of the Army and is operated by the Washington District Office of the Corps of Engineers. The distribution system is owned and operated by the District of Columbia.

Other areas served: Arlington County, Va.; part of Fairfax County, Va.; the city of Falls Church, Va. Arlington County, Falls Church, and areas in Fairfax County are served principally with water from the Dalecarlia Plant.

Population served: Washington, D.C., 763,956; total, about 1,100,000.

Source of supply: Potomac River. The diversion dam and the raw water intake are at Great Falls, Montgomery County, Md., about 10 miles from the District line. The raw water flows by gravity through two conducts into Dalecarlia Reservoir. This reservoir serves not only as a storage reservoir but also as a sedimentation basin, from which the water flows by gravity to the treatment plants.

Emergency supplies: 9.2 mgd of treated water available from Washington Suburban Sanitary District of Maryland.

Lowest mean discharge: Potomac River at Point of Rocks, Md., for 30-day period in climatic water years (April 1–March 31) 1950–59: 743 mgd.

Average amount of water used daily in system during 1962: 167 mgd (U.S. Public Health Service, 1962c).

Treatment:

Dalecarlia filter plant: Prechlorination, coagulation with alum, sedimentation, rapid sand filtration, postchlorination or dechlorination as necessary, chlorine dioxide when necessary for control of tastes and odors, and lime for adjustment of pH.

McMillan filter plant: Water from the Dalecarlia treatment plant flows by gravity to Georgetown Reservoir, part of which serves as a sedimentation basin. Water then flows by gravity to the McMillan Reservoir, where further settling takes place. Water also receives slow sand filtration, chlorination, chlorine dioxide as required, continuous adjustment of pH with lime, and fluoridation with sodium silicofluoride. An average fluoride content of 1.1 ppm is maintained in the finished water in the distribution system.

Rated capacity of treatment plants: Dalecarlia filter plant, 104 mgd; McMillan filter plant, 125 mgd.

Raw-water storage: 560 million gal (30 percent available). The three reservoirs, Dalecarlia, Georgetown, and McMillan, serve as storage reservoirs for unfiltered water.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 3.4.

Finished-water storage: Clear water basins, 79 million gal; ground-surface reservoirs, 102 million gal; elevated tanks, 2.74 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.1.

Regular determinations at filter plants, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Dalecarlia:												
Raw water	69	104	42	8.1	8.4	7.8	101	136	74	49	600	6
Finished water	68	98	44	7.9	8.1	7.7	117	150	93	.0	2.5	0
McMillan: Finished water	65	99	41	8.0	8.1	7.8	110	143	84	0.0	0.1	------

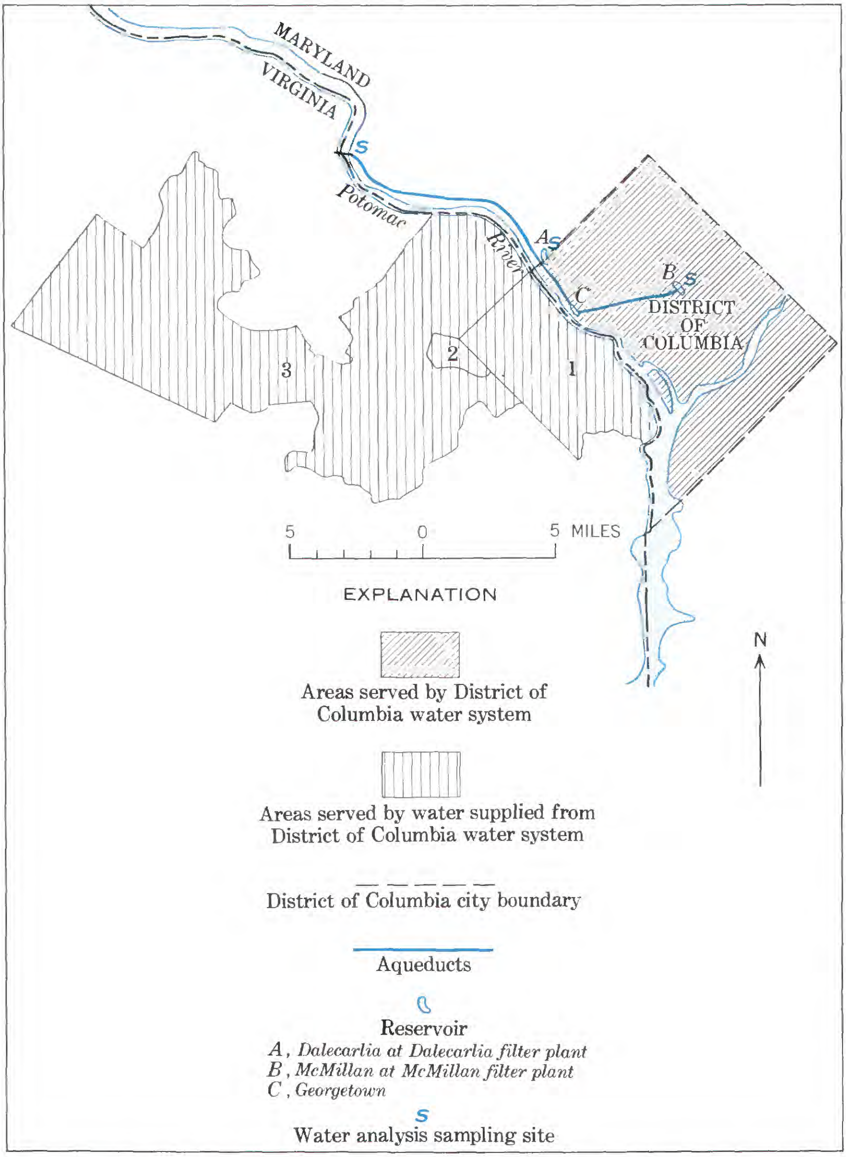

FIGURE 25.—Water supplies and areas served by District of Columbia water system. (Approved by local municipal water officials, June 1963.) List of areas served: 1, Arlington County; 2, Falls Church; 3, Fairfax County.

735–717 O—64——10

Analytical data—Washington, D.C.

	Potomac River	Dalecarlia filter plant	McMillan filter plant
Percent of supply	100	45	55
Date of collection	8-25-61	8-25-61	8-25-61
Type of water: R, raw; F, finished	R	F	F

Chemical analyses

[In parts per million]

	Potomac River	Dalecarlia filter plant	McMillan filter plant
Silica (SiO_2)	5.7	4.8	3.8
Iron (Fe)	.00	.00	.00
Manganese (Mn)	.00	.00	.00
Aluminum (Al)	.0	.1	.0
Calcium (Ca)	35	40	38
Magnesium (Mg)	7.9	8.8	9.5
Sodium (Na)	7.4	8.2	10
Potassium (K)	1.9	1.9	2.0
Bicarbonate (HCO_3)	107	106	96
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	35	45	50
Chloride (Cl)	10	15	18
Fluoride (F)	.1	.9	1.0
Nitrate (NO_3)	1.1	1.2	1.0
Phosphate (PO_4)	.15	.08	.16
Dissolved solids (residue at 180° C)	172	198	204
Hardness as $CaCO_3$	120	137	134
Noncarbonate hardness as $CaCO_3$	33	50	56
Specific conductance (micromhos at 25° C)	279	313	324
pH	7.0	7.9	8.2
Color	5	2	2
Temperature °F	80	78	78

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

	Potomac River	Dalecarlia filter plant	McMillan filter plant
Beta activity	------	------	4.2
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	29	------	------
Radium (Ra)	------	------	.2
Uranium (U)	------	------	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Potomac River	Dalecarlia filter plant	McMillan filter plant
Silver (Ag)	<0.25	<0.28	<0.27
Aluminum (Al)	200	300	160
Boron (B)	20	22	15
Barium (Ba)	85	86	82
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	4.0	6.6	.49
Copper (Cu)	4.0	3.3	36
Iron (Fe)	280	83	30
Lithium (Li)	1.8	1.8	1.7
Manganese (Mn)	100	20	3.3
Molybdenum (Mo)	1.8	2.2	2.3
Nickel (Ni)	7.8	8.3	8.5
Phosphorus (P)	ND	ND	ND
Lead (Pb)	4.8	5.8	5.2
Rubidium (Rb)	<2.5	<2.8	<2.7
Tin (Sn)	ND	ND	ND
Strontium (Sr)	190	210	210
Titanium (Ti)	5.2	3.0	<2.7
Vanadium (V)	<7.5	<8.3	<8.2
Zinc (Zn)	ND	ND	ND

FLORIDA

Jacksonville
Miami
St. Petersburg
Tampa

JACKSONVILLE

Ownership: Municipal.

Population served: Jacksonville, 201,030; about 45,000 outside the city limits; total, about 247,000.

Source of supply: Forty-eight artesian wells ranging in depth from 1,000 to 1,300 feet.

Average amount of water used daily in system during 1962: 36.7 mgd (U.S. Public Health Service, 1962c).

Treatment: Aeration and chlorination at each pumping station.

Finished-water storage: Ground reservoirs, 19 million gal; two elevated tanks, each containing 1 million gal; three elevated tanks, each containing 0.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—Jacksonville

	Well 7	Chlorination plant
Percent of supply	100	100
Depth of well (feet)	1,250	----
Diameter of well (inches)	10	----
Date drilled	1907	----
Date of collection	8–29–61	8–9–61
Type of water: R, raw; F, finished	R	F

Chemical analyses

[In parts per million]

	Well 7	Chlorination plant
Silica (SiO_2)	26	25
Iron (Fe)	.15	.03
Calcium (Ca)	60	65
Magnesium (Mg)	22	23
Sodium (Na)	14	14
Potassium (K)	1.6	1.8
Bicarbonate (HCO_3)	187	179
Carbonate (CO_3)	0	0
Sulfate (SO_4)	87	112
Chloride (Cl)	17	18
Fluoride (F)	.7	.8
Nitrate (NO_3)	.0	.2
Dissolved solids (residue at 180°C)	373	410
Hardness as $CaCO_3$	240	256
Noncarbonate hardness as $CaCO_3$	87	110
Specific conductance (micromhos at 25°C)	504	535
pH	7.9	7.9
Color	5	5
Temperature °F	----	77

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Well 7	Chlorination plant
Beta activity	----	4.7
Radium (Ra)	----	.3
Uranium (U)	----	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Well 7	Chlorination plant
Silver (Ag)	ND	<0.49
Aluminum (Al)	11	18
Boron (B)	34	36
Barium (Ba)	15	30
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	.71	.74
Copper (Cu)	.85	30
Iron (Fe)	320	98
Lithium (Li)	1.1	2.0
Manganese (Mn)	ND	<4.9
Molybdenum (Mo)	ND	ND
Nickel (Ni)	<4.7	ND
Phosphorus (P)	ND	ND
Lead (Pb)	ND	<4.9
Rubidium (Rb)	ND	ND
Tin (Sn)	ND	ND
Strontium (Sr)	400	840
Titanium (Ti)	ND	ND
Vanadium (V)	ND	ND
Zinc (Zn)	<470	ND

MIAMI

(See fig. 26.)

Ownership: Municipal.

Other areas served: El Portal, Miami Shores, Hialeah, Miami Springs, West Miami, Miami Beach, Surfside, Bal Harbour, Bay Harbor Islands, North Bay, Coral Gables, South Miami, Key Biscayne, Virginia Key, Fisher Island, Indian Creek, South Westside, North Bay Island, and Miami airport.

Population served: Miami, 291,688; total, about 550,000.

Sources and percentages of supply: Forty percent of the supply is from two well fields near the Hialeah treatment plant: the two well fields contain twenty-three 12- or 14-inch wells averaging about 90 feet deep. Sixty percent of the supply is from 17 wells at the Alexander Orr, Jr., treatment plant.

Auxiliary and emergency supplies: Seven wells equipped with diesel engines and standby diesel driven pumps are available for high pressure service.

Average amount of water used daily in system during 1962: 102 mgd (U.S. Public Health Service, 1962c).

Treatment:

Hialeah treatment plant: Softening with lime and sodium silicate, sedimentation, iron and color removal, recarbonation, chlorination, fluoridation, and rapid sand filtration.

Orr treatment plant: Softening with lime, iron and color removal, recarbonation, chlorination, and rapid sand filtration.

Rated capacity of treatment plants: Hialeah treatment plant, 60 mgd; Orr treatment plant, 85 mgd.

Raw-water storage: None.

Finished-water storage: Clear wells, 12 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Average regular determinations at treatment plants, 1960–61:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Hialeah:												
Raw water	225	228	220	7.3	7.3	7.3	244	250	240	0	0	0
Finished water	36	60	30	9.0	9.9	8.0	75	85	75	0	0	0
Orr:												
Raw water	207	212	200	7.3	------	------	227	232	222	0	0	0
Finished water	31	45	24	8.8	9.2	8.5	51	66	44	0	0	0

Analytical data—Miami

	Hialeah well fields		Hialeah treatment plant		Orr well field		Orr treatment plant	
Percent of supply	40	--	40	--	60	--	60	--
Date of collection	8-23-61	(1)	(1)	8-23-61	8-23-61	(1)	(1)	8-23-61
Type of water: R, raw; F, finished	R	R	F	F	R	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	9.5	8.5	9.0	--	4.3	5.3	7.0	--
Iron (Fe)	.33	1.7	.00	--	.00	.80	.05	--
Calcium (Ca)	88	85	22	--	82	8[illegible]	20	--
Magnesium (Mg)	5.0	7.3	4.8	--	1.8	2.0	2.0	--
Sodium (Na)	22	} 22	23	--	{ 7.8	} 12	13	--
Potassium (K)	1.6			--	.4			--
Bicarbonate (HCO_3)	272	275	32	--	248	256	45	--
Carbonate (CO_3)	0	--	4	--	0	0	1	--
Sulfate (SO_4)	16	25	26	--	15	2[illegible]	24	--
Chloride (Cl)	30	31	42	--	12	15	16	--
Fluoride (F)	.3	.2	1.0	--	.1	.1	1.0	--
Nitrate (NO_3)	.1	.5	.3	--	.6	.3	.3	--
Dissolved solids (residue at 180°C)	333	340	185	--	263	290	110	--
Hardness as $CaCO_3$	240	244	75	--	212	--	--	--
Noncarbonate hardness as $CaCO_3$	17	--	39	--	9	--	--	--
Specific conductance (micromhos at 25°C)	530	--	--	--	444	--	--	--
pH	7.8	7.3	9.0	--	7.7	7.3	8.7	--
Color	45	44	8	--	5	6	5	--
Turbidity	--	--	0	--	--	--	--	--

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	--	--	--	2.7	--	--	--	5.2
Radium (Ra)	--	--	--	.1	--	--	--	.1
Uranium (U)	--	--	--	.2	--	--	--	.2

Spectrographic analyses

[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND looked for but not found]

Silver (Ag)	<0.50	--	--	ND	ND	--	--	<0.14
Aluminum (Al)	12	--	--	13	6.9	--	--	110
Boron (B)	71	--	--	49	8.5	--	--	49
Barium (Ba)	21	--	--	13	5.7	--	--	17
Beryllium (Be)	ND	--	--	ND	ND	--	--	ND
Cobalt (Co)	ND	--	--	ND	ND	--	--	ND
Chromium (Cr)	ND	--	--	ND	ND	--	--	6.6
Copper (Cu)	2.2	--	--	1.5	1.4	--	--	1.6
Iron (Fe)	230	--	--	29	450	--	--	13
Lithium (Li)	.50	--	--	.70	<.41	--	--	.36
Manganese (Mn)	35	--	--	25	<4.1	--	--	<1.4
Molybdenum (Mo)	2.8	--	--	1.4	ND	--	--	<4.3
Nickel (Ni)	ND	--	--	59	<4.1	--	--	1.4
Phosphorus (P)	ND	--	--	ND	ND	--	--	ND
Lead (Pb)	31	--	--	ND	4.1	--	--	2.3
Rubidium (Rb)	ND	--	--	<2.0	ND	--	--	ND
Tin (Sn)	ND	--	--	ND	ND	--	--	ND
Strontium (Sr)	490	--	--	250	280	--	--	160
Titanium (Ti)	<5.0	--	--	ND	ND	--	--	<1.4
Vanadium (V)	ND	--	--	70	ND	--	--	ND
Zinc (Zn)	ND	--	--	ND	ND	--	--	ND
Zirconium (Zr)	--	--	--	--	ND	--	--	X

[1] Average analyses by the city of Miami for 1960–61.

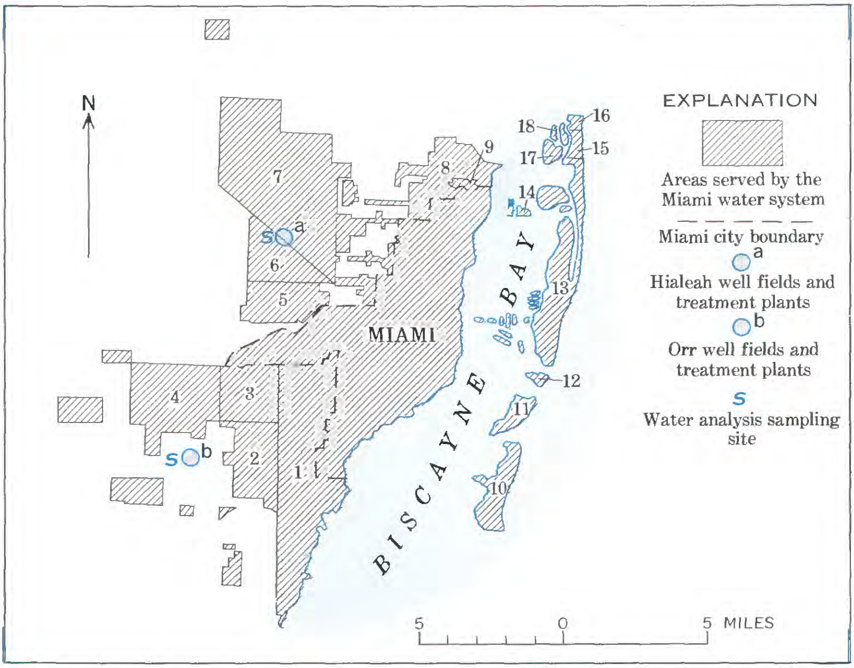

FIGURE 26.—Water supplies and areas served by Miami, Fla., water system. (Approved by local municipal water officials, May 1963.) Areas served by the Miami water system: 1, Coral Gables; 2, South Miami; 3, West Miami; 4, South Westside; 5, Airport; 6, Miami Springs; 7, Hialeah; 8, Miami Shores; 9, El Portal; 10, Key Biscayne; 11, Virginia Key; 12, Fisher Island; 13, Miami Beach; 14, North Bay Island; 15, Surfside; 16, Bal Harbour; 17, Indian Creek; 18, Bay Harbor Islands.

ST. PETERSBURG

Ownership: Municipal.

Other areas served: Gulfport, Pinellas Park, Oldsmar, and Bay Pines Hospital.

Population served: St. Petersburg, 225,000; total, about 250,000 (estimated, 1961).

Source of supply: Twenty-three wells ranging in depth from 300 to 417 feet near Cosme in northwestern part of Hillsborough County. Ten new wells are now being developed.

Average amount of water used daily in system during 1962: 18.1 mgd (U.S. Public Health Service, 1962c).

Treatment: Cosme treatment plant—softening with lime, coagulation with suspension catalyzer, sedimentation, rapid sand filtration, and chlorination.

Rated capacity of treatment plant: Cosme treatment plant, 23 mgd.

Finished-water storage: 17.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.0.

Regular determinations at Cosme treatment plant:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	190	200	180	7.3	------	------	195	200	190	------	------	------
Finished water	90	100	88	7.7	7.8	7.5	92	95	90	7	10	5

Analytical data—St. Petersburg

	Cosme well field	Treatment plant	
Percent of supply	100	100	----------
Date of collection	8-21-61	8-21-61	9-11-61
Type of water: R, raw; F, finished	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	14	----------	15
Iron (Fe)	.01	----------	.12
Calcium (Ca)	70	----------	33
Magnesium (Mg)	3.3	----------	3.3
Sodium (Na)	6.1	----------	6.2
Potassium (K)	.7	----------	.6
Bicarbonate (HCO_3)	232	----------	106
Carbonate (CO_3)	0	----------	0
Sulfate (SO_4)	.8	----------	3.2
Chloride (Cl)	10	----------	16
Fluoride (F)	.1	----------	.2
Nitrate (NO_3)	.7	----------	.4
Dissolved solids (residue at 180°C)	229	----------	152
Hardness as $CaCO_3$	188	----------	96
Noncarbonate hardness as $CaCO_3$	0	----------	9
Specific conductance (micromhos at 25°C)	382	----------	219
pH	7.6	----------	7.5
Color	10	----------	5

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	----------	9.9	----------
Radium (Ra)	----------	.4	----------
Uranium (U)	----------	.1	----------

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	ND	<0.21	ND
Aluminum (Al)	13	130	73
Boron (B)	13	56	75
Barium (Ba)	14	13	5.1
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	<.36	ND	.26
Copper (Cu)	.8	.73	.79
Iron (Fe)	79	56	77
Lithium (Li)	.7	1.0	1.4
Manganese (Mn)	<3.6	6.6	3.0
Molybdenum (Mo)	ND	ND	ND
Nickel (Ni)	<3.6	ND	ND
Phosphorus (P)	ND	ND	ND
Lead (Pb)	ND	ND	<2.0
Rubidium (Rb)	ND	<2.1	ND
Tin (Sn)	ND	ND	ND
Strontium (Sr)	97	68	73
Titanium (Ti)	ND	ND	ND
Vanadium (V)	ND	ND	ND
Zinc (Zn)	ND	ND	ND

TAMPA

Ownership: Municipal.

Population served: About 290,000 including a suburban population of 10,000.

Sources and percentages of supply: Hillsborough River, 97 percent; a few wells, 3 percent. Water from the wells is used only when the flow of the river is not sufficient to supply the demand. A new well field will be put into use in the future, and the present small well field will be abandoned.

Auxiliary and emergency supplies: Sulfur Springs (20 mgd) and a new well field 14 miles east of the city (about 50 mgd), when completed.

Lowest mean discharge: Hillsborough River near Tampa, Fla., for 30-day period in climatic water years (April 1–March 31) 1950–60: 8.0 mgd.

Average amount of water used daily in system during 1962: 29.6 mgd (U.S. Public Health Service, 1962c).

Treatment: Tampa water works—treatment varies from season to season compensating for additional color in times of heavy rains and for increases in hardness. Basic treatment is coagulation with alum; addition of lime, chlorine, and carbon; and rapid sand filtration.

Rated capacity of treatment plant: Tampa waterworks plant, 60 mgd.

Raw-water storage: Lake at 30th Street, 2,500 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 84.

Finished-water storage: Underground storage, 15 million gal; elevated tanks, 9.6 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Remarks: Tampa has completed a 2 million dollar expansion program that is expected to make sufficient water available to the city until at least 1980. Filter capacity has been increased by 25 mgd. A new and more efficient washing system for the filters has been initiated.

For future supplies—that is, beyond 1980—Tampa is looking hopefully to the Green Swamp area, east of the city, which is currently being studied.

Regular determinations at Tampa water works, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	105	125	83	7.7	8.2	7.1	125	148	93	0.23	0.50	0.10
Finished water	72	84	57	8.4	8.7	8.1	115	148	94	------	------	------

Analytical data—Tampa

	Hillsborough River	Tampa water works
Percent of supply	97	97
Date of collection	1-12-62	1-12-62
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	7.8	6.5
Iron (Fe)	.03	.01
Manganese (Mn)	.00	.00
Calcium (Ca)	55	51
Magnesium (Mg)	5.6	5.1
Sodium (Na)	8.0	8.2
Potassium (K)	1.5	1.7
Bicarbonate (HCO_3)	150	98
Carbonate (CO_3)	0	4
Sulfate (SO_4)	28	48
Chloride (Cl)	16	18
Fluoride (F)	.2	.2
Nitrate (NO_3)	1.0	1.4
Dissolved solids (residue at 180° C)	214	212
Hardness as $CaCO_3$	160	148
Noncarbonate hardness as $CaCO_3$	37	11
Specific conductance (micromhos at 25° C)	339	326
pH	8.1	8.4
Color	25	2
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity	----------	6.3
Radium (Ra)	----------	<.1
Uranium (U)	----------	.4
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	----------	0.55
Aluminum (Al)	----------	730
Boron (B)	----------	29
Barium (Ba)	----------	14
Beryllium (Be)	----------	ND
Cobalt (Co)	----------	ND
Chromium (Cr)	----------	5.7
Copper (Cu)	----------	4.4
Iron (Fe)	----------	170
Lithium (Li)	----------	<.26
Manganese (Mn)	----------	2.9
Molybdenum (Mo)	----------	6.2
Nickel (Ni)	----------	7.0
Phosphorus (P)	----------	ND
Lead (Pb)	----------	3.9
Rubidium (Rb)	----------	ND
Tin (Sn)	----------	ND
Strontium (Sr)	----------	240
Titanium (Ti)	----------	3.6
Vanadium (V)	----------	10
Zinc (Zn)	----------	ND

ATLANTA

(See fig. 27.)

Ownership: Municipal.
Other areas served: Forest Park, Fairburn, Hapeville, Union City, and other areas of Fulton County.
Population served: Atlanta, 487,455; total, 600,000.
Source of supply: Chattahoochee River.
Average amount of water used daily in system during 1962: 68.2 mgd (U.S. Public Health Service, 1962c).
Treatment:
Hemphill filter plant: Coagulation with alum, chlorination, ammoniation, treatment with activated carbon, sedimentation, adjustment of pH with lime, and rapid sand filtration.
Chattahoochee River plant: Same as Hemphill plant, except prechlorination and postchlorination also are used.
Rated capacity of treatment plants: Hemphill filter plant, 72.5 mgd. Chattahoochee River plant, 20 mgd.
Raw-water storage: 500 million gal.
Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 7.3.
Finished-water storage: 30.5 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Hemphill filter plant, 1956–60:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	14	16	10	7.0	7.3	6.6	14	16	10	27	200	5
Finished water	16	22	14	8.7	------	------	22	25	20	.1	.1	.0

Analytical data—Atlanta

	Chattahoochee River [1]	Hemphill filter plant [1]		Chattahoochee River [1]	Hemphill filter plant [1]
Percent of supply	100	100	Type of water: R, raw; F, finished	R	F
Date of collection	8-31-61	8-31-61			

Chemical analyses

[In parts per million]

Silica (SiO_2)	8.0	8.2	Dissolved solids (residue at 180° C)	31	44
Iron (Fe)	.07	.00	Hardness as $CaCO_3$	12	23
Calcium (Ca)	2.8	8.0	Noncarbonate hardness as $CaCO_3$	0	6
Magnesium (Mg)	1.2	.7			
Sodium (Na)	2.3	2.2			
Potassium (K)	1.0	1.2			
Bicarbonate (HCO_3)	15	21			
Carbonate (CO_3)	0	0	Specific conductance (micromhos at 25° C)	42	69
Sulfate (SO_4)	.0	8.4	pH	6.6	6.9
Chloride (Cl)	5.0	5.0	Color	10	5
Fluoride (F)	.1	.2	Temperature °F	64	71
Nitrate (NO_3)	.1	.5			

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity	----------	3.3	Radium (Ra)	----------	<0.1
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	13	----------	Uranium (U)	----------	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND, looked for but not found]

Silver (Ag)	<0.03	0.07	Phosphorus (P)	ND	ND
Aluminum (Al)	130	32	Lead (Pb)	8.7	3.5
Boron (B)	68	8.8	Rubidium (Rb)	2.5	5.3
Barium (Ba)	11	29	Tin (Sn)	ND	ND
Beryllium (Be)	ND	ND	Strontium (Sr)	2.4	18
Cobalt (Co)	<.3	ND	Titanium (Ti)	9.6	.7
Chromium (Cr)	.59	.88	Vanadium (V)	ND	ND
Copper (Cu)	84	3.1	Zinc (Zn)	ND	ND
Iron (Fe)	120	12	Ytterbium (Yb)	.0X	ND
Lithium (Li)	.08	<.04	Yttrium (Y)	.X	ND
Manganese (Mn)	27	9.2	Zirconium (Zr)	.X	ND
Molybdenum (Mo)	ND	ND	Gallium (Ga)	.0X	ND
Nickel (Ni)	1.2	.7			

[1] Spectrographic concentrations based on nonacidified residue on evaporation.

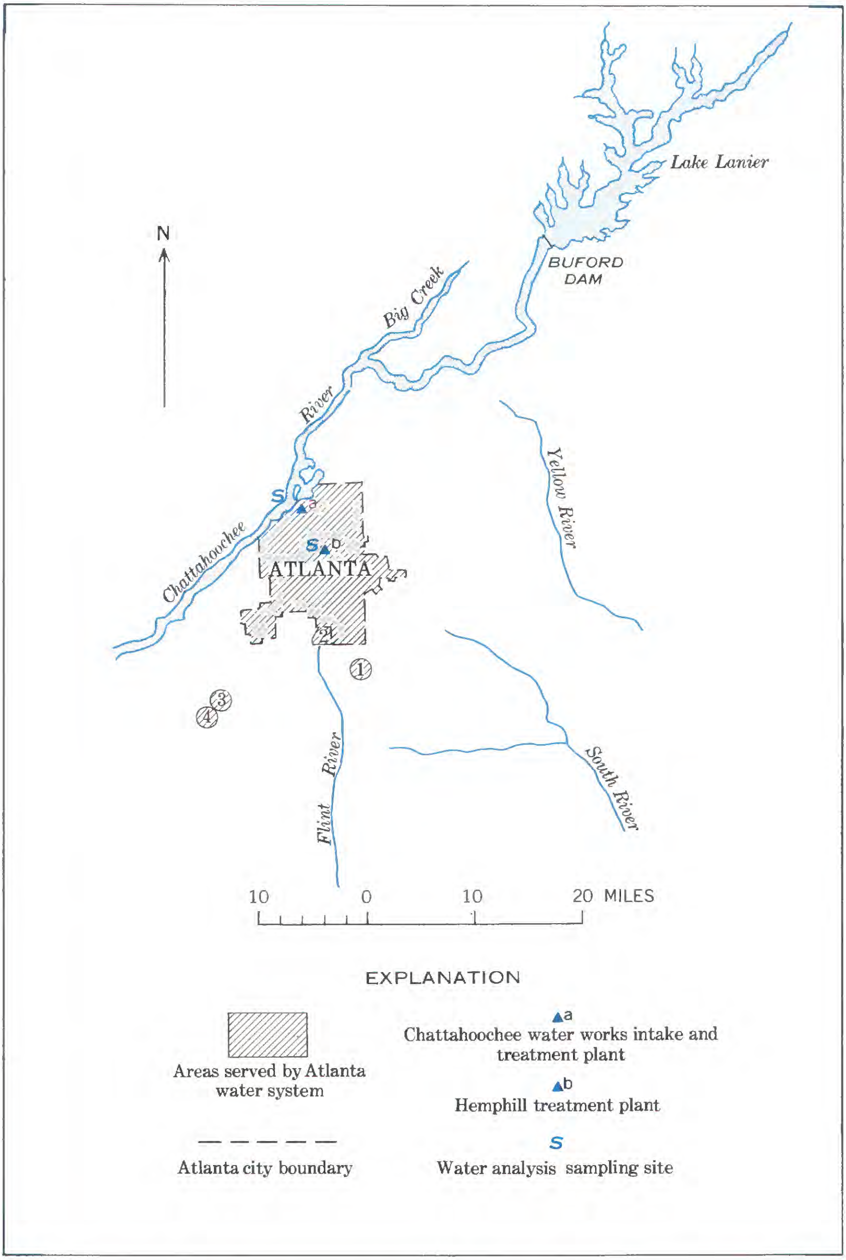

FIGURE 27.—Water supplies and areas served by Atlanta, Ga., water system. (Approved by local municipal water officials, June 1963.) Areas served by the Atlanta water system: 1, Forest Park; 2, Hapeville; 3, Union City; 4, Fairburn.

SAVANNAH

Ownership: Municipal.

Other areas served: Garden City and Hunter Air Force Base during emergencies.

Population served: Savannah, 149,245; total, 170,000.

Sources of supply: Domestic supply obtained from 14 artesian wells ranging in depth from 525 to 1,000 feet; most wells are 650–700 feet deep and yield from 700 to 3,500 gpm.

Abercorn Creek is the source for the Savannah industrial and domestic water supply. This separate system supplies industries with softer water than is available from the principal artesian aquifer. Smaller amounts are used by Savannah during emergencies.

Auxiliary and emergency supplies: Interconnected with Savannah industrial and domestic supply, but the connection is used only during emergencies.

Average amount of water used daily in system during 1962: 55 mgd (U.S. Public Health Service, 1962c).

Treatment:

Cherokee Hill treatment plant (Abercorn Creek): Coagulation with alum, sedimentation, rapid sand filtration, prechlorination, and postchlorination.

Ground water is chlorinated at pumps.

Rated capacity of treatment plant: Cherokee Hill treatment plant, 50 mgd.

Finished-water storage: Industrial and domestic water system: Elevated storage, 10 million gal; reservoir, 4 million gal; clear well, 3 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Cherokee Hill treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	17	19	15	6.6	6.8	6.4	18	20	16	30	43	21
Finished water	25	28	21	8.2	8.3	8.1	39	43	33	1.3	2.5	.3

Analytical data—Savannah

	Abercorn Creek [1]	Cherokee Hill treatment plant	Well 2
Percent of supply	100	100	100
Depth of well (feet)			540
Date of collection	8-30-61	8-30-61	8-30-61
Type of water: R, raw; F, finished	R	F	R

Chemical analyses
[In parts per million]

	Abercorn Creek [1]	Cherokee Hill treatment plant	Well 2
Silica (SiO_2)	10	9.4	53
Iron (Fe)	.27	.00	.02
Calcium (Ca)	4.0	18	28
Magnesium (Mg)	.9	1.1	8.3
Sodium (Na)	3.5	4.2	9.0
Potassium (K)	1.0	1.0	1.7
Bicarbonate (HCO_3)	18	35	133
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	5.2	16	7.2
Chloride (Cl)	4.5	9.5	6.0
Fluoride (F)	.2	.2	.5
Nitrate (NO_3)	.7	.3	.0
Dissolved solids (residue at 180° C)	53	91	184
Hardness as $CaCO_3$	14	50	104
Noncarbonate hardness as $CaCO_3$	0	21	0
Specific conductance (micromhos at 25° C)	45	129	236
pH	6.6	7.3	8.0
Color	115	5	5
Temperature °F		78	73

Radiochemical analyses
[Beta activity and radium in picocuries per liter; urnaium in micrograms per liter; <, less than]

	Abercorn Creek [1]	Cherokee Hill treatment plant	Well 2
Beta activity		6.0	
Radium (Ra)		.1	
Uranium (U)		<.1	

Spectrographic analyses
[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND, looked for but not found]

	Abercorn Creek [1]	Cherokee Hill treatment plant	Well 2
Silver (Ag)	<0.05	<0.11	<0.26
Aluminum (Al)	110	160	2.9
Boron (B)	32	16	10
Barium (Ba)	12	42	13
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	.69	1.3	.31
Copper (Cu)	24	2.5	1.8
Iron (Fe)	140	50	15
Lithium (Li)	.12	.16	1.4
Manganese (Mn)	21	150	<2.6
Molybdenum (Mo)	ND	ND	ND
Nickel (Ni)	.9	1.1	ND
Phosphorus (P)	ND	ND	ND
Lead (Pb)	12	<1.1	<2.6
Rubidium (Rb)	1.6	3.4	3.7
Tin (Sn)	ND	ND	ND
Strontium (Sr)	2.0	26	39
Titanium (Ti)	3.5	1.1	ND
Vanadium (V)	ND	ND	ND
Zinc (Zn)	ND	ND	<262
Ytterbium (Yb)	.0X	X	ND
Yttrium (Y)	.X	X	ND
Zirconium (Zr)	.X	ND	ND

[1] Spectrographic concentrations based on nonacidified residue on evaporation.

735-717 O—64——11

HAWAII

Honolulu

HONOLULU

(See fig. 28.)

Ownership: Municipal.

Population served: Honolulu, 294,179; total, 405,000.

Sources and percentages of supply: Three artesian-well pumping stations, 49 percent; three underground pumping stations, 47 percent; seven spring and mountain tunnel systems, 4 percent. Emergency supply, two connections with the U.S. Navy water system. The three artesian-well groups include 25 wells ranging in depth from 240 to 636 feet.

Average amount of water used daily in system during 1962: 62.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Six of the seven mountain sources are regularly chlorinated. The artesian-well and underground pumping stations are equipped with chlorinators, which are not regularly used.

Finished-water storage: 32 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—Honolulu

	Kaimuki pumping station	Beretania pumping station	Kalihi underground station
Percent of supply	13	23	21
Depth of well (feet)	300	600	----------
Diameter of well (inches)	12	12	----------
Date drilled	1928	1926	1937
Date of collection	8-29-62	8-29-62	8-29-62
Type of water: R, raw	R	R	R

Chemical analyses

[In parts per million]

Silica (SiO_2)	39	41	42
Iron (Fe)	.74	.03	.03
Manganese (Mn)	.00	.00	.00
Aluminum (Al)	.05	.00	.27
Lithium (Li)	.00	.00	.00
Calcium (Ca)	5.9	8.7	3.2
Magnesium (Mg)	6.6	9.2	15
Sodium (Na)	64	35	34
Potassium (K)	2.9	3.2	3.2
Bicarbonate (HCO_3)	81	78	62
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	14	8.6	9.0
Chloride (Cl)	76	45	63
Fluoride (F)	.0	.1	.0
Nitrate (NO_3)	.7	.0	1.0
Phosphate (PO_4)	.24	.08	.12
Dissolved solids (residue at 180°C)	251	184	215
Hardness as $CaCO_3$	42	60	70
Noncarbonate hardness as $CaCO_3$	0	0	19
Specific conductance (micromhos at 25°C)	388	289	312
pH	6.7	7.0	6.6

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	1.8	2.6	4.6
Radium (Ra)	<.1	<.1	<.1
Uranium (U)	<.1	<.1	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.34	<0.26	<0.29
Aluminum (Al)	6.7	7.9	5.5
Boron (B)	24	28	35
Barium (Ba)	5.4	4.6	13
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	1.1	1.1	1.1
Copper (Cu)	1.3	3.1	8.4
Iron (Fe)	15	15	21
Lithium (Li)	.74	.56	<.29
Manganese (Mn)	ND	ND	3.7
Molybdenum (Mo)	ND	<.77	ND
Nickel (Ni)	ND	<2.6	<2.9
Phosphorus (P)	ND	ND	ND
Lead (Pb)	.6	4.9	5.8
Rubidium (Rb)	<3.4	3.3	3.7
Tin (Sn)	ND	ND	ND
Strontium (Sr)	50	67	60
Titanium (Ti)	<1.0	<.8	1.0
Vanadium (V)	11	7.9	12
Zinc (Zn)	ND	ND	ND

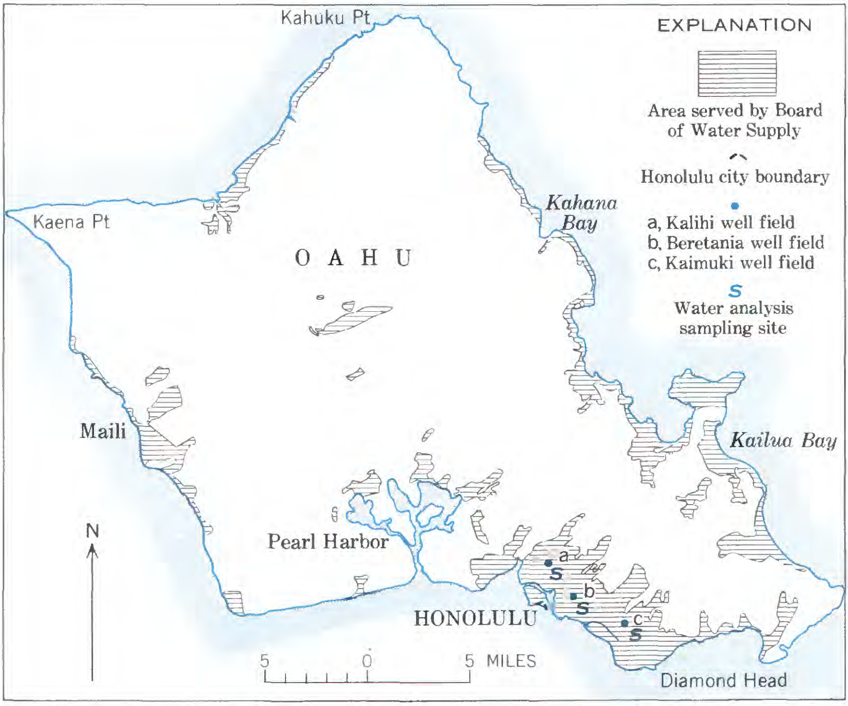

FIGURE 28.—Water supplies and areas served by Honolulu, Hawaii, water system. (Adapted from Honolulu Board of Water Supply, 1963.)

CHICAGO

(See fig. 29.)

Ownership: Municipal.

Other areas served: Fifty-eight municipalities outside the city limits, including Berwyn, Blue Island, Brookfield, Calumet City, Cicero, Elmwood Park, Evergreen Park, Harvey, Maywood, Melrose Park, Morton Grove, Niles, Oak Lawn, Oak Park, Park Ridge, South Stickney Sanitary District, and Skokie.

Population served: Chicago, 3,500,000; total, about 4,423,000.

Source of supply: Lake Michigan. The city is divided into three water districts: North District, Central District, and South District. The North District is supplied by Wilson Avenue Crib intake, 2.1 miles offshore at Wilson Avenue; the Central District, which is north of 39th Street, is supplied by Four Mile Crib, 3.2 miles offshore at 14th Street, and William E. Dever Crib, 2.7 miles offshore at Chicago Avenue; the South District filtration plant, which is supplied by Edward F. Dunne Crib, 2 miles offshore at 68th Street, supplies the South District, which is the area south of 39th Street. The system has a total of 10 pumping stations.

Average amount of water used daily in system during 1962: 1,030 mgd (U.S. Public Health Service, 1962c).

Treatment:

South District filtration plant (three pumping stations): Prechlorination, fluoridation, coagulation with alum and ferrous sulfate (and acid-treated sodium silicate in winter months), activated carbon, lime for corrosion control, sedimentation, rapid sand filtration, and postchlorination with ammonia and chloramine.

North and Central Districts (seven pumping stations): Chlorination and fluoridation. Chlorination equipment is at each pumping station. Fluoridation equipment is at two pumping stations applying fluorine to water in tunnels serving the seven North and Central District pumping stations.

Rated capacity of treatment plants: South District filtration plant, 320 mgd. A new plant, the Central filtration plant, to supply an area north of 39th Street was 64 percent complete at the end of 1960. It will have a capacity of 960 mgd.

Finished-water storage: South District filtration plant: Clear wells, 14.6 million gal; reservoirs, 32.3 million gal. A south-side pumping station: Ground storage, 30 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at South District filtration plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	108	116	102	8.3	8.5	8.0	134	140	130	15	160	1
Finished water	102	106	95	7.8	8.0	7.6	138	144	132	.0	.1	.0

Suburban areas shown in figure 29

Wilson Avenue Crib System:
N1 Golf
N2 Morton Grove
N3 Skokie
N4 Lincolnwood
N5 Niles
N6 Park Ridge
N7 Harwood Heights
N8 Norridge
N9 Schiller Park
N10 Franklin Park
N11 River Grove
N57 Rosemont

Dever Crib System:
C12 Elmwood Park
C13 Melrose Park
C14 Maywood
C15 River Forest
C16 Oak Park
C17 Forest Park
C18 Broadview
C19 Westchester
C20 Lagrange Park
C21 Brookfield
C22 North Riverside
C23 Riverside
C24 McCook
C25 Berwyn
C26 Cicero
C50 Hillside
C51 Burkeley
C52 Leyden Township
C54 Lyons
C55 North Lake
C57 Stone Park

South District Filtration Plant:
S27 Stickney
S28 Forest View
S29 Summit
S30 Bedford Park
S31 Evergreen Park
S32 Oaklawn
S33 Merrionette Park
S34 Blue Island
S35 Robbins
S36 Midlothian
S37 Harvey
S38 Posen
S39 Dixmoor
S40 Marxham
S41 Hazelcrest
S42 Phoenix
S43 South Holland
S44 Calumet Park
S45 Riverdale
S46 Dolton
S47 Burnham
S48 Calumet City
S49 Hometown
S53 South Stickney
S58 Alsip
S59 Bridgeview
S60 East Hazelcrest

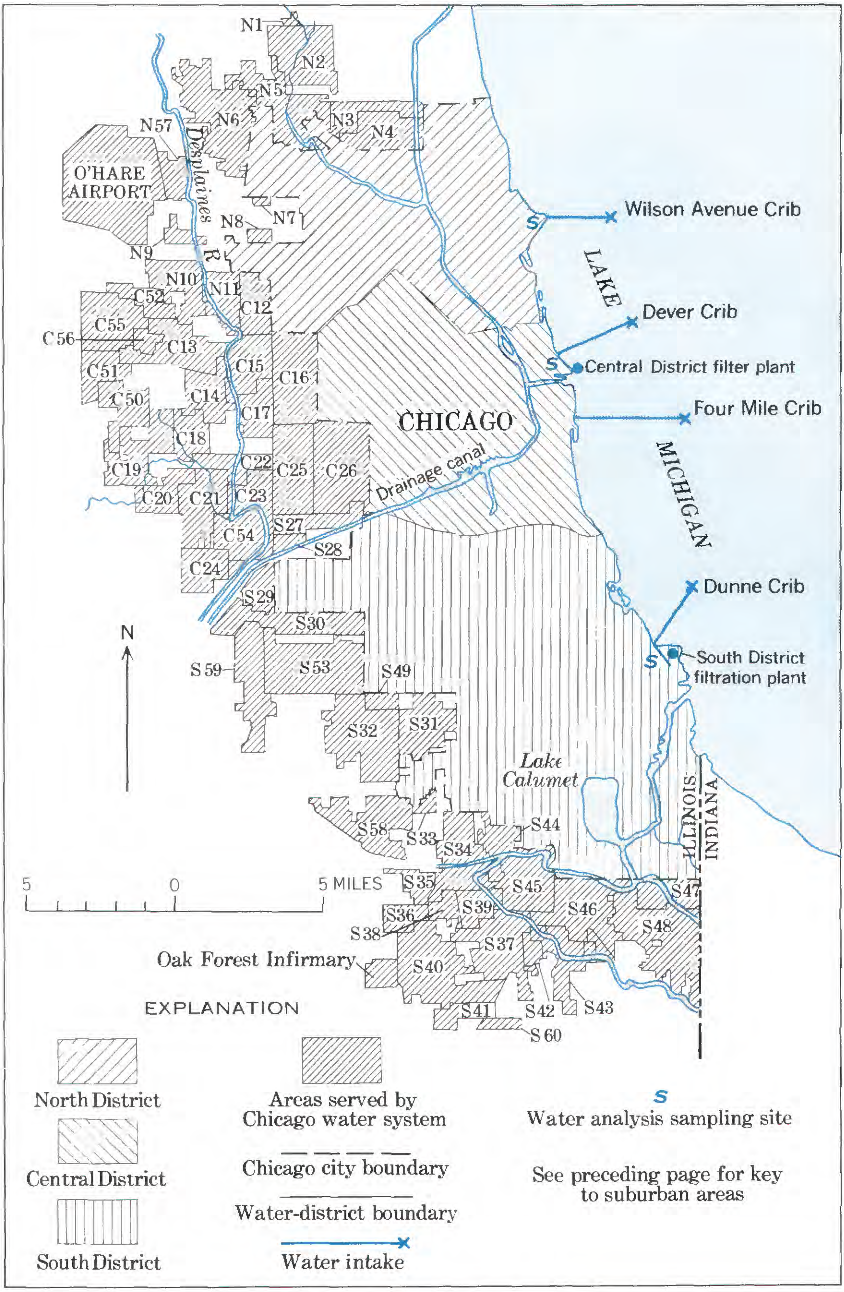

FIGURE 29.—Water supplies and areas served by Chicago, Ill., water system. (Modified from Chicago Dept. of Water and Sewers, 1961. Approved by local municipal water officials, April 1963.)

Analytical data—Chicago

	Lake Michigan		Chicago Avenue Station (Central District)	Lake View Station (North District)	South District filtration plant	
Percent of supply	100	----------	46	20	34	----------
Date of collection	8-25-61	[1] 2-16-61	8-24-61	8-25-61	8-25-61	[1] 2-16-61
Type of water: R, raw; F, finished	R	R	F	F	F	F

Chemical analyses

[In parts per million]

	Lake Michigan 8-25-61 R	Lake Michigan 2-16-61 R	Chicago Avenue Station 8-24-61 F	Lake View Station 8-25-61 F	South District 8-25-61 F	South District 2-16-61 F
Silica (SiO_2)	1.1	1.8	1.3	1.2	1.2	2.2
Iron (Fe)	.03	----------	.05	.06	.04	----------
Manganese (Mn)	.07	.01	.09	.03	.06	.01
Calcium (Ca)	33	31	32	32	35	33
Magnesium (Mg)	11	9.7	11	11	11	10
Sodium (Na)	3.9	3.0	4.0	4.0	4.2	3.3
Potassium (K)	.7	1.2	.8	.8	1.0	1.4
Arsenic (As)	----------	.005	----------	----------	----------	.005
Boron (B)	----------	.03	----------	----------	----------	.02
Chromium (Cr)	----------	.003	----------	----------	----------	----------
Copper (Cu)	----------	.04	----------	----------	----------	.01
Lead (Pb)	----------	.005	----------	----------	----------	.005
Lithium (Li)	----------	.01	----------	----------	----------	.01
Strontium (Sr)	----------	.01	----------	----------	----------	.01
Zinc (Zn)	----------	.02	----------	----------	----------	.03
Bicarbonate (HCO_3)	132	132	128	128	126	123
Carbonate (CO_3)	0	2	0	0	0	0
Sulfate (SO_4)	20	21	20	20	26	24
Chloride (Cl)	6.5	7.0	8.0	8.0	9.0	12
Fluoride (F)	.1	.1	1.0	.8	.9	.8
Nitrate (NO_3)	.4	.5	.4	.3	.4	.5
Phosphate (PO_4)	----------	.015	----------	----------	----------	----------
Dissolved solids (residue at 180° C)	153	159	149	154	168	161
Hardness as $CaCO_3$	128	117	125	125	133	125
Noncarbonate hardness as $CaCO_3$	20	----------	20	20	30	----------
Specific conductance (micromhos at 25 °C)	259	280	261	259	277	292
pH	7.8	8.3	7.5	7.3	7.5	7.9
Color	1	8	2	1	1	2
Turbidity	----------	3	----------	2	----------	----------
Temperature °F	71	38	70	71	71	40

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Lake Michigan 8-25-61 R	Lake Michigan 2-16-61 R	Chicago Avenue Station 8-24-61 F	Lake View Station 8-25-61 F	South District 8-25-61 F	South District 2-16-61 F
Beta activity	----------	----------	8.2	3.2	2.9	----------
Radium (Ra)	----------	----------	.1	<.1	<.1	----------
Uranium (U)	----------	----------	.1	.1	.2	----------

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Lake Michigan 8-25-61 R	Lake Michigan 2-16-61 R	Chicago Avenue Station 8-24-61 F	Lake View Station 8-25-61 F	South District 8-25-61 F	South District 2-16-61 F
Silver (Ag)	<0.2	----------	<0.25	<0.24	<0.27	----------
Aluminum (Al)	72	----------	40	45	350	----------
Boron (B)	7.8	----------	12	15	21	----------
Barium (Ba)	80	----------	30	36	40	----------
Beryllium (Be)	ND	----------	ND	ND	ND	----------
Cobalt (Co)	ND	----------	ND	ND	ND	----------
Chromium (Cr)	1.6	----------	.75	.43	.54	----------
Copper (Cu)	24	----------	7.5	57	1.3	----------
Iron (Fe)	14	----------	52	55	67	----------
Lithium (Li)	.75	----------	.38	1.0	1.2	----------
Manganese (Mn)	<2	----------	4.2	2.9	4.3	----------
Molybdenum (Mo)	<.8	----------	1.9	1.8	2.3	----------
Nickel (Ni)	3.2	----------	3.0	7.4	<2.7	----------
Phosphorus (P)	ND	----------	ND	ND	ND	----------
Lead (Pb)	14	----------	2.5	4.5	4.8	----------
Rubidium (Rb)	ND	----------	ND	ND	ND	----------
Tin (Sn)	ND	----------	ND	ND	ND	----------
Strontium (Sr)	80	----------	120	91	120	----------
Titanium (Ti)	<2	----------	<2.5	<2.4	<2.7	----------
Vanadium (V)	ND	----------	ND	ND	ND	----------
Zinc (Zn)	ND	----------	<250	<240	ND	----------

[1] Analyses by the city of Chicago.

ROCKFORD

Ownership: Municipal.

Population served: Rockford, 128,075; about 4,000 outside the city limits; total, about 132,000.

Source of supply: Thirty-one drilled wells of which 22 are normally used. The wells range in depth from 235 to about 1,600 feet. Six are group wells located at the steam plant; they are pumped as a group, but generally only four, which are electrically pumped, are used in preference to the other two, which are airlift. This group furnishes about 8 percent of the total supply. The remaining wells are pumped as individual units and are located throughout the city; all are tied into the main distribution system, so the water supplied to any section of the city depends on which wells are being pumped at the time.

Average amount of water used daily in system during 1962: 19.8 mgd (U.S. Public Health Service, 1962c).

Treatment: Chlorination.

Raw-water storage: None.

Finished-water storage: Elevated, 15 million gal; ground, 5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.

Analytical data—Rockford

	Unit well 15	Composite of six group wells
Percent of supply	92	8
Depth of well (feet)	1,355	----------
Diameter of well (inches)	20	12
Date drilled	1959	----------
Date of collection	8-23-61	8-23-61
Type of water: F, finished	F	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	9.1	9.8
Iron (Fe)	.10	.14
Manganese (Mn)	.06	.07
Calcium (Ca)	57	73
Magnesium (Mg)	32	38
Sodium (Na)	3.4	7.6
Potassium (K)	1.7	2.1
Bicarbonate (HCO_3)	332	364
Carbonate (CO_3)	0	0
Sulfate (SO_4)	12	36
Chloride (Cl)	3.5	11
Fluoride (F)	.1	.1
Nitrate (NO_3)	.2	2.2
Dissolved solids (residue at 180° C)	284	368
Hardness as $CaCO_3$	274	338
Noncarbonate hardness as $CaCO_3$	2	40
Specific conductance (micromhos at 25° C)	498	628
pH	7.6	7.5
Color	1	2
Temperature °F	53	58
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter]		
Beta activity	----------	7.3
Radium (Ra)	----------	2.5
Uranium (U)	----------	.6
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	<0.5	<0.59
Aluminum (Al)	18	20
Boron (B)	7.0	56
Barium (Ba)	85	200
Beryllium (Be)	ND	ND
Cobalt (Co)	<5	9.5
Chromium (Cr)	ND	.77
Copper (Cu)	3.8	3.9
Iron (Fe)	70	150
Lithium (Li)	.65	.83
Manganese (Mn)	<5	26
Molybdenum (Mo)	1.5	10
Nickel (Ni)	7.5	7.7
Phosphorus (P)	ND	ND
Lead (Pb)	7.5	ND
Rubidium (Rb)	ND	ND
Tin (Sn)	ND	ND
Strontium (Sr)	36	71
Titanium (Ti)	ND	ND
Vanadium (V)	ND	ND
Zinc (Zn)	ND	ND

INDIANA

Evansville	
Fort Wayne	*Indianapolis*
Gary	*South Bend*

EVANSVILLE

Ownership: Municipal.

Population served: Evansville, 141,543; about 18,500 outside the city limits; total, about 160,000.

Source of supply: Ohio River.

Auxiliary and emergency supplies: Several wells can be used in an emergency, and some hotels and industries have their own wells.

Lowest mean discharge: Ohio River at Evansville, Ind., for 30-day period in climatic water years (April 1–March 31) 1950–59: 4,650 mgd.

Average amount of water used daily in system during 1962: 21 mgd (U.S. Public Health Service, 1962c).

Treatment: Evansville filtration plant—breakpoint chlorination, coagulation with alum, treatment with activated carbon, sedimentation, rapid sand filtration, final adjustment of pH by addition of lime and postchlorination. Activated carbon and copper sulfate are added for algae control, when needed.

Rated capacity of treatment plant: Evansville filtration plant, 36 mgd.

Raw-water storage: None.

Finished-water storage: 30 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.4.

Regular determinations at Evansville filtration plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	70	103	29	7.5	8.8	7.0	136	217	72	102	620	6
Finished water	66	100	40	8.2	8.9	7.6	154	232	95	------	------	------

Analytical data, filtration plant—Evansville

[Percent of supply: 100. Date of collection: 5-16-62. Type of water: finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	5.2	Chloride (Cl)	22
Iron (Fe)	.03	Fluoride (F)	.2
Manganese (Mn)	.34	Nitrate (NO_3)	2.8
Calcium (Ca)	47	Dissolved solids (residue at 180° C)	249
Magnesium (Mg)	10	Hardness as $CaCO_3$	158
Sodium (Na)	13	Noncarbonate hardness as $CaCO_3$	88
Potassium (K)	2.0		
Bicarbonate (HCO_3)	86	Specific conductance (micromhos at 25 C°)	388
Carbonate (CO_3)	0	pH	7.5
Sulfate (SO_4)	87	Color	3
		Temperature ° F	74

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter, <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity	6.7	Radium (Ra)	<0.1
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	22	Uranium (U)	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.29	Molybdenum (Mo)	4.4
Aluminum (Al)	320	Nickel (Ni)	3.5
Boron (B)	26	Phosphorus (P)	ND
Barium (Ba)	100	Lead (Pb)	ND
Beryllium (Be)	ND	Rubidium (Rb)	<2.9
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	3.2	Strontium (Sr)	280
Copper (Cu)	2.1	Titanium (Ti)	2.6
Iron (Fe)	16	Vanadium (V)	ND
Lithium (Li)	12	Zinc (Zn)	ND
Manganese (Mn)	ND		

FORT WAYNE

Ownership: Municipal.

Other areas served: New Haven and about 3,000 people outside the city limits.

Population served: Fort Wayne, 161,776; total, about 168,200.

Source of supply: St. Joseph River (impounded).

Average amount of water used daily in system during 1962: 20.8 mgd (U.S. Public Health Service, 1962c).

Treatment: Three Rivers filtration plant—coagulation with ferric sulfate, activated carbon, softening with lime and soda ash; chlorine dioxide, recarbonation, chlorination, sedimentation, rapid sand filtration, ammoniation, and fluoridation. The water is softened to a hardness of about 85 ppm.

Rated capacity of treatment plant: Three Rivers filtration plant, 48 mgd.

Raw-water storage: 710 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 34.

Finished-water storage: 22 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.1.

Regular determinations at Three Rivers filtration plant:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	225	314	84	8.2	8.4	7.80	279	362	128	75	735	30
Finished water	29	42	17	9.7	10.1	9.20	85	92	63	.0	.0	.00

Analytical data—Fort Wayne

	St. Joseph River (impounded)	Three Rivers filtration plant
Percent of supply	100	100
Date of collection	8-22-61	8-22-61
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	8.0	6.1
Iron (Fe)	.56	.03
Manganese (Mn)	.07	.06
Calcium (Ca)	76	28
Magnesium (Mg)	20	4.0
Sodium (Na)	9.7	15
Potassium (K)	2.6	2.6
Bicarbonate (HCO_3)	256	16
Carbonate (CO_3)	0	8
Sulfate (SO_4)	67	72
Chloride (Cl)	10	15
Fluoride (F)	.4	.8
Nitrate (NO_3)	2.6	2.2
Dissolved solids (residue at 180°C)	334	177
Hardness as $CaCO_3$	272	86
Noncarbonate hardness as $CaCO_3$	62	60
Specific conductance (micromhos as 25°C)	535	271
pH	7.6	9.0
Color	22	2
Turbidity	60	----------
Temperature °F	74	74
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; $<$, less than]		
Beta activity	----------	7.1
Radium (Ra)	----------	$<.1$
Uranium (U)	----------	$<.1$
Spectrographic analyses [In micrograms per liter. $<$, less than; ND, looked for but not found]		
Silver (Ag)	<0.54	<0.2
Aluminum (Al)	180	48
Boron (B)	75	<11
Barium (Ba)	130	27
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	2.0	3.1
Copper (Cu)	70	2.3
Iron (Fe)	110	43
Lithium (Li)	1.6	2.5
Manganese (Mn)	22	<2
Molybdenum (Mo)	19	3.9
Nickel (Ni)	9.6	2.5
Phosphorus (P)	ND	ND
Lead (Pb)	20	2.7
Rubidium (Rb)	ND	ND
Tin (Sn)	ND	ND
Strontium (Sr)	540	350
Titanium (Ti)	5.9	<2
Vanadium (V)	ND	ND
Zinc (Zn)	ND	ND

GARY

Ownership: Gary-Hobart Water Co.

Other areas served: Hobart, Griffith, Turkey Creek Meadows (subdivision), and Ogden Dunes.

Population served: Gary, 178,320; total, about 225,000.

Source of supply: Lake Michigan.

Auxiliary and emergency supplies: Lake George can be used to supply Hobart, only, at rate of 1 mgd.

Average amount of water used daily in system during 1962: 23.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Gary-Hobart filter plant—coagulation with alum, chlorination, treatment with activated carbon, addition of clay and lime (either or both) when necessary, rapid sand filtration, ammoniation, fluoridation, and post-chlorination.

Rated capacity of treatment plant: Gary-Hobart filter plant, 52 mgd.

Finished-water storage: Plant, 4 million gal; distribution tanks, 10 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Gary-Hobart filter plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	122	140	108	8.1	8.4	7.7	142	148	132	16	150	3
Finished water	111	126	96	7.5	7.7	7.2	142	148	132	0	0	0

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Analytical data, Gary-Hobart filter plant—Gary

[Percent of supply: 100. Date of collection: 4-4-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	2.3	Fluoride (F)	0.6
Iron (Fe)	.02	Nitrate (NO_3)	.8
Manganese (Mn)	.06	Dissolved solids (residue at 180°C)	158
Calcium (Ca)	35	Hardness as $CaCO_3$	133
Magnesium (Mg)	11	Noncarbonate hardness as $CaCO_3$	32
Sodium (Na)	4.5		
Potassium (K)	1.0	Specific conductance (micromhos at 25°C)	281
Bicarbonate (HCO_3)	123	pH	7.3
Carbonate (CO_3)	0	Color	2
Sulfate (SO_4)	26	Temperature °F	42
Chloride (Cl)	9.5		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter, <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity	6.2	Radium (Ra)	<0.1
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	14	Uranium (U)	.3

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.24	Molybdenum (Mo)	1.0
Aluminum (Al)	96	Nickel (Ni)	3.4
Boron (B)	26	Phosphorus (P)	ND
Barium (Ba)	43	Lead (Pb)	5.5
Beryllium (Be)	ND	Rubidium (Rb)	ND
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	.24	Strontium (Sr)	82
Copper (Cu)	1.7	Titanium (Ti)	1.3
Iron (Fe)	31	Vanadium (V)	ND
Lithium (Li)	.96	Zinc (Zn)	ND
Manganese (Mn)	2.6		

INDIANAPOLIS

(See fig. 30.)

Ownership: Indianapolis Water Co.

Other areas served: Beech Grove, Ben Davis (unincorporated), Crows Nest, Homecroft, Lynhurst, Mars Hill (unincorporated), Meridan Hills, North Crows Nest, Southport, Warren Park, and Williams Creek. Most, but not all, of Indianapolis is served. Fairwood (unincorporated) is supplied by two wells.

Population served: Indianapolis, 476,258; total, about 500,000.

Sources and percentages of supply: White River, 55.2 percent; Fall Creek, 44.8 percent.

Auxiliary and emergency supplies: Several wells.

Lowest mean discharge:

White River near Nora, Ind., for 30-day period in climatic water years (April 1–March 31) 1950–59: 53.3 mgd.

Fall Creek at Millersville, Ind., for 30-day period in climatic water years (April 1–March 31) 1950–59: 25.5 mgd.

Average amount of water used daily in system during 1962: 68 mgd (U.S Public Health Service, 1962c).

Treatment: White River and Fall Creek purifications plants—prechlorination, coagulation with alum and lime, treatment with activated carbon, sedimentation, rapid sand filtration, auxiliary slow sand filtration at times, ammoniation, fluoridation, and postchlorination.

Rated capacity of treatment plant: White River purification plant: 72 mgd, at normal operation; 84 mgd, with three slow sand filters operating. Fall Creek purification plant, 32 mgd.

Raw-water storage: Geist Reservoir, 7,000 million gal; Morse Reservoir, 7,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 206.

Finished-water storage: Underground reservoir, 23 million gal; elevated storage, 3 million gal; ground reservoir, 4 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—Indianapolis

	Fall Creek purification plant		White River purification plant	
Percent of supply	45		55	
Date of collection	5-17-62	(1)	5-17-62	(1)
Type of water: F, finished	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	2.8		2.5	
Iron (Fe)	.02	0.02	.05	
Manganese (Mn)	.01		.00	
Aluminum (Al)		.21		0.42
Calcium (Ca)	57	58	78	75
Magnesium (Mg)	22	22	26	23
Sodium (Na)	8.1	7.0	14	18
Potassium (K)	1.5	1.4	2.2	3.4
Bicarbonate (HCO_3)	204	204	262	245
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	53	50	73	68
Chloride (Cl)	18	20	26	32
Fluoride (F)	1.1	1.0	1.0	1.1
Nitrate (NO_3)	3.2		4.6	
Dissolved solids (residue at 180°C)	285		390	
Hardness as $CaCO_3$	233	238	302	284
Noncarbonate hardness as $CaCO_3$	66	74	87	
Specific conductance (micromhos at 25°C)	474		614	
pH	7.2		7.3	7.3
Color	5		5	
Temperature °F	71		78	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	11		10	
Radium (Ra)	<.1		.1	
Uranium (U)	1.3		1.3	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.39		ND	
Aluminum (Al)	170		400	
Boron (B)	33		60	
Barium (Ba)	77		65	
Beryllium (Be)	ND		ND	
Cobalt (Co)	ND		ND	
Chromium (Cr)	ND		6.5	
Copper (Cu)	220		250	
Iron (Fe)	42		47	
Lithium (Li)	2.2		4.8	
Manganese (Mn)	14		17	
Molybdenum (Mo)	7.3		13	
Nickel (Ni)	<3.9		30	
Phosphorus (P)	ND		ND	
Lead (Pb)	17		ND	
Rubidium (Rb)	ND		ND	
Tin (Sn)	ND		ND	
Strontium (Sr)	150		300	
Titanium (Ti)	3.1		ND	
Vanadium (V)	ND		ND	
Zinc (Zn)	ND		ND	

[1] Average analyses for 1961 by the Indianapolis Water Co.

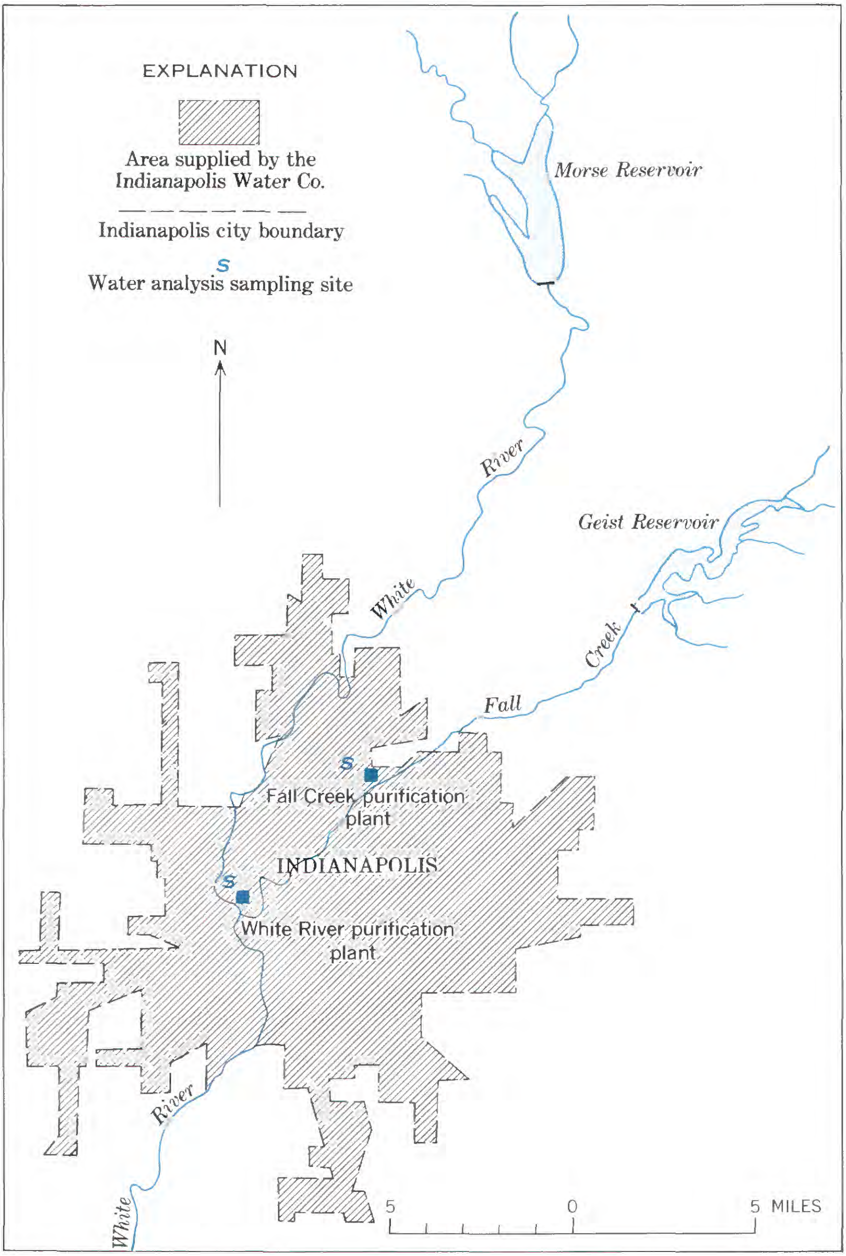

FIGURE 30.—Water supplies and areas served by Indianapolis, Ind., Water Co. (Approved by local municipal water officials, April 1963.)

SOUTH BEND

Ownership: Municipal.

Population served: South Bend, 132,445; about 200 outside city limits; total 132,645.

Source of supply: Located at nine stations throughout the city are 27 wells ranging in depth from 92 to 206 feet: Airport Station, 3 wells, yield 5.5 mgd, 93–107 feet deep; Central Station, 2 wells, yield 3 mgd, 115 feet deep; Coquillard Station, 4 wells, yield 12.5 mgd, 196–206 feet deep; Erskine Station, 1 well, yield 1 mgd, 175 feet deep; North Station, 4 wells, yield 12 mgd, 106–108 feet deep; Oliver Station, 4 wells, yield 13.2 mgd, 155–192 feet deep; Pinhook Station, 4 wells, yield 12 mgd, 122–131 feet deep; Rum Village Station, 1 well, yield 1 mgd, 137 feet deep; South Station, 4 wells, yield 7.5 mgd, 92–108 feet deep.

Figures on yield are based on pumping each well individually without interference due to pumping other wells in immediate vicinity. There is no set pattern in pumping the wells, but those furnishing water low in iron are pumped more than others.

Average amount of water used daily in system during 1962: 20 mgd (U.S. Public Health Service, 1962c).

Treatment:

Coquillard Station and North Station: Chlorination and addition of polyphosphate.

Seven other stations: Chlorination only at present. Polyphosphate will soon be added at Pinhook Station.

Raw-water storage: North Station, 6 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: South Station, 7 million gal; elevated tanks, 3.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—South Bend

	Coquillard Station well 3	Pinhook Station well 3	North Station wells 5 and 7	Oliver Station well 4
Percent of supply	18	18	18	20
Date of collection	4-5-62	4-5-62	4-4-62	7-30-62
Type of water: F, finished	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	14	13	12	14
Iron (Fe)	.92	.97	.16	.02
Manganese (Mn)	.12	.09	.12	.04
Calcium (Ca)	62	62	90	145
Magnesium (Mg)	21	24	28	44
Sodium (Na)	7.5	5.4	8.4	12
Potassium (K)	.6	.7	1.0	2.1
Bicarbonate (HCO_3)	268	256	282	380
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	24	44	102	210
Chloride (Cl)	6.0	7.5	13	20
Fluoride (F)	.1	.1	.1	.0
Nitrate (NO_3)	.1	.2	.3	6.7
Dissolved solids (residue at 180° C)	270	282	410	683
Hardness as $CaCO_3$	241	253	340	544
Noncarbonate hardness as $CaCO_3$	22	43	109	232
Specific conductance (micromhos at 25° C)	464	485	645	970
pH	7.5	7.3	7.3	7.3
Color	3	3	5	1
Temperature °F	54	54	54	----------

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	4.7	6.7	10	----------
Radium (Ra)	.3	.1	.1	----------
Uranium (U)	.2	.2	.3	----------

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.48	<0.24	<0.56	----------
Aluminum (Al)	40	32	11	----------
Boron (B)	40	24	62	----------
Barium (Ba)	150	61	150	----------
Beryllium (Be)	ND	ND	ND	----------
Cobalt (Co)	ND	ND	ND	----------
Chromium (Cr)	ND	ND	ND	----------
Copper (Cu)	2.9	18	31	----------
Iron (Fe)	1,200	1,700	150	----------
Lithium (Li)	1.2	.92	1.1	----------
Manganese (Mn)	120	180	160	----------
Molybdenum (Mo)	2.6	<.73	<1.7	----------
Nickel (Ni)	<4.8	3.2	9.0	----------
Phosphorus (P)	<480	<240	ND	----------
Lead (Pb)	21	5.6	ND	----------
Rubidium (Rb)	ND	ND	ND	----------
Tin (Sn)	ND	ND	ND	----------
Strontium (Sr)	120	41	110	----------
Titanium (Ti)	2.3	2.4	ND	----------
Vanadium (V)	ND	ND	ND	----------
Zinc (Zn)	ND	ND	ND	----------

DES MOINES

(See fig. 31.)

Ownership: Municipal.

Population served: Des Moines, 238,494; about 20,200 in communities outside the city; total, about 258,700.

Sources and percentages of supply: Infiltration gallery along the Raccoon River, 50–75 percent of supply; Raccoon River impounded, 25–50 percent of the supply. The infiltration gallery is constructed of reinforced concrete rings 2 feet long and 4 and 5 feet inside diameter and is placed in sand and gravel 15–31 feet deep in one continuous line parallel with the river and 150–300 feet back from the main channel. It is constructed to permit the entrance of water from the surrounding sand and gravel through openings between each ring, and serves the double purpose of collecting the water and carrying it by gravity to the pumping station. At the present time the gallery is approximately 3 miles long.

Auxiliary and emergency supplies: Water in a 1,500-million-gallon reservoir located southwest of Commerce in the Raccoon River valley may be used during drought periods or in emergencies.

Lowest mean discharge: Raccoon River at Van Meter, Iowa, for 30-day period in climatic water years (April 1–March 31) 1950–59: 30.6 mgd.

Average amount of water used daily in system during 1962: 25.3 mgd (U.S. Public Health Service, 1962c).

Treatment: Des Moines Water Works plant—softening with lime and soda ash, coagulation with alum, recarbonation, rapid sand filtration, addition of polyphosphate for stabilization, chlorination, and fluoridation.

Rated capacity of treatment plant: Des Moines Water Works plant, 96 mgd.

Raw-water storage: Impounding reservoir, 1,570 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 62.

Finished-water storage: Clear well, 10 million gal; towers and standpipes, 12.7 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Des Moines Water Works plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	244	377	188	7.7	8.3	7.2	331	428	228	50	1,330	0.1
Finished water	45	73	21	9.5	10.6	8.4	95	132	65	.1	.8	.1

Analytical data—Des Moines

	Infiltration gallery	Des Moines Water Works		Infiltration gallery	Des Moines Water Works
Percent of supply	75	75	Type of water: R, raw; F, finished	R	F
Date of collection	1-22-62	1-22-62			

Chemical analyses
[In parts per million]

	Infiltration gallery	Des Moines Water Works		Infiltration gallery	Des Moines Water Works
Silica (SiO_2)	19	14	Iodide (I)	0.002	0.000
Iron (Fe)	.08	1.00	Phosphate (PO_4)	.27	.65
Manganese (Mn)	.06	.06	Dissolved solids (residue at 180° C)	464	244
Boron (B)	.08	.06	Hardness as $CaCO_3$	371	108
Calcium (Ca)	95	14	Noncarbonate hardness as $CaCO_3$	92	58
Magnesium (Mg)	33	18	Specific conductance (micromhos at 25° C)	706	394
Sodium (Na)	13	33	pH	7.8	9.5
Potassium (K)	2.8	2.8	Color	3	2
Aluminum (Al)	.00	.00	Turbidity	2	2
Bicarbonate (HCO_3)	340	14	Temperature °F		43
Carbonate (CO_3)	0	23			
Sulfate (SO_4)	89	104			
Chloride (Cl)	11	11			
Fluoride (F)	.3	1.6			
Nitrate (NO_3)	12	13			

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Infiltration gallery	Des Moines Water Works		Infiltration gallery	Des Moines Water Works
Beta activity		5.6	Uranium (U)		1.9
Radium (Ra)		<.1			

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

	Infiltration gallery	Des Moines Water Works		Infiltration gallery	Des Moines Water Works
Silver (Ag)		<0.30	Molybdenum (Mo)		3.0
Aluminum (Al)		130	Nickel (Ni)		<3.0
Boron (B)		39	Phosphorus (P)		ND
Barium (Ba)		18	Lead (Pb)		5.7
Beryllium (Be)		ND	Rubidium (Rb)		ND
Cobalt (Co)		ND	Tin (Sn)		ND
Chromium (Cr)		1.0	Strontium (Sr)		63
Copper (Cu)		1.2	Titanium (Ti)		<.9
Iron (Fe)		36	Vanadium (V)		<9.0
Lithium (Li)		18	Zinc (Zn)		ND
Manganese (Mn)		<3.0			

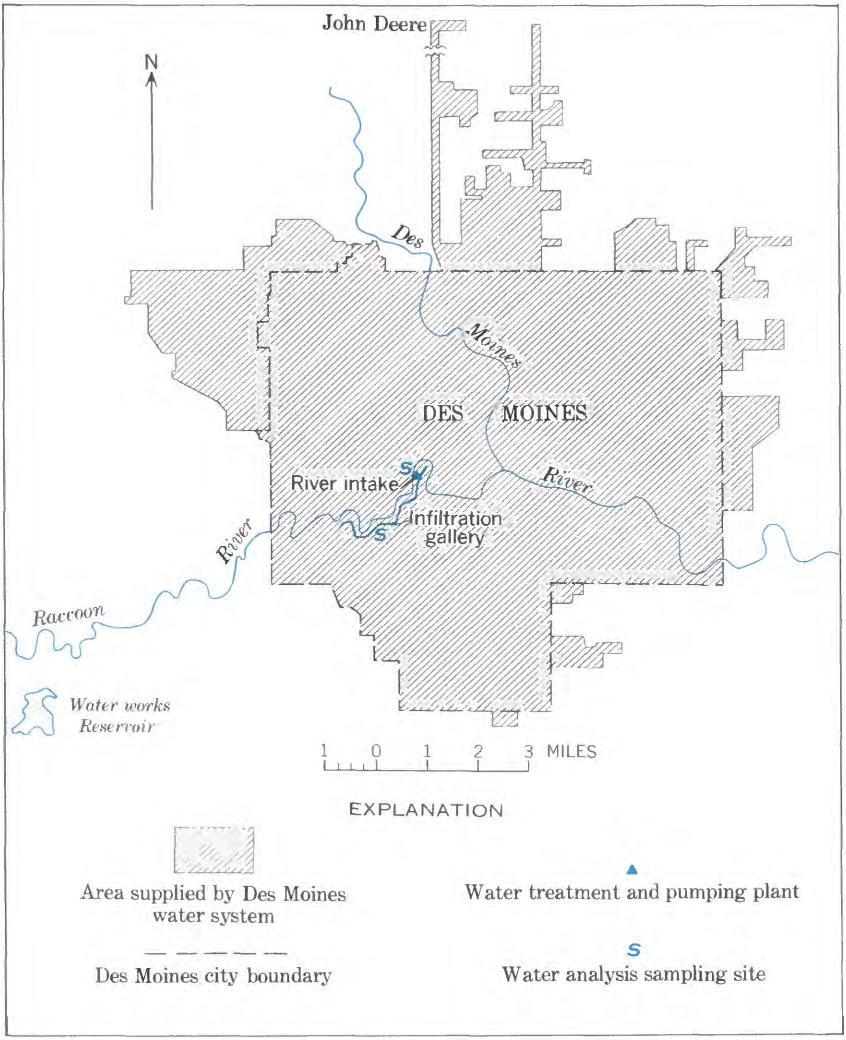

FIGURE 31.—Water supplies and areas served by Des Moines, Iowa, water system. (Approved by local municipal water officials, June 1963.)

KANSAS

Kansas City *Topeka* *Wichita*

KANSAS CITY

(See fig. 32.)

Ownership: Municipal.

Other areas served: Suburban Wyandotte County and some of suburban Johnson County.

Population served: Kansas City, 121,901; total, 200,000.

Source of supply: Missouri River. The raw water is obtained by means of either or both of two intake structures and equipment. It is first pumped to the electric power station, where it is used for condensing purposes. When it leaves the condenser, a sufficient amount is pumped to the settling basins at the water plant for the city supply. The remainder is wasted back into the river.

Average amount of water used daily in system during 1962: 29.3 mgd (U.S. Public Health Service, 1962c).

Treatment: Quindaro treatment plant—coagulation with alum; addition of lime, activated silica, activated carbon; sedimentation; rapid sand filtration; and chlorination.

Rated capacity of treatment plant: Quindaro treatment plant, 60 mgd.

Finished-water storage: Reservoirs and elevated storage, 17 million gal; clear wells at plant, 1.2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Quindaro treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	172	227	142	7.9	8.2	------	231	299	------	810	4,800	10
Finished water	171	250	126	7.9	8.4	------	248	318	------	<1	<1	<1

Analytical data—Kansas City

	Missouri River	Quindaro treatment plant		Missouri River	Quindaro treatment plant
Percent of supply	100	100	Type of water: R, raw; F, finished	R	F
Date of collection	3-15-62	3-15-62			

Chemical analyses

[In parts per million]

Silica (SiO_2)	16	9.7	Iodide (*i*)	0.00	0.00
Iron (Fe)	.01	.00	Phosphate (PO_4)	.54	.28
Manganese (Mn)	.00	.00	Dissolved solids (residue at 180° C)	312	311
Boron (B)	.06	.04	Hardness as $CaCO_3$	174	189
Calcium (Ca)	49	57	Noncarbonate hardness as $CaCO_3$	35	58
Magnesium (Mg)	13	11	Specific conductance (micromhos at 25° C)	464	486
Sodium (Na)	26	25	pH	7.2	7.6
Potassium (K)	4.8	4.3	Color	9	4
Aluminum (Al)	.00	.00	Turbidity	3	2
Bicarbonate (HCO_3)	169	160	Temperature °F	55	53
Carbonate (CO_3)	0	0			
Sulfate (SO_4)	69	81			
Chloride (Cl)	14	20			
Fluoride (F)	.2	.3			
Nitrate (NO_3)	8.3	5.7			

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity		26	Radium (Ra)		<0.1
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	70		Uranium (U)		2.4

Spectrographic analyses

[In micrograms per liter. ND, looked for but not found]

Silver (Ag)		ND	Molybdenum (Mo)		4.9
Aluminum (Al)		340	Nickel (Ni)		4.5
Boron (B)		49	Phosphorus (P)		ND
Barium (Ba)		170	Lead (Pb)		7.5
Beryllium (Be)		ND	Rubidium (Rb)		ND
Cobalt (Co)		ND	Tin (Sn)		ND
Chromium (Cr)		ND	Strontium (Sr)		410
Copper (Cu)		3.3	Titanium (Ti)		3.3
Iron (Fe)		24	Vanadium (V)		11
Lithium (Li)		17	Zinc (Zn)		ND
Manganese (Mn)		6.0			

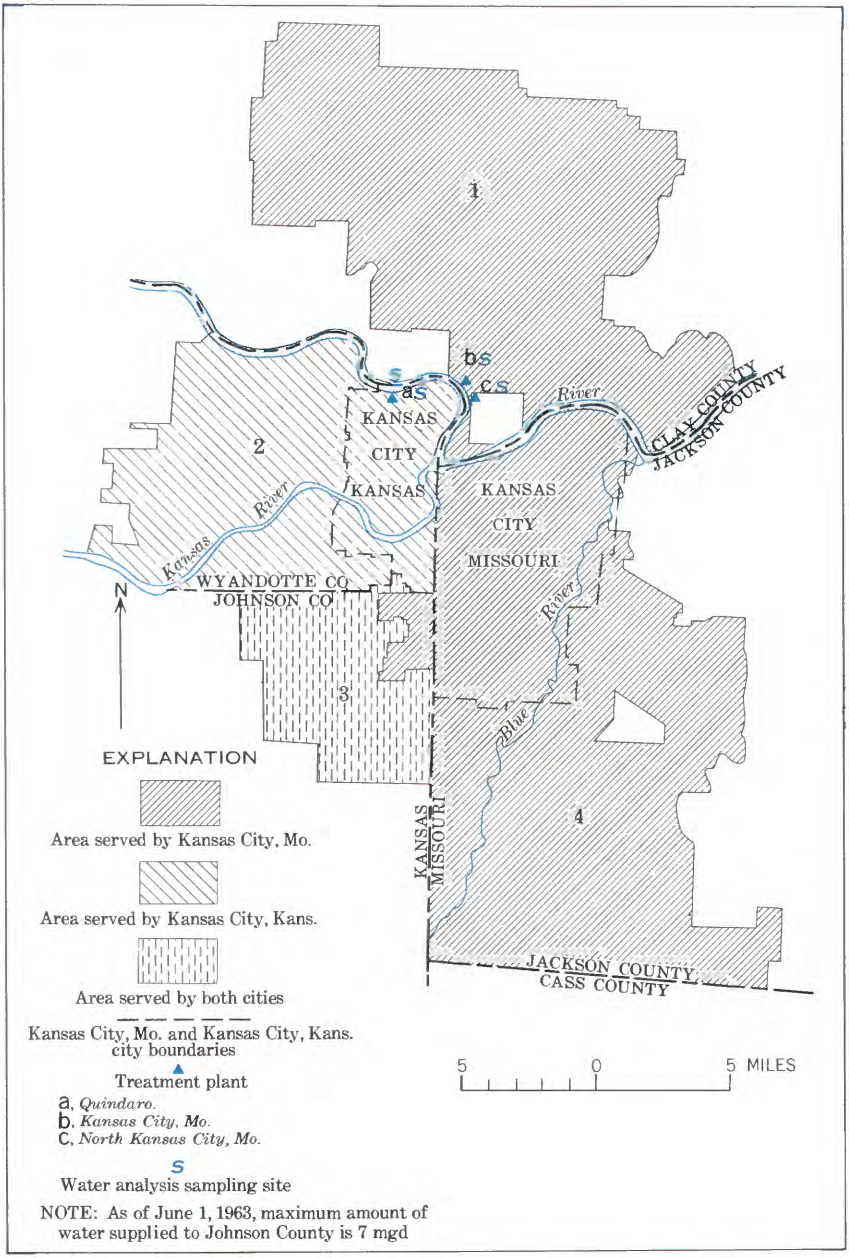

FIGURE 32.—Water supplies and areas served by the water departments of Kansas City, Kans., and Kansas City, Mo. (Approved by local municipal water officials, June 1963.) List of areas served: 1, Clay County; 2, Wyandotte County; 3, Johnson County; 4, Jackson County.

TOPEKA

(See fig. 33.)

Ownership: Municipal.

Population served: Topeka, 119,484; about 3,000 outside city limits and about 9,000 at Forbes Air Force Base; total, about 131,000.

Sources and percentages of supply: Kansas River, more than 99 percent; two wells, 50 feet deep, less than 1 percent.

Lowest mean discharge: Kansas River at Topeka, Kans., for 30-day period in climatic water years (April 1–March 31) 1950–60: 187 mgd.

Average amount of water used daily in system during 1962: 12.4 mgd (U.S. Public Health Service, 1962c).

Treatment: Topeka treatment plant—prechlorination, plain sedimentation, treatment with activated carbon slurry, softening with excess lime and soda ash, coagulation with alum and silicate of soda, recarbonation, coagulation with alum and silicate of soda, settling, chlorination, rapid sand filtration, and fluoridation.

Rated capacity of treatment plant: Topeka treatment plant, 40 mgd.

Raw-water storage: None.

Finished-water storage: Clear well, 40 million gal; reservoir and elevated storage, 16 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.6.

Regular determinations at Topeka treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	203	328	87	7.9	8.2	6.7	292	472	128	912	1,120	375
Finished water	62	135	43	9.1	10	8.1	104	164	59	<1	<1	<1

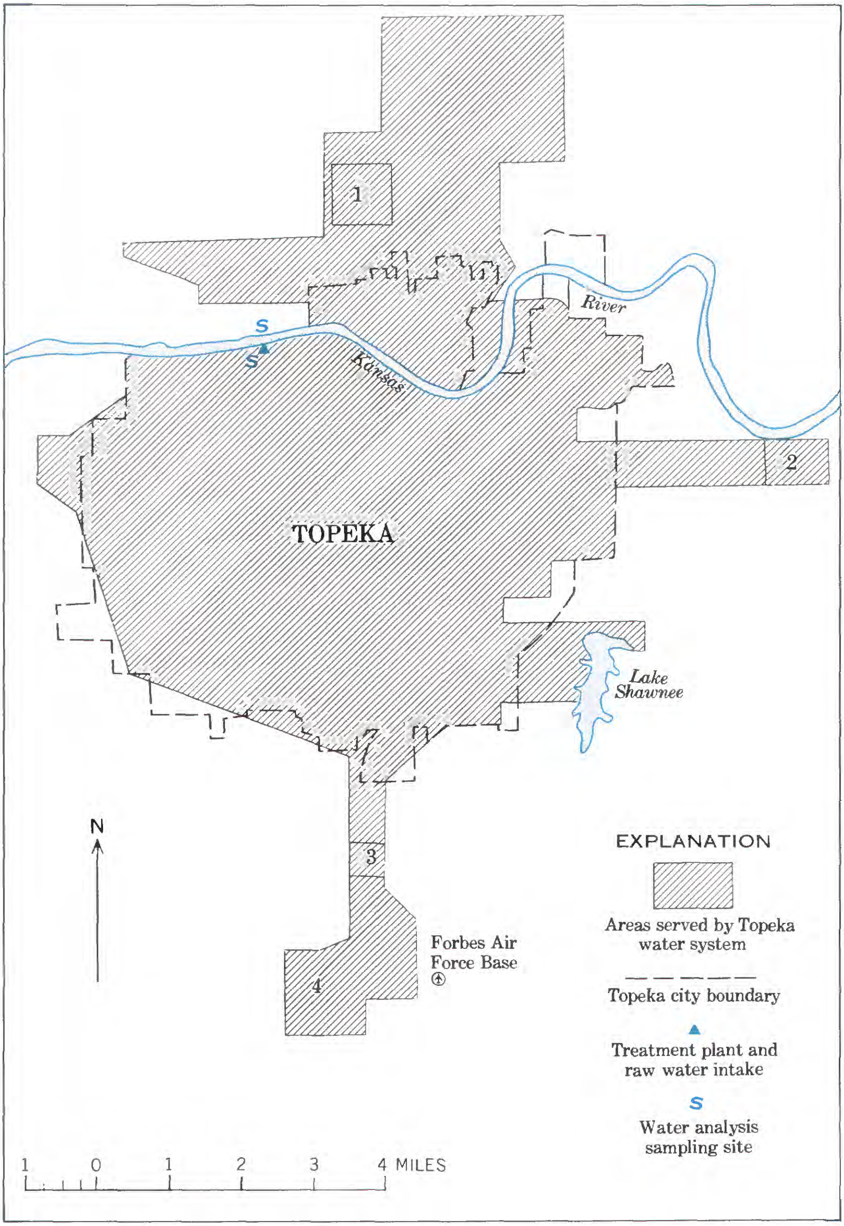

FIGURE 33.—Water supplies and areas served by Topeka, Kans., water system. (Approved by local municipal water officials, June 1963.) List of areas served: 1, Goodyear Co. Plant; 2, Tecumseh; 3, Pauline; 4, Cullen Village.

735-717 O—64——13

Analytical data—Topeka

	Kansas River	Treatment plant	Well 2	Well 3
Percent of supply	100	100	1	1
Depth of well (feet)			50	50
Date of collection	3-9-62	3-9-62	3-9-62	3-9-62
Type of water: R, raw; F, finished	R	F	R	R

Chemical analyses

[In parts per million]

Silica (SiO_2)	17	10	18	17
Iron (Fe)	.03	.02	.38	.03
Manganese (Mn)	.00	.00	.18	.15
Boron (B)	.07	.09	.11	.16
Calcium (Ca)	110	41	112	121
Magnesium (Mg)	23	5.7	18	21
Sodium (Na)	72	111	66	70
Potassium (K)	6.00	5.9	6.4	7.0
Aluminum (Al)	.00	.00	.00	.00
Bicarbonate (HCO_3)	316	10	312	338
Carbonate (CO_3)	0	24	0	0
Sulfate (SO_4)	128	148	131	145
Chloride (Cl)	95	119	82	87
Fluoride (F)	.2	.7	.4	.3
Nitrate (NO_3)	4.9	5.0	.5	.3
Iodide (I)	.005	.001	.005	.007
Phosphate (PO_4)	.58	1.1	.33	.72
Dissolved solids (residue at 180° C)	638	494	611	663
Hardness as $CaCO_3$	368	126	354	390
Noncarbonate hardness as $CaCO_3$	109	78	98	113
Specific conductance (micromhos at 25° C)	994	820	958	1,030
pH	7.5	9.6	7.3	7.4
Color	4	3	3	4
Turbidity		2	2	5
Temperature °F	36	45	54	54

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity		21		
Radium (Ra)		<.1		
Uranium (U)		<.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)		ND		
Aluminum (Al)		220		
Boron (B)		29		
Barium (Ba)		50		
Beryllium (Be)		ND		
Cobalt (Co)		ND		
Chromium (Cr)		<.61		
Copper (Cu)		<.61		
Iron (Fe)		12		
Lithium (Li)		18		
Manganese (Mn)		ND		
Molybdenum (Mo)		5.1		
Nickel (Ni)		ND		
Phosphorus (P)		ND		
Lead (Pb)		ND		
Rubidium (Rb)		ND		
Tin (Sn)		ND		
Strontium (Sr)		550		
Titanium (Ti)		ND		
Vanadium (V)		ND		
Zinc (Zn)		ND		

WICHITA

(See fig. 34.)

Ownership: Municipal.

Other area served: Eastborough, having a population of about 500.

Population served: Wichita, 254,698; total, about 255,000.

Sources of supply: Fifty-five wells ranging in depth from 45 to 265 feet and averaging about 200 feet, located in the Equus Beds about 30–35 miles northwest of Wichita, are used for regular supply. The regular supply wells are spaced at least half a mile apart in the well field and have an average yield of about 900 gpm. The wells, equipped with turbine pumps, pump into spur lines connected to a supply line which conveys the water to the treatment plant located in the city. The control of the wells, the operation of which is manual, is centered at the treatment plant, so that individual wells may be cut in or out of pumpage as desired. There is considerable variation in the chemical composition of the water from individual wells. The hardness ranges from about 115 to 370 ppm.

Auxiliary and emergency supplies: Eighteen local wells near the treatment plant are used for auxiliary supply. Six wells near Bently, 15–20 miles from Wichita, may be used in case of emergency.

Average amount of water used daily in system during 1962: 25 mgd (U.S. Public Health Service, 1962c).

Treatment: Wichita treatment plant—prechlorination at well head, aeration, softening with lime, chlorination, ammoniation, sedimentation, rapid sand filtration, postchlorination, polyphosphate (Calgon) stabilization, and pH adjustment with carbon dioxide.

Rated capacity of treatment plants: Wichita treatment plant, 120 mgd.

Finished-water storage: Clear wells, 4.5 million gal; reservoirs, 10.5 million gal; elevated tanks, 4.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Wichita treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	221	273	137	-----	-----	-----	217	370	114
Finished water	108	118	98	8.1	8.2	8.1	103	109	98

NOTE.—Raw-water figures are from single analyses of water from each of the 55 main wells; finished-water figures are from analyses of monthly composite samples.

Analytical data—Wichita

	Wells in Equus Beds	Well 4 near Bently	Treatment plant
Percent of supply	100	----------	100
Date of collection	2-13-62	2-13-62	2-13-62
Type of water: R, raw; F, finished	R	R	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	22	18	21
Iron (Fe)	.07	.05	.01
Manganese (Mn)	.00	.35	.11
Boron (B)	.02	.08	.22
Calcium (Ca)	66	120	22
Magnesium (Mg)	10	21	9.2
Sodium (Na)	60	148	61
Potassium (K)	3.0	5.4	3.0
Aluminum (Al)	.00	.00	.00
Bicarbonate (HCO_3)	252	330	115
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	68	128	66
Chloride (Cl)	41	221	44
Fluoride (F)	.4	.4	.4
Nitrate (NO_3)	.7	.4	.3
Iodide (I)	.000	.000	.000
Phosphate (PO_4)	.25	.15	.50
Dissolved solids (residue at 180° C)	404	844	284
Hardness as $CaCO_3$	206	384	93
Noncarbonate hardness as $CaCO_3$	0	113	0
Specific conductance (micromhos at 25° C)	651	1,410	476
pH	7.9	7.3	8.0
Color	1	2	1
Turbidity	2	2	2
Temperature ° F	60	50	60

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	----------	----------	4.8
Radium (Ra)	----------	----------	<.1
Uranium (U)	----------	----------	.5

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	----------	----------	ND
Aluminum (Al)	----------	----------	94
Boron (B)	----------	----------	26
Barium (Ba)	----------	----------	34
Beryllium (Be)	----------	----------	ND
Cobalt (Co)	----------	----------	ND
Chromium (Cr)	----------	----------	ND
Copper (Cu)	----------	----------	1.2
Iron (Fe)	----------	----------	21
Lithium (Li)	----------	----------	8.6
Manganese (Mn)	----------	----------	4.3
Molybdenum (Mo)	----------	----------	3.7
Nickel (Ni)	----------	----------	<3.9
Phosphorus (P)	----------	----------	ND
Lead (Pb)	----------	----------	ND
Rubidium (Rb)	----------	----------	ND
Tin (Sn)	----------	----------	ND
Strontium (Sr)	----------	----------	230
Titanium (Ti)	----------	----------	ND
Vanadium (V)	----------	----------	ND
Zinc (Zn)	----------	----------	ND

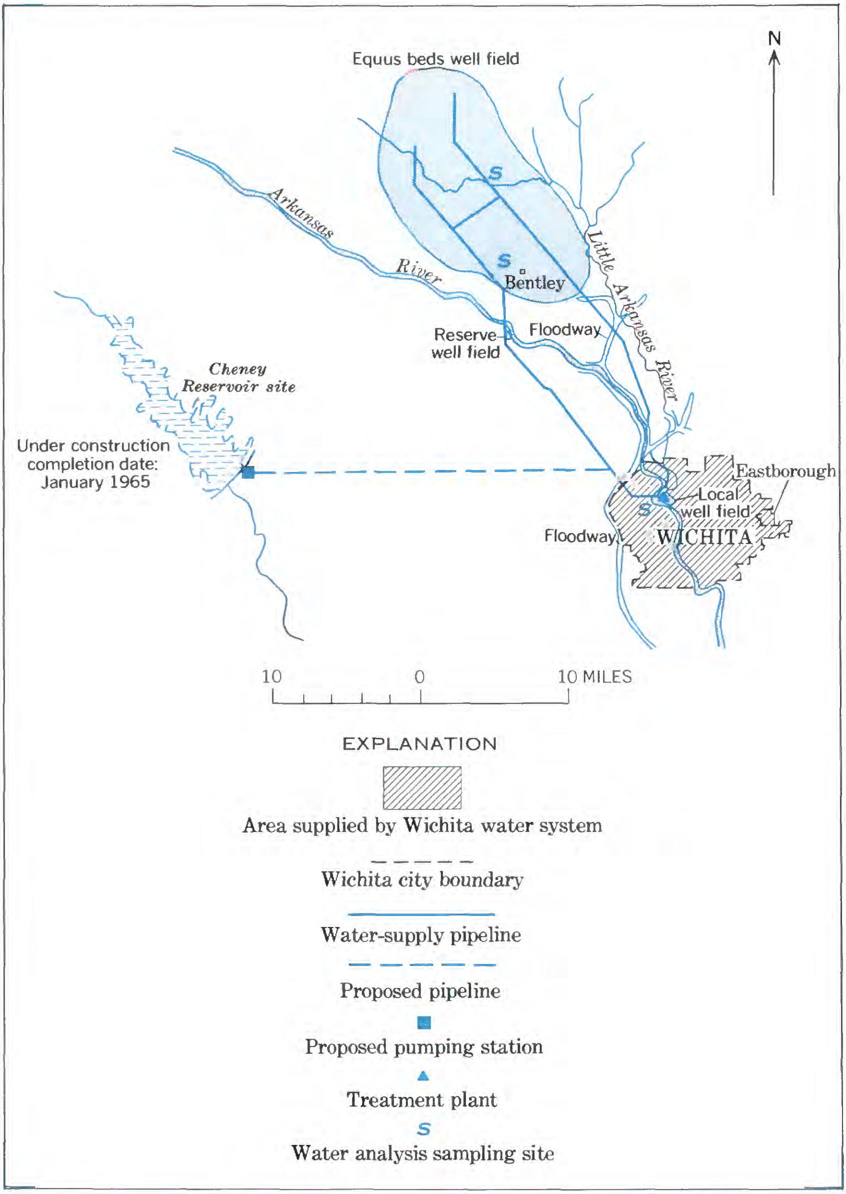

FIGURE 34.—Water supplies and areas served by Wichita, Kans., water system. (Approved by local municipal water officials, June 1963.)

KENTUCKY

Louisville

LOUISVILLE

Ownership: Louisville Water Co. (operated as a private corporation, but stock is owned by city of Louisville).

Other areas served: Towns of St. Matthews, Shively, Middletown, Jeffersontown, and Anchorage; many small cities in Jefferson County.

Population served: Louisville, 390,639; total, about 550,000.

Source of supply: Ohio River.

Lowest mean discharge: Ohio River at Louisville, Ky., for 30-day period in climatic water years (April 1–March 31) 1950–59: 4,530 mgd.

Average amount of water used daily in system during 1962: 83.8 mgd (U.S. Public Health Service, 1962c).

Treatment: Louisville filtration plant—plain sedimentation, prechlorination, coagulation with alum (sometimes with sodium aluminate and activated carbon) softening with lime and soda ash, clarification, recarbonation, rapid sand filtration, postchlorination, ammoniation, adjustment of pH (when not softening) with lime, and fluoridation (with sodium silicofluoride). When necessary for taste and odor control, breakpoint chlorination, activated carbon, and chlorine dioxide are used.

Rated capacity of treatment plants: Softening plant, 160 mgd; filtration plant, 162 mgd.

Raw-water storage: In treatment, 167.5 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.0.

Finished-water storage: 60 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Louisville filtration plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	74	110	46	7.3	7.9	6.9	131	206	78	101	800	4
Finished water	54	87	39	8.4	10.0	7.0	109	228	84	0	0	0

Analytical data—Louisville

	Ohio River	Filtration plant
Percent of supply	100	100
Date of collection	9–13–61	9–13–61
Type of water: R, raw; F, finished	R	F

Chemical analyses

[In parts per million]

	Ohio River	Filtration plant
Silica (SiO_2)	0. 2	0. 9
Iron (Fe)	. 05	. 03
Manganese (Mn)	. 04	. 00
Calcium (Ca)	41	24
Magnesium (Mg)	9. 5	9. 9
Sodium (Na)	16	26
Potassium (K)	2. 6	2. 5
Bicarbonate (HCO_3)	90	46
Carbonate (CO_3)	0	0
Sulfate (SO_4)	74	81
Chloride (Cl)	20	28
Fluoride (F)	. 3	. 4
Nitrate (NO_3)	3. 2	2. 5
Dissolved solids (residue at 180° C)	221	202
Hardness as $CaCO_3$	141	101
Noncarbonate hardness as $CaCO_3$	67	63
Specific conductance (micromhos at 25° C)	370	346
pH	7. 3	7. 8
Color	5	3
Temperature °F	84	84

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

	Ohio River	Filtration plant
Beta activity	----------	5. 6
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	46	----------
Radium (Ra)	----------	<. 1
Uranium (U)	----------	. 4

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Ohio River	Filtration plant
Silver (Ag)	<0. 3	<0. 2
Aluminum (Al)	390	680
Boron (B)	42	37
Barium (Ba)	140	76
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	7. 2	6. 6
Copper (Cu)	17	7. 1
Iron (Fe)	150	76
Lithium (Li)	4. 8	7. 6
Manganese (Mn)	12	5. 6
Molybdenum (Mo)	7. 8	4. 6
Nickel (Ni)	<3. 0	<2. 4
Phosphorus (P)	ND	ND
Lead (Pb)	11	5. 1
Rubidium (Rb)	5. 7	3. 7
Tin (Sn)	ND	ND
Strontium (Sr)	360	180
Titanium (Ti)	4. 2	<2. 4
Vanadium (V)	ND	7. 3
Zinc (Zn)	ND	ND

LOUISIANA

Baton Rouge *New Orleans* *Shreveport*

BATON ROUGE

Ownership: Baton Rouge Water Works Co.

Population served: 152,419.

Source of supply: Seven wells at Lula Street plant range in depth from 1,601 to 2,553 feet, and diameters range from 6 to 12 inches; five wells at Bankston Street plant range in depth from 1,153 to 2,382 feet and are 9 inches in diameter; five wells at Government Street plant range in depth from 1,745 to 2,664 feet, and diameters range from 6 to 10 inches; three wells at Lafayette Street plant are about 2,250 feet deep, and diameters range from 8 to 9 inches.

Average amount of water used daily in system during 1962: 14.8 mgd (U.S. Public Health Service, 1962c).

Treatment: Lafayette Street plant, Bankston Street plant, Lula Street plant, and Government Street plant—chlorination.

Rated capacity of treatment plants: Lafayette Street plant, 1.8 mgd; Lula Street plant, 4.7 mgd; Bankston Street plant, 5.0 mgd; Government Street plant, 6.7 mgd.

Finished-water storage: 6.1 million gal.

Days of finished-water storage (storage, in million gal/average daily water used in mgd): Less than 1.

Analytical data—Baton Rouge

	7 wells, Lula Street plant	3 wells, Lafayette Street plant	5 wells, Government Street plant	5 wells, Bankston Street plant
Percent of supply	26	10	37	27
Date of collection	3-30-62	3-30-62	3-30-62	4-24-62
Type of water: F, finished	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	32	19	22	27
Iron (Fe)	.01	.03	.01	.01
Calcium (Ca)	.9	.0	.0	1.2
Magnesium (Mg)	.4	.0	.0	.5
Sodium (Na)	72	97	78	67
Potassium (K)	.5	1.3	.8	.8
Bicarbonate (HCO_3)	174	241	190	165
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	11	11	9.6	8.4
Chloride (Cl)	5.2	4.6	6.2	7.0
Fluoride (F)	.2	.3	.2	.0
Nitrate (NO_3)	.1	.1	.0	.0
Dissolved solids (residue at 180° C)	239	276	229	209
Hardness as $CaCO_3$	4	0	0	5
Noncarbonate hardness as $CaCO_3$	0	0	0	0
Specific conductance (micromhos at 25° C)	299	397	323	285
pH	7.6	8.3	8.0	7.7
Color	10	20	20	10

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	1.4	1.3	1.8	1.9
Radium (Ra)	.1	.1	.1	<.1
Uranium (U)	<.1	<.1	<.1	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	0.80	<0.39	<0.33	<0.30
Aluminum (Al)	27	120	120	33
Boron (B)	73	43	33	36
Barium (Ba)	28	36	31	36
Beryllium (Be)	ND	ND	ND	ND
Cobalt (Co)	ND	ND	ND	ND
Chromium (Cr)	<.32	.39	<.33	<.30
Copper (Cu)	3.0	19	16	63
Iron (Fe)	51	39	49	17
Lithium (Li)	7.6	7.0	7.5	9.3
Manganese (Mn)	14	17	14	22
Molybdenum (Mo)	<.95	<1.2	<.98	ND
Nickel (Ni)	ND	<3.9	<3.3	<3.0
Phosphorus (P)	ND	ND	ND	ND
Lead (Pb)	ND	ND	3.9	4.5
Rubidium (Rb)	ND	ND	ND	ND
Tin (Sn)	ND	ND	ND	ND
Strontium (Sr)	13	20	19	29
Titanium (Ti)	1.0	5.1	3.1	3.6
Vanadium (V)	ND	ND	ND	ND
Zinc (Zn)	ND	ND	ND	ND

NEW ORLEANS

Ownership: Municipal.

Population served: New Orleans, 627,525.

Source of supply: Mississippi River.

Auxiliary and emergency supplies: Jefferson Parish, East Jefferson Water District 1.

Lowest mean discharge: Mississippi River near Vicksburg, Miss., for 30-day period in climatic water years (April 1–March 31) 1950–59: 91,500 mgd.

Average amount of water used daily in system during 1962: 105 mgd (U.S. Public Health Service, 1962c).

Treatment:

Carrollton purification plant: Softening with lime, sedimentation, treating with activated carbon at times, chlorination, coagulation with ferrous sulfate, sedimentation, ammoniation, addition of polyphosphates for stabilization, chlorination, and rapid sand filtration.

Algiers purification plant: Prechlorination, coagulation with ferrous sulfate, softening with lime, sedimentation, rapid sand filtration, and addition of activated carbon when required.

Rated capacity of treatment plants: Carrollton purification plant, 232 mgd; Algiers purification plant, 7.8 mgd.

Raw-water storage: None.

Finished-water storage: Carrollton purification plant, 35 million gal; Algiers purification plant, 7 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—New Orleans

	Mississippi River	Algiers purification plant	Carrollton purification plant
Percent of supply	100	3	97
Date of collection	7-21-61	7-21-61	7-21-61
Type of water: R, raw; F, finished	R	F	F

Chemical analyses

[In parts per million]

	Mississippi River	Algiers purification plant	Carrollton purification plant
Silica (SiO_2)	5.3	4.5	4.5
Iron (Fe)	.01	.01	.02
Calcium (Ca)	48	29	20
Magnesium (Mg)	11	6.7	7.8
Sodium (Na)	17	19	18
Potassium (K)	2.8	2.8	2.8
Bicarbonate (HCO_3)	148	46	36
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	43	49	46
Chloride (Cl)	26	36	32
Fluoride (F)	.2	.3	.2
Nitrate (NO_3)	.2	1.6	1.4
Dissolved solids (residue at 180° C)	254	212	187
Hardness as $CaCO_3$	163	100	82
Noncarbonate hardness as $CaCO_3$	42	62	52
Specific conductance (micromhos at 25° C)	414	316	284
pH	6.8	8.3	7.9
Color	10	10	10

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

	Mississippi River	Algiers purification plant	Carrollton purification plant
Beta activity		6.2	6.3
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	38		
Radium (Ra)		<.1	.1
Uranium (U)		.2	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Mississippi River	Algiers purification plant	Carrollton purification plant
Silver (Ag)	<0.39	<0.25	7.0
Aluminum (Al)	710	47	23
Boron (B)	74	71	34
Barium (Ba)	170	91	82
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	1.6	.78	.55
Copper (Cu)	15	2.7	2.5
Iron (Fe)	430	384	59
Lithium (Li)	4.3	3.4	3.8
Manganese (Mn)	47	<2.5	<2.1
Molybdenum (Mo)	3.9	4.9	3.2
Nickel (Ni)	9.4	<2.5	2.7
Phosphorus (P)	ND	ND	ND
Lead (Pb)	5.9	4.9	2.3
Rubidium (Rb)	3.9	<2.5	<2.1
Tin (Sn)	ND	ND	ND
Strontium (Sr)	200	190	97
Titanium (Ti)	30	<2.5	<2.1
Vanadium (V)	<12	7.6	<6.3
Zinc (Zn)	ND	ND	ND

SHREVEPORT

Ownership: Municipal.
Other area served: Barksdale Field.
Population served: Shreveport, 164,372.
Source of supply: Cross Lake.
Average amount of water used daily in system during 1962: 20.1 mgd (U.S. Public Health Service, 1962c).
Treatment:
  Cross Lake treatment plant: pH adjustment with lime, ammoniation, coagulation with alum, sedimentation, rapid sand filtration, and chlorination.
  McNeill Street treatment plant: pH adjusted with lime, ammoniation, coagulation with alum, sedimentation, rapid sand filtration, and chlorination.
Rated capacity of treatment plants: Cross Lake treatment plant, 40 mgd; McNeill Street treatment plant, 14 mgd.
Finished-water storage: Cross Lake, 6 million gal; McNeill Street, 4 million gal; 69th Street (Cross Lake), 5 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Cross Lake treatment plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	25	36	15	6.9	7.1	6.7	42	44	39	17	27	8
Finished water	34	44	26	8.5	8.7	8.3	60	64	58	0	0	0

Analytical data—Shreveport

	Cross Lake	Cross Lake treatment plant	McNeill Street treatment plant
Percent of supply	100	74	26
Date of collection	7-27-61	7-27-61	7-27-61
Type of water: R, raw; F, finished	R	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	3.7	3.9	3.7
Iron (Fe)	.02	.02	.02
Calcium (Ca)	10	19	18
Magnesium (Mg)	4.2	3.8	4.2
Sodium (Na)	24	24	24
Potassium (K)	2.0	1.9	2.0
Bicarbonate (HCO_3)	33	37	36
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	12	17	20
Chloride (Cl)	40	50	48
Fluoride (F)	.1	.1	.1
Nitrate (NO_3)	.3	.1	.1
Dissolved solids (residue at 180° C)	142	176	176
Hardness as $CaCO_3$	42	63	62
Noncarbonate hardness as $CaCO_3$	15	33	32
Specific conductance (micromhos at 25° C)	231	279	276
pH	6.6	6.5	6.4
Color	10	0	10

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity		24	5.7
Radium (Ra)		.1	<.1
Uranium (U)		<.1	<.1

Spectrographic analyses
[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND looked for but not found]

Silver (Ag)	<0.18	<0.19	0.24
Aluminum (Al)	46	680	540
Boron (B)	80	31	69
Barium (Ba)	78	91	120
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	<2.2
Chromium (Cr)	.34	.41	.52
Copper (Cu)	6.0	2.1	18
Iron (Fe)	100	81	280
Lithium (Li)	1.3	1.7	2.1
Manganese (Mn)	100	58	71
Molybdenum (Mo)	ND	ND	.67
Nickel (Ni)	21	2.1	3.5
Phosphorus (P)	ND	ND	ND
Lead (Pb)	11	3.1	6.7
Rubidium (Rb)	3.5	3.3	3.9
Tin (Sn)	ND	ND	<2.2
Stronium (Sr)	85	150	240
Titanium (Ti)	2.3	2.7	4.5
Vanadium (V)	ND	ND	ND
Zinc (Zn)	ND	ND	ND
Ytterbium (Yb)	ND	ND	X
Yttrium (Y)	ND	ND	X

BALTIMORE

(See fig. 35.)

Ownership: Municipal.

Other areas served: A large population of the Metropolitan District of Anne Arundel, Baltimore, and Howard Counties.

Population served: Baltimore, 939,024; total, about 1,387,000.

Sources and percentages of supply: Water from Gunpowder River, impounded in Loch Raven Reservoir and supplemented from Susquehanna River below Conowingo Dam, is treated at the Montebello plant and constitutes approximately 55 percent of the total supply. Water from North Branch Patapsco River, impounded in Liberty Reservoir, is treated at the Ashburton plant and supplies 45 percent of the population served.

Average amount of water used daily in system during 1962: 211 mgd (U.S. Public Health Service, 1962c).

Treatment: Montebello (Gunpowder River) and Ashburton (North Branch Patapsco River) filtration plants—plain sedimentation, prechlorination, coagulation with alum, sedimentation, rapid sand filtration, and adjustment of pH to 7.8 with lime. Fluoridation with fluosilicic acid to increase concentration of fluoride to 1.0 ppm in the finished water.

Rated capacity of treatment plants: Montebello filtration plant, 240 mgd; Ashburton filtration plant, 120 mgd.

Raw-water storage: 86,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.1 years.

Finished-water storage: Filtered water reservoirs, elevated tanks, standpipes, 775 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 3.7.

Remarks: The water supply for the Metropolitan District of Baltimore County, which borders the city of Baltimore on three sides, is obtained from the city of Baltimore. The Metropolitan District installs the distribution system and then turns it over to the city of Baltimore, where it becomes an integral part of that city's system.

Commercial consumption is primarily from the Montebello plant.

Construction of facilities to add 250 mgd from the Susquehanna River has begun; completion is expected in 1963.

Regular determinations at filter plants, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Montebello: Finished water	43	49	39	7.9	8.0	7.5	60	66	57	0.1	0.2	0.1
Ashburton:												
Raw water	39			7.7						3		
Finished water	32	37	28	7.8	7.9	7.7	47	54	41	.1	.1	.1

Analytical data—Baltimore

	Loch Raven Reservoir	Montebello filtration plant	Liberty Reservoir	Ashburton filtration plant
Percent of supply	55	55	45	45
Date of collection	8-22-61	8-22-61	8-22-61	8-22-61
Type of water: R, raw; F, finished	R	F	R	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	5.5	5.9	5.9	6.2
Iron (Fe)	.01	.00	.00	.00
Manganese (Mn)	.00	.00	.00	.00
Aluminum (Al)	.0	.0	.00	.0
Calcium (Ca)	12	18	8.5	18
Magnesium (Mg)	3.2	3.5	2.6	2.2
Sodium (Na)	3.7	3.1	3.6	4.0
Potassium (K)	1.8	1.6	1.5	1.8
Bicarbonate (HCO_3)	43	48	25	43
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	8.4	10	9.0	12
Chloride (Cl)	5.5	9.0	5.5	9.0
Fluoride (F)	.0	1.0	.1	.9
Nitrate (NO_3)	3.3	3.4	4.7	5.4
Phosphate (PO_4)	.17	.06	.20	.06
Dissolved solids (residue at 180° C)	68	89	59	89
Hardness as $CaCO_3$	43	58	32	55
Noncarbonate hardness as $CaCO_3$	8	19	11	20
Specific conductance (micromhos at 25° C)	111	141	91	141
pH	7.0	7.7	6.4	7.7
Color	3	2	5	3
Temperature °F	66	67	54	56

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	----------	2.9	----------	2.9
Radium (Ra)	----------	.1	----------	.1
Uranium (U)	----------	<.1	----------	<.1

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	0.74	<0.13	----------	0.25
Aluminum (Al)	99	260	----------	180
Boron (B)	16	13	----------	15
Barium (Ba)	39	44	----------	28
Beryllium (Be)	.75	ND	----------	ND
Cobalt (Co)	.99	ND	----------	ND
Chromium (Cr)	2.6	2.0	----------	1.7
Copper (Cu)	26	1.9	----------	3.7
Iron (Fe)	280	640	----------	310
Lithium (Li)	.16	.14	----------	.16
Manganese (Mn)	52	10	----------	8.0
Molybdenum (Mo)	.83	.78	----------	ND
Nickel (Ni)	5.8	4.0	----------	4.7
Phosphorus (P)	ND	ND	----------	ND
Lead (Pb)	43	7.2	----------	5.9
Rubidium (Rb)	3.3	3.0	----------	3.1
Tin (Sn)	1.1	ND	----------	ND
Strontium (Sr)	32	43	----------	42
Titanium (Ti)	2.7	2.1	----------	3.2
Vanadium (V)	<3.0	<3.8	----------	<3.7
Zinc (Zn)	99	<130	----------	<120

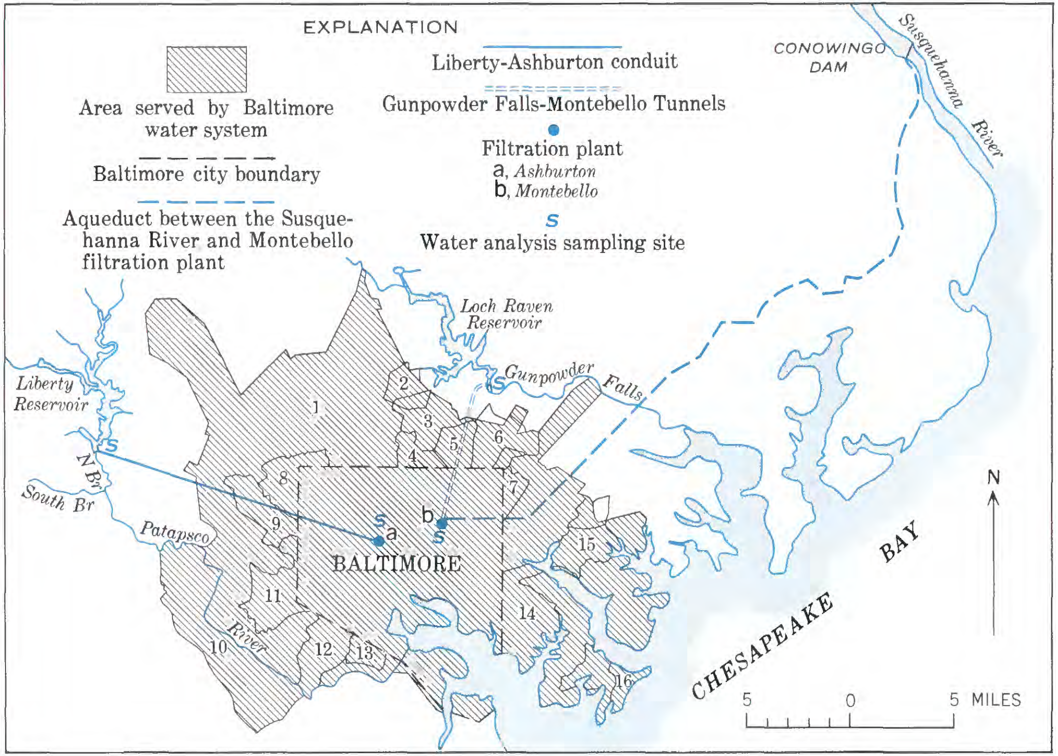

FIGURE 35.—Water supplies and areas served by Baltimore, Md., water system. (Approved by local municipal water officials, Feb. 1963.) Areas served by Baltimore water system: 1, Baltimore County; 2, Timonium-Lutherville; 3, Towson; 4, Stoneleigh-Rodgers Forge; 5, Loch Raven; 6, Parkville-Carney; 7, Overlea; 8, Pikesville; 9, Woodlawn-Rockdale-Millford Mills; 10, Howard County; 11, Catonsville; 12, Arbutus-Halethorpe-Relay; 13, Lansdowne-Baltimore Highlands; 14, Dundalk; 15, Essex; 16, Sparrows Point-Fort Howard-Edgemere.

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MASSACHUSETTS

Boston *Springfield* *Worcester*

BOSTON

(See fig. 36.)

Ownership: Metropolitan District Commission, Commonwealth of Massachusetts.

Other areas served: Member towns: Arlington, Belmont, Brookline, Cambridge, Chelsea, Everett, Lexington, Lynnfield Water District, Malden, Marblehead, Medford, Melrose, Milton, Nahant, Needham, Newton, Norwood, Peabody, Quincy, Revere, Saugus, Somerville, Stoneham, Swampscott, Wakefield, Waltham, Watertown, Winchester, and Winthrop. The following nonmember towns: South Hadley, Chicopee, Wilbraham, Lancaster, Clinton, Northboro, Southboro, Framingham, Marlboro. (Cambridge, Needham, Peabody, Wakefield and Winchester are only partially supplied.)

Population served: Boston, 679,197; total, about 2 million (supplies 48 percent of the State).

Sources and percentages of supply: Swift River, impounded in Quabbin Reservoir, and Ware River diverted into Quabbin Reservoir through a deep rock tunnel. Water from Quabbin Reservoir is conducted through a tunnel to Wachusett Reservoir, then to Norumbega and Weston Reservoirs, the two principal distribution reservoirs.

Auxiliary and emergency supplies: Sudbury Reservoir goes into Framingham Reservoir No. 3; it has a capacity of 1,200 million gal and has been used intermittently.

Average amount of water used daily in system during 1962: 215 mgd (U.S. Public Health Service, 1962c).

Treatment:

Weston Reservoir plant and Norumbega Reservoir plant: Chlorination and ammoniation.

Newton Pumping plant: Chlorination and partial dechlorination (sulfur dioxide).

Six small plants: All use chlorination.

Rated capacity of treatment plants: Weston Reservoir plant, 100 mgd; Sudbury plant, 100 mgd; Norumbega plant, 225 mgd.

Raw-water storage, in million gallons: Reservoirs: Quabbin, 412,240; Wachusett, 65,000; Sudbury, 7,254; Framingham No. 3, 1,180.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 6.2 years.

Finished-water storage, in million gallons: Reservoirs: Norumbega, 204.6; Weston, 200; Spot Pond, 1,892.7; Fells, 85.2; Waban Hill, 16.7; Chestnut Hill, 522.8; Bear Hill, 2.5; Arlington (open reservoir), 2.0; Arlington (two steel standpipes), 2.0 (each); Bellevue No. 1, 2.5; Bellevue No. 2, 3.7; Lexington, 2.0; Nash Hill, 25.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 14.

Regular determinations at Norumbega treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	6.6	8.0	5.5	6.6	6.9	6.4	13	18	11	0.8	1.5	0.4
Finished water	6.0	7.2	4.7	6.5	6.7	6.2	13	18	11	.8	1.5	.4

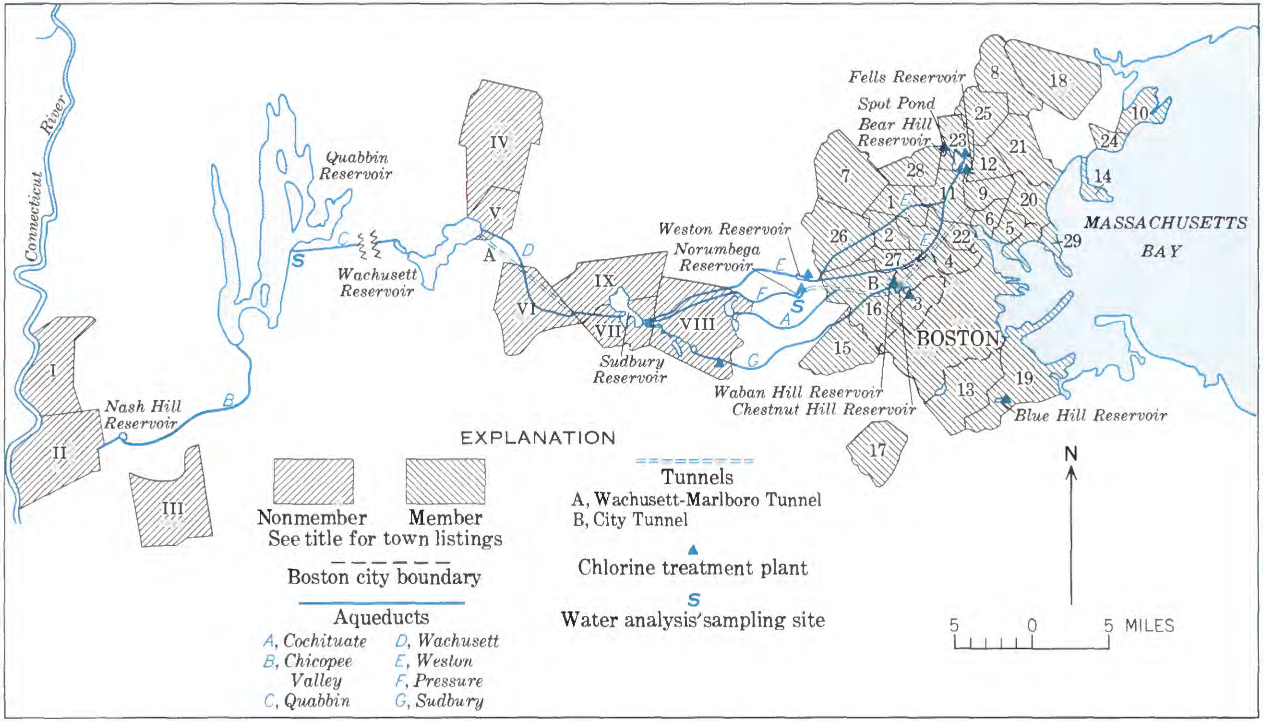

FIGURE 36.—Water supplies and areas served by the Metropolitan (Boston, Mass.) District Commission water system. (Approved by local municipal water officials, March 1963.) Areas supplied by Metropolitan District Commission water system; Nonmembers: I, South Hadley; II, Chicopee; III, Wilbraham; IV, Lancaster; V, Clinton; VI, Northboro: VII, Southboro; VIII, Framingham; IX, Marlboro; Members: 1, Arlington; 2, Belmont; 3, Brookline; 4, Cambridge; 5, Chelsea; 6, Everett; 7, Lexington; 8, Lynnfield water district; 9, Malden; 10, Marblehead; 11, Medford; 12, Melrose; 13, Milton; 14, Nahant; 15, Needham; 16, Newton; 17, Norwood; 18, Peabody; 19, Quincy; 20, Revere; 21, Saugus; 22, Somerville; 23, Stoneham; 24, Swampscott; 25, Wakefield; 26, Waltham; 27, Watertown; 28, Winchester; 29, Winthrop.

Analytical data—Boston

	Quabbin Reservoir [1]	Norumbega Reservoir
Percent of supply	100	100
Date of collection	1–15–62	4–17–62
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	1.0	3.1
Iron (Fe)	.04	.04
Manganese (Mn)	.00	.00
Aluminum (Al)	.15	----------
Copper (Cu)	.04	----------
Calcium (Ca)	2.9	4.5
Magnesium (Mg)	.6	.4
Sodium (Na)	1.7	2.4
Potassium (K)	.7	.8
Arsenic (As)	.00	----------
Bicarbonate (HCO_3)	5	8
Carbonate (CO_3)	0	0
Sulfate (SO_4)	6.9	7.0
Chloride (Cl)	2.1	3.5
Fluoride (F)	.1	.0
Nitrate (NO_3)	.0	.0
Dissolved solids (residue at 180°C)	25	31
Hardness as $CaCO_3$	10	13
Noncarbonate hardness as $CaCO_3$	----------	6
Specific conductance (micromhos at 25°C)	----------	47
pH	6.3	6.4
Color	5	4
Turbidity	0	1
Temperature °F	----------	42
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter]		
Beta activity	----------	24
Radium (Ra)	----------	.1
Uranium (U)	----------	.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	----------	0.18
Aluminum (Al)	----------	37
Boron (B)	----------	8.8
Barium (Ba)	----------	19
Beryllium (Be)	----------	ND
Cobalt (Co)	----------	ND
Chromium (Cr)	----------	.07
Copper (Cu)	----------	4.1
Iron (Fe)	----------	32
Lithium (Li)	----------	.21
Manganese (Mn)	----------	13
Molybdenum (Mo)	----------	<.10
Nickel (Ni)	----------	1.1
Phosphorus (P)	----------	ND
Lead (Pb)	----------	5.4
Rubidium (Rb)	----------	1.6
Tin (Sn)	----------	ND
Strontium (Sr)	----------	30
Titanium (Ti)	----------	.7
Vanadium (V)	----------	1.0
Zinc (Zn)	----------	ND

[1] Analyzed by the Metropolitan District Commission.

SPRINGFIELD

(See fig. 37.)

Ownership: Municipal.

Other areas served: Agawan, Longmeadow, East Longmeadow, Southwick, and Ludlow. Westfield, Wilbraham, and West Springfield receive a small part of their supply from Springfield.

Population served: Springfield, 178,700; total, 236,290.

Sources and percentages of supply: Little River impounded in Borden Brook and Cobble Mountain Reservoirs, 91 percent; Ludlow Reservoir, 9 percent.

Average amount of water used daily in system during 1962: 31.5 mgd (U.S. Public Health Service, 1962c).

Treatment:

West Parish filters (Cobble Mountain Reservoir): Aeration, slow sand filtration, and marble contact filtration.

Ludlow filter plant: Slow sand filtration and chlorination.

Rated capacity of treatment plants: West Parish filters, 45 mgd; Ludlow filter plant, 10 mgd.

Raw-water storage: Little River system, 25,429 million gal; Ludlow Reservoir, 1,500 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.3 years.

Finished-water storage: Provin Mountain Reservoir, 60 million gal, with 30 million gal to be added in summer 1962; Ludlow Reservoir, 10 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 3.2.

Regular determinations at West Parish treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	5	7	4	6.4	6.5	6.2	12	13	9	3	5	2
Finished water	5	7	4	6.7	6.7	6.6	12	13	9	------	------	------

Analytical data—Springfield

	Little River (Cobble Mountain Reservoir)	Ludlow Reservoir
Percent of supply	91	9
Date of collection	4-16-62	4-16-62
Type of water: F, finished	F	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	4.1	3.2
Iron[1] (Fe)	.04	.08
Manganese[1] (Mn)	.00	.00
Calcium (Ca)	3.2	5.1
Magnesium (Mg)	1.1	1.1
Sodium (Na)	2.9	2.8
Potassium (K)	.7	.9
Bicarbonate (HCO_3)	7	8
Carbonate (CO_3)	0	0
Sulfate (SO_4)	6.6	8.9
Chloride (Cl)	5.0	6.0
Fluoride (F)	.0	.0
Nitrate (NO_3)	.2	.1
Dissolved solids (residue at 180° C)	33	34
Hardness as $CaCO_3$	13	17
Noncarbonate hardness as $CaCO_3$	7	11
Specific conductance (micromhos at 25° C)	47	55
pH	6.2	6.4
Color	6	4
Turbidity	1	0
Temperature °F	40	49
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity	6.6	6.5
Radium (Ra)	<.1	<.1
Uranium (U)	<.1	<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	0.14	0.49
Aluminum (Al)	17	14
Boron (B)	5.9	10
Barium (Ba)	15	31
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	<.04	<.04
Copper (Cu)	41	4.9
Iron (Fe)	25	70
Lithium (Li)	.21	.12
Manganese (Mn)	1.5	11
Molybdenum (Mo)	ND	ND
Nickel (Ni)	.9	.7
Phosphorus (P)	ND	ND
Lead (Pb)	1.6	1.3
Rubidium (Rb)	1.3	1.9
Tin (Sn)	ND	ND
Strontium (Sr)	8.1	20
Titanium (Ti)	.4	.4
Vanadium (V)	ND	ND
Zinc (Zn)	ND	ND

[1] In solution when collected.

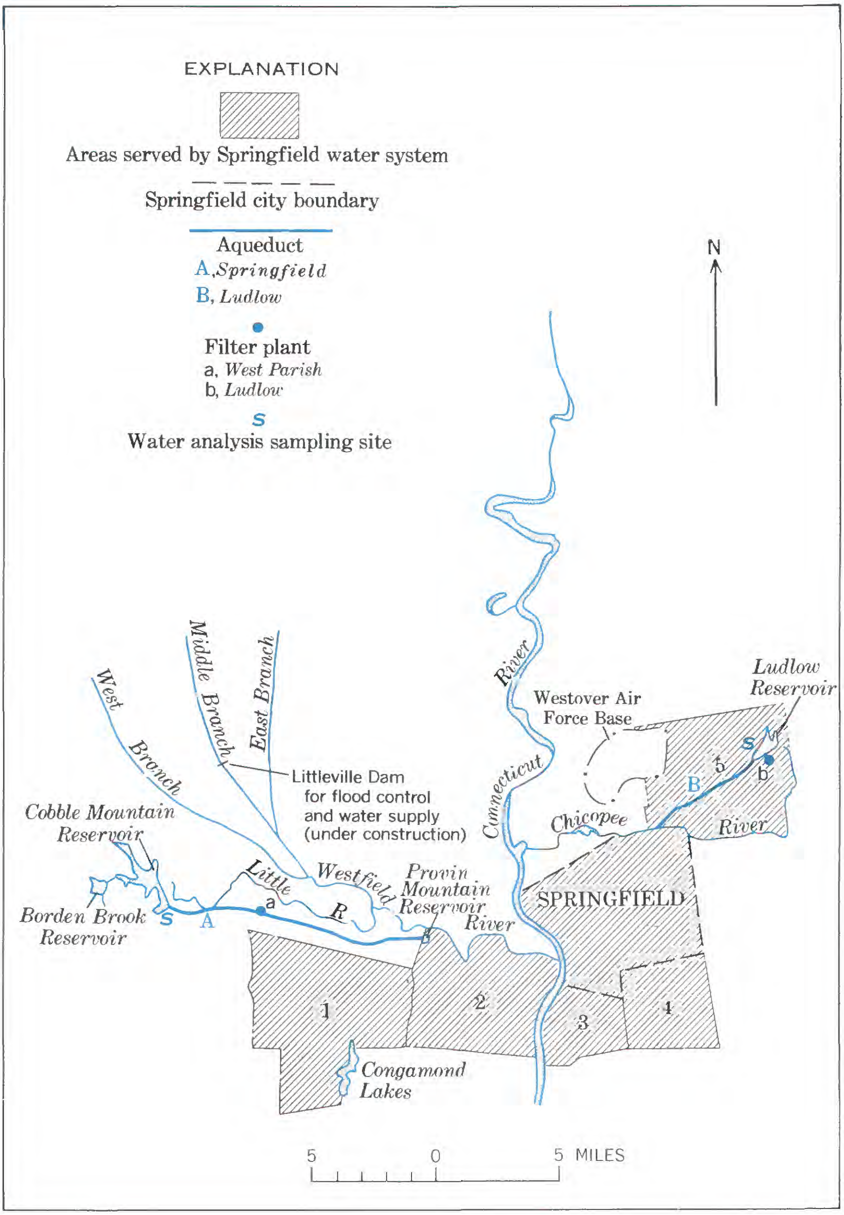

FIGURE 37.—Water supplies and areas served by Springfield, Mass., water system. (Approved by local municipal water officials, March 1963.) Areas served by Springfield water system: 1, Southwick; 2, Agawan; 3, Longmeadow; 4, East Longmeadow; 5, Ludlow.

WORCESTER

(See fig. 38.)

Ownership: Municipal.

Other areas served: Woodland Water District, Elm Hill Water District, and Pinecroft Water District.

Population served: Worcester, 186,587.

Sources and percentages of supply: Lynde Brook Reservoir fed by Kettle Brook Reservoirs 1, 2, 3, and 4, 65 percent; Holden Reservoir 2, fed by Pine Hill, Kendall, and Holden 1 Reservoirs, 35 percent.

Auxiliary and emergency supplies: Wachusett and Quinapoxet Reservoirs.

Average amount of water used daily in system during 1962: 23.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Lynde Brook Reservoir, Worcester, Apricot Street, and Olean Street plants—chlorination.

Rated capacity of treatment plants: Olean Street plant, 30 mgd; other plants, 12 mgd.

Raw-water storage: 7,760 million gal, including the Quinapoxet Reservoir.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 330.

Finished-water storage: 3.75 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

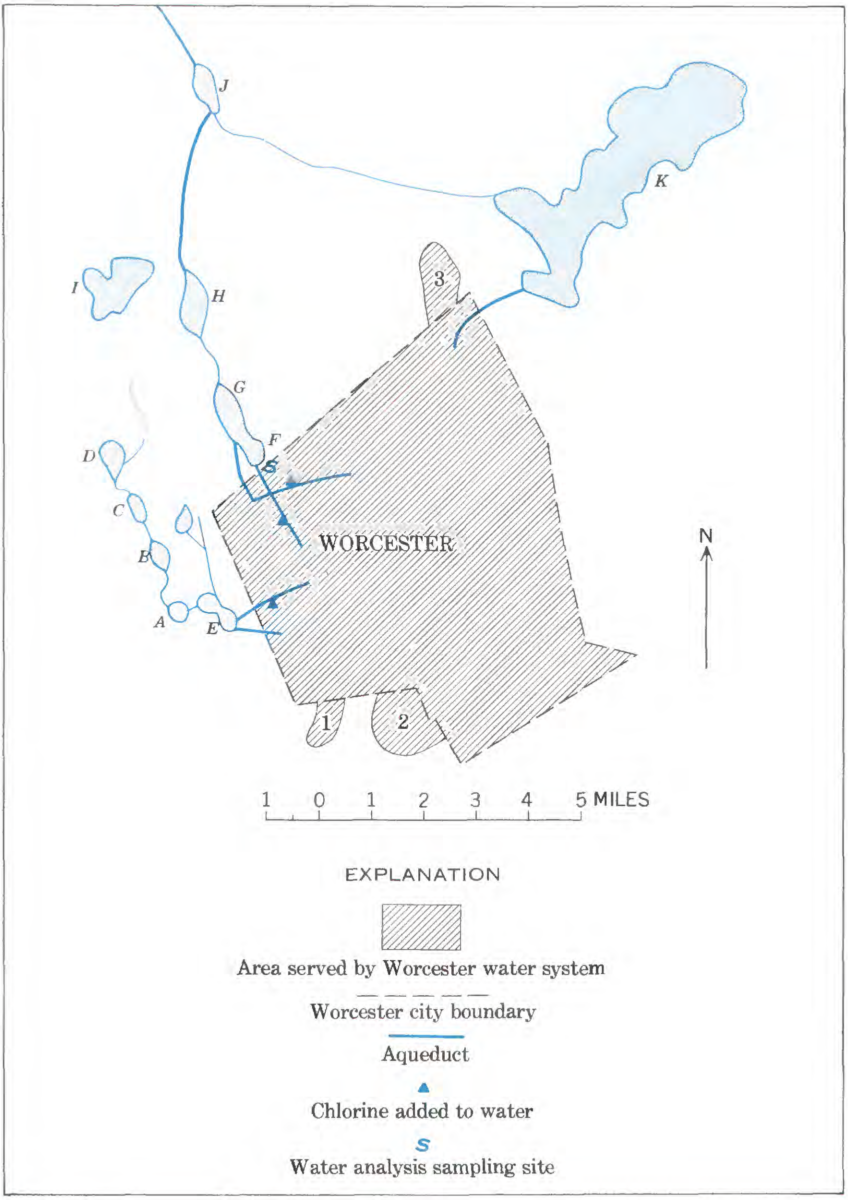

FIGURE 38.—Water supplies and areas served by Worcester, Mass., water system. (Approved by local municipal water officials, March 1963.) High service supply reservoirs: *A*, Kettle Brook 1; *B*, Kettle Brook 2; *C*, Kettle Brook 3; *D*, Kettle Brook 4; *E*, Lynde Brook. Low service supply reservoirs: *F*, Holden 2; *G*, Holden 1; *H*, Kendall; *I*, Pine Hill. Emergency supply reservoirs: *J*, Quinapoxet; *K*, Wachusett (owned by Metropolitan District Comm. (Boston).) Water districts: 1, Woodland; 2, Elm Hill; 3, Pinecroft.

Analytical data—Worcester

	Holden Reservoir 2	Lynde Brook and Holden Reservoir
Percent of supply	35	65
Date of collection	4-17-62	[1]
Type of water: F, finished	F	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	4.6	4.8
Iron[2] (Fe)	.09	.34
Manganese[2] (Mn)	.03	.00
Calcium (Ca)	3.4	4.4
Magnesium (Mg)	.5	.0
Sodium (Na)	2.0	3.2
Potassium (K)	.9	.0
Bicarbonate (HCO_3)	5	----------
Carbonate (CO_3)	0	4
Sulfate (SO_4)	6.6	0
Chloride (Cl)	3.8	3.2
Fluoride (F)	.0	----------
Nitrate (NO_3)	.0	.1
Dissolved solids (residue at 180° C)	28	37
Hardness as $CaCO_3$	11	15
Noncarbonate hardness as $CaCO_3$	7	----------
Specific conductance (micromhos at 25° C)	39	----------
pH	6.0	6.5
Color	4	12
Turbidity	1	2
Temperature °F	42	----------
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity	36	----------
Radium (Ra)	<.1	----------
Uranium (U)	<.1	----------
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	0.06	----------
Aluminum (Al)	26	----------
Boron (B)	12	----------
Barium (Ba)	9.3	----------
Beryllium (Be)	ND	----------
Cobalt (Co)	ND	----------
Chromium (Cr)	.03	----------
Copper (Cu)	5.2	----------
Iron (Fe)	61	----------
Lithium (Li)	.20	----------
Manganese (Mn)	29	----------
Molybdenum (Mo)	ND	----------
Nickel (Ni)	.8	----------
Phosphorus (P)	ND	----------
Lead (Pb)	1.6	----------
Rubidium (Rb)	1.4	----------
Tin (Sn)	ND	----------
Strontium (Sr)	8.1	----------
Titanium (Ti)	.4	----------
Vanadium (V)	<.9	----------
Zinc (Zn)	ND	----------

[1] Average of analyses for the year 1961 by city of Worcester.
[2] In solution when collected.

MICHIGAN

Detroit — *Flint* — *Grand Rapids*

DETROIT

Ownership: Municipal.

Other areas served: Cities of Allen Park, Belleville, Berkley, Birmingham, Center Line, Clawson, Dearborn, East Detroit, Ecorse, Farmington, Ferndale, Fraser, Garden City, Grosse Pointe Park, Grosse Pointe Woods, Hamtramck, Harper Woods, Hazel Park, Huntington Woods, Lathrup Village, Lincoln Park, Livonia, Madison Heights, Melvindale, Oak Park, Pleasant Ridge, River Rouge, Riverview, Roseville, Royal Oak, St. Clair Shores, Southfield, Southgate, Trenton, and Warren. Villages of Beverly Hills, Gibraltar, Grosse Pointe Shores, Inkster, and Wayne; townships of Brownstown, Canton, Dearborn, Farmington, Grosse Isle, Huron, Nankin, Plymouth, Redford, Romulus, Royal Oak, Sterling, and Taylor; Wayne County General Hospital (Eloise), Detroit House of Correction, and Wayne County Training School.

Population served: Detroit, 1,654,100; total, about 3,078,200.

Source of supply: Detroit River.

Average amount of water used daily in system during 1962: 483 mgd (U.S. Public Health Service, 1962c).

Treatment: Water Works Park Station, Springwells Station, and Northeast Station—all raw water is pumped first to the Water Works Park Station for prechlorination and distribution to the three stations, where identical treatment is given as follows: Coagulation with alum, treatment with activated carbon, sedimentation, rapid sand filtration, and postchlorination.

Rated capacity of treatment plants: Water Works Park Station, 320 mgd; Springwells Station, 452 mgd; Northeast Station, 192 mgd.

Raw-water storage: None.

Finished-water storage: Detroit owned, 197.4 million gal; on Detroit system but not Detroit-owned, 42.75 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Water Works Park Station, July 1959–June 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	80	84	78	8.0	8.1	7.9	100	104	96	11	20	2
Finished water	76	78	74	7.6	7.7	7.4	100	104	96	.4	.6	.1

Analytical data—Detroit

	Detroit River			Water Works Park Station	Treated water	
Percent of supply	100	----	----	100	----	----
Date of collection	9-1-61	(1)	(2)	9-1-61	(1)	(2)
Type of water: R, raw; F, finished	R	R	R	F	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	2.1	2.8	1.2	1.5	3.1	1.0
Iron (Fe)	.17	.16	.03	.06	.01	.01
Manganese (Mn)	.14	----	----	.03	----	----
Calcium (Ca)	28	30	26	28	30	26
Magnesium (Mg)	7.0	8	6	7.0	8	6
Sodium (Na)	4.1	6 (Na + K)	2 (Na + K)	3.9	8 (Na + K)	1 (Na + K)
Potassium (K)	.9			.8		
Bicarbonate (HCO_3)	92	100	93	94	96	92
Carbonate (CO_3)	0	4	0	0	0	0
Sulfate (SO_4)	18	16	12	19	20	15
Chloride (Cl)	8.0	10	7	9.0	11	7
Fluoride (F)	.0	----	----	.0	----	----
Nitrate (NO_3)	.5	.39	.10	.4	.28	.10
Dissolved solids (residue at 180° C)	129	156	121	131	145	115
Hardness as $CaCO_3$	99	100	96	99	99	96
Noncarbonate hardness as $CaCO_3$	24	19	16	22	23	19
Specific conductance (micromhos at 25° C)	213	----	----	217	227	208
pH	7.6	8.5	8.0	7.1	7.8	7.5
Color	3	----	----	1	----	----
Turbidity	30	60	2	----	.5	.2
Temperature ° F	73	----	----	73	----	----

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity	----	----	----	2.8	----	----
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	16	----	----	----	----	----
Radium (Ra)	----	----	----	.1	----	----
Uranium (U)	----	----	----	.1	----	----

Spectrographic analyses
[In micrograms per liter. ND, looked for but not found]

Silver (Ag)	0.21	----	----	0.22	----	----
Aluminum (Al)	410	----	----	960	----	----
Boron (B)	33	----	----	22	----	----
Barium (Ba)	100	----	----	40	----	----
Beryllium (Be)	ND	----	----	ND	----	----
Cobalt (Co)	ND	----	----	ND	----	----
Chromium (Cr)	1.5	----	----	1.1	----	----
Copper (Cu)	43	----	----	22	----	----
Iron (Fe)	250	----	----	56	----	----
Lithium (Li)	.79	----	----	.72	----	----
Manganese (Mn)	18	----	----	8.7	----	----
Molybdenum (Mo)	1.6	----	----	1.4	----	----
Nickel (Ni)	11	----	----	5.6	----	----
Phosphorus (P)	ND	----	----	ND	----	----
Lead (Pb)	15	----	----	4.0	----	----
Rubidium (Rb)	2.1	----	----	2.2	----	----
Tin (Sn)	ND	----	----	ND	----	----
Strontium (Sr)	97	----	----	110	----	----
Titanium (Ti)	7.5	----	----	2.2	----	----
Vanadium (V)	ND	----	----	ND	----	----
Zinc (Zn)	210	----	----	ND	----	----

1 Maximum value of constituents in monthly averages of analyses by the city of Detroit during 1961.
2 Minimum value of constituents in monthly averages of analyses by the city of Detroit during 1961.

FLINT

Ownership: Municipal.

Population served: Flint, 194,940; about 1,000 outside the city limits; total, about 195,940.

Source of supply: Flint River (impounded). Water is stored in Earl L. Holloway Reservoir, about 10 miles above the water plant. Water is taken from the Flint River at the plant. Depth of water in the river at the intake is regulated by two downstream dams, Utah and Hamilton, in conjunction with control of the release of water from Holloway Reservoir. Another reservoir, on Kearsley Creek, a tributary of the Flint River below Holloway Reservoir, can be used in the event of an emergency.

Average amount of water used daily in system during 1962: 32 mgd (U.S. Public Health Service, 1962c).

Treatment: Flint filtration plant—prechlorination, addition of activated carbon, chlorine dioxide, coagulation with alum, softening with lime and soda ash, sedimentation, recarbonation, rapid sand filtration, and postchlorination.

Rated capacity of treatment plant: Flint filtration plant, 56 mgd.

Raw-water storage: 6,400 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 200.

Finished-water storage: 25 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Flint filtration plant, 1960:

	pH			Turbidity		
	Avg	Max	Min	Avg	Max	Min
Raw water	8.3	8.4	8.1	15	23	3.8
Finished water	10.2	10.5	10.2	.01	.0	.0

Analytical data—Flint

	Flint River (impounded)			Filtration plant		
Percent of supply	100			100		
Date of collection	8-31-61	(1)	(2)	8-31-61	(1)	(2)
Type of water: R, raw; F, finished	R	R	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	4.6			5.7		
Iron (Fe)	.24	1.00		.06	0.20	
Manganese (Mn)	.17			.02		
Aluminum (Al)	.2	2.4		.1	2.9	0.86
Calcium (Ca)	71	85	56	29	30	25
Magnesium (Mg)	24	29	16	3.9	5.0	.9
Sodium (Na)	15			28		
Potassium (K)	2.4			2.8		
Bicarbonate (HCO_3)	254	265	180	12	57	39
Carbonate (CO_3)	0			16		
Sulfate (SO_4)	60	90	41	64	92	39
Chloride (Cl)	26	26	12	34	34	20
Fluoride (F)	.1			.1		
Nitrate (NO_3)	1.1			.8		
Dissolved solids (residue at 180°C)	348	429	270	204	246	172
Hardness as $CaCO_3$	276	312	202	88	90	80
Noncarbonate hardness as $CaCO_3$	68	103	46	52	55	42
Specific conductance (micromhos at 25°C)	578			343		
pH	7.4			9.4		
Color	17			3		
Temperature °F	74			74		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity				3.1		
Radium (Ra)				<.1		
Uranium (U)				<.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.53			<0.25		
Aluminum (Al)	690			160		
Boron (B)	79			25		
Barium (Ba)	150			36		
Beryllium (Be)	ND			ND		
Cobalt (Co)	ND			ND		
Chromium (Cr)	.90			1.1		
Copper (Cu)	17			4.8		
Iron (Fe)	850			43		
Lithium (Li)	3.0			4.6		
Manganese (Mn)	170			<2.5		
Molybdenum (Mo)	5.8			5.1		
Nickel (Ni)	15			6.1		
Phosphorus (P)	ND			ND		
Lead (Pb)	15			3.3		
Rubidium (Rb)	ND			<2.5		
Tin (Sn)	ND			ND		
Strontium (Sr)	260			180		
Titanium (Ti)	11			<2.5		
Vanadium (V)	ND			<7.6		
Zinc (Zn)	ND			ND		

1 Maximum value of constituents in analyses by the city of Flint of monthly composite sample during 1960.
2 Minimum value of constituents in analyses by the city of Flint of monthly composite sample during 1960.

GRAND RAPIDS

Ownership: Municipal.
Other areas served: Parts of neighboring towns.
Population served: Grand Rapids, 175,741; total, about 200,000.
Source of supply: Lake Michigan (99 percent in 1960).
Auxiliary and emergency supplies: Grand River used when pumping system at lake breaks down and to make up high demand. Less than 1 percent in 1960.
Average amount of water used daily in system during 1962: 34 mgd (U.S. Public Health Service, 1962c).
Treatment: Grand Rapids filtration plant—prechlorination, pH adjusted with lime to 8.2, addition of activated carbon and sodium silicofluoride, sedimentation, postchlorination, when needed, and rapid sand filtration. Auxiliary supply softened with lime.
Rated capacity of treatment plant: Grand Rapids filtration plant, 66 mgd. A new 66-mgd filtration plant at Lake Michigan is scheduled to be completed by January 1963. After completion the present plant will be used to treat the auxiliary supply (Grand River) and to mix water from the two sources in the clear well.
Finished-water storage: 52.75 million gal; includes 9 million gal in clear well at plant.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.6.

Regular determinations at Grand Rapids filtration plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	109	125	100	8.1	8.5	7.5	137	170	122	5.5	20	1
Finished water	107	115	80	7.7	8.6	7.1	140	170	126	.02	.7	.0

Analytical data—Grand Rapids

	Lake Michigan	Filtration plant
Percent of supply	100	100
Date of collection	8-30-61	8-30-61
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	1. 8	1. 8
Iron (Fe)	. 01	. 00
Manganese (Mn)	. 03	. 02
Calcium (Ca)	34	34
Magnesium (Mg)	11	11
Sodium (Na)	4. 1	4. 9
Potassium (K)	. 9	. 9
Bicarbonate (HCO_3)	136	126
Carbonate (CO_3)	0	0
Sulfate (SO_4)	21	24
Chloride (Cl)	7. 0	8. 5
Fluoride (F)	. 0	1. 1
Nitrate (NO_3)	. 5	. 5
Dissolved solids (residue at 180° C)	153	153
Hardness as $CaCO_3$	130	130
Noncarbonate hardness as $CaCO_3$	18	27
Specific conductance (micromhos at 25° C)	265	273
pH	7. 8	7. 5
Color	4	2
Temperature °F	65	65
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter]		
Beta activity	----------	8. 5
Radium (Ra)	----------	. 1
Uranium (U)	----------	. 2
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	<0. 25	<0. 23
Aluminum (Al)	77	280
Boron (B)	15	14
Barium (Ba)	74	39
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	. 52	. 90
Copper (Cu)	52	. 97
Iron (Fe)	59	28
Lithium (Li)	. 71	1. 5
Manganese (Mn)	<2. 5	<2. 3
Molybdenum (Mo)	<1. 7	1. 9
Nickel (Ni)	6. 2	<2. 3
Phosphorus (P)	ND	ND
Lead (Pb)	7. 1	4. 4
Rubidium (Rb)	ND	ND
Tin (Sn)	ND	ND
Strontium (Sr)	84	100
Titanium (Ti)	<2. 5	<2. 3
Vanadium (V)	ND	<6. 9
Zinc (Zn)	ND	ND

MINNESOTA

MINNEAPOLIS

(See fig. 39.)

Ownership: Municipal.

Other areas served: Columbia Heights, New Hope, Crystal, Bloomington, Morningside, Golden Valley, Metropolitan Airport, University Center, and parts of Edina and Fort Snelling.

Population served: Minneapolis, 482,000; total, 582,000.

Source of supply: Mississippi River.

Lowest mean discharge: Mississippi River at Anoka, Minn., for 30-day period in climatic water years (April 1–March 31) 1950–59: 692 mgd.

Average amount of water used daily in system during 1962: 58.7 mgd (U.S. Public Health Service, 1962c).

Treatment:

Fridley softening plant: Softening with lime and soda ash; clarification and stabilization with alum, carbon, and carbon dioxide as required.

Fridley and Columbia Heights filtration plants: Prechlorination, treatment with alum, rapid sand filtration, postchlorination, ammoniation, and fluoridation.

Intermediate water storage: Open reservoir, 75 million gal (after softening and before filtration).

Finished-water storage: Standpipes, 1.5 million gal; reservoirs, 117 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.0.

Regular determinations at filtration plants, 1960:

Plant	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Fridley:												
Raw water	158	214	97	8.2	8.85	7.6	169	219	103	6.7	60	0.8
Finished water	47	59	26	8.4	9.5	7.50	60	88	36	.4	1.0	.0
Columbia Heights: Finished water	41	59	26	8.6	9.5	7.5	67	88	48	.3	1.0	.0

Analytical data—Minneapolis

	Mississippi River	Fridley filtration plant	Columbia Heights filtration plant
Percent of supply	100	51	49
Date of collection	7-31-61	7-31-61	7-31-61
Type of water: R, raw; F, finished	R	F	F

Chemical analyses

[In parts per million]

	Mississippi River	Fridley filtration plant	Columbia Heights filtration plant
Silica (SiO_2)	11	3.3	4.0
Iron (Fe)	.02	.00	.01
Manganese (Mn)	.00	.01	.00
Boron (B)	.04	.04	.03
Aluminum (Al)	.4	.8	1.1
Calcium (Ca)	48	20	15
Magnesium (Mg)	16	4.6	5.5
Sodium (Na)	7.3	6.6	6.3
Potassium (K)	1.5	2.0	1.8
Bicarbonate (HCO_3)	222	36	35
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	16	41	33
Chloride (Cl)	1.6	12	7.5
Fluoride (F)	.2	1.3	1.0
Nitrate (NO_3)	.4	.0	.0
Phosphate (PO_4)	.32	.11	.19
Dissolved solids (residue at 180° C)	228	116	112
Hardness as $CaCO_3$	185	69	60
Noncarbonate hardness as $CaCO_3$	3	39	31
Specific conductance (micromhos at 25° C)	366	195	170
pH	7.5	7.5	7.8
Color	17	2	3
Turbidity	5	1	1
Temperature °F	80	76	80

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

	Mississippi River	Fridley filtration plant	Columbia Heights filtration plant
Beta activity	----------	4.1	4.1
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	66	----------	----------
Radium (Ra)	----------	<.1	<.1
Uranium (U)	----------	.1	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Mississippi River	Fridley filtration plant	Columbia Heights filtration plant
Silver (Ag)	0.48	<0.15	<0.15
Aluminum (Al)	88	420	560
Boron (B)	68	22	19
Barium (Ba)	96	22	26
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	1.4	.68	.59
Copper (Cu)	17	8.4	4.4
Iron (Fe)	29	5.9	19
Lithium (Li)	6.0	14	5.9
Manganese (Mn)	24	2.1	2.8
Molybdenum (Mo)	1.2	.45	<.44
Nickel (Ni)	4.4	2.0	8.4
Phosphorus (P)	ND	ND	ND
Lead (Pb)	6.8	2.1	3.5
Rubidium (Rb)	16	1.6	1.9
Tin (Sn)	ND	ND	ND
Strontium (Sr)	52	15	12
Titanium (Ti)	<4.0	<1.5	<1.5
Vanadium (V)	ND	<4.5	<4.4
Zinc (Zn)	ND	ND	ND

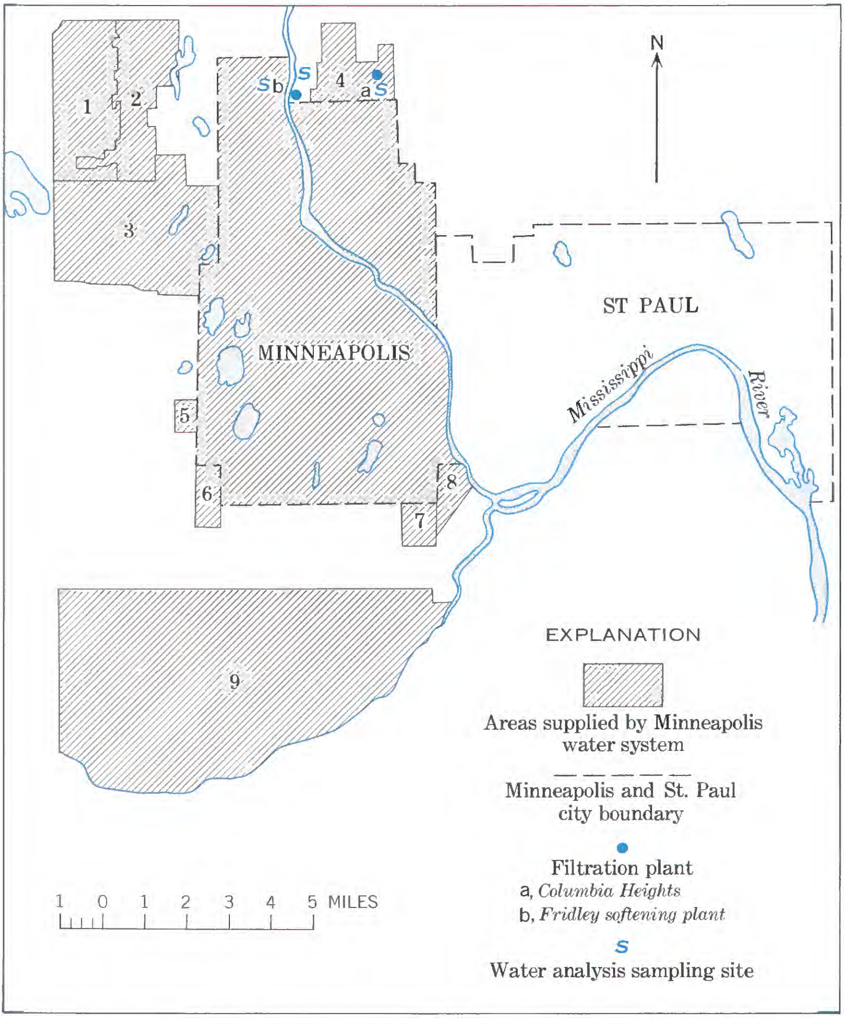

FIGURE 39.—Water supplies and areas served by Minneapolis, Minn., water system. (Approved by local municipal water officials, June 1963.) Areas served by Minneapolis water system: 1, New Hope; 2, Crystal; 3, Golden Valley; 4, Columbia Heights; 5, Morningside; 6, Edina; 7, Airport; 8, Fort Snelling; 9, Bloomington.

ST. PAUL

(See fig. 40.)

Ownership: Municipal.

Other areas served: Falcon Heights, Lauderdale, Maplewood, Mendota Heights, Roseville, and West St. Paul.

Population served: St. Paul, 313,000; total, 334,000.

Sources and percentages of supply: Mississippi River, 90 percent; watershed of impounding lakes, 10 percent.

Auxiliary and emergency supplies: Two artesian well fields and Centerville impounding lake system.

Lowest mean discharge: Mississippi River at Anoka, Minn., for 30-day period in climatic water years (April 1–March 31) 1950–59: 1,070 mgd.

Average amount of water used daily in system during 1962: 42.6 mgd (U.S. Public Health Service, 1962c).

Treatment: McCarron purification plant—aeration, coagulation with alum, softening with lime, recarbonation, sedimentation, rapid sand filtration, chlorination, and fluoridation.

Rated capacity of treatment plants: McCarron purification plant, 100 mgd.

Raw-water storage: 6,750 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 158.

Finished-water storage: Reservoirs, 84 million gal; tanks and standpipes, 7.2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.1.

Regular determinations at McCarron purification plant, 1959:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	164	193	140	8.3	8.6	8.2	178	208	54	1.0	2.0	------
Finished water	61	83	44	8.6	9.0	8.2	88	111	72	.2	1.0	0.1

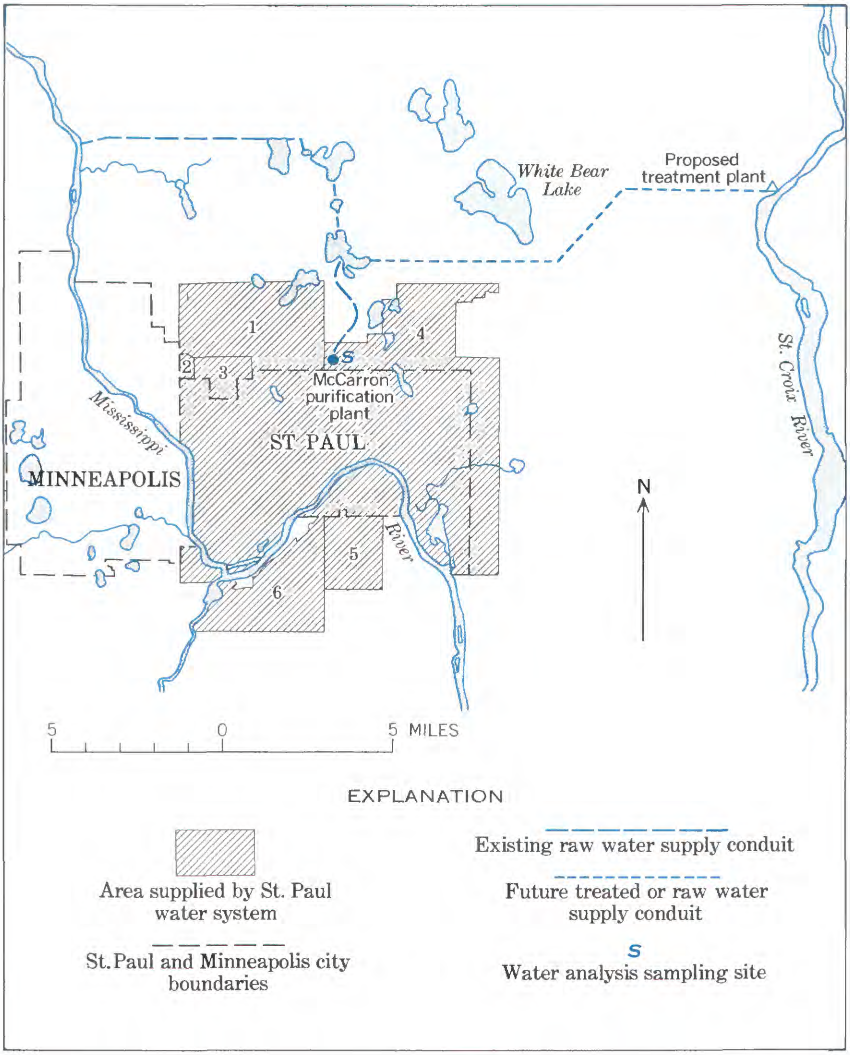

FIGURE 40.—Water supplies and areas served by St. Paul, Minn., water system. (Approved by local municipal water officials, June 1963.) Areas served by St. Paul water system: 1, Roseville; 2, Lauderdale; 3, Falcon Heights; 4, Maplewood; 5, West St. Paul; 6, Mendota Heights.

Analytical data—St. Paul

	Mississippi River	McCarron purification plant
Percent of supply	90	90
Date of collection	7-31-61	7-31-61
Type of water: R, raw; F, finished	R	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	2.5	3.2
Iron (Fe)	.02	.00
Manganese (Mn)	.04	.00
Boron (B)	.04	.08
Aluminum (Al)	.5	.3
Calcium (Ca)	44	25
Magnesium (Mg)	10	.9
Sodium (Na)	6.9	6.0
Potassium (K)	2.8	2.2
Bicarbonate (HCO_3)	180	56
Carbonate (CO_3)	0	0
Sulfate (SO_4)	14	20
Chloride (Cl)	4.0	11
Fluoride (F)	.2	1.3
Nitrate (NO_3)	.2	.1
Phosphate (PO_4)	.19	.13
Dissolved solids (residue at 180° C)	199	109
Hardness as $CaCO_3$	153	66
Noncarbonate hardness as $CaCO_3$	5	20
Specific conductance (micromhos at 25° C)	312	178
pH	7.5	7.8
Color	15	2
Turbidity	1	0
Temperature °F	79	80

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity		11
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	66	
Radium (Ra)		.1
Uranium (U)		<.1

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.34	<0.17
Aluminum (Al)	55	210
Boron (B)	51	98
Barium (Ba)	120	45
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	1.3	1.7
Copper (Cu)	44	24
Iron (Fe)	25	58
Lithium (Li)	1.7	8.9
Manganese (Mn)	41	5.0
Molybdenum (Mo)	1.5	1.4
Nickel (Ni)	4.1	5.3
Phosphorus (P)	ND	ND
Lead (Pb)	8.9	4.8
Rubidium (Rb)	<3.4	5.5
Tin (Sn)	ND	ND
Strontium (Sr)	82	91
Titanium (Ti)	<3.4	3.1
Vanadium (V)	ND	5.3
Zinc (Zn)	<340	ND

JACKSON

Ownership: Municipal.
Population served: Jackson, 150,000.
Source of supply: Pearl River.
Lowest mean discharge: Pearl River at Jackson, Miss., for 30-day period in climatic water years (April 1–March 31) 1950–59: 61.2 mgd.
Average amount of water used daily in system during 1962: 15 mgd (U.S. Public Health Service, 1962c).
Treatment: Jackson treatment plant—coagulation with alum and lime, treatment with carbon for taste and odor control, sedimentation, rapid sand filtration, ammoniation, and chlorination.
Rated capacity of treatment plant: Jackson treatment plant, 37 mgd.
Finished-water storage: 3 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Jackson treatment plant:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	16	24	8	6.6	7.9	6.0	35	48	6	60	1,000	8
Finished water	25	40	15	9.0	9.2	8.0	50	60	60			

Analytical data, treatment plant—Jackson

[Percent of supply: 100. Date of collection: 4-30-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	6.3	Nitrate (NO_3)	0.2
Iron (Fe)	.03	Dissolved solids (residue at 180°C)	95
Calcium (Ca)	16	Hardness as $CaCO_3$	45
Magnesium (Mg)	1.2	Noncarbonate hardness as $CaCO_3$	24
Sodium (Na)	3.4	Specific conductance (micromhos at 25°C)	117
Potassium (K)	1.1	pH	7.0
Bicarbonate (HCO_3)	26	Color	10
Carbonate (CO_3)	0		
Sulfate (SO_4)	23		
Chloride (Cl)	5.9		
Fluoride (F)	.0		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	21	Uranium (U)	0.1
Radium (Ra)	.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	0.68	Molybdenum (Mo)	ND
Aluminum (Al)	210	Nickel (Ni)	1.1
Boron (B)	21	Phosphorus (P)	ND
Barinm (Ba)	28	Lead (Pb)	3.7
Beryllium (Be)	ND	Rubidium (Rb)	1.6
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	<.03	Strontium (Sr)	9.6
Copper (Cu)	2.2	Titanium (Ti)	.4
Iron (Fe)	44	Vanadium (V)	ND
Lithium (Li)	.32	Zinc (Zn)	ND
Manganese (Mn)	44		

KANSAS CITY

(See fig. 32.)

Ownership: Municipal.

Other areas served: Towns of Avondale, Grandview, and Lee's Summit; a number of water districts in Clay and Jackson Counties; and Leawood and Lenexa, Kans.

Population served: Kansas City, 502,390; total, about 750,000.

Source of supply: Missouri River. Raw water is pumped from the river at a location about 4 miles upstream from the city to the purification works by the Low Lift Pumping Station. From the finished-water reservoirs at the purification site, the water is pumped by the Secondary Pumping Station through a tunnel under the Missouri River to reservoirs at the sites of two pumping stations in the city, Turkey Creek and East Bottoms Pumping Stations. The water is delivered from these reservoirs by these two pumping stations into the city's main distribution system. Turkey Creek Pumping Station handles about two-thirds of the total demand on the distribution system. All pumping stations are electrically operated. Repumping is ordinarily required in the area in the south and southwest part of the city and in the area south of the city limits.

Lowest mean discharge: Missouri River at St. Joseph, Mo., for 30-day period in climatic water years (April 1–March 31) 1950–59: 5,970 mgd.

Average amount of water used daily in system during 1962: 88 mgd (U.S. Public Health Service, 1962c).

Treatment: Kansas City treatment plant—plain sedimentation (clarifier equipped basins), softening with excess lime (supplemented with soda ash during critical periods), clarification and coagulation with recirculated sludge (supplemented with ferric sulfate and alum during critical periods), chlorination and ammoniation, flocculation, treatment with activated carbon, recarbonation, sedimentation, rapid sand filtration, and postchlorination.

Rated capacity of treatment plant: Kansas City treatment plant, 210 mgd.

Finished-water storage: 72 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Kansas City treatment plant, May 1960–April 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	163	221	130	8.2	8.3	8.1	218	278	162	800	1,800	70
Finished water	40	51	33	9.5	9.5	9.3	85	95	71	.0	.3	.0

Analytical data—Kansas City

	Missouri River		Treatment plant	
Percent of supply	100	100	100	100
Date of collection	10-17-61	(1)	7-26-61	(1)
Type of water: R, raw; F, finished	R	R	F	F
Chemical analyses [In parts per million]				
Silica (SiO_2)	7.0	11	4.8	7.7
Iron (Fe)	.10		.00	
Manganese (Mn)	.00		.01	
Calcium (Ca)	55	59	20	26
Magnesium (Mg)	16	17	4.8	4.8
Sodium (Na)	35	} 49	{ 33	} 53
Potassium (K)	6.6		5.4	
Bicarbonate (HCO_3)	196	199	25	
Carbonate (CO_3)	0	0	3	
Sulfate (SO_4)	101	122	111	128
Chloride (Cl)	12	21	13	22
Fluoride (F)	.5	.4	.4	.2
Nitrate (NO_3)	3.8	1.3	1.8	.8
Dissolved solids (residue at 180° C)	350		23[illegible]	
Hardness as $CaCO_3$	203	219	70	85
Noncarbonate hardness as $CaCO_3$	42		44	
Specific conductance (micromhos at 25° C)	522		33[illegible]	
pH	7.8		8.7	9.5
Color	15		5	
Turbidity		854		0
Temperature °F	78		7[illegible]	
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter. Maximum beta activity data from U.S. Public Health Service, 1962]				
Beta activity			9.3	
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	70			
Radium (Ra)			.5	
Uranium (U)			.2	
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]				
Silver (Ag)	<0.56		<0.28	
Aluminum (Al)	[2] 2,400		53	
Boron (B)	110		82	
Barium (Ba)	340		85	
Beryllium (Be)	ND		ND	
Cobalt (Co)	ND		ND	
Chromium (Cr)	7.8		1.2	
Copper (Cu)	6.1		7.4	
Iron (Fe)	[3] 3,800		24	
Lithium (Li)	25		25	
Manganese (Mn)	290		<2.8	
Molybdenum (Mo)	3.1		4.4	
Nickel (Ni)	15		3.6	
Phosphorus (P)	<560		ND	
Lead (Pb)	38		5.2	
Rubidium (Rb)	7.8		ND	
Tin (Sn)	ND		ND	
Strontium (Sr)	610		270	
Titanium (Ti)	15		<2.8	
Vanadium (V)	<17		8.2	
Zinc (Zn)	ND		ND	

[1] Average of monthly composite samples (May 1, 1960, to June 30, 1961); analyses by the city of Kansas City.
[2] Water on April 11, 1962, had aluminum content of 170 micrograms per liter.
[3] Water on April 11, 1962, had iron content of 8.0 micrograms per liter.

ST. LOUIS

(See fig. 41.)

Ownership: Municipal.

Population served: St. Louis, 756,000; also supplies a few noncity consumers; total, 760,000. Number of city water subscribers has actually diminished slightly in the past 10 years. Private companies operating outside city limits have vastly increased in number of subscribers, but much less water is used per capita there, since rates are more than double city rates.

Sources and percentages of supply: Mississippi River at the Chain of Rocks plant, 5 miles below the confluence with the Missouri River, 66 percent of supply. (Although the Chain of Rocks intake is in the Mississippi River, nearly all the water drawn into the plant is derived from the Missouri River owing to natural channeling of flow.) Missouri River at the Howard Bend Plant, 37 miles above confluence of Missouri and Mississippi River, 34 percent of supply.

Lowest mean discharge:

Missouri River at Herman, Mo., for 30-day period in climatic water years (April 1–March 31) 1950–59: 9,630 mgd.

Mississippi River at Alton, Ill., for 30-day period in climatic water years (April 1–March 31) 1950–59: 14,100 mgd.

Average amount of water used daily in system during 1962: 181 mgd (U.S. Public Health Service, 1962c).

Treatment: Howard Bend and Chain of Rocks purification plants—sedimentation, softening with lime, coagulation with ferrous sulfate, sedimentation, secondary coagulation and sedimentation with alum, ammoniation (ammonium hydroxide), chlorination, rapid sand filtration, postchlorination, and fluoridation to 1.0 ppm.

Rated capacity of treatment plants: Howard Bend purification plant, 120 mgd; Chain of Rocks purification plant, 240 mgd.

Raw-water storage: Chain of Rocks purification plant, 24 million gal; Howard Bend purification plant, 11 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: Chain of Rocks clear well, 11 million gal; Compton Hill Reservoir, 85 million gal; Howard Bend Basin, 5 million gal; Stacy Park Reservoir, 100 million gal.

The finished water from the Chain of Rocks plant is pumped from the new dual pressure distributive station 3½ miles south to the Boden area and 3½ miles farther south to the Bissell Point area, where the water is fed into the distributing system. Three-fourths of the output of the plant is pumped into the city mains connected with the Compton Hill Reservoir, which supplies the lower part of the city. The remainder of the output is pumped through the Boden area directly into the mains at a higher pressure and serves the higher sections of the city.

The finished water from the Howard Bend plant is pumped about 9 miles into the Stacy Park Reservoir, which is at an altitude high enough to supply by gravity flow the highest section of the city.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.1.

Regular determination at purification plants, April 1960–March 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Howard Bend:												
Raw water	153	260	87	8.1	8.4	7.7	208	320	112	850	4300	50
Finished water	43	107	23	9.2	9.8	8.2	107	180	76	.1	.8	.0
Chain of Rocks:												
Raw water	154	253	88	8.1	8.5	7.8	206	314	109	700	3600	25
Finished water	46	107	25	9.2	9.8	8.6	104	158	70	.1	.6	.0

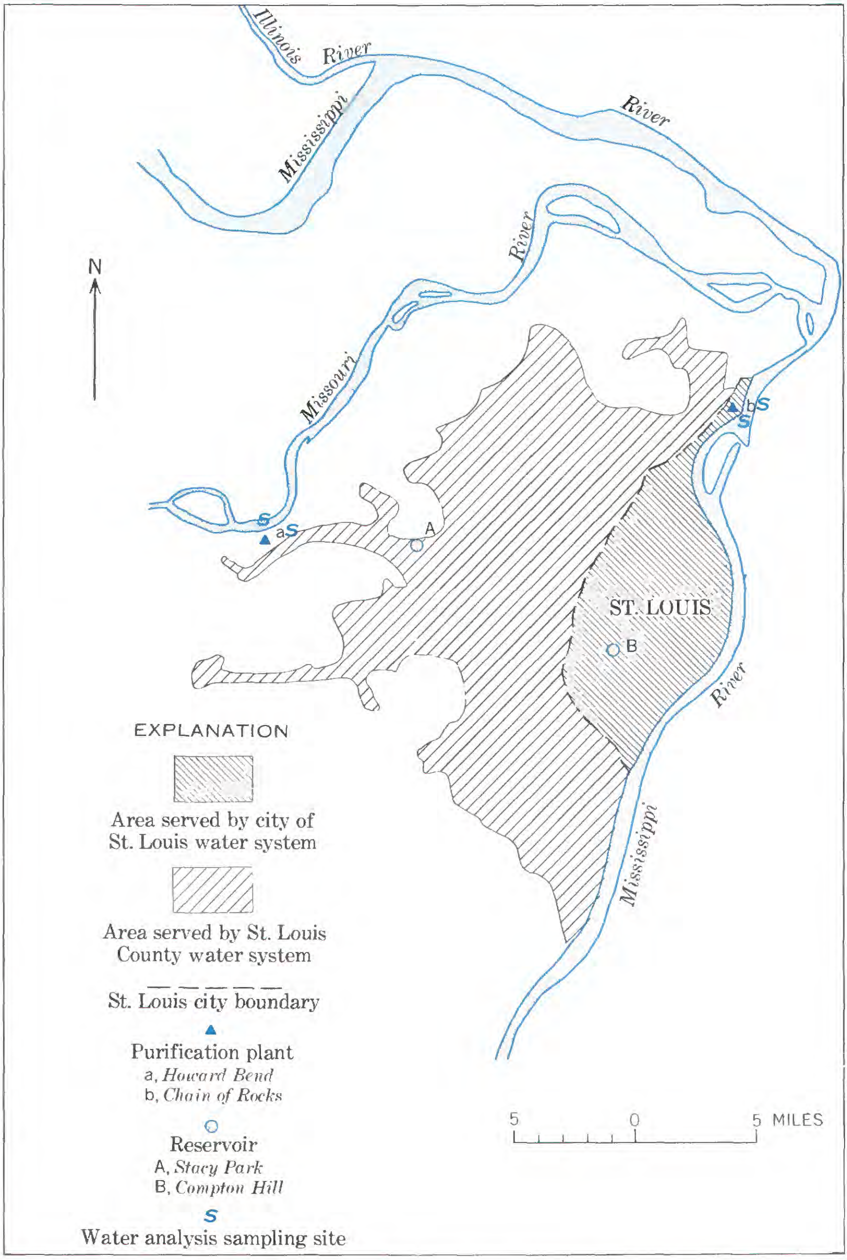

FIGURE 41.—Water supplies and areas served by major water supply systems in the St. Louis, Mo., area. (Approved by local municipal water officials, March 1963.)

Analytical data—St. Louis

	Missouri River	Howard Bend purification plant	Mississippi River	Chain of Rocks purification plant
Percent of supply	34	34	66	66
Date of collection	10-18-61	10-18-61	10-19-61	10-19-61
Type of water: R, raw; F, finished	R	F	R	F

Chemical analyses

[In parts per million]

	Missouri River	Howard Bend purification plant	Mississippi River	Chain of Rocks purification plant
Silica (SiO_2)	6.2	5.4	5.5	5.6
Iron (Fe)	.20	.03	.40	.02
Manganese (Mn)	.00	.00	.00	.01
Calcium (Ca)	36	23	37	22
Magnesium (Mg)	8.8	5.0	8.9	5.9
Sodium (Na)	17	22	17	22
Potassium (K)	5.1	5.1	5.1	5.0
Bicarbonate (HCO_3)	127	39	128	44
Carbonate (CO_3)	0	4	0	0
Sulfate (SO_4)	47	69	48	70
Chloride (Cl)	10	13	10	13
Fluoride (F)	.4	1.2	.4	1.7
Nitrate (NO_3)	3.4	2.9	3.2	2.9
Dissolved solids (residue at 180° C)	220	176	222	183
Hardness as $CaCO_3$	126	77	129	80
Noncarbonate hardness as $CaCO_3$	22	38	24	44
Specific conductance (micromhos at 25° C)	323	268	324	274
pH	7.8	9.2	7.7	8.2
Color	5	10	5	15

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

	Missouri River	Howard Bend purification plant	Mississippi River	Chain of Rocks purification plant
Beta activity		9.9		11
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	48		78	
Radium (Ra)		.1		<.1
Uranium (U)		.5		1.0

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Missouri River	Howard Bend purification plant	Mississippi River	Chain of Rocks purification plant
Silver (Ag)		<0.22		<0.23
Aluminum (Al)		850		[1] 2,200+
Boron (B)		37		43
Barium (Ba)		59		77
Beryllium (Be)		ND		ND
Cobalt (Co)		ND		ND
Chromium (Cr)		1.5		2.0
Copper (Cu)		8.5		2.5
Iron (Fe)		95		39
Lithium (Li)		15		15
Manganese (Mn)		4.3		3.4
Molybdenum (Mo)		5.4		7.0
Nickel (Ni)		4.1		4.8
Phosphorus (P)		ND		ND
Lead (Pb)		2.8		3.0
Rubidium (Rb)		<2.2		<2.3
Tin (Sn)		ND		ND
Strontium (Sr)		150		250
Titanium (Ti)		2.4		15
Vanadium (V)		8.9		11
Zinc (Zn)		ND		ND

[1] Water on April 12, 1962, had an aluminum content of 270 micrograms per liter.

LINCOLN

(See fig. 42.)

Ownership: Municipal.

Population served: Lincoln, 128,000; suburban areas, about 300; total, 128,300.

Sources and percentages of supply: Thirty-three wells near Ashland, 96.5 percent; 21 wells in Lincoln, 3.5 percent. Two collecting pipelines carry the water from the Ashland wells to the treatment plant. After treatment the water is pumped into a concrete reservoir and then into a reinforced concrete pipeline for transmission to Lincoln, a distance of about 25 miles.

Auxiliary and emergency supplies: The 21 wells in Lincoln area are used also as auxiliary supply and in emergencies.

Average amount of water used daily in system during 1962: 23.6 mgd (U.S. Public Health Service, 1962c).

Treatment:

Ashland purification plant: Prechlorination, aeration, rechlorination, ammoniation, sedimentation, and rapid sand filtration.

Auxiliary supply: Chlorination only.

Rated capacity of treatment plants: Ashland purification plant, 60 mgd.

Raw-water storage: None.

Finished-water storage: Closed reservoirs, 44.1 million gal; elevated storage, 0.4 million gal; concrete tanks, 2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.

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Analytical data—Lincoln

	Composite of Ashland wells 1, 2A, and 56-4	Composite of Ashland wells 6; 9; 54-1, -4, -7, -9, -11	Lincoln wells [1]	Ashland purification plant
Percent of supply		96	4	100
Date of collection	1-23-62	1-23-62	7-10-61	1-23-62
Type of water: R, raw; F, finished	R	R	R	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	36	34	36	35
Iron (Fe)	.03	.00	.04	.00
Manganese (Mn)	.00	.34	.00	.00
Boron (B)	.06	.05		.05
Aluminum (Al)	.00	.00		.00
Calcium (Ca)	58	58	54	56
Magnesium (Mg)	6.2	9.4	16	9.1
Sodium (Na)	26	25	25	25
Potassium (K)	8.0	8.4	4.5	9.2
Iodide (I)	.000	.000		.000
Bicarbonate (HCO_3)	191	199	248	192
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	63	68	59	67
Chloride (Cl)	8.3	8.5	15	10
Fluoride (F)	.4	.4	.3	.4
Nitrate (NO_3)	.0	.0	5.0	.3
Phosphate (PO_4)	.53	.47		.61
Dissolved solids (residue at 180°C)	309	317	333	312
Hardness as $CaCO_3$	170	183	162	177
Noncarbonate hardness as $CaCO_3$	13	20	0	20
Specific conductance (micromhos at 25°C)	461	475		467
pH	7.5	7.4		7.6
Color	3	2		6
Turbidity	2	2		2
Temperature °F	49	51		52

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity				14
Radium (Ra)				.3
Uranium (U)				5.2

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)				<0.41
Aluminum (Al)				28
Boron (B)				65
Barium (Ba)				150
Beryllium (Be)				ND
Cobalt (Co)				ND
Chromium (Cr)				ND
Copper (Cu)				3.8
Iron (Fe)				22
Lithium (Li)				9.3
Manganese (Mn)				<4.1
Molybdenum (Mo)				2.8
Nickel (Ni)				<4.1
Phosphorus (P)				ND
Lead (Pb)				ND
Rubidium (Rb)				ND
Tin (Sn)				ND
Strontium (Sr)				230
Titanium (Ti)				ND
Vanadium (V)				<12
Zinc (Zn)				ND

[1] Analyzed by the city of Lincoln.

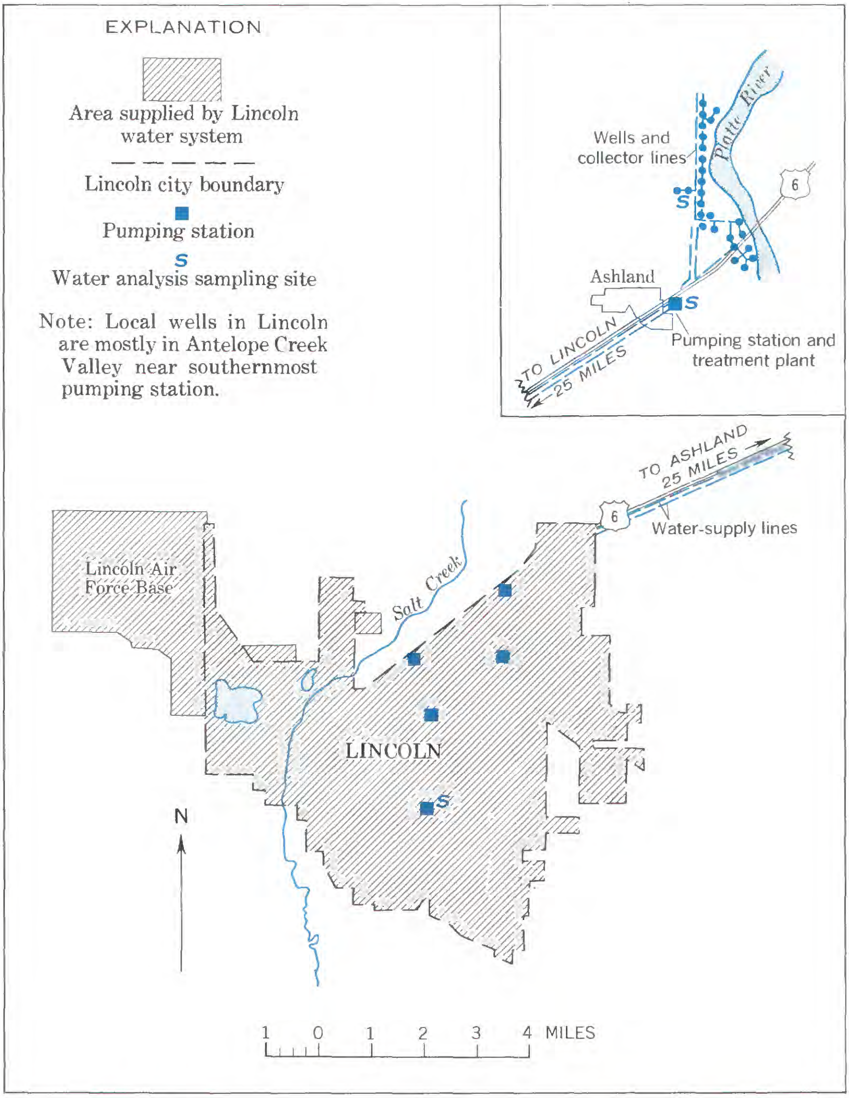

FIGURE 42.—Water supplies and areas served by Lincoln, Nebr., water system. (Approved by local municipal water officials, June 1963.)

OMAHA

(See fig. 43.)

Ownership: Metropolitan Utilities District.

Population served: Omaha, 301,598; about 25,000 outside the city limits; total, about 327,000.

Source of supply: Missouri River. The intake and treatment plant are located on the Missouri River at Florence, Nebr.

Lowest mean discharge: Missouri River at Omaha, Nebr., for 30-day period in climatic water years (April 1–March 31) 1950–59: 4,650 mgd.

Average amount of water used daily in system during 1962: 64.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Minne Lusa treatment plant—Plain sedimentation, prechlorination, split treatment in which part is lime-softened and the remainder is coagulated with alum and activated silica, sedimentation, rapid sand filtration, and postchlorination.

Rated capacity of treatment plant: Minne Lusa treatment plant, 140 mgd.

Raw-water storage: 86 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.3.

Finished-water storage: 56 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Minne Lusa treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	172	254	122	8.2	8.5	7.8	245	336	158	280	780	15
Finished water	68	122	37	9.5	9.9	9.1	148	201	121	.2	1.1	.1

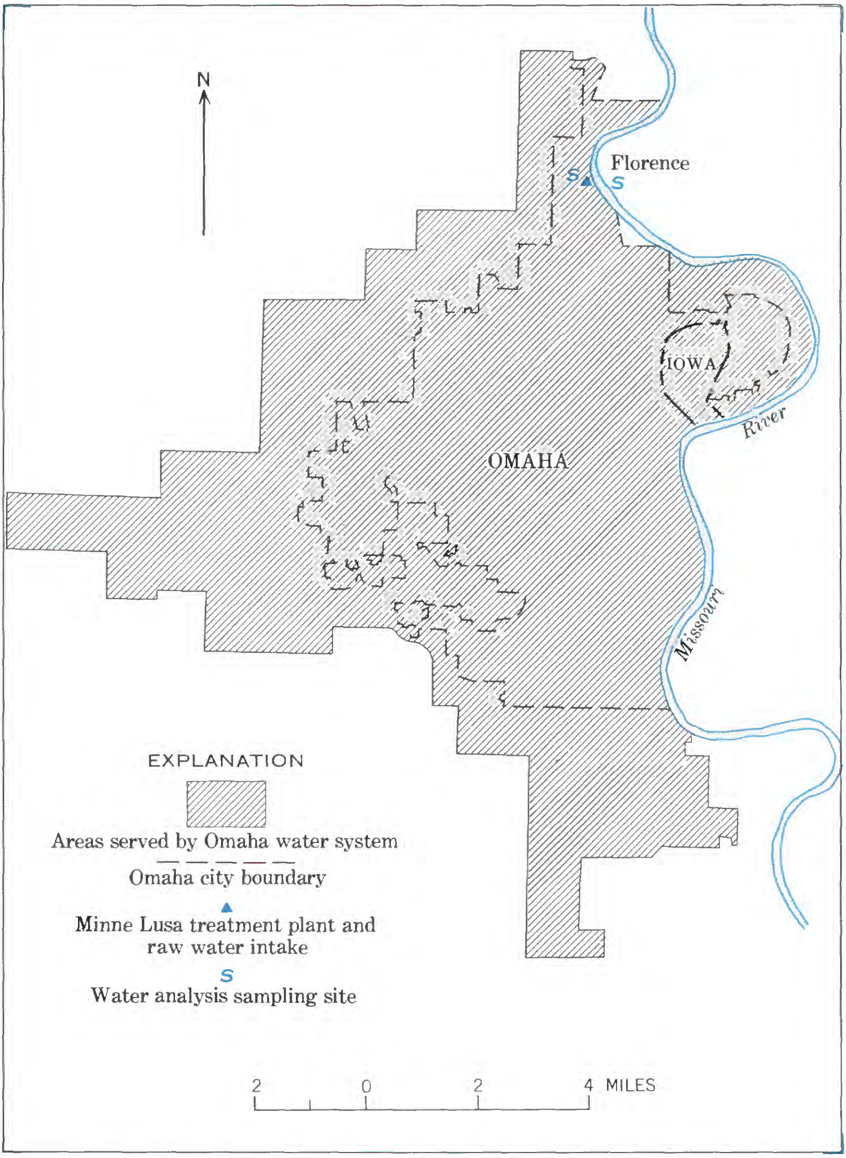

FIGURE 43.—Water supplies and areas served by Omaha, Nebr., water system. (Approved by local municipal water officials, June 1963.)

Analytical data—Omaha

	Missouri River	Minne Lusa treatment plant		Missouri River	Minne Lusa treatment plant
Percent of supply	100	100	Type of water: R, raw; F, finished	R	F
Date of collection	1-23-62	1-23-62			

Chemical analyses

[In parts per million]

Silica (SiO_2)	16	11	Nitrate (NO_3)	0.4	0.9
Iron (Fe)	.02	.02	Phosphate (PO_4)	.19	.35
Manganese (Mn)	.00	.00	Dissolved solids (residue at 180° C)	523	382
Boron (B)	.13	.11	Hardness as $CaCO_3$	279	144
Aluminum (Al)	.00	.00	Noncarbonate hardness as $CaCO_3$	84	90
Calcium (Ca)	74	35			
Magnesium (Mg)	23	14			
Sodium (Na)	65	65			
Potassium (K)	6.4	6.0	Specific conductance (micromhos at 25° C)	797	612
Iodide (I)	.005	.000	pH	7.3	8.3
Bicarbonate (HCO_3)	238	58	Color	7	3
Carbonate (CO_3)	0	4	Turbidity	2	2
Sulfate (SO_4)	210	211	Temperature °F	33	33
Chloride (Cl)	13	6.0			
Fluoride (F)	.6	.4			

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity	----------	12	Radium (Ra)	----------	<0.1
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	78	----------	Uranium (U)	----------	2.6

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	----------	<0.46	Molybdenum (Mo)	----------	4.6
Aluminum (Al)	----------	300	Nickel (Ni)	----------	<4.6
Boron (B)	----------	87	Phosphorus (P)	----------	ND
Barium (Ba)	----------	46	Lead (Pb)	----------	ND
Beryllium (Be)	----------	ND	Rubidium (Rb)	----------	ND
Cobalt (Co)	----------	ND	Tin (Sn)	----------	ND
Chromium (Cr)	----------	ND	Strontium (Sr)	----------	410
Copper (Cu)	----------	1.7	Titanium (Ti)	----------	<1.4
Iron (Fe)	----------	13	Vanadium (V)	----------	ND
Lithium (Li)	----------	39	Zinc (Zn)	----------	ND
Manganese (Mn)	----------	<4.6			

NEW JERSEY

Jersey City *Newark* *Paterson*

JERSEY CITY

(See fig. 44.)

Ownership: Municipal.
Other areas served: All or part of Hoboken, Lyndhurst, and North Arlington.
Population served: Jersey City, 276,101; total, about 350,000.
Source of supply: Rockaway River impounded in Split Rock and Boonton Reservoirs.
Auxiliary and emergency supplies: The supply system is interconnected with the North Jersey District Water Supply Commission, Newark municipal, and Passaic Valley Water Commission systems.
Average amount of water used daily in system during 1962: 61.0 mgd (U.S. Public Health Service, 1962c).
Treatment: Boonton Reservoir plant—sedimentation and chlorination.
Rated capacity of treatment plant: Boonton Reservoir plant, 100 mgd.
Raw-water storage: Boonton, 7,500 million gal; Split Rock, 3,300 million gal.
Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 177.
Finished-water storage: 100 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.6.

Analytical data, Boonton Reservoir—Jersey City

[Percent of supply: 100. Date of collection: 4-3-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	7.6	Nitrate (NO_3)	1.1
Iron (Fe)	.02	Dissolved solids (residue at 180° C)	75
Manganese (Mn)	.04	Hardness as $CaCO_3$	42
Calcium (Ca)	11	Noncarbonate hardness as $CaCO_3$	23
Magnesium (Mg)	3.5	Specific conductance (micromhos at 25° C)	110
Sodium (Na)	4.6	pH	7.0
Potassium (K)	1.0	Color	5
Bicarbonate (HCO_3)	24		
Carbonate (CO_3)	0		
Sulfate (SO_4)	18		
Chloride (Cl)	8.2		
Fluoride (F)	.4		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	17	Uranium (U)	0.1
Radium (Ra)	<.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.09	Molybdenum (Mo)	ND
Aluminum (Al)	20	Nickel (Ni)	2.2
Boron (B)	15	Phosphorus (P)	ND
Barium (Ba)	14	Lead (Pb)	3.4
Beryllium (Be)	ND	Rubidium (Rb)	<.9
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	<.09	Strontium (Sr)	5.3
Copper (Cu)	3.4	Titanium (Ti)	1.0
Iron (Fe)	64	Vanadium (V)	<2.6
Lithium (Li)	.24	Zinc (Zn)	ND
Manganese (Mn)	67		

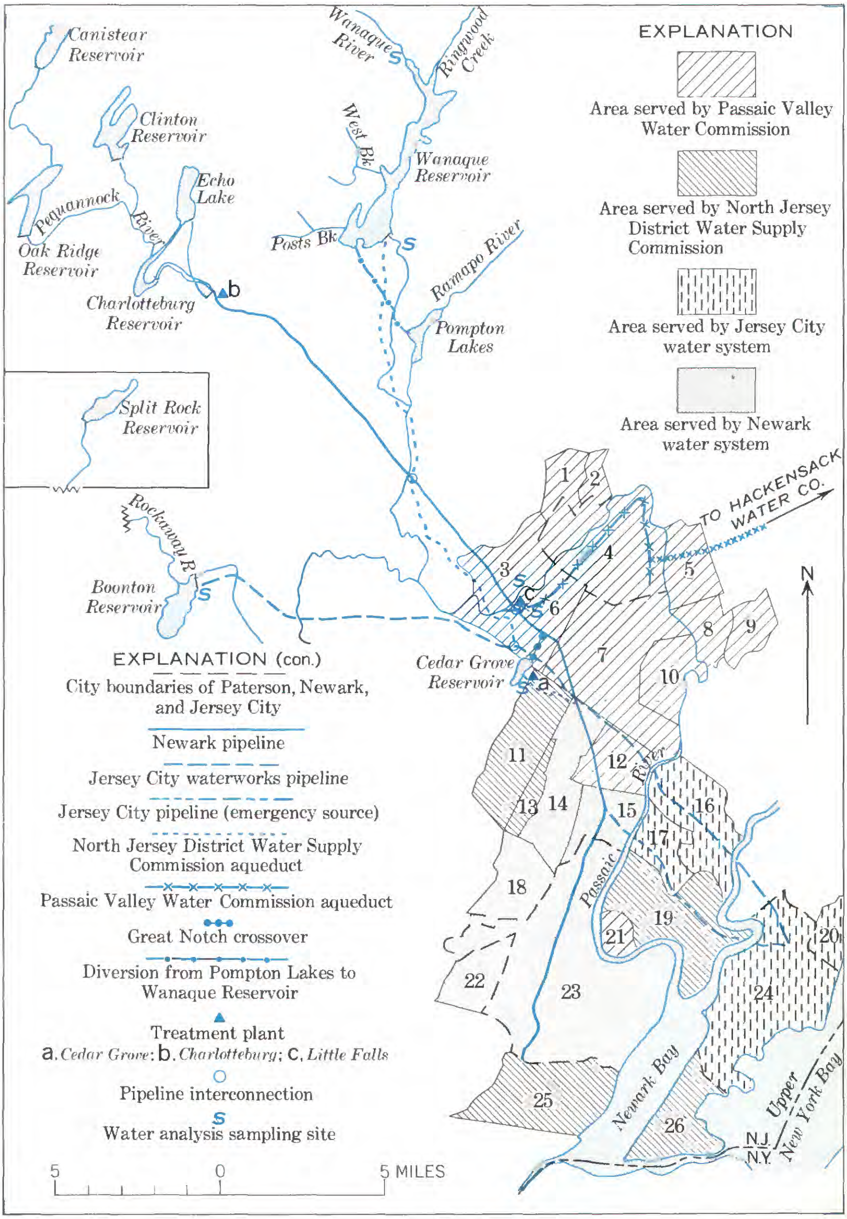

FIGURE 44.—Water supplies and areas served by northern New Jersey water systems. (Approved by local municipal water officials, March 1963.) Areas served by northern New Jersey water systems: 1, Haledon; 2, Prospect Park; 3, Totowa; 4, Paterson; 5, East Paterson; 6, West Paterson; 7, Clifton; 8, Garfield; 9, Lodi; 10, Passaic; 11, Montclair; 12, Nutley; 13, Glen Ridge; 14, Bloomfield; 15, Belleville; 16, Lyndhurst; 17, North Arlington; 18, East Orange; 19, Kearny; 20, Hoboken; 21, Harrison; 22, Irvington; 23, Newark; 24, Jersey City; 25, Elizabeth; 26, Bayonne.

NEWARK

(See fig. 44.)

Ownership: Municipal.

Other areas served: All or part of Belleville, Bloomfield, Elizabeth, East Orange, Wayne Township, Pequannock Township, and Irvington.

Population served: Newark, 405,220; total, about 750,000.

Sources and percentages of supply: Pequannock River and tributaries impounded in five interconnecting storage reservoirs—Canistear, Oak Ridge, Clinton, Echo Lake, Charlotteburg—55 percent. Wanaque and Ramapo Rivers impounded in Wanaque Reservoir, 45 percent. The division of this impoundment is administered by North Jersey District Water Supply Commission. The city of Newark controls 40.5 percent of the North Jersey District Water Supply Commission system.

Auxiliary and emergency supplies: Interconnections with Passaic Valley Water Commission and Jersey City Water Company.

Average amount of water used daily in system during 1962: 55.7 mgd (U.S. Public Health Service, 1962c).

Treatment:

Charlotteburg treatment plant: Prechlorination, screening, aeration, and adjustment of pH with lime and soda ash. Equipment available for ammoniation and flucridation. Water chlorinated again at Cedar Grove Reservoir.

Wanaque Reservoir plant: Chlorination and adjustment of pH with lime.

Rated capacity of treatment plants: Charlotteburg treatment plant, 150 mgd; Wanaque Reservoir plant, 146 mgd.

Raw-water storage: Canistear, 2,407 million gal; Oak Ridge, 3,895 million gal; Clinton, 3,518 million gal; Charlotteburg, 2,964 million gal; Wanaque, 28,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2 years.

Finished-water storage: Cedar Grove Reservoir (distribution), 679 million gal; Belleville Reservoir (balancing), 13 million gal; South Orange Avenue Reservoir (balancing), 9 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 12.6.

Average monthly determinations at Cedar Grove treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Finished water	21	29	12	------	8.6	7.2	42	53	30	2	4	2

Analytical data—Newark

	Wanaque River	Wanaque Reservoir		Cedar Grove treatment plant
Percent of supply	45			55
Date of collection	7-31-62	8-22-62	(1)	3-30-62
Type of water; R, raw; F, finished	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	1.9	3.1	1.4	6.4
Iron (Fe)	.00	.07	.08	.01
Manganese (Mn)	.00	.00	.08	.02
Aluminum (Al)		.00		
Lithium (Li)		.00		
Calcium (Ca)	8.8	11	10	10
Magnesium (Mg)	3.4	3.2	2.0	2.8
Sodium (Na)	3.6	3.4		4.2
Potassium (K)	.8	1.4		.5
Bicarbonate (HCO_3)	23	26	26	30
Carbonate (CO_3)	0	0		0
Sulfate (SO_4)	17	15	10	14
Chloride (Cl)	5.6	8.0	6.7	5.5
Fluoride (F)	.1	.1		.2
Nitrate (NO_3)	.6	.2		.2
Phosphate (PO_4)		.08		
Dissolved solids (residue at 180° C)	55	66	65	65
Hardness as $CaCO_3$	36	41	34	37
Noncarbonate hardness as $CaCO_3$	17	19		12
Specific conductance (micromhos at 25° C)	96	99		96
pH	6.5	6.5	8.7	7.2
Color	5		11	3
Turbidity			3	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity		14		16
Radium (Ra)		.1		<.1
Uranium (U)		.2		.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)		0.09		0.38
Aluminum (Al)		39		46
Boron (B)		7.7		17
Barium (Ba)		18		16
Beryllium (Be)		ND		ND
Cobalt (Co)		ND		ND
Chromium (Cr)		.69		<.09
Copper (Cu)		14		10
Iron (Fe)		78		280
Lithium (Li)		.11		.43
Manganese (Mn)		170		95
Molybdenum (Mo)		.58		ND
Nickel (Ni)		.9		1.6
Phosphorus (P)		ND		ND
Lead (Pb)		6.0		13
Rubidium (Rb)		1.1		1.0
Tin (Sn)		ND		ND
Strontium (Sr)		50		12
Titanium (Ti)		1.4		1.2
Vanadium (V)		ND		<2.6
Zinc (Zn)		ND		ND

[1] Average of analyses by the North Jersey District Water Supply Commission-Wanaque Laboratory for the year 1961.

PATERSON

(See fig. 44.)

Ownership: Supplied by Passaic Valley Water Commission.

Other areas served: Passaic Valley Water Commission (a) owns and operates the distribution system in Paterson, Passaic, Prospect Park, and a part of Clifton (population served in 1961, 286,700), (b) sells water wholesale to New Jersey Service Company and water departments of Harrison, Nutley, Totowa, West Paterson, and parts of Clifton (population served in 1961, 71,182), and (c) sells subsidiary water supplies to Hackensack and water departments of Haledon, Garfield, Lodi, and East Paterson (population served in 1961, 149,700).

Population served: Paterson, 143,663; total, approximately 550,000.

Sources and percentages of supply: Wanaque River, Ringwood Creek, and West Brook impounded in Wanaque Reservoir, and Posts Brook and Ramapo River diverted to Wanaque Reservoir, 53 percent. The division of this impoundment is administered by North Jersey District Water Supply Commission. The Passaic Valley Water Commission controls 37.75 percent of the North Jersey District Water Supply Commission System. Passaic River, 47 percent. Passaic Valley Water Commission has rights to divert 75 mgd from the Passaic River at Little Falls, N.J., whenever such quantities are available. Diversion is made directly without storage.

Average amount of water used daily in system during 1962: 80.8 mgd (W. M. Secker, written commun., 1963).

Treatment:

Little Falls treatment plant: Aeration, coagulation with alum, treatment with activated carbon, sedimentation, rapid and antl rafilt filtration, chlorination, adjustment of pH with lime, and dechlorination with sulfur dioxide.

Wanaque Reservoir plant: Chlorination and adjustment of pH with lime. Wanaque water is filtered at Little Falls plant.

Rated capacity of treatment plant: Little Falls plant: gravity, 55 mgd; pressure, 40 mgd.

Raw-water storage: Wanaque Reservoir, 28,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 347.

Finished-water storage: Great Notch Reservoir, 178.5 million gal; New Street Reservoir, 63.9 million gal; Grand Street Reservoir, 20.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 3.3.

Average monthly determinations at Little Falls treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	51	73	23	------	7.4	6.9	69	94	44	10	13	7
Finished water	48	67	24	------	7.3	6.9	97	140	60	0	0	0

Analytical data—Paterson

	Passaic River [1]			Little Falls treatment plant	Wanaque River	Wanaque Reservoir	
Percent of supply	----	----	47	47	53	----	----
Date of collection	(2)	(3)	(4)	4-3-62	7-31-62	8-22-62	(1 4)
Type of water: R, raw; F, finished	R	R	R	F	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	17	8.8	13	6.5	1.9	3.1	1.4
Iron (Fe)	1.1	.31	.47	.01	.00	.07	.08
Manganese (Mn)	.14	.04	.10	.02	.00	.00	.08
Aluminum (Al)	----	----	----	----	----	.00	----
Lithium (Li)	----	----	----	----	----	.00	----
Calcium (Ca)	25	12	19	16	8.8	11	10
Magnesium (Mg)	8.0	3.5	5.8	3.5	3.4	3.2	2.0
Sodium (Na)	----	20	----	4.6	3.6	3.4	----
Potassium (K)	----	----	----	1.0	.8	1.4	----
Bicarbonate (HCO_3)	89	28	62	26	23	26	26
Carbonate (CO_3)	----	----	----	0	0	0	----
Sulfate (SO_4)	45	----	30	24	17	15	10
Chloride (Cl)	25	8.0	15	11	5.6	8.0	6.7
Fluoride (F)	----	----	----	.2	.1	.1	----
Nitrate (NO_3)	1.0	.3	.6	.8	.6	.2	----
Phosphate (PO_4)	----	----	----	----	----	.08	----
Dissolved solids (residue at 180°C)	220	85	152	90	55	66	65
Hardness as $CaCO_3$	94	44	69	55	36	41	34
Noncarbonate hardness as $CaCO_3$	----	----	----	33	17	19	----
Specific conductance (micromhos at 25°C)	----	----	----	138	96	99	----
pH	7.4	6.9	7.1	7.4	6.5	6.5	8.7
Color	53	30	40	2	5	----	11
Turbidity	13	7	10	----	----	----	3
Temperature °F	75	33	55	----	----	----	----

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	----	----	----	11	----	14	----
Radium (Ra)	----	----	----	<.1	----	.1	----
Uranium (U)	----	----	----	<.1	----	.2	----

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	----	----	----	<0.09	----	0.09	----
Aluminum (Al)	----	----	----	180	----	39	----
Boron (B)	----	----	----	38	----	7.7	----
Barium (Ba)	----	----	----	25	----	18	----
Beryllium (Be)	----	----	----	ND	----	ND	----
Cobalt (Co)	----	----	----	ND	----	ND	----
Chromium (Cr)	----	----	----	.41	----	.69	----
Copper (Cu)	----	----	----	5.4	----	14	----
Iron (Fe)	----	----	----	120	----	78	----
Lithium (Li)	----	----	----	.46	----	.11	----
Manganese (Mn)	----	----	----	53	----	170	----
Molybdenum (Mo)	----	----	----	ND	----	.58	----
Nickel (Ni)	----	----	----	3.7	----	.9	----
Phosphorus (P)	----	----	----	ND	----	ND	----
Lead (Pb)	----	----	----	4.2	----	6.0	----
Rubidium (Rb)	----	----	----	1.2	----	1.1	----
Tin (Sn)	----	----	----	ND	----	ND	----
Strontium (Sr)	----	----	----	33	----	50	----
Titanium (Ti)	----	----	----	1.7	----	1.4	----
Vanadium (V)	----	----	----	<2.8	----	ND	----
Zinc (Zn)	----	----	----	ND	----	ND	----

[1] Analyzed by the Passaic Valley Water Commission.
[2] Maximum value of constituents in monthly averages of analyses during 1961.
[3] Minimum value of constituents in monthly averages of analyses during 1961.
[4] Average value of constituents for the year 1961.

NEW MEXICO

ALBUQUERQUE

Ownership: Municipal.
Population served: 201,189.
Sources of supply:
  Seventy-nine wells in 14 well fields:
    Main plant (along east edge of valley between Central Avenue and Indian School Road), 19 wells, 60–716 feet deep.
    Candelaria (Candelaria Road at Arno Street), 4 wells, 288–553 feet deep.
    Griegos (vicinity of Rio Grande between Montano Road and Candelaria Road), 5 wells, 820–900 feet deep.
    San Jose (South Broadway at San Jose Road), 7 wells, 306–510 feet deep.
    Bel Air (San Mateo Blvd. at Menaul Blvd.), 2 wells, 376–402 feet deep.
    Burton (Burton Park), 1 well, 1,000 feet deep.
    Love (Los Altos Park), 5 wells, 1,170–1,284 feet deep.
    Atrisco 1 (vicinity of Rio Grande between Rincon Road and Gonzales Road), 3 wells, 500–813 feet deep.
    Atrisco 2 (vicinity of Rio Grande between Osage Road and Five Points Road), 10 wells, 207–504 feet deep.
    Duranes (vicinity of Rio Grande between Mountain Road and Matthew Avenue), 8 wells, 834–1,000 feet deep.
    West Mesa (Central Avenue West at 96th Street), 1 well, 1,100 feet deep.
    Thomas (vicinity of Wyoming Blvd. at Montgomery Blvd.), 4 wells, 1,020–1,224 feet deep.
    Leyendecker (vicinity of Louisiana Blvd. at Montgomery Blvd.), 4 wells, 1,000–1,020 feet deep.
    Vol Andia well field (along Montgomery Blvd. between San Mateo Blvd. and Carlisle Blvd.), 6 wells, 1,010–1,025 feet deep will supply part of the east mesa by the summer of 1962.
Auxiliary and emergency supplies: Main plant with 19 wells used during periods of heavy water demand.
Average amount of water used daily in system during 1962: 30.0 mgd (U.S. Public Health Service, 1962c).
Treatment: Chlorination and settling in clear wells.
Finished-water storage: 80 million gal in 12 reservoirs.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.7.
Remarks: All well fields supplying the west mesa are connected, and all well fields supplying the valley and east mesa are connected. As the demand in an area exceeds storage water, available water can be pumped to the area of deficient supply.

Water from Candelaria, Griegos, San Jose, and Duranes well fields supply the valley area of the city. Water that is not used in the valley is pumped to nearby parts of the city on the east mesa. Water from Bel Air, Burton, Love, Atrisco 2, Thomas, and Leyendecker well fields, in addition to the unused water in the valley, supply the east mesa. Water from Atrisco 1 and West Mesa well fields supply the west mesa.

Analytical data—Albuquerque

	40 wells, West Mesa Station [1]	Santa Barbara Station [2]	44 wells, Eubank Station [3]	8 wells, Thomas Station [4]
Percent of supply	4	34	50	6
Date of collection	7-25-61	7-25-61	7-26-61	7-26-61
Type of water: F, finished	F	F	F	F
Chemical analyses [In parts per million]				
Silica (SiO_2)	47	69	34	33
Iron (Fe)	.0	.00	.00	.01
Calcium (Ca)	8.5	29	34	55
Magnesium (Mg)	1.7	6.4	2.9	4.1
Sodium (Na) / Potassium (K)	107	52	33	47
Bicarbonate (HCO_3)	155	153	139	158
Carbonate (CO_3)	16	0	0	0
Sulfate (SO_4)	81	66	32	30
Chloride (Cl)	11	11	14	67
Fluoride (F)	.9	.6	.6	.5
Nitrate (NO_3)	5.0	.2	.9	.3
Dissolved solids (residue at 180° C)	346	306	214	316
Hardness as $CaCO_3$	28	99	97	154
Noncarbonate hardness as $CaCO_3$	0	0	0	24
Specific conductance (micromhos at 25° C)	505	409	327	514
pH	8.9	8.0	7.9	7.8
Color	0	0	0	0
Temperature °F	85	70	73	73
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]				
Beta activity	7.1	9.8	5.0	----------------
Radium (Ra)	<.1	<.1	<.1	----------------
Uranium (U)	9.8	4.7	2.9	----------------
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]				
Silver (Ag)	<0.5	ND	<0.3	----------------
Aluminum (Al)	42	13	40	----------------
Boron (B)	75	47	60	----------------
Barium (Ba)	29	47	210	----------------
Beryllium (Be)	ND	ND	ND	----------------
Cobalt (Co)	ND	ND	ND	----------------
Chromium (Cr)	8.4	.55	4.6	----------------
Copper (Cu)	2.1	4.7	2.9	----------------
Iron (Fe)	22	13	23	----------------
Lithium (Li)	40	3.9	25	----------------
Manganese (Mn)	4.7	3.9	<3	----------------
Molybdenum (Mo)	2.2	<1	2.8	----------------
Nickel (Ni)	ND	ND	3.3	----------------
Phosphorus (P)	ND	ND	ND	----------------
Lead (Pb)	ND	3.9	3.7	----------------
Rubidium (Rb)	ND	7.5	4.0	----------------
Tin (Sn)	ND	ND	ND	----------------
Strontium (Sr)	180	310	330	----------------
Titanium (Ti)	ND	ND	<3	----------------
Vanadium (V)	70	15	21	----------------
Zinc (Zn)	ND	ND	ND	----------------

[1] Composite of Atrisco 1 and West Mesa well fields.
[2] Composite of Griegos, Candelaria, and Duranes well fields.
[3] Composite of Griegos, San Jose, Atrisco 2, Leyendecker, Burton, and Love well fields.
[4] Composite of Thomas and Leyendecker well fields.

NEW YORK

Albany	*Rochester*
Buffalo	*Syracuse*
New York City	*Yonkers*

ALBANY

Ownership: Municipal.

Other areas served: Hamlets of Hurstville and Karlsfeld in town of Bethlehem; Niagara Mohawk steam-electric plant in town of Bethlehem; Ann Lee Home and the county jail in town of Colonie.

Population served: Albany, 129,726; total, 142,000.

Sources and percentages of supply: Hannacrois Creek, impounded in Alcove Reservoir, about 92 percent; Basic Creek, impounded in Basic Reservoir, about 8 percent.

Auxiliary and emergency supplies: Hudson River is used as source of unfiltered industrial water to extent of about 6.5 million gal per week.

Average amount of water used daily in system during 1962: 24.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Feura Bush filter plant—aeration, coagulation with alum, sedimentation, rapid sand filtration, chlorination, and adjustment of pH with lime.

Rated capacity of treatment plant: Feura Bush filter plant, 32 mgd.

Raw-water storage: Alcove Reservoir, 12,100 million gal; Basic Reservoir, 716 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.4 years.

Finished-water storage: City reservoirs, 210 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 8.6.

Regular determinations at Feura Bush filter plant, November 1958–October 1959:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	23	42	18	7.0	7.5	6.5	43	51	20	4.8	15	0
Finished water	30	45	25	8.6	9.1	7.6	52	78	28	.3	4	0

Analytical data—Albany

	Alcove Reservoir [1]		Feura Bush filter plant [1]	
Percent of supply	92	100	92	100
Date of collection	8-17-61	(2)	8-17-61	(2)
Type of water: R, raw; F, finished	R	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	9.3	--	6.3	2.0
Iron (Fe)	.11	.08	.03	.02
Manganese (Mn)	.60	.28	.00	.02
Calcium (Ca)	11	--	15	19
Magnesium (Mg)	2.8	--	2.4	1.0
Sodium (Na)	1.8	--	1.8	1.2
Potassium (K)	1.0	--	.8	--
Bicarbonate (HCO_3)	34	28	37	28
Carbonate (CO_3)	0	--	0	4
Sulfate (SO_4)	13	--	20	20
Chloride (Cl)	2.1	1.0	1.7	2.0
Fluoride (F)	.0	--	.0	--
Nitrate (NO_3)	.0	.5	.1	.3
Dissolved solids (residue at 180° C)	56	84	68	88
Hardness as $CaCO_3$	39	43	48	52
Noncarbonate hardness as $CaCO_3$	11	--	17	--
Specific conductance (micromhos at 25° C)	92	--	112	--
pH	7.1	7.0	7.2	8.5
Color	6	13	2	2
Turbidity	1	5	0	0
Temperature ° F	58	--	61	--

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	--	--	4.5	--
Radium (Ra)	--	--	.1	--
Uranium (U)	--	--	<.1	

Spectrographic analyses

[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND, looked for but not found]

Silver (Ag)	0.12	--	0.07	--
Aluminum (Al)	17	--	28	--
Boron (B)	3.6	--	3.8	--
Barium (Ba)	10	--	9.5	--
Beryllium (Be)	ND	--	ND	--
Cobalt (Co)	ND	--	ND	--
Chromium (Cr)	.72	--	.43	--
Copper (Cu)	73	--	140	--
Iron (Fe)	39	--	21	--
Lithium (Li)	.07	--	.07	--
Manganese (Mn)	450	--	75	--
Molybdenum (Mo)	ND	--	ND	--
Nickel (Ni)	2.6	--	1.4	--
Phosphorus (P)	ND	--	ND	--
Lead (Pb)	11	--	1.1	--
Rubidium (Rb)	1.2	--	ND	--
Tin (Sn)	ND	--	ND	--
Strontium (Sr)	21	--	20	--
Titanium (Ti)	.6	--	<.7	--
Vanadium (V)	ND	--	ND	--
Zinc (Zn)	ND	--	<68	--
Zirconium (Zr)	.X	--	ND	--

[1] Spectrographic concentrations based on nonacidified residue on evaporation.
[2] Average of daily analyses by the city of Albany from November 1, 1959, to October 31, 1960.

BUFFALO

Ownership: Municipal.
Other areas served: Erie County Water Authority.
Population served: Buffalo, 532,759; total, 592,982.
Source of supply: Lake Erie.
Auxiliary and emergency supplies: Niagara River could be used in the event of a failure of Lake Erie intake.
Average amount of water used daily in system during 1962: 145 mgd (U.S. Public Health Service, 1962c).
Treatment: Buffalo filtration plant—coagulation with alum, sedimentation, rapid sand filtration, chlorination, and fluoridation.
Rated capacity of treatment plant: Buffalo filtration plant, 160 mgd.
Finished-water storage: Clear well, 30 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Collins Park treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			Turbidity		
	Avg	Min	Min	Avg	Max	Min
Raw water	95	95	95	12	200	1
Finished water	89	90	85	.0	.0	.0

Analytical data—Buffalo

	Lake Erie		Filtration plant	
Percent of supply	100	100	100	100
Date of collection	8-22-61	(1)	8-22-61	(2)
Type of water: R, raw; F, finished	R	R	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	2.0		0.7	
Iron (Fe)	.01		.04	
Manganese (Mn)	.00		.00	
Calcium (Ca)	38		38	
Magnesium (Mg)	8.6		9.1	
Sodium (Na)	9.5		9.4	
Potassium (K)	1.4		1.2	
Bicarbonate (HCO_3)	116	106	107	109
Carbonate (CO_3)	0		0	
Sulfate (SO_4)	23		26	
Chloride (Cl)	23	22	24	
Fluoride (F)	.1		1.2	.9
Nitrate (NO_3)	.2		.1	
Phosphate (PO_4)		.8		
Dissolved solids (residue at 180°C)	177	204	186	
Hardness as $CaCO_3$	131	127	133	
Noncarbonate hardness as $CaCO_3$	36	40	45	
Specific conductance (micromhos at 25°C)	306		309	
pH	8.0	8.1	7.7	
Color	1	0	1	
Turbidity	0	28	0	0
Temperature °F	75		74	

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity			5.1	
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	22			
Radium (Ra)			<.1	
Uranium (U)			.2	

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.26		<0.26	
Aluminum (Al)	41		500	
Boron (B)	10		39	
Barium (Ba)	31		37	
Beryllium (Be)	ND		ND	
Cobalt (Co)	ND		ND	
Chromium (Cr)	2.8		.31	
Copper (Cu)	22		4.2	
Iron (Fe)	28		26	
Lithium (Li)	.92		1.0	
Manganese (Mn)	3.1		3.1	
Molybdenum (Mo)	.77		2.9	
Nickel (Ni)	5.1		<2.6	
Phosphorus (P)	ND		ND	
Lead (Pb)	6.4		<2.6	
Rubidium (Rb)	ND		ND	
Tin (Sn)	ND		ND	
Strontium (Sr)	110		160	
Titanium (Ti)	<2.6		ND	
Vanadium (V)	ND		7.9	
Zinc (Zn)	<260		ND	

1 Average of seven monthly analyses by Erie County Health Department from January to July 1961.
2 Average of 210 daily analyses from January to July 1961 by the City of Buffalo.

NEW YORK CITY

(See figs. 45 and 46.)

Ownership: Municipal.

Other areas served (wholly or in part): Elmsford, Mount Vernon, New Castle, New Rochelle, North Tarrytown, Ossining, Peekskill, Pleasantville, Scarsdale, Tarrytown, White Plains, and Yonkers.

Population served: Municipal system supplies 7,350,000 in New York City and about 500,000 in suburbs; Jamaica Water Supply Co. supplies about 450,000 people in the borough of Queens; New York Water Service Corp. (Woodhaven Plant) supplies about 50,000 people in the Fourth Ward of Queens; total supplied, about 8,350,000.

Sources and percentages of supply:

Catskill sources: Forty-three percent of 1961 supply. Schoharie Creek is impounded in Schoharie Reservoir, and the water is carried by Shandaken Tunnel to Esopus Creek, which is impounded in Ashokan Reservoir. The mixed water is carried to Kensico Reservoir by Catskill Aqueduct. A small amount of water is supplied to consumers directly from the aqueduct before it reaches Kensico Reservoir.

Delaware sources: Thirty-six percent of 1961 supply. East Branch Delaware River is impounded in Pepacton Reservoir, and Neversink River is impounded in Neversink Reservoir. The water of these two reservoirs is carried to Rondout Reservoir; Rondout Creek is also impounded in Rondout Reservoir. Water from Rondout Reservoir is carried by the Delaware Aqueduct to West Branch (Croton) Reservoir and then into Kensico Reservoir. Construction of Cannonsville Reservoir on the West Branch Delaware River is in process. The water from Cannonsville Reservoir will be carried by tunnel to Rondout Reservoir.

Croton sources: Eighteen percent of 1961 supply. Waters from Rondout Reservoir, Boyd Corners Reservoir, and other related tributary sources mix in West Branch (Croton) Reservoir. Part of the mixed water is carried to the Rye Lake area of Kensico Reservoir. Some water from Middle Branch and Cross River Reservoirs is carried to Kensico Reservoir. The New Croton Reservoir is formed by waters of the Croton River basin and the Delaware Aqueduct. Water from the New Croton Reservoir serves areas in Manhattan and the Bronx as well as some outside communities. Kensico Reservoir receives water from the Bronx River basin, which mingles with water from the Catskill, Delaware, and Croton River waters. From Kensico, these mixed waters flow through the Catskill and Delaware Aqueducts to Hillview Reservoir. Water is supplied to several communities between Kensico and Hillview. Water from Hillview is supplied to the five boroughs and some outside communities.

Richmond wells: Less than 1 percent of 1961 supply. Supplement the supply to the borough of Richmond.

The Long Island system of wells and ponds is seldom used for supply.

Private water companies: The Jamaica Water Supply Co., about 3 percent of 1961 supply, and Utilities and Industries Corp., New York Water Service Division (Woodhaven Plant), less than 1 percent of 1961 supply, are franchised to supply water in part to the borough of Queens. Jamaica Water Supply Co. furnished about 3 percent of the 1961 supply, and New York Water Service Division Supply furnished less than 1 percent of 1961 supply. Source is driven wells.

Average amount of water used daily in system during 1962: 1,190 mgd (U.S. Public Health Service, 1962c).

Treatment:

Surface water: Plain sedimentation in large storage reservoirs, chlorination and rechlorination of supplies after leaving open surface reservoirs. The Catskill supply receives, in addition, aeration and coagulation with alum when necessary at the Pleasantville plant.

Ground water: Private companies operate two gravity and three pressure filters for iron removal. Some wells have lime treatment for corrosion control. Treatment with caustic soda is planned for the near future.

Water storage, in million gallons:

Impounding and storage reservoirs: Pepacton, 143,701; Neversink, 35,466; Rondout, 50,048; Schoharie, 19,538; Ashokan, 130,478; Kensico, 30,573; 12 reservoirs and 5 controlled lakes in Croton basin, 97,381; East Meadow Pond, 19; Wantagh Pond, 44; Massapequa Pond, 17.

Distribution reservoirs and standpipes: Central Park Reservoir, 1,021; Hillview Reservoir, 929; Jerome Park Reservoir, 773; Ridgewood Reservoir (two basins), 208; Far Rockaway Standpipe, 0.3; Silver Lake Reservoir, 438; Grimes Hill Standpipe, 0.2.

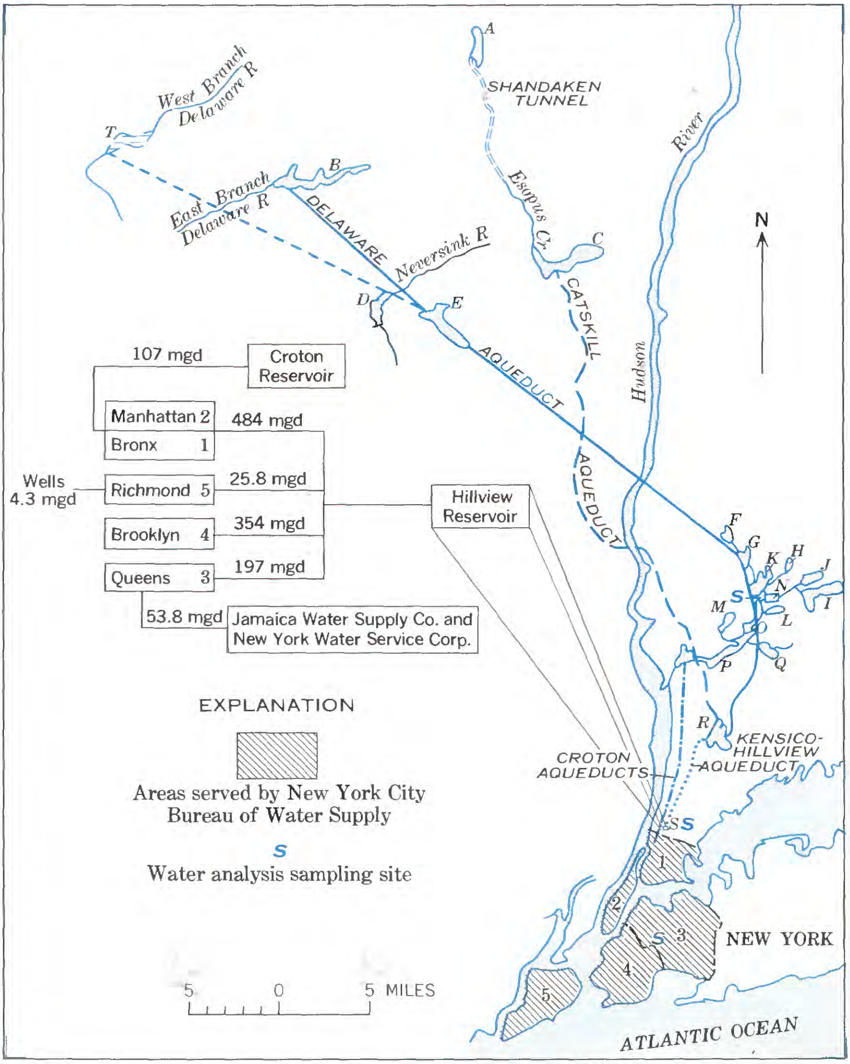

FIGURE 45.—Water supplies and areas served by New York City Bureau of Water Supply. Note-For other areas supplied by New York City Bureau of Water Supply see map of Yonkers. Water-use data based on 1960. Approval by local municipal water officials, April 1963. List of reservoirs: *A*, Schoharie; *B*, Pepacton; *C*, Ashokan; *D*, Neversink; *E*, Rondout; *F*, Boyds Corners; *G*, West Branch; *H*, Middle Branch; *I*, East Branch; *J*, Bog Brook; *K*, Croton Falls Main; *L*, Titicus; *M*, Amawalk; *N*, Croton Falls Diverting; *O*, Muscoot; *P*, New Croton; *Q*, Cross River; *R*, Kensico; *S*, Hillview; *T*, Cannonsville Reservoir (under construction).

Analytical data—New York City

	Catskill and Delaware supplies		Croton supply		Jamaica wells (8, 8A, 17A, and 31)	Jamaica wells [1] (wells 1–48A)	
Percent of supply	79	----	18	----	3	----	----
Date of collection	5–16–62	(2)	5–16–62	(2)	5–16–62	(3)	(4)
Type of water: F, finished	F	F	F	F	F	F	F
Chemical analyses [In parts per million]							
Silica (SiO_2)	2.0	2.5	3.8	4.5	21	----	----
Iron[5] (Fe)	.06	.07	.07	.11	.05	1.3	0.00
Manganese[5] (Mn)	.00	----	.02	----	.04	----	----
Calcium (Ca)	6.9	5.6	14	14	45	----	----
Magnesium (Mg)	1.0	1.0	4.8	4.4	19	----	----
Sodium (Na)	1.8	1.7	4.2	3.3	17	----	----
Potassium (K)	.5	.7	1.4	1.3	1.6	----	----
Bicarbonate (HCO_3)	13	7	40	37	158	256	4
Carbonate (CO_3)	0	0	0	0	0	0	0
Sulfate (SO_4)	9.0	12	16	19	53	----	----
Chloride (Cl)	3.8	3.5	10	8.9	28	35	4.0
Fluoride (F)	.0	.0	.1	.1	.0	----	----
Nitrate (NO_3)	.9	.3	.8	.3	8.6	17	.0
Dissolved solids (residue at 180° C)	41	42	87	97	283	422	37
Hardness as $CaCO_3$	21	18	55	54	191	307	9
Noncarbonate hardness as $CaCO_3$	11	----	22	----	61	----	----
Specific conductance (micromhos at 25° C)	62	50	142	137	453	590	45
pH	6.5	6.7	6.7	7.5	7.1	7.4	5.0
Color	3	7	2	5	2	24	1
Turbidity	1	3	0	4	1	13	0
Temperature °F	----	51	50	51	----	----	----
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]							
Beta activity	9.5	----	14	----	3.5	----	----
Radium (Ra)	<.1	----	<.1	----	.1	----	----
Uranium (U)	.2	----	.2	----	1.0	----	----
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]							
Silver (Ag)	0.23	----	0.27	----	0.39	----	----
Aluminum (Al)	85	----	48	----	9.3	----	----
Boron (B)	2.5	----	14	----	58	----	----
Barium (Ba)	23	----	28	----	62	----	----
Beryllium (Be)	ND	----	ND	----	ND	----	----
Cobalt (Co)	ND	----	ND	----	ND	----	----
Chromium (Cr)	.35	----	.52	----	<.39	----	----
Copper (Cu)	22	----	63	----	2.9	----	----
Iron (Fe)	85	----	87	----	120	----	----
Lithium (Li)	.27	----	.16	----	1.5	----	----
Manganese (Mn)	39	----	47	----	190	----	----
Molybdenum (Mo)	ND	----	1.2	----	ND	----	----
Nickel (Ni)	1.6	----	2.3	----	<3.9	----	----
Phosphorus (P)	ND	----	ND	----	ND	----	----
Lead (Pb)	2.3	----	8.2	----	ND	----	----
Rubidium (Rb)	.7	----	1.1	----	ND	----	----
Tin (Sn)	ND	----	ND	----	ND	----	----
Strontium (Sr)	20	----	49	----	89	----	----
Titanium (Ti)	2.9	----	2.1	----	ND	----	----
Vanadium (V)	<1.4	----	ND	----	ND	----	----
Zinc (Zn)	ND	----	ND	----	ND	----	----

[1] Analyzed by the Jamaica Water Supply Co.
[2] Average analyses by the city of New York for 1960.
[3] Maximum value of constituents measured during 1961.
[4] Minimum value of constituents measured during 1961.
[5] In solution when collected.

ROCHESTER

Ownership: Municipal.
Other area served: Livonia.
Population served: 292,000 by municipal system.
Sources and percentages of supply: Upland Supply (Hemlock and Canadice Lakes), 79 percent; Lake Ontario, 21 percent.
Average amount of water used daily in system during 1962: 62. 9 mgd (U.S. Public Health Service, 1962c).
Treatment:

Upland Supply plant: Chlorination, ammoniation, and fluoridation.

Lake Ontario filter plant: Coagulation, flocculation, and rapid sand filtration.

Rated capacity of treatment plants: Upland Supply plant, 36 mgd: Lake Ontario filter plant, 36 mgd.
Finished-water storage: 231 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 3.7.
Remarks: Monroe County Water Authority supplies about 30,000 people in Rochester. Its source of water is Lake Ontario. Directly or indirectly it serves about 203,000 customers in Monroe County.

The Monroe County Water Authority and Rochester are building a new intake into Lake Ontario. They will share the intake, but each will have its own treatment plant.

Regular determinations at Lake Ontario filter plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	92	95	91	8.0	8.3	7.9	127	130	120	5.6	40	1.0
Finished water	83	86	78	7.4	7.9	6.9	124	128	120	.5	2.0	.1

Analytical data—Rochester

	Lake Ontario[1]			Lake Ontario filter plant		Rochester treatment plant[1]	Hemlock Lake	Canadice Lake	Upland supply
Percent of supply	21			21			79		79
Date of collection	6-19-61	(2)	(3)	5-23-62	(1 2)	(3)	6-9-61	6-9-61	5-23-62
Type of water: R, raw; F, finished	R	R	R	F	F	F	R	R	F

Chemical analyses

[In parts per million]

	Lake Ontario[1]			Lake Ontario filter plant		Rochester treatment plant[1]	Hemlock Lake	Canadice Lake	Upland supply
Silica (SiO_2)	3.0	3.0	3.0	.5	5.0	4.0	5.0	2.9	2.5
Iron[4] (Fe)	.07			.37			.00	.00	.06
Manganese[4] (Mn)	.01			.01			.00	.00	.01
Calcium (Ca)	36	36	20	41	24	18	21	12	24
Magnesium (Mg)	9.7	11	5.4	8.0	7.2	4.1	5.0	2.9	5.0
Sodium (Na)				10			5.2	3.0	4.7
Potassium (K)				1.2			1.2	1.0	1.2
Aluminum (Al)	.09	.15	.04			.03			
Bicarbonate (HCO_3)	93	94	90	108	52	49	62	31	61
Carbonate (CO_3)		0	0	0	0	0	0	0	0
Sulfate (SO_4)	17		12	29	17	4.0	23	19	24
Chloride (Cl)	27		25	26	14	13	7.1	2.6	10
Fluoride (F)	.3		.2	1.1	1.2	1.0	.0	.1	1.1
Nitrate (NO_3)	.1	.2	.1	.3	.2	.1	.7	.6	.1
Phosphate (PO_4)		2.0	1.0	.09	1.3				.07
Dissolved solids (residue at 180° C)	233		193	194			107	62	111
Hardness as $CaCO_3$	130	130	82	136	86	66	73	42	81
Noncarbonate hardness as $CaCO_3$	54			47			22	17	31
Specific conductance (micromhos at 25° C)				319			178	104	189
pH	8.3	8.3	7.9	7.4	7.5	7.0	6.9	6.8	7.3
Color		2	0	2	1	0	2	2	3
Turbidity	2	40	1	1	3	1			2
Temperature °F	60			49			62	65	62

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Lake Ontario[1]			Lake Ontario filter plant		Rochester treatment plant[1]	Hemlock Lake	Canadice Lake	Upland supply
Beta activity				6.1					7.9
Radium (Ra)				<.1					<.1
Uranium (U)				<.1					<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Lake Ontario[1]			Lake Ontario filter plant		Rochester treatment plant[1]	Hemlock Lake	Canadice Lake	Upland supply
Silver (Ag)				0.30					<0.14
Aluminum (Al)				47					95
Boron (B)				20					12
Barium (Ba)				40					35
Beryllium (Be)				ND					ND
Cobalt (Co)				ND					ND
Chromium (Cr)				1.4					ND
Copper (Cu)				23					83
Iron (Fe)				27					150
Lithium (Li)				1.2					.58
Manganese (Mn)				3.0					17
Molybdenum (Mo)				2.4					1.5
Nickel (Ni)				<2.5					<1.4
Phosphorus (P)				ND					ND
Lead (Pb)				4.7					4.1
Rubidium (Rb)				ND					ND
Tin (Sn)				ND					ND
Strontium (Sr)				150					65
Titanium (Ti)				1.7					5.2
Vanadium (V)				ND					ND
Zinc (Zn)				ND					ND

[1] Analyzed by the city of Rochester.
[2] Maximum value of constituents in monthly analyses during 1961.
[3] Minimum value of constituents in monthly analyses during 1961.
[4] In solution when collected.

SYRACUSE

Ownership: Municipal.

Other areas served: Parts of Dewitt, Onondaga, Geddess, Manlius, Elbridge, and Skaneateles.

Population served: Syracuse, 216,038; total, about 235,000.

Source of supply: Skaneateles Lake. A legal limit for withdrawal from Skaneateles Lake is set at 58 mgd.

Auxiliary and emergency supplies: Otisco Lake (Onondaga County Water Authority).

Average amount of water used daily in system during 1962: 42.3 mgd (U.S. Public Health Service, 1962c).

Treatment: Syracuse treatment plant—chlorination.

Rated capacity of treatment plant: Syracuse treatment plant, 58 mgd.

Finished-water storage: 235 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 5.6.

Analytical data—Syracuse

	Skaneateles Lake	Treatment plant
Percent of supply	100	100
Date of collection	6-7-61	5-22-62
Type of water: R, raw; F, finished	R	F

Chemical analyses

[In parts per million]

	Skaneateles Lake	Treatment plant
Silica (SiO_2)	1.7	1.0
Iron[1] (Fe)	.00	.16
Manganese[1] (Mn)	.00	.01
Calcium (Ca)	34	35
Magnesium (Mg)	5.8	6.0
Sodium (Na)	1.6	1.7
Potassium (K)	.9	.8
Bicarbonate (HCO_3)	110	111
Carbonate (CO_3)	0	0
Sulfate (SO_4)	17	18
Chloride (Cl)	2.6	4.0
Fluoride (F)	.0	.1
Nitrate (NO_3)	2.2	1.8
Dissolved solids (residue at 180°C)	132	132
Hardness as $CaCO_3$	109	112
Noncarbonate hardness as $CaCO_3$	19	21
Specific conductance (micromhos at 25°C)	227	226
pH	7.1	7.9
Color	1	2
Turbidity		3
Temperature °F	59	54

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Skaneateles Lake	Treatment plant
Beta activity		7.3
Radium (Ra)		.3
Uranium (U)		<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Skaneateles Lake	Treatment plant
Silver (Ag)		<0.19
Aluminum (Al)		26
Boron (B)		13
Barium (Ba)		33
Beryllium (Be)		ND
Cobalt (Co)		ND
Chromium (Cr)		ND
Copper (Cu)		10
Iron (Fe)		33
Lithium (Li)		.52
Manganese (Mn)		3.0
Molybdenum (Mo)		ND
Nickel (Ni)		ND
Phosphorus (P)		ND
Lead (Pb)		17
Rubidium (Rb)		ND
Tin (Sn)		ND
Strontium (Sr)		54
Titanium (Ti)		1.1
Vanadium (V)		ND
Zinc (Zn)		ND

[1] In solution when collected.

YONKERS

(See fig. 46.)

Ownership: Municipal.
Population served: Yonkers, 190,634.
Sources and percentages of supply: Saw Mill River and Grassy Sprain Brook, 35 percent; New York City supply from Hillview Reservoir, 65 percent; well supply, 250,000 gpd pumped directly into system.
Average amount of water used daily in system during 1962: 12 mgd (U.S. Public Health Service, 1962c).
Treatment:
Saw Mill River filter plant: Slow sand filtration and chlorination.
Grassy Sprain Brook plant: Chlorination.
Rated capacity of treatment plant: Saw Mill River filter plant, 16 mgd.
Raw-water storage: Grassy Sprain Reservoir, 1,000 million gal.
Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 83.
Finished-water storage: Nodine Hill Tower, 1 million gal; Concord Road Tower, 1 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations of finished water at Yonkers Laboratory, January–May 1962:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Saw Mill River supply	------	104	74	------	7.4	7.1	------	164	134	------	5	------
Grassy Sprain Reservoir supply	------	36	30	------	7.0	6.6	------	96	84	------	10	------

Analytical data—Yonkers

	Saw Mill Reservoir	Grassy Sprain Reservoir	Catskill Aqueduct
Percent of supply	18	17	65
Date of collection	5-15-62	5-15-62	5-15-62
Type of water: F, finished	F	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	3.5	6.5	2.0
Iron[1] (Fe)	.05	.24	.03
Manganese[1] (Mn)	.00	.00	.03
Calcium (Ca)	41	17	5.9
Magnesium (Mg)	16	7.1	1.7
Sodium (Na)	20	19	1.6
Potassium (K)	4.0	2.7	.8
Bicarbonate (HCO_3)	142	42	14
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	39	27	9.1
Chloride (Cl)	38	37	3.9
Fluoride (F)	.0	.0	.0
Nitrate (NO_3)	3.1	2.0	.1
Dissolved solids (residue at 180° C)	250	165	37
Hardness as $CaCO_3$	169	72	22
Noncarbonate hardness as $CaCO_3$	52	37	10
Specific conductance (micromhos at 25° C)	436	265	62
pH	7.4	7.0	6.7
Color	1	4	4
Turbidity	1	1	2
Temperature °F	61	54	----

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	10	13	7.5
Radium (Ra)	.2	<.1	<.1
Uranium (U)	.3	.1	.1

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.41	0.32	0.34
Aluminum (Al)	65	140	120
Boron (B)	73	45	12
Barium (Ba)	77	84	23
Beryllium (Be)	ND	ND	ND
Cobalt (Co)	ND	ND	ND
Chromium (Cr)	1.8	.34	.14
Copper (Cu)	27	68	58
Iron (Fe)	97	810	68
Lithium (Li)	.97	.39	.20
Manganese (Mn)	4.5	1,100	34
Molybdenum (Mo)	1.7	ND	ND
Nickel (Ni)	<4.1	6.8	1.4
Phosphorus (P)	ND	ND	ND
Lead (Pb)	9.7	4.3	7.1
Rubidium (Rb)	ND	4.8	.4
Tin (Sn)	ND	ND	ND
Strontium (Sr)	130	79	12
Titanium (Ti)	1.5	5.2	1.7
Vanadium (V)	ND	<5.4	<1.0
Zinc (Zn)	ND	ND	ND

[1] In solution when collected.

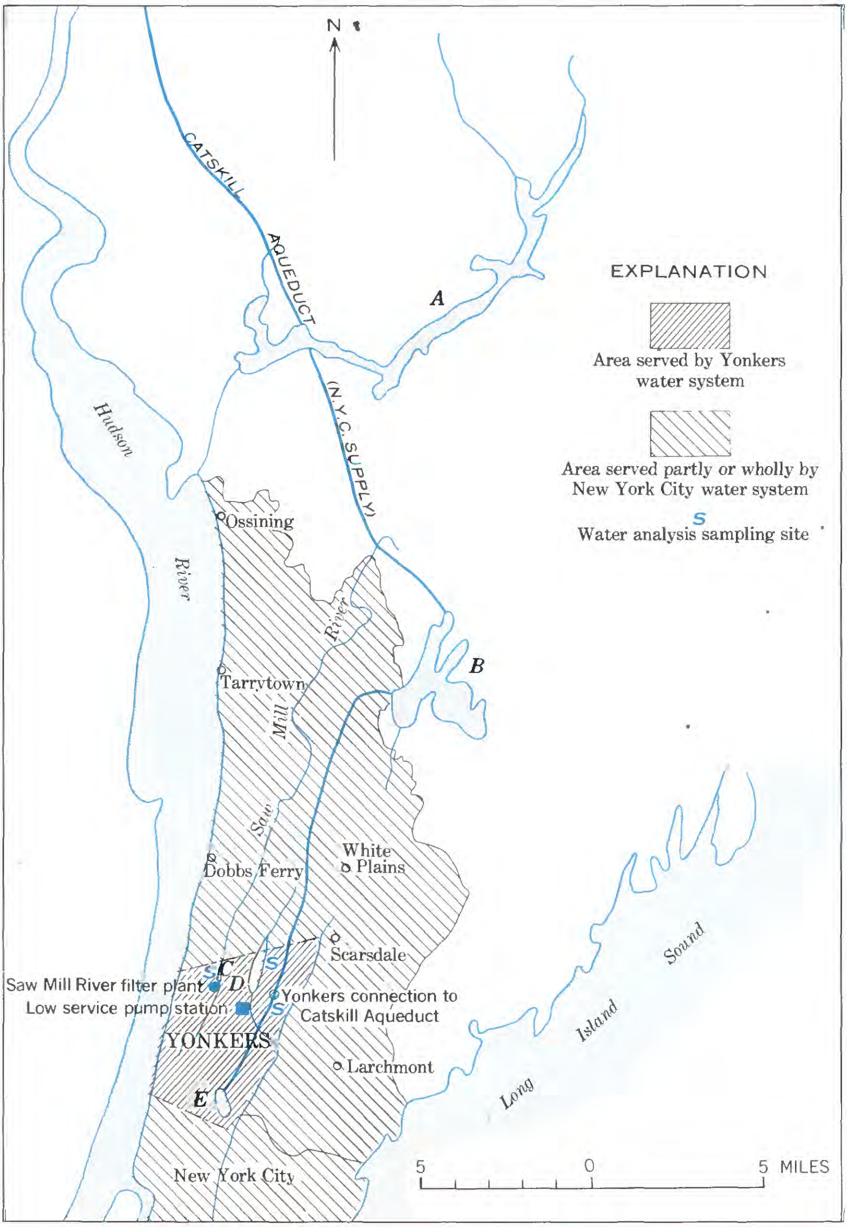

FIGURE 46.—Water supplies and areas served by Yonkers, N.Y., water system. (Approved by local municipal water officials, April 1963.) List of reservoirs: *A*, Croton and New Croton; *B*, Kensico; *C*, Saw Mill; *D*, Grassy Sprain; *E*, Hillview. Note: Catskill Aqueduct brings water from Ashokian and Schoharie Reservoirs to Hillview Reservoir.

NORTH CAROLINA

CHARLOTTE

(See fig. 47.)

Ownership: Municipal.
Other areas served: Suburban areas and Pineville.
Population served: Charlotte, 201,564; total, 212,946.
Source of supply: Catawba River impounded in Mountain Island Lake.
Average amount of water used daily in system during 1962: 22.1 mgd (U.S. Public Health Service, 1962c).
Treatment: Hoskins treatment plant and Vest Station treatment plant—aeration, coagulation with alum, carbon, primary chlorination, sedimentation, rapid sand filtration, final pH adjustment with hydrated lime, secondary chlorination, ammoniation, and fluoridation with sodium silicofluoride.
Rated capacity of treatment plants: Hoskins treatment plant, 12 mgd; Vest treatment plant, 24.6 mgd.
Raw-water storage: Two reservoirs, 50 million gal each.
Finished-water storage: Two clear wells, 12 and 6 million gal; four elevated tanks, 1.3, 1.0, 0.5, and 0.5 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.0.
Remarks: The water is pumped from the Catawba River to raw-water storage; then it flows by gravity through the treatment plant to clear-water wells, where it is then pumped to distribution system and elevated storage tanks.
Future plans: Hoskins plant capacity is to be increased by 24 mgd during 1964–65. Enlarged Catawba River pumping station with additional pumps and emergency pumping equipment, construction to begin in 1963. A 72-inch raw-water line from Catawba River pumping station to Hoskins plant reservoir is to be installed 1963–64. Tanks to supply an added 4.5 mgd are planned.

Regular determinations at Vest treatment plant, 1960–1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	16	19	13	7.4	8.0	7.1	13	15	10	25	142	5
Finished water	19	22	16	9.0	9.2	8.1	24	28	19	.0	.2	.0

Analytical data—Charlotte

	Catawba River[1]	Hoskins treatment plant[1]	
Percent of supply	100	100	
Date of collection	8-15-61	8-15-61	[2] 2-21-62
Type of water: R, raw; F, finished	R	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	10	11	7.8
Iron (Fe)	.00	.01	.01
Manganese (Mn)	.00	.00	.00
Aluminum (Al)			.02
Calcium (Ca)	3.2	8.7	7.4
Magnesium (Mg)	1.2	1.5	1.0
Sodium (Na)	3.8	4.1	4.0
Potassium (K)	1.2	1.2	
Bicarbonate (HCO_3)	20	22	15
Carbonate (CO_3)	0	3	7
Sulfate (SO_4)	3.8	7.4	6.3
Chloride (Cl)	1.5	3.5	4.0
Fluoride (F)	.1	1.1	1.0
Nitrate (NO_3)	.3	.4	
Dissolved solids (residue at 180° C)	37	53	50
Hardness as $CaCO_3$	13	28	25
Noncarbonate hardness as $CaCO_3$	0	10	
Specific conductance (micromhos at 25° C)	46	82	
pH	7.2	8.9	9.0
Color	3	0	0
Turbidity			0

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity		3.0	
Radium (Ra)		<.1	
Uranium (U)		.1	

Spectrographic analyses
[In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND, looked for but not found]

Silver (Ag)	<0.04	0.17	
Aluminum (Al)	59	8.5	
Boron (B)	250	7.0	
Barium (Ba)	8.9	12	
Beryllium (Be)	ND	ND	
Cobalt (Co)	<.37	ND	
Chromium (Cr)	.10	<.05	
Copper (Cu)	.78	1.1	
Iron (Fe)	52	5.1	
Lithium (Li)	.06	.06	
Manganese (Mn)	11	12	
Molybdenum (Mo)	ND	ND	
Nickel (Ni)	.7	.5	
Phosphorus (P)	ND	ND	
Lead (Pb)	4.4	<.5	
Rubidium (Rb)	1.2	2.3	
Tin (Sn)	ND	ND	
Strontium (Sr)	2.4	5.3	
Titanium (Ti)	3.5	<.5	
Vanadium (V)	<1.1	<1.6	
Zinc (Zn)	<37	ND	
Ytterbium (Yb)	.0X	ND	
Yttrium (Y)	.X	ND	
Zirconium (Zr)	.X	ND	

[1] Spectrographic concentrations based on nonacidified residue on evaporation.
[2] Analysis by city of Charlotte.

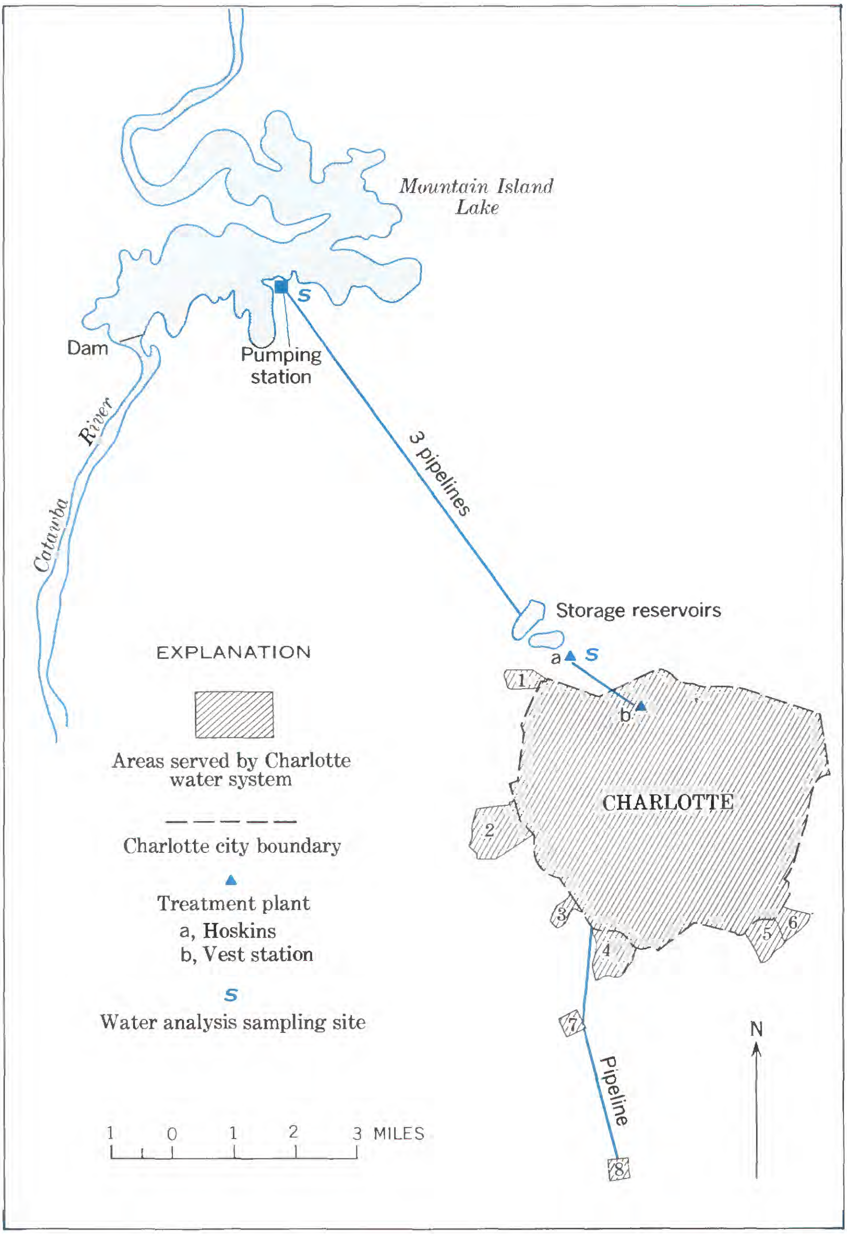

FIGURE 47.—Water supplies and areas served by Charlotte, N. C., water system. (Approved by local municipal water officials, February 1963.). List of areas served: 1, Residential area; 2, Airport area; 3, Yorkmont Park; 4, Montclair; 5, Lawsdowe; 6, Stonehaven; 7, Arrowood; 8, Pineville.

GREENSBORO

(See fig. 48.)

Ownership: Municipal.

Population served: Greensboro, 119,184; about 5,000 people outside the city limits; total, 124,184.

Source of supply: Reedy Fork, Horsepen Creek, and Brush Creek impounded in Lake Brandt.

Average amount of water used daily in system during 1962: 13 mgd (U.S. Public Health Service, 1962c).

Treatment: Greensboro filter plant—prechlorination, coagulation with alum, sedimentation, rapid sand filtration, adjustment of pH with lime, addition of Calgon for corrosion control, and postchlorination.

Rated capacity of treatment plant: Greensboro filter plant, 20 mgd.

Raw-water storage: Reedy Fork impoundment, 19 million gal; Horsepen Creek impoundment, 800 million gal; Lake Brandt, 2,200 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 232.

Finished-water storage: Three elevated tanks, 0.2, 0.5, and 0.5 million gal; one clear well, 2.5 million gal; one reservoir, 18 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.7.

Regular determinations at Greensboro filter plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	26	38	19	7.1	7.9	6.3	30	52	10	54	340	3
Finished water	30	45	19	7.8	9.7	6.3	47	66	25	0	0	0

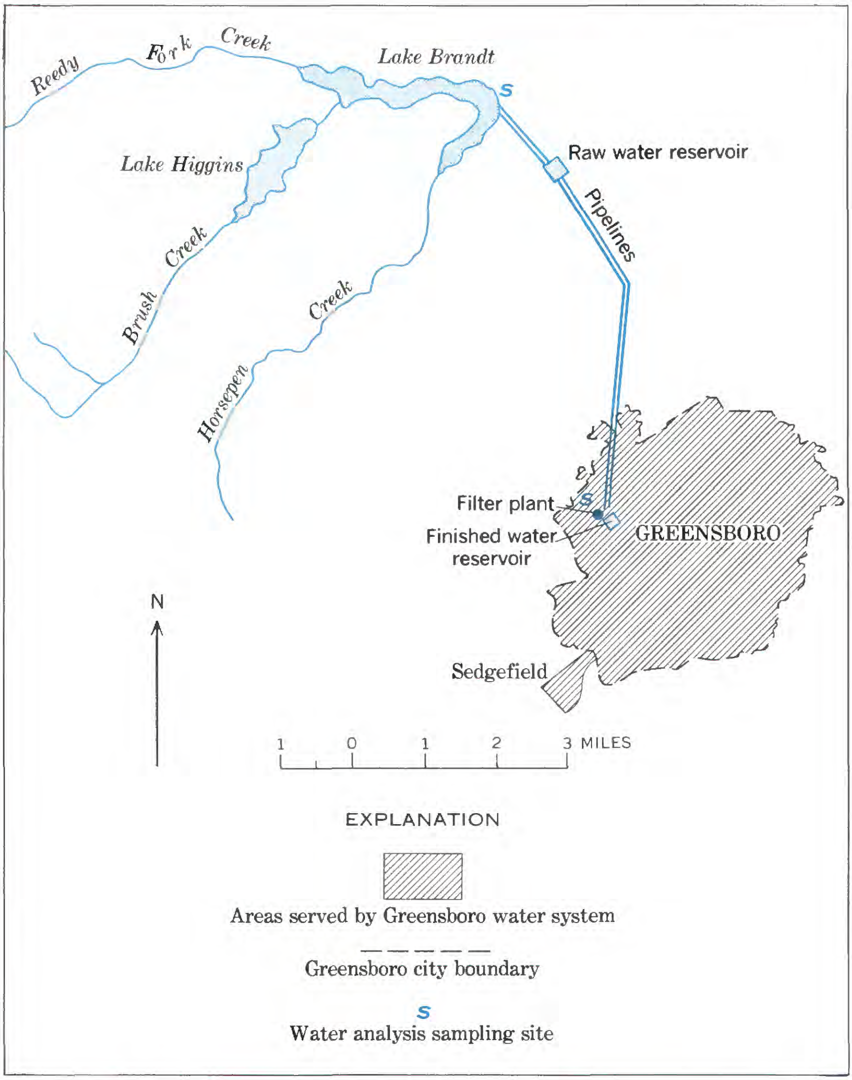

FIGURE 48.—Water supplies and areas served by Greensboro, N. C., water system. (Approved by local municipal water officials, February 1963.)

Analytical data—Greensboro

	Lake Brandt	Filter plant
Percent of supply	100	100
Date of collection	1–16–62	1–16–62
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	9.4	7.0
Iron (Fe)	.02	.01
Manganese (Mn)	.04	.00
Aluminum (Al)	.1	.5
Lithium (Li)	.0	.0
Calcium (Ca)	4.4	21
Magnesium (Mg)	1.7	1.6
Sodium (Na)	2.9	2.7
Potassium (K)	2.4	2.6
Bicarbonate (HCO_3)	20	15
Carbonate (CO_3)	0	13
Sulfate (SO_4)	7.2	27
Chloride (Cl)	3.5	4.5
Fluoride (F)	.1	.2
Nitrate (NO_3)	1.5	1.1
Phosphate (PO_4)	.1	.1
Dissolved solids (residue at 180°C)	49	96
Hardness as $CaCO_3$	18	65
Noncarbonate hardness as $CaCO_3$	2	31
Specific conductance (micromhos at 25°C)	59	148
pH	7.0	9.6
Color	10	2
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity		12
Radium (Ra)		.3
Uranium (U)		<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)		ND
Aluminum (Al)		1,500
Boron (B)		11
Barium (Ba)		8.6
Beryllium (Be)		ND
Cobalt (Co)		ND
Chromium (Cr)		1.1
Copper (Cu)		7.8
Iron (Fe)		48
Lithium (Li)		ND
Manganese (Mn)		16
Molybdenum (Mo)		ND
Nickel (Ni)		1.3
Phosphorus (P)		ND
Lead (Pb)		<1.3
Rubidium (Rb)		5.2
Tin (Sn)		ND
Strontium (Sr)		71
Titanium (Ti)		.4
Vanadium (V)		<3.8
Zinc (Zn)		ND

OHIO

Akron
Cincinnati
Cleveland
Columbus
Dayton
Toledo
Youngstown

AKRON

(See fig. 49.)

Ownership: Municipal.

Other areas served: Mogadore, Stow, Tallmadge, the Chrysler Corp. at Twinsburg, and the General Motors Corp. at Hudson

Population served: Akron, 290,351; total about 315,000.

Source of supply: Cuyahoga River impounded in Lake Rockwell, East Branch Reservoir, and Wendell R. LaDue Reservoir. (Water from Mogadore Reservoir is used by industries.)

Auxiliary and emergency supplies: Wells at Kenmore field and pumping station near Nesmith Lake can supply 1.5 mgd.

Average amount of water used daily in system during 1962: 41.1 mgd (U.S. Public Health Service, 1962c).

Treatment: Akron water treatment plant—coagulation with alum and ferrous sulfate, treatment with activated carbon when necessary, flocculation, sedimentation, filtration (anthrafilt), chlorination, and final adjustment of pH by addition of lime.

Rated capacity of treatment plant: Akron water treatment plant, 60 mgd.

Raw-water storage: 10,100 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 250.

Finished-water storage: 48 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.2.

Remarks: The watershed can be depended upon to yield an annual average of 65 mgd.

Regular determinations at Akron water treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	74	121	28	7.9	9.1	7.2	107	156	56	5	36	1
Finished water	79	137	39	8.3	8.8	7.7	130	184	76	.4	5	.05

Analytical data, treatment plant—Akron

[Percent of supply: 100. Date of collection: 5-2-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	1.3	Fluoride (F)	0.1
Iron (Fe)	.03	Nitrate (NO_3)	.2
Manganese (Mn)	.03	Dissolved solids (residue at 180° C)	172
Calcium (Ca)	35	Hardness as $CaCO_3$	115
Magnesium (Mg)	6.7	Noncarbonate hardness as $CaCO_3$	54
Sodium (Na)	6.2		
Potassium (K)	1.7	Specific conductance (micromhos at 25° C)	264
Bicarbonate (HCO_3)	74	pH	7.5
Carbonate (CO_3)	0	Color	5
Sulfate (SO_4)	46	Temperature °F	63
Chloride (Cl)	15		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	8.6	Uranium (U)	0.1
Radium (Ra)	<.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.17	Molybdenum (Mo)	<0.52
Aluminum (Al)	790	Nickel (Ni)	2.6
Boron (B)	26	Phosphorus (P)	ND
Barium (Ba)	43	Lead (Pb)	3.1
Beryllium (Be)	ND	Rubidium (Rb)	ND
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	.65	Strontium (Sr)	71
Copper (Cu)	4.8	Titanium (Ti)	1.4
Iron (Fe)	48	Vanadium (V)	ND
Lithium (Li)	1.2	Zinc (Zn)	ND
Manganese (Mn)	6.4		

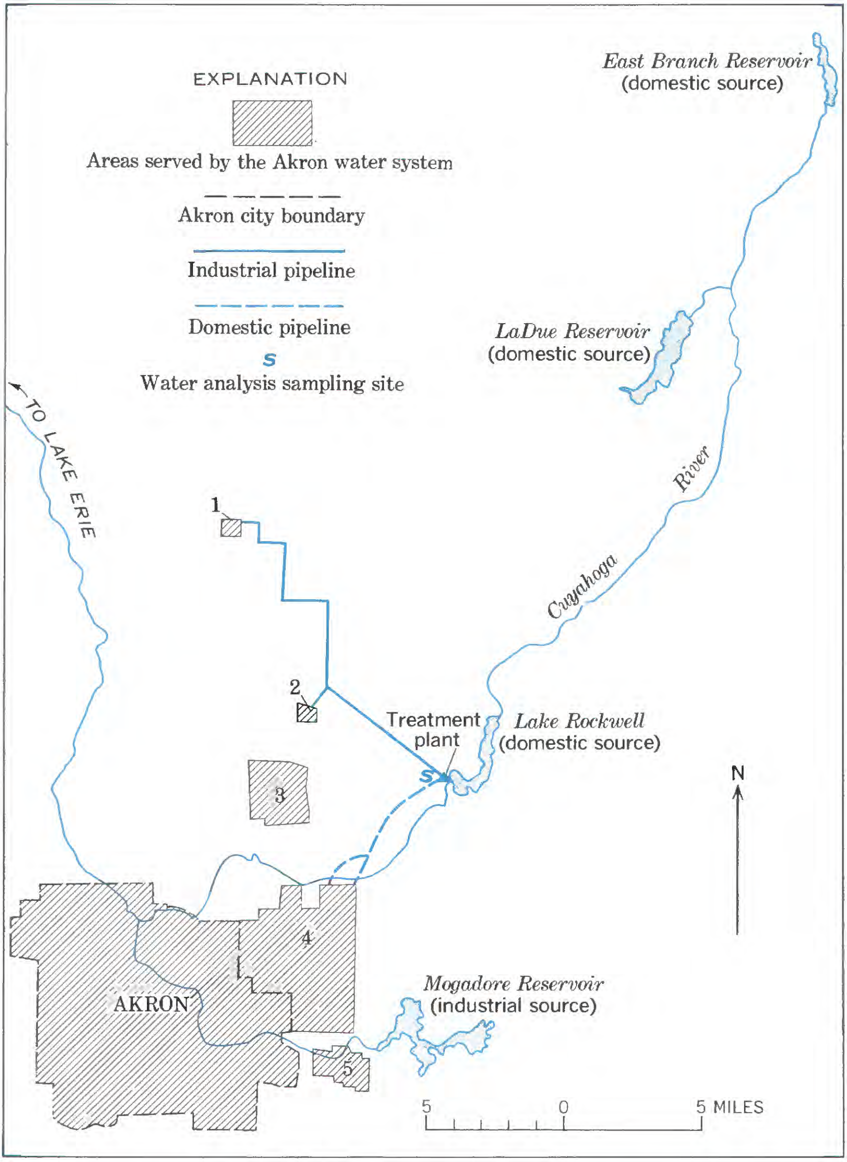

FIGURE 49.—Water supplies and areas served by Akron, Ohio, water system. (Approved by local municipal water officials, April 1963.) List of areas served: 1, Chrysler Corp.; 2, General Motors Corp.; 3, Stow; 4, Tallmadge; 5, Mogadore.

CINCINNATI

(See fig. 50.)

Ownership: Municipal.

Other areas served: Addyston, Amberley, Arlington Heights, Blue Ash, Cheviot, Deer Park, Elmwood Place, Evandale, Fairfax, Golf Manor, Greenhills, Lincoln Heights, Mariemont, Montgomery, Mt. Healthy, Newtown, North Bend, North College Hill, Norwood, St. Bernard, Sharonville, Silverton, Woodlawn, other cities on occasion, and suburban districts.

Population served: Cincinnati, 502,550; total, about 750,000.

Source of supply: Ohio River.

Lowest mean discharge: Ohio River at Cincinnati, Ohio, for 30-day period in climatic water years (April 1–March 31) 1950–59: 5,120 mgd.

Average amount of water used daily in system during 1962: 97 mgd (U.S. Public Health Service, 1962c).

Treatment: Cincinnati treatment plant—prechlorination, coagulation with iron salts and lime (and periodically with alum), treatment with activated carbon, sedimentation, chlorination, rapid sand filtration, and ammoniation.

Rated capacity of treatment plant: Cincinnati treatment plant, 200 mgd.

Raw-water storage: 300 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 3.4.

Finished-water storage: 131 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.4.

Regular determinations at Cincinnati treatment plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	40	56	15	7.5	9.0	6.9	137	224	63	70	1,100	1
Finished water	43	59	25	8.6	9.3	7.8	159	240	97	0	0	0

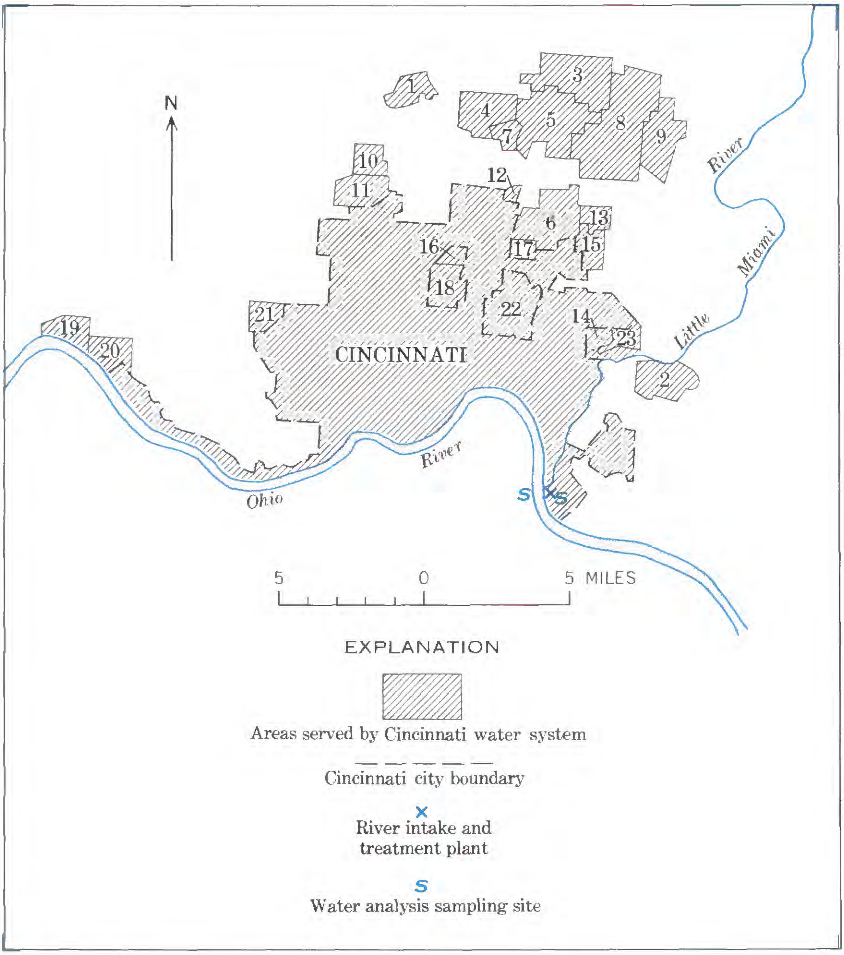

FIGURE 50.—Water supplies and areas served by Cincinnati, Ohio, water system. (Approved by local municipal water officials, April 1963.) List of areas served: 1, Greenhills; 2, Newtown; 3, Sharonville; 4, Woodlawn; 5, Evandale; 6, Amberley; 7, Lincoln Heights; 8, Blue Ash; 9, Montgomery; 10, Mt. Healthy; 11, North College Hill; 12, Arlington Heights; 13, Deer Park; 14, Fairfax; 15, Silverton; 16, Elmwood Place; 17, Golf Manor; 18, St. Bernard; 19, North Bend; 20, Addyston; 21, Cheviot; 22, Norwood; 23, Mariemont.

Analytical data—Cincinnati

	Ohio River		Treatment plant		
Percent of supply			100		
Date of collection	(1)	(2)	5-15-62	(1)	(2)
Type of water: R, raw; F, finished	R	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)			3.4		
Iron (Fe)	0.04	0.00	.02	0.02	0.00
Manganese (Mn)			.02		
Calcium (Ca)	51	25	45	59	34
Magnesium (Mg)	12	5.5	10	12	7.8
Sodium (Na)			18		
Potassium (K)			1.8		
Bicarbonate (HCO_3)	58	35	50		33
Carbonate (CO_3)	0		0		0
Sulfate (SO_4)	132	62	114	138	80
Chloride (Cl)	59	15	28	66	18
Fluoride (F)	.4	.1	.2	.4	.1
Nitrate (NO_3)			2.0		
Dissolved solids (residue at 180° C)	377	151	261	410	185
Hardness as $CaCO_3$	178	91	153	199	116
Noncarbonate hardness as $CaCO_3$			112		
Specific conductance (micromhos at 25° C)			403		
pH	8.3	7.2	8.1	8.9	8.3
Color			3		
Turbidity	180	7			
Temperature °F			67		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity			5.3		
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	20				
Radium (Ra)			<.1		
Uranium (U)			<.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)			<0.29		
Aluminum (Al)			190		
Boron (B)			28		
Barium (Ba)			84		
Beryllium (Be)			ND		
Cobalt (Co)			ND		
Chromium (Cr)			2.0		
Copper (Cu)			17		
Iron (Fe)			11		
Lithium (Li)			7.5		
Manganese (Mn)			ND		
Molybdenum (Mo)			3.8		
Nickel (Ni)			<2.9		
Phosphorus (P)			ND		
Lead (Pb)			ND		
Rubidium (Rb)			3.2		
Tin (Sn)			ND		
Strontium (Sr)			210		
Titanium (Ti)			ND		
Vanadium (V)			ND		
Zinc (Zn)			ND		

[1] Maximum constituents in monthly analyses by the city of Cincinnati during 1961.
[2] Minimum constituents in monthly analyses by the city of Cincinnati during 1961.

CLEVELAND

(See fig. 51.)

Ownership: Municipal.

Other areas served: Sixty suburban areas and most of the remainder of Cuyahoga County.

Population served: Cleveland, 876,050; total, about 1,675,000.

Source of supply: Lake Erie.

Average amount of water used daily in system during 1962: 319 mgd (U.S. Public Health Service, 1962c).

Treatment: Nottingham, Baldwin, Division, and Crown filtration plants—prechlorination, treatment with activated carbon and lime when necessary, sedimentation, fluoridation, rapid sand filtration, and postchlorination when necessary.

Rated capacity of treatment plants: Nottingham filtration plant, 150 mgd; Baldwin filtration plant, 165 mgd; Division filtration plant, 150 mgd; Crown filtration plant, 50 mgd.

Raw-water storage: 80 million gal.

Finished-water storage: 293 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Nottingham filtration plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	94	102	83	8.0	8.5	7.3	127	132	118	8.7	140	1.0
Finished water	86	94	73	7.5	7.9	7.0	127	132	116	0	1.0	.0

Analytical data, Nottingham filtration plant—Cleveland

[Percent of supply: 100. Date of collection: 5-2-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	0.5	Fluoride (F)	1.0
Iron (Fe)	.05	Nitrate (NO_3)	1.1
Manganese (Mn)	.10	Dissolved solids (residue at 180° C)	185
Calcium (Ca)	35	Hardness as $CaCO_3$	116
Magnesium (Mg)	6.9	Noncarbonate hardness as $CaCO_3$	44
Sodium (Na)	11		
Potassium (K)	1.5	Specific conductance (micromhos at 25° C)	290
Bicarbonate (HCO_3)	88		
Carbonate (CO_3)	0	pH	6.9
Sulfate (SO_4)	30	Color	7
Chloride (Cl)	26	Temperature °F	47

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; $<$, less than]

Beta activity	10	Uranium (U)	0.3
Radium (Ra)	<0.1		

Spectrographic analyses

[In micrograms per liter. ND, looked for but not found]

Silver (Ag)	0.23	Molybdenum (Mo)	2.1
Aluminum (Al)	250	Nickel (Ni)	6.5
Boron (B)	53	Phosphorus (P)	ND
Barium (Ba)	32	Lead (Pb)	7.9
Beryllium (Be)	ND	Rubidium (Rb)	ND
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	3.5	Strontium (Sr)	160
Copper (Cu)	6.0	Titanium (Ti)	4.9
Iron (Fe)	85	Vanadium (V)	ND
Lithium (Li)	1.2	Zinc (Zn)	ND
Manganese (Mn)	3.9		

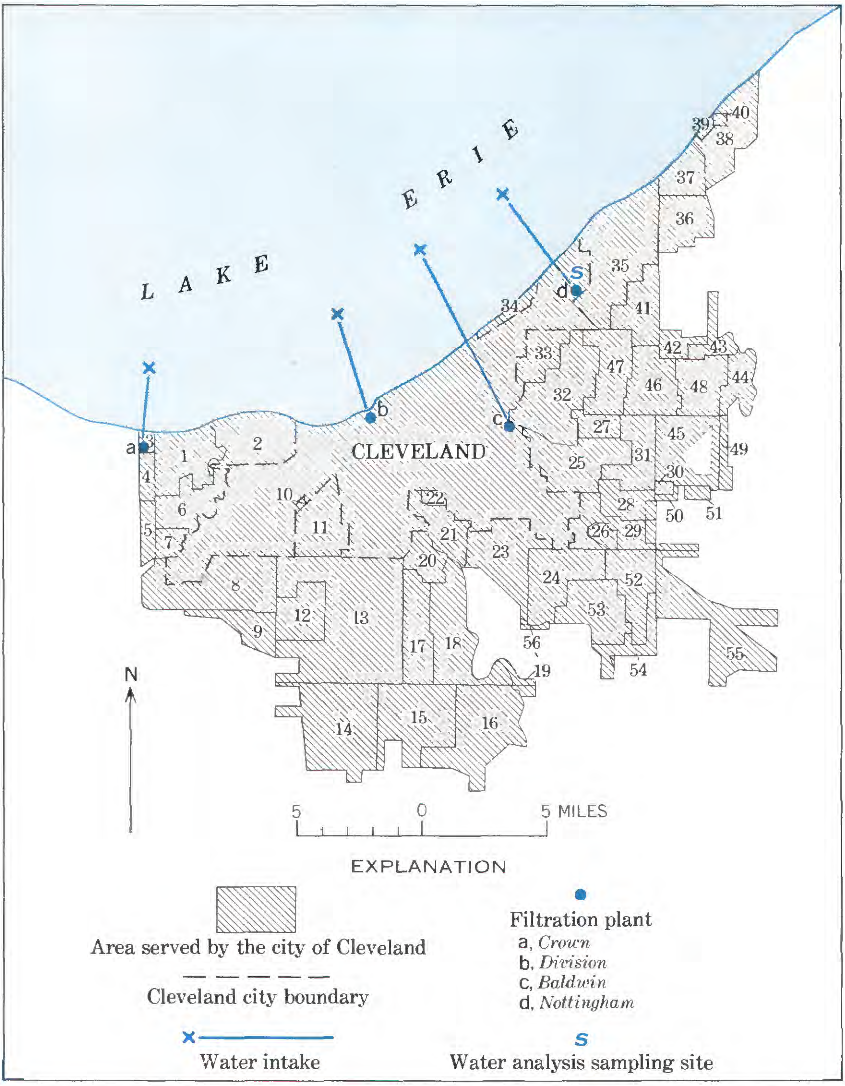

FIGURE 51.—Water supplies and areas served by Cleveland, Ohio, water system. (Approved by local municipal water officials, April 1963.) List of suburban areas—does not include Cleveland: 1, Rocky River; 2, Lakewood; 3, Bay Village; 4, Westlake; 5, North Olmstead; 6, Fairview Park; 7, Park View; 8, Brook Park; 9, Middleburg Heights; 10, Linndale; 11, Brooklyn; 12, Parma Heights; 13, Parma; 14, North Royalton; 15, Broadview Heights; 16, Brecksville; 17, Seven Hills; 18, Independence; 19, Valleyview; 20, Brooklyn Heights; 21, Cuyahoga Heights; 22, Newburg Heights; 23, Garfield Heights; 24, Maple Heights; 25, Shaker Heights; 26, North Randall; 27, University Heights; 28, Warrensville Township; 29, Warrensville Heights; 30, Woodmere; 31, Beachwood; 32, Cleveland Heights; 33, East Cleveland; 34, Bratenahl; 35, Euclid; 36, Wickliffe; 37, Willowick; 38, East Lake; 39, Lakeline; 40, Timberlake; 41, Richmond Heights; 42, Highland Heights; 43, Mayfield; 44, Gates Mills; 45, Pepper Pike; 46, Lyndhurst; 47, South Euclid; 48, Mayfield Heights; 49, Hunting Valley; 50, Orange; 51, Moreland Hills; 52, Bedford Heights; 53, Bedford; 54, Oakwood; 55, Solon; 56, Walton Hills.

COLUMBUS

(See fig. 52.)

Ownership: Municipal.

Other areas served: Bexley, Clifton, Franklin, Gahanna, Grandview Heights, Grove City, Lincoln Village, Marble Cliff, Mifflin, Minerva Park, New Rome, Riverlea, Upper Arlington, Valleyview, Whitehall, Worthington, and most of the remainder of Franklin County.

Population served: Columbus, 471,316; total, about 593,964.

Sources of supply: Scioto River impounded in Griggs and O'Shaughnessy Reservoirs; Big Walnut Creek impounded in Hoover Reservoir. No definite percentage served by the two sources. Big Walnut Creek furnished more than half of supply in 1961, and its proportion will increase because the city is growing more to the east and northeast.

Auxiliary and emergency supplies: White Sulfur Quarry, Olentangy River, and Nelson Road wells.

Lowest mean discharge: Scioto River at Columbus, Ohio, for 30-day period in climatic water years (April 1–March 31) 1950–59: 56.4 mgd.

Average amount of water used daily in system during 1962: 71.3 mgd (U.S. Public Health Service, 1962c).

Treatment:

Dublin Road treatment plant (Scioto River): Coagulation with alum, softening with lime and soda ash, treatment with activated carbon at times, sedimentation, recarbonation, rapid sand filtration, addition of phosphate (Calgon), chlorination, and treatment with chlorine dioxide when necessary. Water is softened to a hardness of about 100 ppm.

Morse Road treatment plant (Big Walnut Creek): Treatment same as Dublin Road plant, except chlorine dioxide is not used and soda ash is used when needed for turbid water.

Rated capacity of treatment plants: Dublin Road treatment plant, 50 mgd; Nelson Road treatment (standby) plant, 10 mgd; Morse Road treatment plant, 60 mgd.

Raw-water storage: Griggs and O'Shaughnessy Reservoirs, 6,500 million gal; Hoover Reservoir, normally 19,500 million gal with provision for storage of additional 5,500 million gal with flash boards.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.2 years.

Finished-water storage: Dublin Road plant, 25 million gal; Morse Road plant, 12 million gal; elevated and underground storage at various places in distribution system, 12 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations of monthly composites at treatment plants, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Dublin Road:												
Raw water	159	204	108	8.2	8.3	8.1	272	350	204	40	110	15
Finished water	33	48	27	10.1	10.2	9.9	104	114	98	0	0	0
Morse Road:												
Raw water	92	116	76	8.0	8.2	7.9	152	200	128	12.6	27.0	2.9
Finished water	34	46	22	9.7	10.5	9.0	98	118	76	.6	2.4	.2

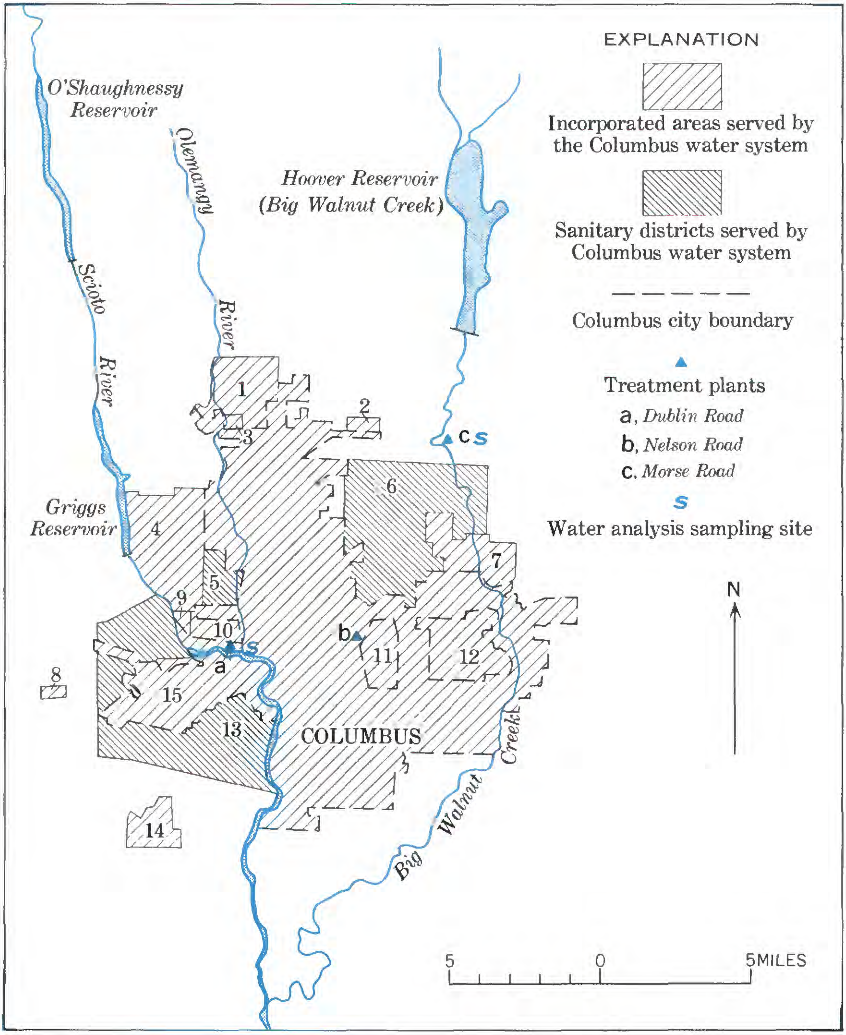

FIGURE 52.—Water supplies and areas served by Columbus, Ohio, water system. (Approved by local municipal water officials, April 1963.) Areas served by the Columbus water system: 1, Worthington; 2, Minerva Park; 3, Riverlea; 4, Upper Arlington; 5, Clinton; 6, Mifflin; 7, Gahanna; 8, New Rome; 9, Marble Cliff; 10, Grandview Heights; 11, Bexley; 12, Whitehall; 13, Franklin; 14, Grove City; 15, Valleyview.

Analytical data—Columbus

	Big Walnut Creek		Morse Road treatment plant			Scioto River		Dublin Road treatment plant		
Percent of supply			55					45		
Date of collection	(1)	(2)	5-29-62	(1)	(2)	(1)	(2)	5-29-62	(1)	(2)
Type of water: R, raw; F, finished	R	R	F	F	F	R	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	10	0.0	3.1	7	5	7	5	4.5	3.6	0.4
Iron (Fe)			.03					.02		
Manganese (Mn)			.00					.00		
Calcium (Ca)	48	32	34	34	28	84	52	30	30	24
Magnesium (Mg)	19	12	4.5	9	5	34	18	6.4	9	3
Sodium (Na)			5.8					34		
Potassium (K)			2.5					2.6		
Bicarbonate (HCO_3)	142	94	52	32	16	249	132	9	24	8
Carbonate (CO_3)	0	0	0	4	0	0	0	10	7	
Sulfate (SO_4)	81	44	54	197	77	182	77	127	78	47
Chloride (Cl)	10	5.0	14	32	12	32	12	20	11	7.0
Fluoride (F)			.2					.2		
Nitrate (NO_3)	7.0	7.0	4.2	1.0	1.0	3	1.0	1.2	6.0	.7
Dissolved solids (residue at 180° C)	313	206	168	442	230	574	318	247	209	141
Hardness as $CaCO_3$	200	128	104	114	98	350	204	102	118	76
Noncarbonate hardness as $CaCO_3$	84	47	61	75	62	146	88	78	81	52
Specific conductance (micromhos at 25° C)			253					395		
pH	8.2	7.9	8.2	10.2	9.9	8.3	8.1	9.3	10.5	9.0
Color	40	10	3					3	5	3
Turbidity	27	6		0	0	105	15		2	0
Temperature °F			65					71		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, <]

Beta activity			9.1					11		
Radium (Ra)			.1					.1		
Uranium (U)			<.1					<.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)			ND					<0.26		
Aluminum (Al)			59					15		
Boron (B)			24					23		
Barium (Ba)			55					40		
Beryllium (Be)			ND					ND		
Cobalt (Co)			ND					ND		
Chromium (Cr)			2.6					4.0		
Copper (Cu)			.99					1.5		
Iron (Fe)			7.9					5.8		
Lithium (Li)			2.8					6.3		
Manganese (Mn)			ND					ND		
Molybdenum (Mo)			12					9.0		
Nickel (Ni)			ND					<2.6		
Phosphorus (P)			ND					ND		
Lead (Pb)			ND					ND		
Rubidium (Rb)			3.5					<2.6		
Tin (Sn)			ND					ND		
Strontium (Sr)			220					740		
Titanium (Ti)			2.6					ND		
Vanadium (V)			ND					ND		
Zinc (Zn)			ND					ND		

[1] Maximum value of constituents in analyses by the city of Columbus of monthly composite, 1961.
[2] Minimum value of constituents in analyses by the city of Columbus of monthly composite, 1961.

DAYTON

Ownership: Municipal.

Other areas served: Part of Montgomery County, the town of Trotwood, and, sometimes, the city of Oakwood.

Population served: Dayton, 262,332; total, about 320,000.

Sources of supply: Total of 59 wells. Mad River valley—10 deep wells and 37 shallow wells 18 to 38 inches in diameter—most wells are 26 inches in diameter. Miami River valley—12 wells, 26 inches in diameter and ranging in depth from 80 to 180 feet.

Average amount of water used daily in system during 1962: 46.6 mgd (U.S. Public Health Service, 1962c).

Treatment: Ottawa Street treatment plant—lime-soda ash softening, split recarbonation, rapid sand filtration, and chlorination. Alum is sometimes used for coagulation. In summer chlorine is added ahead of plant for algae control in filter. Split treatment is used whereby 20–25 percent of raw water bypasses first softening stage directly to second stage. This serves to recarbonate overtreated primary settled water, which will, in turn, soften the bypassed water to some extent. Final hardness is about 100 ppm.

Rated capacity of treatment plant: Ottawa Street treatment plant, 96 mgd.

Raw-water storage: None.

Finished-water storage: Clear well, 10 million gal; low service, 46 million gal; high service, 8.9 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.4.

Regular determinations at Buffalo filtration plant, January 1961–July 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	326	-----	-----	7.6	-----	-----	356	-----	----
Finished water	48	-----	-----	8.8	-----	-----	103	-----	----

Analytical data—Dayton

	Well water	Ottawa Street treatment plant	
Percent of supply	100	100	------------
Date of collection	(1)	5-14-62	(1)
Type of water: R, raw; F, finished	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	------------	6.4	------------
Iron (Fe)	0.23	.00	0.00
Manganese (Mn)	------------	.03	------------
Calcium (Ca)	89	27	28
Magnesium (Mg)	33	9.5	8
Sodium (Na)	11	17	23
Potassium (K)		1.8	
Bicarbonate (HCO_3)	326	46	48
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	83	80	84
Chloride (Cl)	19	18	19
Fluoride (F)	------------	.2	------------
Nitrate (NO_3)	------------	5.0	------------
Dissolved solids (residue at 180° C)	439	190	203
Hardness as $CaCO_3$	356	107	103
Noncarbonate hardness as $CaCO_3$	89	69	64
Specific conductance (micromhos at 25° C)	------------	214	------------
pH	7.6	7.5	8.8
Color	------------	3	------------
Temperature °F	------------	64	------------

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	------------	6.8	------------
Radium (Ra)	------------	.1	------------
Uranium (U)	------------	<.1	------------

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	------------	1.1	------------
Aluminum (Al)	------------	32	------------
Boron (B)	------------	13	------------
Barium (Ba)	------------	100	------------
Beryllium (Be)	------------	ND	------------
Cobalt (Co)	------------	ND	------------
Chromium (Cr)	------------	3.4	------------
Copper (Cu)	------------	4.7	------------
Iron (Fe)	------------	21	------------
Lithium (Li)	------------	2.1	------------
Manganese (Mn)	------------	<2.1	------------
Molybdenum (Mo)	------------	5.4	------------
Nickel (Ni)	------------	34	------------
Phosphorus (P)	------------	ND	------------
Lead (Pb)	------------	5.1	------------
Rubidium (Rb)	------------	ND	------------
Tin (Sn)	------------	ND	------------
Strontium (Sr)	------------	510	------------
Titanium (Ti)	------------	1.4	------------
Vanadium (V)	------------	ND	------------
Zinc (Zn)	------------	ND	------------

[1] Average of analyses by the city of Dayton of monthly composite samples, 1960.

TOLEDO

(See fig. 53.)

Ownership: Municipal.

Other areas served: Maumee, Oregon, Ottawa Hills, Perrysburg, Rossford, and suburban districts.

Population served: Toledo, 318,000; total, about 400,000.

Source of supply: Lake Erie. The raw water intake is at a crib in Lake Erie, about 9 miles east of Toledo near Reno Beach and 2 miles offshore.

Average amount of water used daily in system during 1962: 65.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Collins Park treatment plant—activated carbon at low service (4 hours precontact time), prechlorination, coagulation with alum, lime and soda ash softening, recarbonation, rapid sand filtration, postchlorination, and fluoridation. Water softened to 70 ppm.

Rated capacity of treatment plant: Collins Park treatment plant, 120 mgd.

Finished-water storage: 35 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Ottawa Street treatment plant, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	-----	-----	-----	8. 3	8. 9	7. 4	124	186	104
Finished water	33	-----	-----	9. 5	9. 9	8. 5	70	84	54

Analytical data—Toledo

	Lake Erie		Collins Park treatment plant		
Percent of supply			100		
Date of collection	(1)	(2)	4-6-62	(1)	(2)
Type of water: R, raw; F, finished	R	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)			2.9		
Iron (Fe)			.10		
Manganese (Mn)			.00		
Calcium (Ca)	48	30	19	14	26
Magnesium (Mg)	11	6.8	5.1	2.4	7.3
Sodium (Na)	12	3.0	12	6.8	18
Potassium (K)			1.7		
Bicarbonate (HCO_3)			14		
Carbonate (CO_3)			8		
Sulfate (SO_4)	38	18	28	21	48
Chloride (Cl)	28	15	27	16	29
Fluoride (F)			1.0		
Nitrate (NO_3)	1.5	.0	2.6	.0	2.0
Dissolved solids (residue at 180° C)	319	172	122	172	109
Hardness as $CaCO_3$	186	104	68	84	54
Noncarbonate hardness as $CaCO_3$	97	24	44	20	55
Specific conductance (micromhos at 25° C)			214		
pH	8.9	7.4	8.9	8.5	9.9
Color			3		
Temperature ° F			44		

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity			12		
Radium (Ra)			.1		
Uranium (U)			.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)			<.16		
Aluminum (Al)			330		
Boron (B)			30		
Barium (Ba)			25		
Beryllium (Be)			ND		
Cobalt (Co)			ND		
Chromium (Cr)			3.7		
Copper (Cu)			4.5		
Iron (Fe)			56		
Lithium (Li)			2.8		
Manganese (Mn)			2.7		
Molybdenum (Mo)			2.8		
Nickel (Ni)			3.9		
Phosphorus (P)			<160		
Lead (Pb)			6.6		
Rubidium (Rb)			3.0		
Tin (Sn)			ND		
Strontium (Sr)			110		
Titanium (Ti)			2.2		
Vanadium (V)			8.0		
Zinc (Zn)			ND		

[1] Maximum value of constituents in monthly analyses by city of Toledo during 1961.
[2] Minimum value of constituents in monthly analyses by the city of Toledo during 1961.

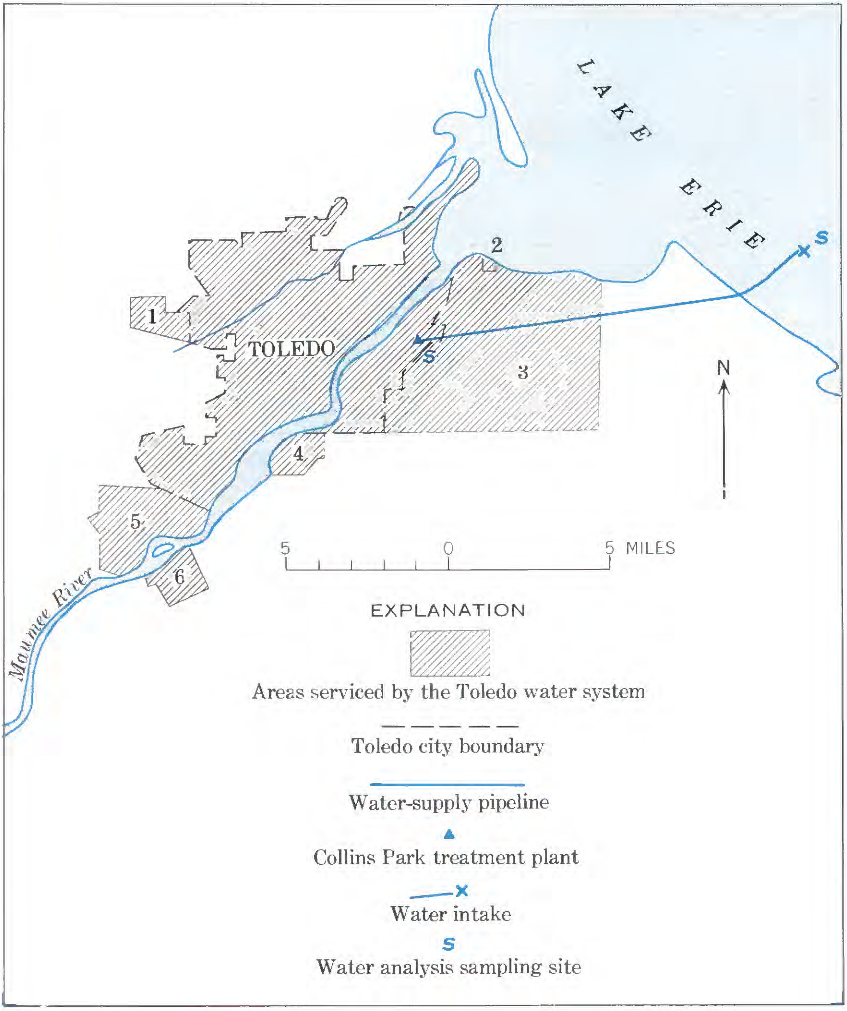

FIGURE 53.—Water supplies and areas served by the Toledo, Ohio, water system. (Approved by local municipal water officials, April 1963.) List of areas served: 1, Ottawa Hills; 2, Harbor View; 3, Oregon; 4, Rossford; 5, Maumee; 6, Perrysburg.

YOUNGSTOWN

(See fig. 54.)

Ownership: Mahoning Valley Sanitary District (controlled by cities of Youngstown and Niles).

Other areas served: Niles and McDonald, directly; Austintown, Boardman, Canfield, Girard, and Mineral Ridge, indirectly.

Population served: Youngstown, 166,689; total, about 250,000.

Source of supply: Meander Creek impounded in Meander Creek Reservoir.

Auxiliary and emergency supplies: May buy as much as 30 mgd from Berlin Reservoir in emergency.

Average amount of water used daily in system during 1962: 22.2 mgd (U.S. Public Health Service, 1962c).

Treatment: Mahoning Valley Sanitary District-Meander Creek treatment plant—coagulation with alum, softening with lime and soda ash, sedimentation, recarbonation, addition of activated carbon, rapid sand filtration, ammoniation, and chlorination.

Rated capacity of treatment plant: Meander Creek treatment plant, 64 mgd.

Raw-water storage: About 11,000 million gal (with flashboards).

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.4 years.

Finished-water storage: 35 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.6.

Remarks: The cities of Youngstown and Niles control the Mahoning Valley Sanitary District, which sells water to them directly. These two cities can (and do) make contracts to supply water through their own lines to other communities.

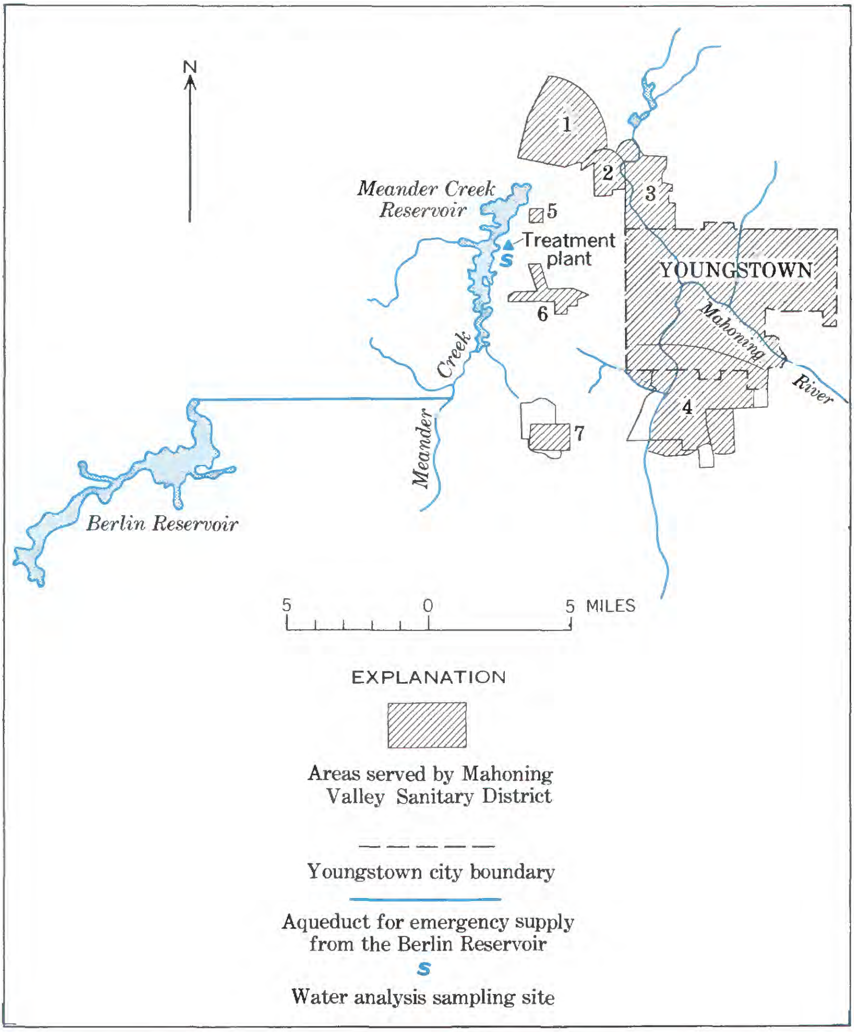

FIGURE 54.— Water supplies and areas served by the Mahoning Valley Sanitary District, Youngstown, Ohio. (Approved by local municipal water officials, April 1963.) Areas served by Mahoning Valley Sanitary District: 1, Niles; 2, McDonald; 3, Girard; 4, Boardman; 5, Mineral Ridge; 6, Austintown; 7, Canfield.

Analytical data, Meander Creek treatment plant—Youngstown

[Percent of supply: 100. Date of collection: 5-3-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	5.5	Fluoride (F)	1.0
Iron (Fe)	.06	Nitrate (NO_3)	1.3
Manganese (Mn)	.03	Dissolved solids (residue at 180° C)	199
Calcium (Ca)	25	Hardness as $CaCO_3$	86
Magnesium (Mg)	5.7	Noncarbonate hardness as $CaCO_3$	56
Sodium (Na)	26		
Potassium (K)	2.9		
Bicarbonate (HCO_3)	0	Specific conductance (micromhos at 25° C)	337
Carbonate (CO_3)	14	pH	10.0
Sulfate (SO_4)	87	Color	3
Chloride (Cl)	18	Temperature °F	66

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	12	Uranium (U)	<0.1
Radium (Ra)	<0.1		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.23	Molybdenum (Mo)	<0.70
Aluminum (Al)	35	Nickel (Ni)	3.0
Boron (B)	35	Phosphorus (P)	ND
Barium (Ba)	26	Lead (Pb)	4.0
Beryllium (Be)	ND	Rubidium (Rb)	3.0
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	<.23	Strontium (Sr)	87
Copper (Cu)	2.0	Titanium (Ti)	<.7
Iron (Fe)	15	Vanadium (V)	<7.0
Lithium (Li)	3.5	Zinc (Zn)	ND
Manganese (Mn)	ND		

OKLAHOMA

Oklahoma City *Tulsa*

OKLAHOMA CITY

Ownership: Municipal.

Other areas served: Warr Acres and Village. Emergency connections to Tinker Air Force Base and Nichols Hills.

Population served: Oklahoma City, 324,253; total, 340,000.

Sources of supply: North Canadian River by diversion into two off-channel reservoirs, Lake Hefner and Lake Overholser, both within the city limits.

Auxiliary and emergency supplies: 105 wells.

Average amount of water used daily in system during 1962: 31.1 mgd (U.S. Public Health Service, 1962c).

Treatment: Lake Hefner and Lake Overholser treatment plants—softening with lime, coagulation with alum, addition of carbon at times for taste and color control, sedimentation, recarbonation, rapid sand filtration, addition of Calgon if needed, chlorination, and fluoridation.

Rated capacity of treatment plants: Lake Hefner plant, 37.5 mgd, Lake Overholser plant, 24 mgd.

Raw-water storage, in million gallons: Atoka Reservoir, 40,730; Lake Hefner, 24,440; Lake Overholser, 4,888; Canton Reservoir, 29,330.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 8.8 years.

Finished-water storage: Elevated, 11 million gal; other, 35 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.5.

Remarks: The Atoka Reservoir does not yet supply water to Oklahoma City. A 60-inch pipeline is currently under construction from Atoka to Elm Creek Reservoir southeast of Oklahoma City and should be completed in 1964. Elm Creek Reservoir, now under construction, will have 33,000 million gal storage. The Elm Creek water treatment plant will provide an additional 30 mgd.

Regular determinations at Lake Hefner treatment plant, January 1961–July 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	143	145	138	8.7	8.8	8.5	246	255	237	6	6	6
Finished water	39	45	33	10.2	10.3	10.1	132	149	117	0	0	0

Analytical data—Oklahoma City

	Lake Hefner	Lake Hefner treatment plant
Percent of supply	100	100
Date of collection	7–28–61	7–28–61
Type of water: R, raw; F, finished	R	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	3. 2	2. 6
Iron (Fe)	. 02	. 00
Manganese (Mn)	. 00	. 00
Calcium (Ca)	58	29
Magnesium (Mg)	26	16
Sodium (Na)	90	84
Potassium (K)	7. 6	7. 6
Bicarbonate (HCO_3)	182	8
Carbonate (CO_3)	0	14
Sulfate (SO_4)	152	135
Chloride (Cl)	107	104
Fluoride (F)	. 6	. 6
Nitrate (NO_3)	. 5	. 4
Dissolved solids (residue at 180° C)	518	418
Hardness as $CaCO_3$	250	138
Noncarbonate hardness as $CaCO_3$	101	108
Specific conductance (micromhos at 25° C)	865	712
pH	7. 8	9. 7
Color	2	0
Turbidity	1	1
Temperature °F	78	79

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	----------	12
Radium (Ra)	----------	<. 1
Uranium (U)	----------	. 3

Spectrographic analyses
[In micrograms per liter. <, less then; ND, looked for but not found]

Silver (Ag)	<0. 76	0. 54
Aluminum (Al)	130	650
Boron (B)	170	76
Barium (Ba)	140	260
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	1. 9	4. 6
Copper (Cu)	14	11
Iron (Fe)	39	100
Lithium (Li)	20	8. 6
Manganese (Mn)	7. 6	48
Molybdenum (Mo)	4. 5	3. 2
Nickel (Ni)	7. 6	25
Phosphorus (P)	ND	ND
Lead (Pb)	13	16
Rubidium (Rb)	ND	7. 0
Tin (Sn)	ND	ND
Strontium (Sr)	530	140
Titanium (Ti)	<7. 6	15
Vanadium (V)	ND	<16
Zinc (Zn)	ND	ND

TULSA

Ownership: Municipal.

Other areas served: Skiatook, Sperry, Turley, and other consumers outside city limits. Also serves raw water to Owasso and Spavinaw.

Population served: Tulsa, 261,285; total, 292,000.

Source of supply: Spavinaw Creek impounded in Upper Spavinaw Lake, about 60 miles east of Tulsa, and in Lower Spavinaw Lake, which is about 3 miles downstream of Upper Spavinaw Lake.

Average amount of water used daily in system during 1962: 42.5 mgd (U.S. Public Health Service, 1962c).

Treatment: Mohawk treatment plant—prechlorination, coagulation by alum (with lime if necessary), and fluoridation, followed by mixing, sedimentation, and filtration.

Rated capacity of treatment plant: Mohawk treatment plant, 120 mgd.

Raw-water storage: Lower Spavinaw Lake, 10,100 million gal: Upper Spavinaw Lake, 26,070 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.3 years.

Finished-water storage: 55 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.3.

Regular determinations at Mohawk treatment plant, January 1961–July 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	86	94	71	8.1	8.2	7.8	----	------	------	7.4	13.5	4.0
Finished water	84	90	67	7.8	8.2	7.4	93	100	77	1.0	1.8	------

Analytical data—Tulsa

	Spavinaw Creek	Treatment plant
Percent of supply	----------	100
Date of collection	7-27-61	7-28-61
Type of water: R, raw; F, finished	R	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	----------	5.8
Iron (Fe)	----------	.01
Manganese (Mn)	----------	.00
Calcium (Ca)	----------	31
Magnesium (Mg)	----------	2.1
Sodium (Na)	----------	4.3
Potassium (K)	----------	1.6
Bicarbonate (HCO_3)	----------	94
Carbonate (CO_3)	----------	0
Sulfate (SO_4)	----------	5.8
Chloride (Cl)	----------	6.8
Fluoride (F)	----------	.2
Nitrate (NO_3)	----------	1.1
Dissolved solids (residue at 180° C)	----------	108
Hardness as $CaCO_3$	----------	86
Noncarbonate hardness as $CaCO_3$	----------	9
Specific conductance (micromhos at 25° C)	----------	176
pH	----------	7.5
Color	----------	1
Turbidity	----------	1
Temperature ° F	----------	84

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	----------	3.4
Radium (Ra)	----------	<.1
Uranium (U)	----------	.2

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.19	<0.20
Aluminum (Al)	330	70
Boron (B)	63	28
Barium (Ba)	63	92
Beryllium (Be)	ND	ND
Cobalt (Co)	<1.9	ND
Chromium (Cr)	3.8	.88
Copper (Cu)	8.4	18
Iron (Fe)	63	4.8
Lithium (Li)	.23	4.2
Manganese (Mn)	23	2.6
Molybdenum (Mo)	1.7	2.0
Nickel (Ni)	9.2	2.0
Phosphorus (P)	ND	ND
Lead (Pb)	94	6.6
Rubidium (Rb)	ND	ND
Tin (Sn)	ND	ND
Strontium (Sr)	46	240
Titanium (Ti)	3.1	<2.0
Vanadium (V)	<5.8	ND
Zinc (Zn)	<190	ND

PORTLAND

Ownership: Municipal.

Other areas served: Gresham, Beaverton, part of Lake Oswego, and 52 private water districts.

Population served: Portland, 372,676; total, 542,000.

Source of supply: Bull Run River impounded in Lake Ben Morrow Reservoir and Bull Run Lake, the source of the main branch of the river close to the summit of the Cascades.

Lowest mean discharge: Bull Run River near Bull Run, Oreg., for 30-day period in climatic water years (April 1–March 31) 1950–60: 80.1 mgd.

Average amount of water used daily in system during 1962: 69 mgd (U.S. Public Health Service, 1962c).

Treatment: Headworks near Bull Run plant—chlorination and ammoniation.

Rated capacity of treatment plant: Bull Run headworks plant, 225 mgd.

Raw-water storage: 20,000 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 290.

Finished-water storage: 207.6 million gal in 7 reservoirs, 7 standpipes, and 27 tanks.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 3.

Analytical data, Bull Run Headworks—Portland

[Percent of supply: 100. Date of collection: 1-8-62. Type of water: Finished]

Chemical analyses

[In parts per million]

Silica (SiO_2)	7.1	Chloride (Cl)	2.2
Iron (Fe)	.12	Fluoride (F)	.0
Manganese (Mn)	----------	Nitrate (NO_3)	.2
Calcium (Ca)	1.0	Dissolved solids (residue at 180° C)	22
Magnesium (Mg)	.6	Hardness as $CaCO_3$	5
Sodium (Na)	1.1	Noncarbonate hardness as $CaCO_3$	0
Potassium (K)	.4		
Bicarbonate (HCO_3)	8	Specific conductance (micromhos at 25° C)	18
Carbonate (CO_3)	0	pH	6.4
Sulfate (SO_4)	.8	Color	5
		Temperature ° F	45

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	18	Uranium (U)	0.2
Radium (Ra)	.2		

Spectrographic anaylses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.02	Molybdenum (Mo)	ND
Aluminum (Al)	62	Nickel (Ni)	.6
Boron (B)	5.3	Phosphorus (P)	<22
Barium (Ba)	4.4	Lead (Pb)	.5
Beryllium (Be)	ND	Rubidium (Rb)	<.2
Cobalt (Co)	ND	Tin (Sn)	ND
Chromium (Cr)	.04	Strontium (Sr)	2.9
Copper (Cu)	.75	Titanium (Ti)	3.3
Iron (Fe)	70	Vanadium (V)	<.7
Lithium (Li)	<.02	Zinc (Zn)	ND
Manganese (Mn)	7.0		

PENNSYLVANIA

Erie *Philadelphia* *Pittsburgh*

ERIE

Ownership: Municipal.
Other areas served: Wesleyville, Millcreek, Lawrence Park, and Harborcreek.
Population served: Erie, 138,440; total, 160,000.
Source of supply: Lake Erie.
Average amount of water used daily in system during 1962: 38 mgd (U.S. Public Health Service, 1962c).
Treatment: Chestnut Street and West filtration plants—coagulation with alum, rapid sand filtration, and chlorination.
Rated capacity of treatment plants: Chestnut Street filtration plant, 3[illegible] mgd; West Street filtration plant, 35 mgd.
Finished-water storage: Reservoir "A," 33 million gal; Reservoir "B," 10 million gal; East Grandview Standpipe, 0.8 million gal; West Grandview Standpipe, 0.8 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.2.
Remarks: Construction ot a new 5 million gal reservoir at 33d and Page Streets will be completed and in operation fall of 1962.

Average monthly determination at filtration plants, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Chestnut Street:									
Raw water	91	97	81	-----	7.8	7.3	9	40	1
Finished water	87	93	78	-----	7.6	7.3	0	0	0
West Street:									
Raw water	92	96	87	-----	-----	-----	9	35	1
Finished water	89	92	83	-----	-----	-----	0	0	0

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Analytical data—Erie

	Lake Erie [1]	Chestnut Street filtration plant
Percent of supply	100	100
Date of collection	[2]	3-27-62
Type of water: F, finished	F	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	1.5	0.0
Iron (Fe)	.02	.00
Manganese (Mn)		.02
Calcium (Ca)	40	41
Magnesium (Mg)	9.7	6.3
Sodium (Na)	8.2	12
Potassium (K)	.5	1.5
Bicarbonate (HCO_3)	107	108
Carbonate (CO_3)	0	0
Sulfate (SO_4)	25	28
Chloride (Cl)	23	26
Fluoride (F)	.1	.1
Nitrate (NO_3)	.6	.2
Dissolved solids (residue at 180° C)	182	175
Hardness as $CaCO_3$	121	129
Noncarbonate hardness as $CaCO_3$	34	40
Specific conductance (micromhos at 25° C)		316
pH	7.4	7.7
Color	1	3
Turbidity	0	
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity		8.8
Radium (Ra)		<.1
Uranium (U)		.3
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)		<0.26
Aluminum (Al)		110
Boron (B)		44
Barium (Ba)		41
Beryllium (Be)		ND
Cobalt (Co)		ND
Chromium (Cr)		12
Copper (Cu)		4.4
Iron (Fe)		87
Lithium (Li)		2.0
Manganese (Mn)		9.7
Molybdenum (Mo)		3.8
Nickel (Ni)		8.4
Phosphorus (P)		ND
Lead (Pb)		9.0
Rubidium (Rb)		ND
Tin (Sn)		ND
Strontium (Sr)		170
Titanium (Ti)		4.1
Vanadium (V)		ND
Zinc (Zn)		ND

[1] Analyzed by the city of Erie.
[2] Average analyses for 1960.

PHILADELPHIA

(See fig. 55.)

Ownership: Municipal.
Population served: 2,002,512.
Sources and percentages of supply: Delaware River, 50 percent; Schuylkill River, 50 percent.
Lowest mean discharge:
Delaware River at Trenton, N.J., for 30-day period in climatic water years (April 1–March 31) 1950–60: 1,151 mgd.
Schuylkill River at Philadelphia, Pa., for 30-day period in climatic water years (April 1–March 31) 1950–60: 95 mgd.
Average amount of water used daily in system during 1962: 510 mgd (U.S. Public Health Service, 1962c).
Treatment: Torresdale (Delaware River), Queen Lane (Schuylkill River), and Belmont (Schuylkill River) filter plants—prechlorination; presedimentation; addition of carbon, lime and alum; rapid and slow mixing; sedimentation; rapid sand filtration; posttreatment with fluorine, chlorine, lime, and phosphates.
Rated capacity of treatment plants: Torresdale filter plant, 423 mgd. Queen Lane filter plant, 150 mgd, Belmont filter plant, 80 mgd.
Finished-water storage: East Park Reservoir, 677 million gal; Oak Lane Reservoir, 70 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.5.
Remarks: Modernization of Belmont plant started late in 1961 and is scheduled for completion in 1963; this includes installation of new rapid sand filter beds, sedimentation basin, and chemical facilities. Capacity to be increased to 105 mgd.

Average monthly determinations at filter plants, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Torresdale:												
Raw water	32	41	24	------	7.3	7.2	56	71	42	126	183	44
Finished water	33	42	15	------	8.0	6.6	84	95	63	0	0	0
Belmont:												
Raw water	54	71	41	------	7.6	7.4	125	156	100	32	81	9
Finished water	40	61	24	------	7.0	6.5	131	164	99	0	1	0

Analytical data—Philadelphia

	Delaware River		Torresdale filter plant			Schuylkill River		Belmont filter plant		
Percent of supply					50					50
Date of collection	(1)	(2)	(1)	(2)	3-16-62	(1)	(2)	(1)	(2)	3-19-62
Type of water: R, raw; F, finished	R	R	F	F	F	R	R	F	F	F
Chemical analyses [In parts per million]										
Silica (SiO_2)					5.7					9.4
Iron (Fe)	1.5	0.35	0.21	0.00	.06	1.9	0.34	0.18	0.00	.06
Manganese (Mn)	.19	.00	.15	.00	.00	.38	.15	.05	.01	.00
Aluminum (Al)			.10	.00				.10	.00	
Calcium (Ca)					27					22
Magnesium (Mg)					3.9					6.8
Sodium (Na)					4.7					7.2
Potassium (K)					2.8					2.2
Bicarbonate (HCO_3)	50	29	51	18	32	87	50	74	29	26
Carbonate (CO_3)	0	0	0	0	0	0	0	0	0	0
Sulfate (SO_4)	36	21	50	32	43	100	59	130	61	51
Chloride (Cl)	11	4.0	19	11	16	23	8.0	31	10	14
Fluoride (F)					.8					.8
Nitrate (NO_3)	.9	.3	.9	.2	3.6	1.9	1.3	2.2	1.0	6.7
Dissolved solids (residue at 180° C)	345	129	178	102	130	320	180	290	151	139
Hardness as $CaCO_3$	71	42	95	63	84	156	100	164	99	83
Noncarbonate hardness as $CaCO_3$					58					62
Specific conductance (micromhos at 25° C)					211					225
pH	7.3	7.2	8.0	6.6	7.2	7.6	7.4	7.0	6.5	6.7
Color	25	8	6	0	2	40	8	3	0	2
Turbidity	183	44	0	0		81	9	0	0	
Temperature °F	78	35				80	38			
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]										
Beta activity					13					9.6
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	24					30				
Radium (Ra)					<.1					<.1
Uranium (U)					<.1					<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]										
Silver (Ag)					<0.17					<0.15
Aluminum (Al)					120					25
Boron (B)					42					25
Barium (Ba)					62					32
Beryllium (Be)					ND					ND
Cobalt (Co)					<1.7					ND
Chromium (Cr)					3.5					<.15
Copper (Cu)					14					35
Iron (Fe)					69					17
Lithium (Li)					1.7					1.8
Manganese (Mn)					5.0					5.7
Molybdenum (Mo)					2.0					ND
Nickel (Ni)					7.7					13
Phosphorus (P)					<170					150
Lead (Pb)					5.9					4.8
Rubidium (Rb)					4.4					1.7
Tin (Sn)					ND					ND
Strontium (Sr)					92					34
Titanium (Ti)					3.2					1.2
Vanadium (V)					5.0					ND
Zinc (Zn)					ND					ND

1 Maximum value of constituents in monthly average of analyses by the city of Philadelphia water department during 1960.
2 Minimum value of constituents in monthly average of analyses by the city of Philadelphia water department during 1960.

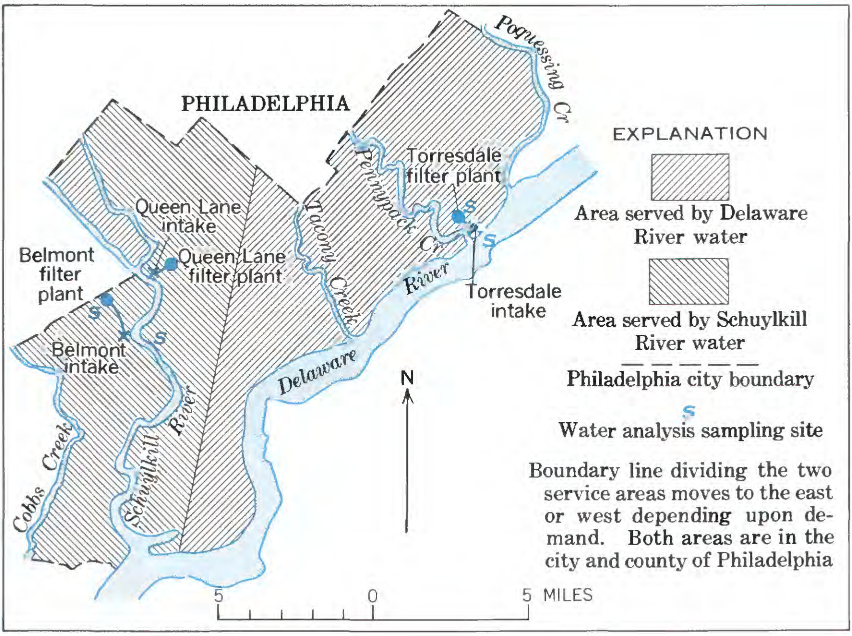

FIGURE 55.—Water supplies and areas served by Philadelphia, Pa., Water Department. (Approved by local municipal water officials, April 1963.)

PITTSBURGH

Ownership: Municipal—Aspinwall plant. South Pittsburgh Water Co.—Hays Mine filter plant and E. H. Aldrich plant.

Other areas served: Homestead, O'Hara, and Reserve, by municipal system; Bethel, Brentwood, Bridgeville, Carnegie, Castle Shannon, Crafton, Dormont, Green Tree, Heidelberg, Ingram, Mount Oliver, Munhall, Pleasant Hills, Rosslyn Farms, Thornburg, West Mifflin, Whitake, Whitehall, Baldwin, Collier, Jefferson, Mount Lebanon, Scott, Snowden, and Upper St. Clair, by South Pittsburgh Water Co.

Population served: Municipal, about 720,000; South Pittsburgh Water Co., about 490,000.

Sources and percentages of supply: Allegheny River, used by municipal system, 60 percent; Monongahela River, used by South Pittsburgh Water Co., 40 percent.

Lowest mean discharge:

Allegheny River at Natrona, Pa., for 30-day period in climatic water years (April 1–March 31) 1950–60: 886 mgd.

Monongahela River at Charleroi, Pa., for 30-day period in climatic water years (April 1–March 31) 1950–60: 239 mgd.

Average amount of water used daily in system during 1962: 137 mgd (U.S. Public Health Service, 1962c).

Treatment:

Aspinwall filtration plant (Allegheny River): Sedimentation, slow sand filtration, chlorination, and addition of soda ash.

Hays Mine Filter and E. H. Aldrich filtration plants: Screening, coagulation with alum, treatment with activated carbon, softening with lime and soda ash, rapid sand filtration, chlorination, sulfuric acid, and fluoridation with hydrofluosilicic acid.

Rated capacity of treatment plants: Aspinwall filtration plant, 140 mgd; E. H. Aldrich filtration plant, 25 mgd; Hays Mine Filter plant, 50 mgd.

Raw-water storage: Municipal system, 100 million gal; South Pittsburgh Water Co. system, 10 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: Municipal system, 502 million gal; South Pittsburgh Water Co. system, 29 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 3.9.

Remarks: South Pittsburgh Water Co.—provisions incorporated in the design of E. H. Aldrich plant to allow for future expansions from an existing capacity of 25 mgd to 100 mgd.

Determinations at filtration plants, 1961:

Determination and plant	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Regular; Aspinwall: Finished water	7	16	4	-----	7.1	4.6	120	184	60	-----	-----	-----
Monthly average; Aldrich:												
Raw water	4	11	1	-----	7.0	4.40	112	195	69	-----	139	25
Finished water	33	41	26	-----	9.1	7.6	101	110	92	-----	-----	-----

Analytical data—Pittsburgh

	Allegheny River			Aspinwall filtration plant	Aldrich filtration plant
Percent of supply				60	40
Date of collection	(1)	(2)	(3)	3-26-62	3-26-62
Type of water: F, finished	F	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	8.0	5.2	6.5	5.3	4.2
Iron (Fe)	.30	.10	.20	.00	.00
Manganese (Mn)	2.5	.10	.60	.24	.03
Calcium (Ca)	48	14	30	17	25
Magnesium (Mg)	15	5.2	9.5	4.3	5.4
Sodium (Na)	38	12	22	6.9	17
Potassium (K)				1.8	1.5
Bicarbonate (HCO_3)	20	4	9	4	24
Carbonate (CO_3)				0	0
Sulfate (SO_4)	189	56	112	53	88
Chloride (Cl)	46	13	27	11	4.3
Fluoride (F)	1.1	.8	.9	.3	.9
Nitrate (NO_3)	3.5	1.6	2.3	2.0	2.2
Dissolved solids (residue at 180° C)	402	122	239	110	165
Hardness as $CaCO_3$	183	57	114	60	85
Noncarbonate hardness as $CaCO_3$	166	54	108	57	65
Specific conductance (micromhos at 25° C)	541	186	351	181	265
pH	6.9	5.1		5.4	7.6
Color				2	2

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

Beta activity				7.7	15
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	19				
Radium (Ra)				<.1	<.1
Uranium (U)				<.1	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)				<0.12	<0.19
Aluminum (Al)				140	400
Boron (B)				24	21
Barium (Ba)				63	48
Beryllium (Be)				ND	ND
Cobalt (Co)				ND	ND
Chromium (Cr)				<.12	<.48
Copper (Cu)				18	12
Iron (Fe)				150	52
Lithium (Li)				4.8	6.3
Manganese (Mn)				200	84
Molybdenum (Mo)				ND	ND
Nickel (Ni)				31	2.1
Phosphorus (P)				ND	ND
Lead (Pb)				7.1	4.8
Rubidium (Rb)				1.5	1.9
Tin (Sn)				ND	ND
Strontium (Sr)				57	150
Titanium (Ti)				1.1	1.4
Vanadium (V)				ND	ND
Zinc (Zn)				ND	ND

[1] Maximum values of constituents for the year 1961.
[2] Minimum values of constituents for the year 1961.
[3] Average values of constituents for the year 1961.

RHODE ISLAND

Providence

PROVIDENCE

(See fig. 56.)

Ownership: Municipal.

Other areas served: Cranston, Johnston, and parts of North Providence, Warwick, Smithfield, Coventry, and West Warwick. Kent County Water Authority receives water which is not chlorinated or fluoridated.

Population served: Providence, 207,498; total, 383,134.

Source of supply: North Branch Pawtuxet River impounded.

Average amount of water used daily in system during 1962: 45.2 mgd (U.S. Public Health Service, 1962c).

Treatment: Municipal plant—coagulation with ferric sulfate (Ferrifloc) and lime, sedimentation, rapid sand filtration, fluoridation (sodium silicofluoride), and chlorination.

Rated capacity of treatment plant: Providence filter plant, 105 mgd.

Raw-water storage: 39,746 million gal in following reservoirs—Regulating, 42 million gal; West Connaug, 453 million gal; Barden, 853 million gal; Moswansicut, 715 million gal; Ponagonset, 693 million gal; and Scituate, 36,611 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.4 years.

Finished-water storage: 54.4 million gal. An additional 40 million gallon reservoir became available in the summer of 1962.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.2.

Regular determinations at Providence filter plant, October 1960–September 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	4.7	5.1	4.3	6.2	6.6	6.0	10	10	9	0.2	0.2	0.2
Finished water	15	17	14	10.0	10.1	9.9	28	30	27	.1	.1	.0

Analytical data—Providence

	Scituate Reservoir		Filter plant	
Percent of supply	92		92	
Date of collection	4-18-62	[1]	4-18-62	[1]
Type of water: R, raw; F, finished	R	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	5.0	5.1	5.9	4.6
Iron (Fe)	.05	.09	.03	.01
Manganese (Mn)	.00	.02	.00	.00
Aluminum (Al)		.02		.07
Arsenic (As)		.00		.00
Copper (Cu)		.03		.01
Calcium (Ca)	2.6	3.0	11	9.6
Magnesium (Mg)	.6		.5	
Sodium (Na)	2.9		3.2	
Potassium (K)	.6		.7	
Lead (Pb)		.0		.0
Selenium (Se)		.0		.00
Zinc (Zn)		.0		.0
Bicarbonate (HCO_3)	5	6	5	19
Carbonate (CO_3)	0		6	
Sulfate (SO_4)	6.0	7.2	14	13
Chloride (Cl)	4.5	3.7	5.0	4.1
Fluoride (F)	.0	.2	1.0	1.1
Nitrate (NO_3)	.0		.1	
Dissolved solids (residue at 180° C)	28	33	51	50
Hardness as $CaCO_3$	9	10	30	28
Noncarbonate hardness as $CaCO_3$	5		16	
Specific conductance (micromhos at 25° C)	40		88	
pH	[2] 9.8	6.2	9.6	10.0
Color	7	0	3	
Turbidity	[2] 0		2	0
Temperature °F	43		47	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity			6.4	
Radium (Ra)			<.1	
Uranium (U)			<.1	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)			0.07	
Aluminum (Al)			49	
Boron (B)			8.5	
Barium (Ba)			12	
Beryllium (Be)			ND	
Cobalt (Co)			ND	
Chromium (Cr)			<.06	
Copper (Cu)			2.0	
Iron (Fe)			37	
Lithium (Li)			.51	
Manganese (Mn)			1.6	
Molybdenum (Mo)			ND	
Nickel (Ni)			.9	
Phosphorus (P)			ND	
Lead (Pb)			3.4	
Rubidium (Rb)			2.0	
Tin (Sn)			ND	
Strontium (Sr)			14	
Titanium (Ti)			.9	
Vanadium (V)			ND	
Zinc (Zn)			ND	

[1] Average analyses by the city of Providence for October 1960–September 1961.
[2] Value reported is for Aug. 15, 1962.

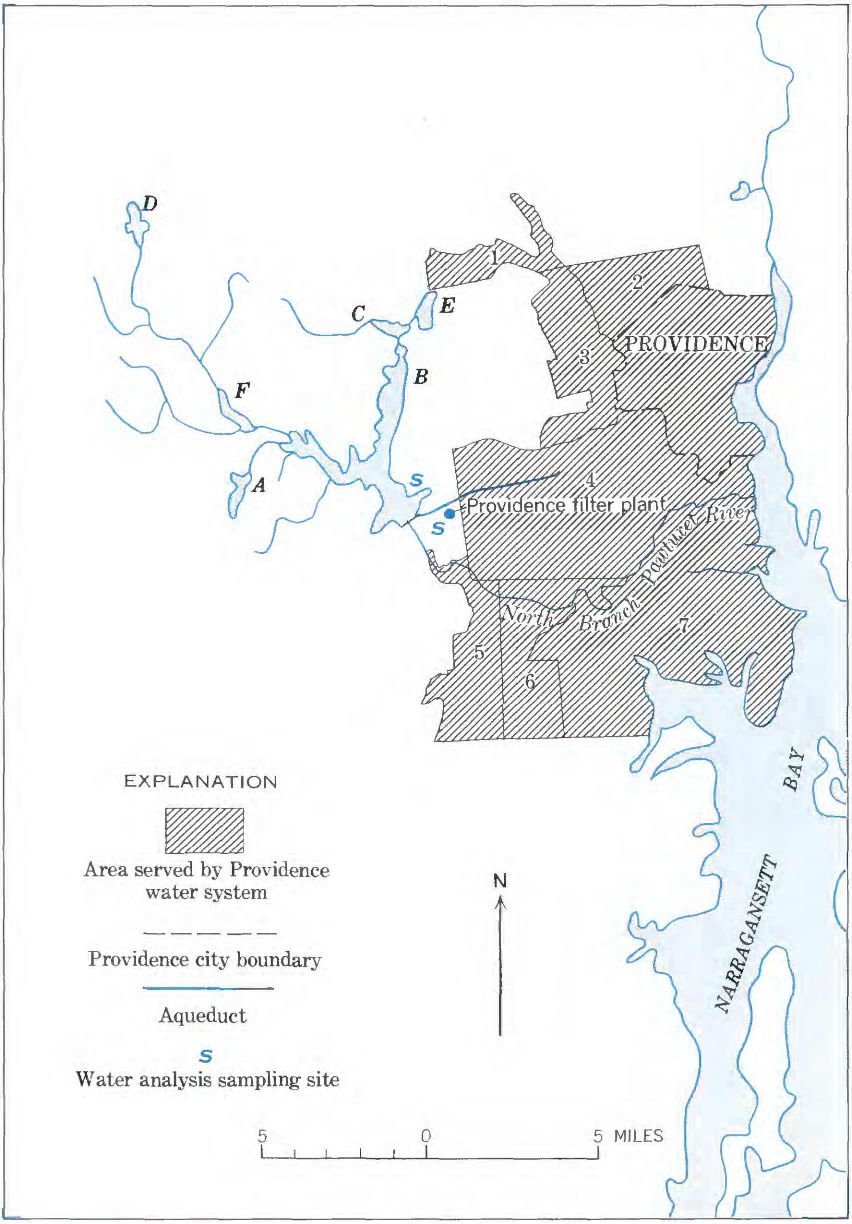

Figure 56.—Water supplies and areas served by Providence, R.I., water system. (Approved by local municipal water officials, March 1963.) List of areas served by Providence water system: 1, Smithfield; 2, North Providence; 3, Johnston; 4, Cranston; 5, Coventry; 6, West Warwick; 7, Warwick. List of reservoirs: *A*, Barden; *B*, Scituate; *C*, Regulating; *D*, Ponaganset; *E*, Moswansicut; *F*, West Connaug.

TENNESSEE

Chattanooga *Memphis* *Nashville*

CHATTANOOGA

Ownership: City Water Co. of Chattanooga, Inc. (a private company).
Other areas served: Ridgeside, East Ridge, Redbank-Whiteoak, Lookout Mountain, part of Dade County, Ga., city of Rossville, Ga., and furnishes treated water on wholesale basis to various nearby utility districts located in Hamilton County, Tenn., and Catoosa and Walker Counties, Ga.
Population served: Chattanooga, 130,000; total, 231,000.
Source of supply: Tennessee River.
Lowest mean discharge: Tennessee River at Chattanooga Tenn., for 30-day period in climatic water years (April 1–March 30) 1950–60: 11,600 mgd.
Average amount of water used daily in system during 1962: 38 mgd (U.S. Public Health Service, 1962c).
Treatment: Chattanooga treatment plant—Addition of copper sulfate for algae control and activated carbon when needed, coagulation with alum and ferric chloride in emergency conditions, addition of limestone to adjust pH and for reduction of manganese, rapid sand filtration, chlorination, and fluoridation to maintain 1 ppm of fluoride.
Rated capacity of treatment plant: Chattanooga treatment plant, 52 mgd.
Raw-water storage: None.
Finished-water storage: 13 million gal.
Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.
Remarks: Quality of raw water varies from time to time due to control of upstream dams and lakes by Tennessee Valley Authority.

Regular determinations at Chattanooga treatment plant, January 1960–August 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	52	56	46	7.4	7.5	7.3	73	81	59	25	340	15
Finished water	56	59	49	7.7	7.9	7.7	87	97	75	0	0	0

Analytical data—Chattanooga

	Tennessee River	Treatment plant
Percent of supply	100	100
Date of collection	9-14-61	9-14-61
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	3.8	3.7
Iron (Fe)	.05	.00
Manganese (Mn)	.01	.01
Calcium (Ca)	23	28
Magnesium (Mg)	5.0	4.9
Sodium (Na)	8.2	8.4
Potassium (K)	1.1	.9
Bicarbonate (HCO_3)	70	78
Carbonate (CO_3)	0	0
Sulfate (SO_4)	13	17
Chloride (Cl)	16	18
Fluoride (F)	.2	1.0
Nitrate (NO_3)	2.9	2.5
Dissolved solids (residue at 180° C)	125	148
Hardness as $CaCO_3$	78	90
Noncarbonate hardness as $CaCO_3$	20	26
Specific conductance (micromhos at 25° C)	195	219
pH	8.0	8.0
Color	5	5
Temperature °F	79	79
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]		
Beta activity	----------	6.5
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	58	----------
Radium (Ra)	----------	<.1
Uranium (U)	----------	.5
Spectrographic analyses [In micrograms per liter. <, less than; X, semiquantitative determination in digit order shown; ND, looked for but not found]		
Silver (Ag)	ND	<0.24
Aluminum (Al)	290	680
Boron (B)	22	16
Barium (Ba)	67	61
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	5.2	5.0
Copper (Cu)	4.9	5.4
Iron (Fe)	250	40
Lithium (Li)	1.7	.94
Manganese (Mn)	100	24
Molybdenum (Mo)	1.6	2.0
Nickel (Ni)	<2.2	<2.4
Phosphorus (P)	ND	ND
Lead (Pb)	14	4.5
Rubidium (Rb)	2.5	<2.4
Tin (Sn)	ND	ND
Strontium (Sr)	110	99
Titanium (Ti)	6.5	2.4
Vanadium (V)	ND	7.1
Zinc (Zn)	ND	ND
Gallium (Ga)	ND	.X

MEMPHIS

(See fig. 57.)

Ownership: Municipal.

Other areas served: Surrounding county areas.

Population served: Memphis, 501,524; total, about 600,000.

Sources and percentages of supply: Water is obtained from deep wells tapping two aquifers; one, the Claiborn Sand, is about 500 feet deep and the other, the Wilcox Sand, is about 1,400 feet deep. About 11 percent of the total supply comes from the deeper aquifer. Four well fields containing 128 wells supply four pumping stations: Parkway well field, 28 percent of supply; Sheahan well field, 28 percent of supply; Allen well field, 28 percent of supply; and McCord well field, 16 percent of supply. Fifty-six wells are electrically operated and pump from the 500-foot sand; 72 are airlift wells, of which 53 pump from the 500-foot sand and 19 from the 1,400-foot sand. The airlift wells operate at 400–500 gpm. The electric-pump wells operate at 1,000–1,200 gpm. The Allen and McCord fields are supplied from the 500-foot sand and are electrically powered. The Parkway and Sheahan fields include wells in both the 500-foot and 1,400-foot sands and are partly pumped by electric-powered pumps and partly by airlift pumps.

Average amount of water used daily in system during 1962: 68.8 mgd (U.S. Public Health Service, 1962c).

Treatment: Parkway, Sheahan, Allen, and McCord filtration plants—aeration over coke or limestone trays, and rapid sand filtration for removal of iron, hydrogen sulfide, and carbon dioxide, followed by slight chlorination.

Rated capacity of treatment plants: The total peak pumping capacity of the system is slightly more than double the following operating capacities: Parkway filtration plant, 30 mgd; Allen filtration plant, 30 mgd; Sheahan filtration plant, 30 mgd; McCord filtration plant, 15 mgd.

Raw-water storage: 2 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: 75 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.1.

Remarks: Test wells, tapping the 2,600-foot sand, show water from that depth to be several degrees warmer, to contain 110 ppm of carbon dioxide, and to have considerably higher total dissolved solids than water from the shallower sands. Therefore, this source is not being used at the present time.

Industrial users in the Memphis area are pumping from their own private wells about 50 percent as much water as the combined municipal fields are supplying the city.

Analytical data—Memphis

	Allen well field	Allen filtration plant	Sheahan well field	Sheahan filtration plant	McCord well field	McCord filtration plant	Parkway well field	Parkway filtration plant
Percent of supply	28	28	28	28	16	16	28	28
Date of collection	9-15-61	9-15-61	9-15-61	9-15-61	9-15-61	9-15-61	9-15-61	9-15-61
Type of water: R, raw; F, finished	R	F	R	F	R	F	R	F

Chemical analyses

[In parts per million]

	Allen well field	Allen filtration plant	Sheahan well field	Sheahan filtration plant	McCord well field	McCord filtration plant	Parkway well field	Parkway filtration plant
Silica (SiO_2)	8.3	7.8	8.7	8.8	6.8	7.3	8.5	8.8
Iron (Fe)	.72	.16	.75	.00	1.2	.00	.74	.03
Manganese (Mn)	.01	.01	.02	.02	.01	.01	.01	.00
Calcium (Ca)	12	12	7.5	7.3	7.6	8.6	8.4	8.7
Magnesium (Mg)	6.1	5.9	3.0	3.1	5.1	4.6	3.8	3.7
Sodium (Na)	7.5	7.6	12	12	6.3	6.3	17	17
Potassium (K)	.7	.7	.7	.7	.7	.7	.9	.9
Bicarbonate (HCO_3)	78	77	61	59	55	54	82	82
Carbonate (CO_3)	0	0	0	0	0	0	0	0
Sulfate (SO_4)	3.8	3.6	3.0	3.4	5.2	5.4	3.4	3.4
Chloride (Cl)	3.0	3.5	4.2	4.0	3.0	3.5	2.0	2.0
Fluoride (F)	.4	.4	.0	.1	.3	.1	.3	.3
Nitrate (NO_3)	1.2	1.3	.9	.7	.8	1.2	.9	.9
Dissolved solids (residue at 180° C)	87	84	80	72	68	68	97	100
Hardness as $CaCO_3$	55	54	31	30	40	40	36	36
Noncarbonate hardness as $CaCO_3$	0	0	0	0	0	0	0	0
Specific conductance (micromhos at 25° C)	137	135	114	114	108	107	138	137
pH	6.8	8.0	6.9	7.4	6.7	7.6	7.4	7.7
Color	5	5	5	5	5	5	5	5
Temperature °F	63	63	64	68	63	68	67	73

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Allen well field	Allen filtration plant	Sheahan well field	Sheahan filtration plant	McCord well field	McCord filtration plant	Parkway well field	Parkway filtration plant
Beta activity	--------	3.3	---------	2.5	---------	1.9	--------	2.6
Radium (Ra)	--------	.3	---------	.1	---------	.2	--------	.1
Uranium (U)	--------	<.1	---------	<.1	---------	<.1	--------	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Allen well field	Allen filtration plant	Sheahan well field	Sheahan filtration plant	McCord well field	McCord filtration plant	Parkway well field	Parkway filtration plant
Silver (Ag)	--------	0.19	---------	<0.12	---------	<0.13	--------	ND
Aluminum (Al)	--------	19	---------	70	---------	10	--------	190
Boron (B)	--------	9.1	---------	12	---------	14	--------	29
Barium (Ba)	--------	38	---------	56	---------	60	--------	84
Beryllium (Be)	--------	ND	---------	ND	---------	ND	--------	ND
Cobalt (Co)	--------	2.1	---------	ND	---------	ND	--------	ND
Chromium (Cr)	--------	ND	---------	1.6	---------	ND	--------	ND
Copper (Cu)	--------	2.4	---------	3.4	---------	17	--------	9.1
Iron (Fe)	--------	21	---------	42	---------	22	--------	56
Lithium (Li)	--------	.51	---------	2.0	---------	.56	--------	3.8
Manganese (Mn)	--------	2.7	---------	2.3	---------	31	--------	4.6
Molybdenum (Mo)	--------	ND	---------	ND	---------	ND	--------	ND
Nickel (Ni)	--------	1.7	---------	<1.2	---------	<1.3	--------	<1.7
Phosphorus (P)	--------	ND	---------	ND	---------	ND	--------	ND
Lead (Pb)	--------	<1.7	---------	2.2	---------	1.9	--------	3.2
Rubidium (Rb)	--------	5.8	---------	3.7	---------	6.3	--------	4.1
Tin (Sn)	--------	ND	---------	ND	---------	ND	--------	ND
Strontium (Sr)	--------	9.9	---------	42	---------	22	--------	62
Titanium (Ti)	--------	ND	---------	ND	---------	ND	--------	<1.7
Vanadium (V)	--------	ND	---------	ND	---------	ND	--------	ND
Zinc (Zn)	--------	ND	---------	ND	---------	ND	--------	<170

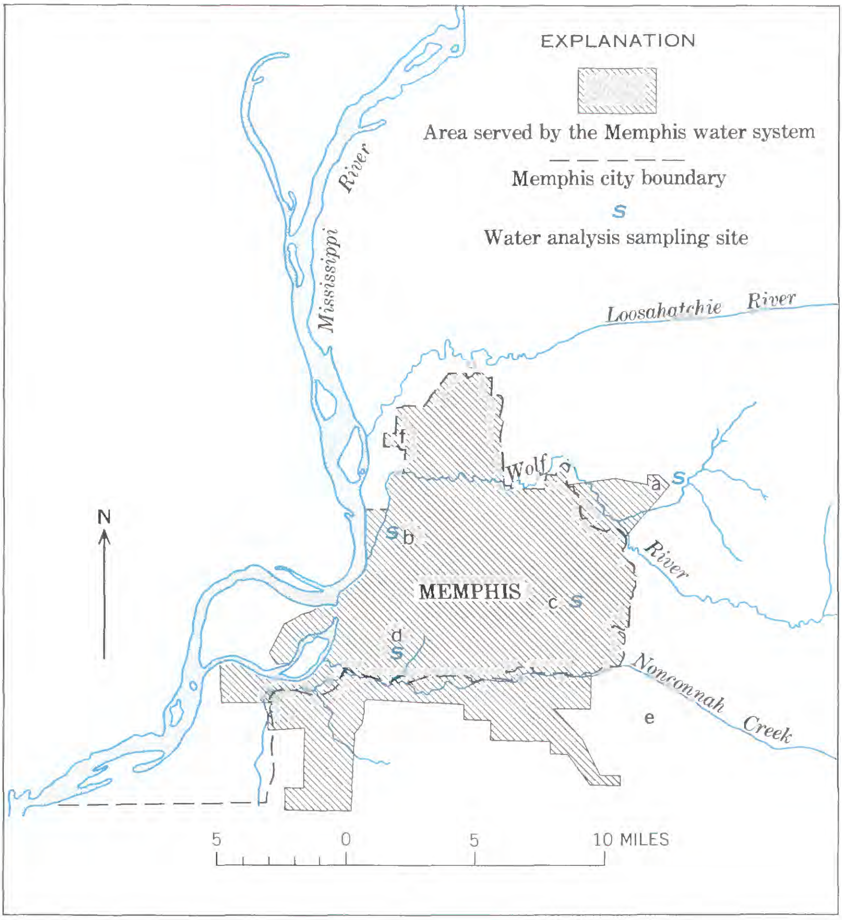

FIGURE 57.—Water supplies and areas served by Memphis, Tenn., water system. (Approved by local municipal water officials, May 1963.) List of filtration plants and pumping stations: a, McCord filtration plant; b, Parkway filtration plant; c, Sheahan filtration plant; d, Allen filtration plant; e, Proposed pumping station; f, Frayser pumping station (standby).

735-717 O—64——21

NASHVILLE

Ownership: Municipal.

Other areas served: Suburban areas about city including Forrest Hills, Oak Hills, Berry Hills, and Belle Meade.

Population served: Nashville, 253,900; total, about 350,000.

Source of supply: Cumberland River.

Lowest mean discharge: Cumberland River below Old Hickory, Tenn., for 30-day period in climatic water years (April 1–March 31) 1950–60: 1,400 mgd.

Average amount of water used daily in system during 1962: 37.8 mgd (U.S. Public Health Service, 1962c).

Treatment: Nashville treatment plant—prechlorination, coagulation with alum and lime, sedimentation, rapid sand filtration, postchlorination, ammoniation, adjustment of pH with lime, and fluoridation to 1.0 ppm of fluoride.

Rated capacity of treatment plant: Nashville treatment plant: Normally operated near 40 mgd, peak of 60 mgd to be increased to 89 mgd.

Finished-water storage: 60 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.6.

Regular determinations at Nashville treatment plant, August 1960–June 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	65	87	46	7.5	7.8	7.3	81	108	60	29	60	13
Finished water	67	88	50	8.4	8.5	8.3	92	117	71	0	1	0

Analytical data—Nashville

	Cumberland River		Treatment plant	
Percent of supply	100	100	100	
Date of collection	9-13-61	(1)	9-13-61	(1)
Type of water: R, raw; F, finished	R	R	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	2.7	4.1	2.7	4.0
Iron (Fe)	.24	.19	.00	.04
Manganese (Mn)	.01	.50	.01	.00
Aluminum (Al)		.12		.14
Calcium (Ca)	22	25	25	33
Magnesium (Mg)	3.1	8.0	4.0	6.8
Sodium (Na)	2.9	3.7	3.5	4.0
Potassium (K)	.9	.8	.9	.6
Bicarbonate (HCO_3)	64		70	
Carbonate (CO_3)	0		0	
Sulfate (SO_4)	17	31	21	36
Chloride (Cl)	2.0	3.9	3.5	7.1
Fluoride (F)	.2		1.2	
Nitrate (NO_3)	2.8		1.7	
Dissolved solids (residue at 180° C)	88	106	107	117
Hardness as $CaCO_3$	68	104	79	108
Noncarbonate hardness as $CaCO_3$	15	15	22	24
Specific conductance (micromhos at 25° C)	142	123	168	131
pH	7.6	7.5	8.2	8.4
Color	5		5	
Turbidity		29		0
Temperature °F	75		75	

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity			2.3	
Radium (Ra)			<.1	
Uranium (U)			<.1	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.16		<0.16	
Aluminum (Al)	310		490	
Boron (B)	21		14	
Barium (Ba)	33		34	
Beryllium (Be)	ND		ND	
Cobalt (Co)	2.3		ND	
Chromium (Cr)	3.7		.50	
Copper (Cu)	3.1		1.4	
Iron (Fe)	260		53	
Lithium (Li)	.60		.40	
Manganese (Mn)	100		44	
Molybdenum (Mo)	1.8		1.6	
Nickel (Ni)	1.6		<1.6	
Phosphorus (P)	ND		ND	
Lead (Pb)	60		2.4	
Rubidium (Rb)	2.0		ND	
Tin (Sn)	ND		ND	
Strontium (Sr)	80		70	
Titanium (Ti)	4.9		2.3	
Vanadium (V)	5.1		4.9	
Zinc (Zn)	ND		ND	

[1] Average analyses by the city of Nashville of monthly composited daily samples, August 1, 1960, to June 30, 1961.

TEXAS

Amarillo	*Dallas*	*Houston*
Austin	*El Paso*	*Lubbock*
Corpus Christi	*Fort Worth*	*San Antonio*

AMARILLO

Ownership: Municipal.

Population served: Amarillo, 137,969; total about 150,000 (1962).

Sources and percentages of supply: Total of 94 wells: 69 wells in several well fields southwest of Amarillo in northern Randall and northwest Deaf Smith Counties, 55 percent; 25 wells east of Amarillo in southern Carson County, 45 percent.

Randall County:

Palo Duro Field: Ten wells, each 200 feet deep, with an estimated average minimum potential yield of 350 gpm.

McDonald Field: Six wells, 260–289 feet deep, with an estimated average minimum potential yield of 465 gpm.

Bush Field: Six wells, 234–307 feet deep, with an estimated average minimum potential yield of 535 gpm.

Greely Field: Eight wells, 257–303 feet deep, with an estimated average minimum potential yield of 510 gpm.

Brinkman Field: One well, 267 feet deep, with an estimated minimum potential yield of 390 gpm.

Bassett Field: Three wells, 286–290 feet deep, with an estimated average minimum potential yield of 410 gpm.

Westex Field: Eight wells, 223–289 feet deep, with an estimated average minimum potential yield of 585 gpm.

Section 98: Five wells, 245–306 feet deep, with an estimated average minimum potential yield of 560 gpm.

Section 1, 4, 6, 59, and 60: Fourteen wells, 228–302 feet deep, with an estimated average minimum potential yield of 600 gpm.

Deaf Smith County: Sections 48 and 49: Eight wells (sec. 48, 1 and 2; sec. 49, 1–6), 255–323 feet deep, with an estimated average minimum potential yield of 600 gpm.

Carson County:

Cornelius Field: Three wells, 495–530 feet deep, with an estimated average minimum potential yield of 1,050 gpm.

Deahl Field: Five wells (1–4, 17), 515–565 feet deep, with an estimated average minimum potential yield of 1,050 gpm.

Masterson Field: Seventeen wells (4–16, 18–21), 480–552 feet deep, with an estimated average minimum potential yield ot 1,050 gpm.

Average amount of water used daily in system during 1962: 21.6 mgd (U.S. Public Health Service, 1962c).

Treatment: Chlorination.

Rated capacity of transmission plants: 57 mgd.

Raw-water storage: One ground storage reservoir, 1.5 million gal; one ground storage reservoir, 0.5 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: Four ground storage reservoirs, 5 million gal each; one surface tank, 5 million gal; three elevated tanks, 1 million gal each; one elevated tank, 0.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used in mgd): 1.3.

Analytical data—Amarillo

	Composite of wells southwest of city	Palo Duro well field	McDonald well 2	Bush well 4	Westex well 3	Well 6, section 49	Composite of 25 wells in Carson County
Percent of supply	55						45
Depth of well (feet)		200	267	307	223	304	
Diameter of well (inches)		10	18	16			
Date drilled		1927	1929	1944	1948	1952	
Date of collection	2-12-62	2-12-62	2-12-62	2-12-62	2-12-62	2-12-62	2-12-62
Type of water: R, raw; F, finished	F	R	R	R	R	R	F

Chemical analyses

[In parts per million]

	Composite of wells southwest of city	Palo Duro well field	McDonald well 2	Bush well 4	Westex well 3	Well 6, section 49	Composite of 25 wells in Carson County
Silica (SiO_2)	63	56	59	72	71	64	30
Iron (Fe)	.02	.02	.00	.02	.01	.00	.00
Manganese (Mn)	.00	.00	.01	.00	.01	.00	.00
Calcium (Ca)	40	44	41	39	44	32	35
Magnesium (Mg)	34	39	37	43	28	34	22
Sodium (Na)	25	19	17	29	27	35	21
Potassium (K)	5.0	3.8	4.9	6.2	5.6	5.6	5.5
Bicarbonate (HCO_3)	302	316	305	296	292	313	237
Carbonate (CO_3)	0	0	0	0	0	0	0
Sulfate (SO_4)	33	37	30	78	31	24	15
Chloride (Cl)	8.2	5.8	3.8	7.8	6.2	6.8	8.2
Fluoride (F)	3.4	4.0	3.3	2.8	3.3	3.5	1.3
Nitrate (NO_3)	3.2	2.8	3.2	4.3	2.0	4.9	4.9
Dissolved solids (residue at 180° C)	364	368	352	428	362	364	260
Hardness as $CaCO_3$	240	270	254	274	225	220	178
Noncarbonate hardness as $CaCO_3$	0	12	4	32	0	0	0
Specific conductance (micromhos at 25° C)	545	565	536	625	529	547	428
pH	7.3	7.1	7.1	7.1	7.1	7.2	7.2
Color	0	0	0	0	0	0	0
Turbidity	0	0	0	0	0	0	0
Temperature °F	63		62	62	61	62	64

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

	Composite of wells southwest of city	Palo Duro well field	McDonald well 2	Bush well 4	Westex well 3	Well 6, section 49	Composite of 25 wells in Carson County
Beta activity	8.6						8.8
Radium (Ra)	.5						1.0
Uranium (U)	7.4						4.9

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Composite of wells southwest of city	Palo Duro well field	McDonald well 2	Bush well 4	Westex well 3	Well 6, section 49	Composite of 25 wells in Carson County
Silver (Ag)	ND						ND
Aluminum (Al)	3.3						14
Boron (B)	120						190
Barium (Ba)	83						170
Beryllium (Be)	ND						ND
Cobalt (Co)	ND						ND
Chromium (Cr)	<.55						<.41
Copper (Cu)	2.4						1.8
Iron (Fe)	7.2						78
Lithium (Li)	16						19
Manganese (Mn)	ND						<4.1
Molybdenum (Mo)	ND						2.3
Nickel (Ni)	ND						ND
Phosphorus (P)	ND						ND
Lead (Pb)	ND						9.1
Rubidium (Rb)	ND						ND
Tin (Sn)	ND						ND
Strontium (Sr)	190						390
Titanium (Ti)	ND						<1.2
Vanadium (V)	<17						<12
Zinc (Zn)	ND						ND

AUSTIN

Ownership: Municipal.

Other areas served: Twelve water districts which serve areas outside city limits, including towns of West Lake Hills and Oak Hill.

Population served: Austin 186,545; total, about 206,000.

Source of supply: Colorado River.

Lowest mean discharge: Colorado River at Austin, Tex., for 30-day period in climatic water years (April 1-March 31) 1950–59: 1,030 mgd.

Average amount of water used daily in system during 1962: 29.7 mgd (U.S. Public Health Service, 1962c).

Treatment: Filter plants 1 and 2—coagulation with iron salts (ferrous sulfate), softening with lime, ammoniation, chlorination, sedimentation, rapid sand filtration, and stabilization with sodium hexametaphosphate.

Rated capacity of treatment plants: Filter plant 1, 33 mgd; filter plant 2, 30 mgd. Filter plant 2 is being enlarged to 60 mgd; it is scheduled for completion in April 1963.

Raw-water storage: Chain of seven lakes on Colorado River: 741,000 million gal (2,276,000 acre feet).

Days of raw-water storage (storage, in million gal/average daily water used in mgd): 68 years.

Finished-water storage: Four high-level ground storage reservoirs—two, 10 million gal each; one, 8 million gal; and one, 2 million gal; four clear wells, 14 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.5.

Remarks: Intake to filter plant 1 is in Town Lake; intake to filter plant 2 is in Lake Austin. Both intakes and both filter plants are located within city limits.

Regular determinations at filter plants 1 and 2, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	155	185	137	8.1	8.5	7.6	187	222	172	10	91	6
Finished water	54	58	50	10.0	10.5	9.8	88	95	82	0	0	0

Analytical data—Austin

	Colorado River		Filter plant 1	Filter plant 2	Tap at 807 Brazos Street
Percent of supply	100	100	53	47	100
Date of collection	(1)	(2)	6-28-62	6-28-62	1-12-62
Type of water: R, raw; F, finished	R	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	9.9	10	7.7	8.8	11
Iron (Fe)			.00	.02	.01
Manganese (Mn)			.00	.00	.00
Calcium (Ca)	40	44	15	14	17
Magnesium (Mg)	20	19	15	15	16
Sodium (Na)	39 (Na + K)	34	33	33	33
Potassium (K)		3.8	4.0	4.1	3.7
Bicarbonate (HCO_3)	187	177	8	12	32
Carbonate (CO_3)	0	0	26	23	14
Sulfate (SO_4)	34	34	36	36	35
Chloride (Cl)	55	60	63	63	60
Fluoride (F)	.3	.3	.3	.3	.4
Nitrate (NO_3)	1.2	.8	.5	.8	.5
Dissolved solids (residue at 180° C)	294	306	255	219	235
Hardness as $CaCO_3$	182	188	99	97	108
Noncarbonate hardness as $CaCO_3$	30	43	49	48	43
Specific conductance (micromhos at 25° C)	526	526	390	379	395
pH	7.6	7.6	9.3	9.2	9.8
Color			0	0	0
Turbidity			0	0	0
Temperature °F					56

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity			7.2	6.8	
Radium (Ra)			<.1	<.1	
Uranium (U)			<.1	<.1	

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)			<0.27	<0.29	ND
Aluminum (Al)			15	5.2	39
Boron (B)			71	61	81
Barium (Ba)			35	27	22
Beryllium (Be)			ND	ND	ND
Cobalt (Co)			ND	ND	ND
Chromium (Cr)			<.27	<.29	<.30
Copper (Cu)			.84	1.2	.69
Iron (Fe)			17	18	21
Lithium (Li)			6.3	7.5	5.4
Manganese (Mn)			ND	ND	<3.0
Molybdenum (Mo)			1.0	<.87	<.9
Nickel (Ni)			<2.7	<2.9	3.3
Phosphorus (P)			ND	ND	100
Lead (Pb)			ND	ND	4.5
Rubidium (Rb)			<2.7	<2.9	<3.0
Tin (Sn)			ND	ND	ND
Strontium (Sr)			140	130	170
Titanium (Ti)			.9	ND	<.9
Vanadium (V)			<8.2	ND	<9.0
Zinc (Zn)			ND	ND	ND

[1] Composite of daily samples, January 1-31, 1962.
[2] Composite of daily samples, June 1-30, 1962.

CORPUS CHRISTI

(See fig. 58.)

Ownership: Municipal.

Other areas served: Aransas Pass, Clarkwood, Flour Bluff, Gregory, Ingleside, Odem, and Portland.

Population served: Corpus Christi, 167,690; total, 211,500.

Source of supply: Nueces River, impounded in Lake Corpus Christi, about 35 miles from Corpus Christi. Water flows from the lake to the treatment plants at Calallen.

Average amount of water used daily in system during 1962: 48.1 mgd (U.S. Public Health Service, 1962c).

Treatment: Cunningham and Stevens treatment plants—prechlorination, partial softening with lime, coagulation with ferrous sulfate, sedimentation, fluoridation, rapid sand filtration, and postchlorination.

Rated capacity of treatment plants: Cunningham treatment plant, 33 mgd; Stevens treatment plant, 48 mgd.

Raw-water storage: Lake Corpus Christi, 98,400 million gal (302,100 acre-feet).

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 5.5 years.

Finished-water storage: Elevated tanks, 2.75 million gal; ground storage, 41.2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Stevens treatment plant, August 1960–July 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	133	170	60	8.1	8.7	7.1	153	232	84	54	890	10
Finished water	88	110	50	8.4	9.2	8.0	130	170	88	0	0	0

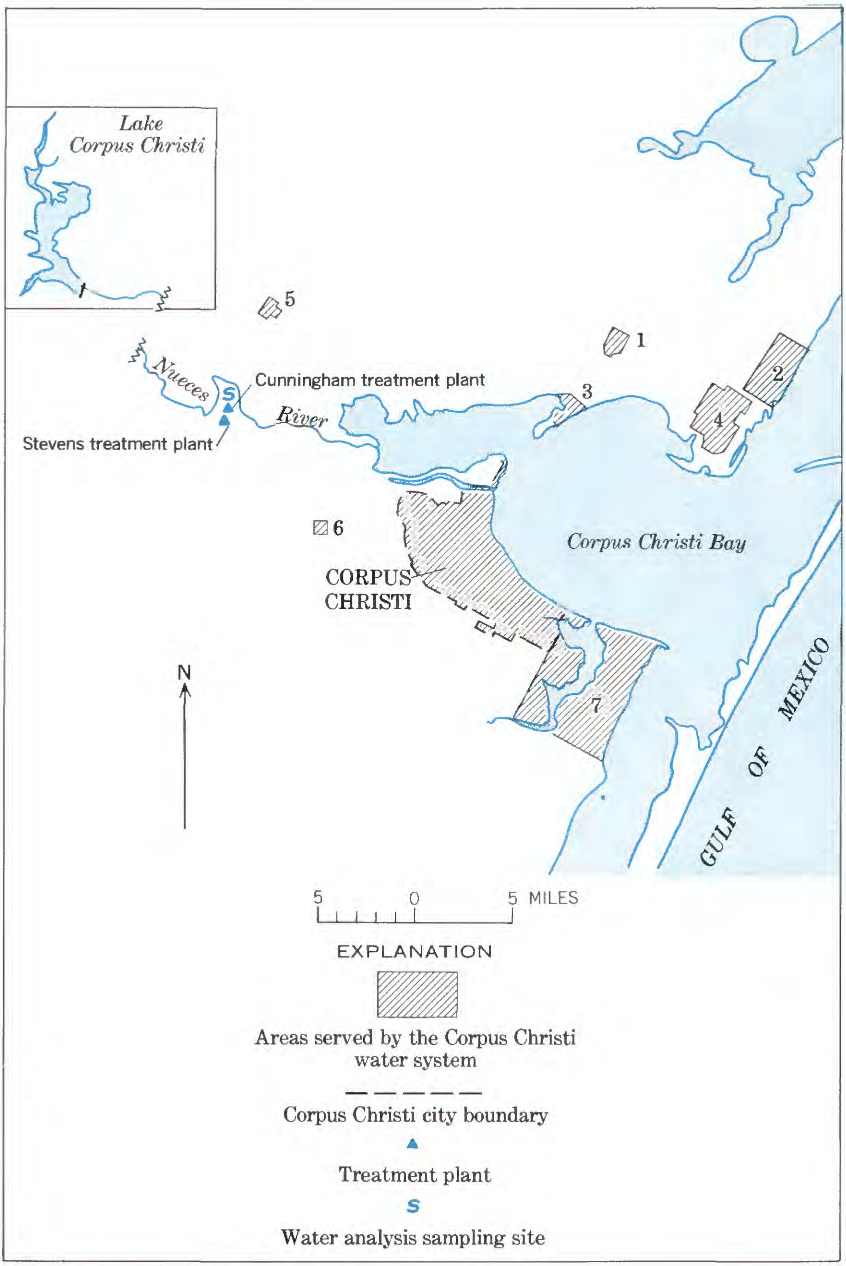

FIGURE 58.—Water supplies and areas served by Corpus Christi, Tex., water system. (Approved by local municipal water officials, April 1963.) List of areas: 1, Gregory; 2, Aransas Pass; 3, Portland; 4, Ingleside; 5 Odem; 6, Clarkwood; 7, Flour Bluff.

Analytical data—Corpus Christi

	Nueces River	Cunningham treatment plant
Percent of supply	100	100
Date of collection	1-31-62	1-31-62
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	15	15
Iron (Fe)	.10	.06
Manganese (Mn)	.01	.01
Calcium (Ca)	42	42
Magnesium (Mg)	8.3	8.0
Sodium (Na)	62	62
Potassium (K)	7.9	7.9
Bicarbonate (HCO_3)	122	120
Carbonate (CO_3)	0	0
Sulfate (SO_4)	45	45
Chloride (Cl)	96	96
Fluoride (F)	.4	1.1
Nitrate (NO_3)	.0	.0
Dissolved solids (residue at 180° C)	348	354
Hardness as $CaCO_3$	139	138
Noncarbonate hardness as $CaCO_3$	39	40
Specific conductance (micromhos at 25° C)	597	603
pH	7.6	8.0
Color	0	0
Turbidity	----------	0
Temperature °F	58	57
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter]		
Beta activity	----------	13
Radium (Ra)	----------	.1
Uranium (U)	----------	.9
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	----------	ND
Aluminum (Al)	----------	83
Boron (B)	----------	270
Barium (Ba)	----------	140
Beryllium (Be)	----------	ND
Cobalt (Co)	----------	ND
Chromium (Cr)	----------	<.49
Copper (Cu)	----------	2.0
Iron (Fe)	----------	140
Lithium (Li)	----------	16
Manganese (Mn)	----------	18
Molybdenum (Mo)	----------	3.5
Nickel (Ni)	----------	<4.9
Phosphorus (P)	----------	ND
Lead (Pb)	----------	7.3
Rubidium (Rb)	----------	5.3
Tin (Sn)	----------	ND
Strontium (Sr)	----------	420
Titanium (Ti)	----------	2.5
Vanadium (V)	----------	<15
Zinc (Zn)	----------	ND

DALLAS

(See fig. 59.)

Ownership: Municipal.

Other areas served: Carrollton, Cockrell Hill, Farmers Branch, Fruitdale, Grand Prairie, Irving, and Richardson.

Population served: Dallas, 679,684; total, 800,000.

Sources and percentages of supply: Elm Fork, impounded in Garza-Little Elm Reservoir, 67 percent; Denton Creek, impounded in Grapevine Reservoir, 26 percent; Lake Lavon (finished water purchased from North Texas Municipal Water District), 7 percent.

Auxiliary and emergency supplies: White Rock Lake; four wells used in periods of high water demand.

Average amount of water used daily in system during 1962: 89.8 mgd (U.S. Public Health Service, 1962c).

Treatment:

Bachman treatment plant: Prechlorination, softening with lime, addition of activated carbon for odor and taste control, coagulation with iron salts (ferric sulfate), sedimentation, rapid sand filtration, chlorination, and ammoniation.

Elm Fork treatment plant: Prechlorination, softening with lime, addition of activated carbon for odor and taste control, primary coagulation, primary sedimentation, secondary coagulation, rapid sand filtration, chlorination, and ammoniation.

Wells: Chlorination.

Rated capacity of treatment plants: Bachman treatment plant, 116 mgd; Elm Fork treatment plant, 196 mgd.

Raw-water storage, in million gallons: Garza-Little Elm Reservoir, 157,000; White Rock Lake, 4,600; Grapevine Reservoir, 61,000; Lake Lavon, 42,000; Lake Tawakoni, 305,000.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 17 years.

Finished-water storage: 10 elevated tanks, 9 million gal; 7 ground storage reservoirs, 128 million gal; clear wells, 24 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.8.

Remarks: Garza-Little Elm Reservoir (also known as Lake Lewisville) is on Elm Fork Trinity River about 10 miles upstream from the Elm Fork treatment plant at Carrollton. Grapevine Reservoir is on Denton Creek, 12 miles upstream from Elm Fork Trinity River. A diversion dam on the Elm Fork just downstream from the mouth of Denton Creek makes water from both reservoirs available to the Elm Fork treatment plant. Water from both reservoirs is diverted to the Bachman treatment plant from the Elm Fork, about 12 miles downstream from Denton Creek. East Side treatment plant has an initial capacity of 100 mgd, and a pipe line to Lake Tawakoni will be in use in 1963.

Regular determination at treatment plants, October 1960–September 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Bachman:												
Raw water	119	213	72	8.1	8.2	8.0	164	305	95	62	732	15
Finished water	31	69	23	10.3	10.4	10.2	92	137	70	0	0	0
Elm Fork:												
Raw water	110	122	84	7.9	8.1	6.2	152	190	119	49	1,120	13
Finished water	32	67	20	10.4	10.4	10.2	89	143	74	0	0	0

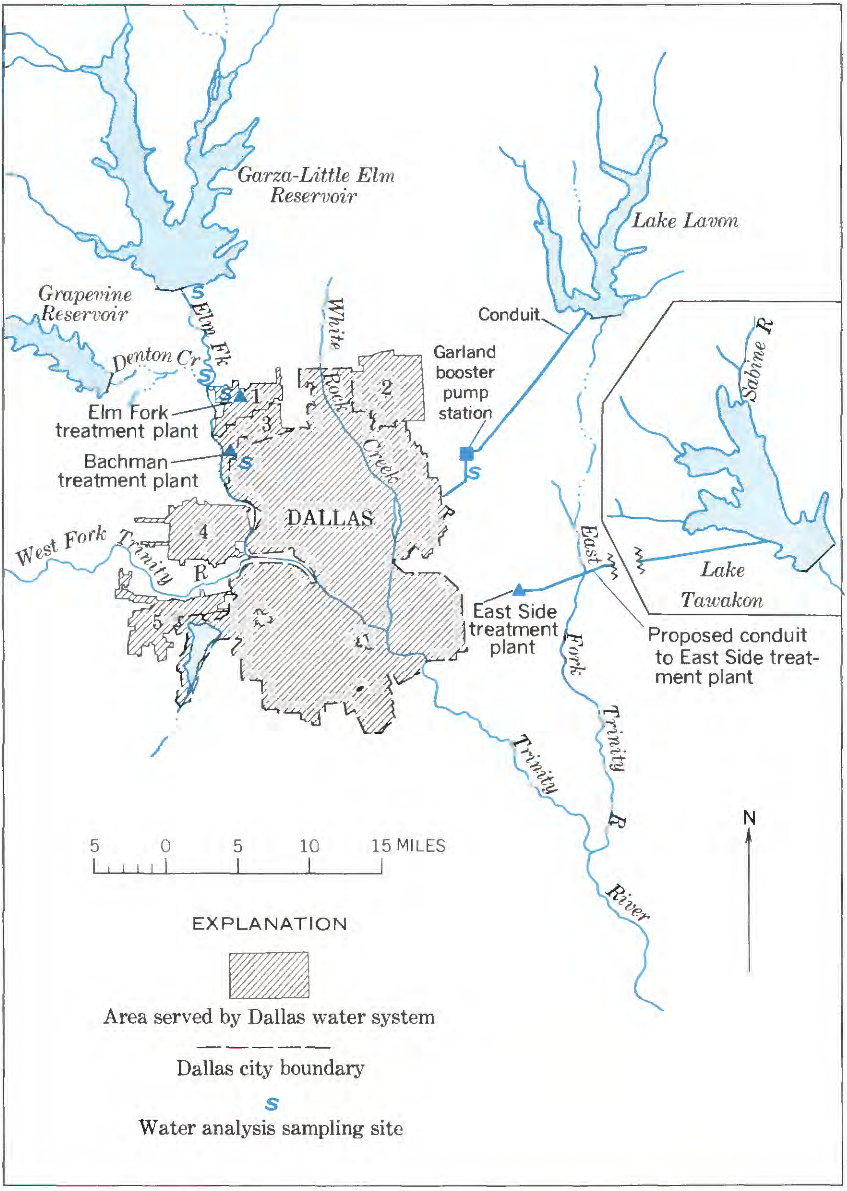

FIGURE 59.—Water supplies and areas served by Dallas, Tex., water system. (Approved by local municipal water officials, April 1963.) List of areas served: 1, Carrollton; 2, Richardson; 3, Farmers Branch; 4, Irving; 5, Grand Prairie.

Analytical data—Dallas

	Garza-Little Elm Reservoir	Elm Fork treatment plant	Grapevine and Garza-Little Elm Reservoir	Bachman treatment plant	Lake Lavon
Percent of supply	67	67	26	26	7
Date of collection	3-22-62	3-22-62	3-22-62	3-22-62	2-26-62
Type of water: R, raw; F, finished	R	F	R	F	F

Chemical analyses

[In parts per million]

	Garza-Little Elm Reservoir	Elm Fork treatment plant	Grapevine and Garza-Little Elm Reservoir	Bachman treatment plant	Lake Lavon
Silica (SiO_2)	2.1	2.5	2.2	2.6	4.8
Iron (Fe)	.06	.01	.04	.00	.04
Manganese (Mn)	.00	.00	.00	.00	.00
Calcium (Ca)	53	25	55	25	18
Magnesium (Mg)	6.2	4.3	7.1	4.6	3.5
Sodium (Na)	39	41	33	41	15
Potassium (K)	4.4	4.1	4.4	4.7	3.3
Hydroxide (OH)	----	----	----	1.7	----
Bicarbonate (HCO_3)	139	2	157	----	7
Carbonate (CO_3)	0	14	0	14	10
Sulfate (SO_4)	44	55	52	64	52
Chloride (Cl)	64	65	42	55	13
Fluoride (F)	.4	.7	.4	.6	.5
Nitrate (NO_3)	.5	.2	1.0	1.0	.0
Dissolved solids (residue at 180° C)	291	222	282	215	134
Hardness as $CaCO_3$	158	80	166	81	59
Noncarbonate hardness as $CaCO_3$	44	55	38	53	37
Specific conductance (micromhos at 25° C)	515	410	491	405	228
pH	7.5	9.6	7.4	9.7	9.0
Color	----	0	----	0	----
Turbidity	----	0	----	0	----

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Garza-Little Elm Reservoir	Elm Fork treatment plant	Grapevine and Garza-Little Elm Reservoir	Bachman treatment plant	Lake Lavon
Beta activity	----	11	----	12	10
Radium (Ra)	----	.1	----	<.1	<.1
Uranium (U)	----	2	----	.2	.3

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Garza-Little Elm Reservoir	Elm Fork treatment plant	Grapevine and Garza-Little Elm Reservoir	Bachman treatment plant	Lake Lavon
Silver (Ag)	----	<0.29	----	<0.28	0.15
Aluminum (Al)	----	72	----	54	70
Boron (B)	----	83	----	74	52
Barium (Ba)	----	29	----	28	32
Beryllium (Be)	----	ND	----	ND	ND
Cobalt (Co)	----	ND	----	ND	ND
Chromium (Cr)	----	<.29	----	<.28	2.6
Copper (Cu)	----	2.4	----	2.0	150
Iron (Fe)	----	66	----	28	130
Lithium (Li)	----	7.2	----	5.7	4.7
Manganese (Mn)	----	<2.9	----	<2.8	<1.5
Molybdenum (Mo)	----	4.0	----	3.7	4.6
Nickel (Ni)	----	2.9	----	<2.8	5.2
Phosphorus (P)	----	310	----	280	ND
Lead (Pb)	----	8.6	----	4.0	3.8
Rubidium (Rb)	----	4.3	----	4.0	2.4
Tin (Sn)	----	ND	----	ND	ND
Strontium (Sr)	----	210	----	180	490
Titanium (Ti)	----	2.6	----	2.0	1.8
Vanadium (V)	----	ND	----	ND	<4.6
Zinc (Zn)	----	ND	----	ND	ND

EL PASO

(See fig. 60.)

Ownership: Municipal.

Other areas served: Biggs Air Force Base.

Population served: El Paso, 276,687; total, about 280,000.

Sources and percentages of suppply: Rio Grande, 14 percent (includes 4 percent pumped from 8 shallow wells near Canutillo and transported to city by river); 6 wells in Canutillo well field northwest of city (exclusive of shallow wells), 25 percent; 6 wells in Mesa field, 16 percent; 11 wells in Nevins field, 14 percent; 14 wells in Lower Valley, 15 percent; 6 wells supplying airport station, 13 percent; 5 wells in downtown field, 1 percent; 2 wells in Montana field, 2 percent.

Average amount of water used daily in system during 1962: 45 mgd (U.S. Public Health Service, 1962c).

Treatment:

Well water: Chlorination.

Rio Grande treatment plant: Screening, grit removal, prechlorination, aeration by forced air, primary settling, coagulation with alum or ferric sulfate, softening with lime, addition of activated carbon for taste and odor control as required, settling, reflocculation, settling, recarbonation, chlorination, and rapid sand filtration.

Rated capacity of treatment plants: Rio Grande treatment plant, 20 mgd; Mesa station, 10 mgd; Canutillo station, 20 mgd; Lower Valley station, 10 mgd; Nevins station, 27 mgd; Airport station, 14 mgd; Downtown station, 6 mgd; Montana station, 3 mgd.

Finished-water storage: Ground reservoirs and elevated tanks, 92.6 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.1.

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Analytical data—El Paso

	Rio Grande	Rio Grande treatment plant	Wells, at Mesa Station	Six wells, at Canutillo Station	Three wells, at Airport Station	Seven wells, at Nevins Station	Well V-70, in Lower Valley
Percent of supply	14	14	16	25	13	14	15
Depth of well (feet)	----------	----------	----------	----------	----------	----------	704
Date drilled	----------	----------	----------	----------	----------	----------	1946
Date of collection	4-24-62	4-24-62	1-18-62	1-18-62	1-18-62	4-24-62	4-24-62
Type of water: R, raw; F, finished	R	F	F	F	F	F	F

Chemical analyses
[In parts per million]

	Rio Grande	Rio Grande treatment plant	Wells, at Mesa Station	Six wells, at Canutillo Station	Three wells, at Airport Station	Seven wells, at Nevins Station	Well V-70, in Lower Valley
Silica (SiO_2)	16	15	32	30	37	31	31
Iron (Fe)	.46	.07	.00	.00	.00	.00	.01
Manganese (Mn)	.00	.00	.00	.00	.00	.00	.00
Calcium (Ca)	92	28	42	7.5	24	28	32
Magnesium (Mg)	20	17	14	.7	8.7	7.5	9.6
Sodium (Na)	165	184	93	88	119	85	172
Potassium (K)	7.8	7.6	6.1	1.1	11	6.6	8.8
Bicarbonate (HCO_3)	236	10	193	77	188	154	162
Carbonate (CO_3)	0	20	0	0	0	0	0
Sulfate (SO_4)	290	294	70	79	87	60	75
Chloride (Cl)	127	138	91	48	82	73	204
Fluoride (F)	.6	.5	1.4	1.0	1.1	.8	1.0
Nitrate (NO_3)	.2	.5	5.0	.0	4.5	5.4	1.0
Dissolved solids (residue at 180° C)	835	727	455	302	470	373	615
Hardness as $CaCO_3$	312	140	162	22	96	101	120
Noncarbonate hardness as $CaCO_3$	118	98	4	0	0	0	0
Specific conductance (micromhos at 25° C)	1,270	1,140	746	464	751	615	1,050
pH	7.8	9.2	7.1	8.0	7.3	7.2	7.3
Color	10	0	0	0	0	0	5
Turbidity	----------	0	0	0	0	0	0

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]

	Rio Grande	Rio Grande treatment plant	Wells, at Mesa Station	Six wells, at Canutillo Station	Three wells, at Airport Station	Seven wells, at Nevins Station	Well V-70, in Lower Valley
Beta activity	----------	24	14	<1.9	13	11	20
Maximum beta activity, raw water, July 1, 1961 to June 30, 1962	34	----------	----------	----------	----------	----------	----------
Radium (Ra)	----------	<.1	.2	.5	.1	.1	.1
Uranium (U)	----------	2.3	3.4	.1	5.4	2.9	4.7

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

	Rio Grande	Rio Grande treatment plant	Wells, at Mesa Station	Six wells, at Canutillo Station	Three wells, at Airport Station	Seven wells, at Nevins Station	Well V-70, in Lower Valley
Silver (Ag)	----------	<0.86	<0.64	<0.37	<0.63	ND	ND
Aluminum (Al)	----------	340	64	19	31	37	18
Boron (B)	----------	85	100	59	88	77	110
Barium (Ba)	----------	46	210	44	110	98	170
Beryllium (Be)	----------	ND	ND	ND	ND	ND	ND
Cobalt (Co)	----------	ND	ND	ND	ND	ND	ND
Chromium (Cr)	----------	<.86	1.4	<.37	1.4	1.5	ND
Copper (Cu)	----------	3.5	3.7	1.5	4.0	35	16
Iron (Fe)	----------	19	44	20	21	50	52
Lithium (Li)	----------	170	26	37	94	39	120
Manganese (Mn)	----------	ND	ND	<3.7	ND	ND	ND
Molybdenum (Mo)	----------	5.6	7.1	4.8	6.9	2.8	<2.5
Nickel (Ni)	----------	ND	<6.4	<3.7	6.3	ND	ND
Phosphorus (P)	----------	ND	ND	ND	ND	ND	ND
Lead (Pb)	----------	ND	9.6	ND	ND	14	ND
Rubidium (Rb)	----------	14	19	4.8	16	67	9.3
Tin (Sn)	----------	ND	ND	ND	ND	ND	ND
Strontium (Sr)	----------	760	1,200	190	1,000	520	1,000
Titanium (Ti)	----------	ND	<1.9	ND	<1.9	ND	ND
Vanadium (V)	----------	ND	<19	ND	<19	<15	<25
Zinc (Zn)	----------	ND	ND	ND	ND	ND	ND

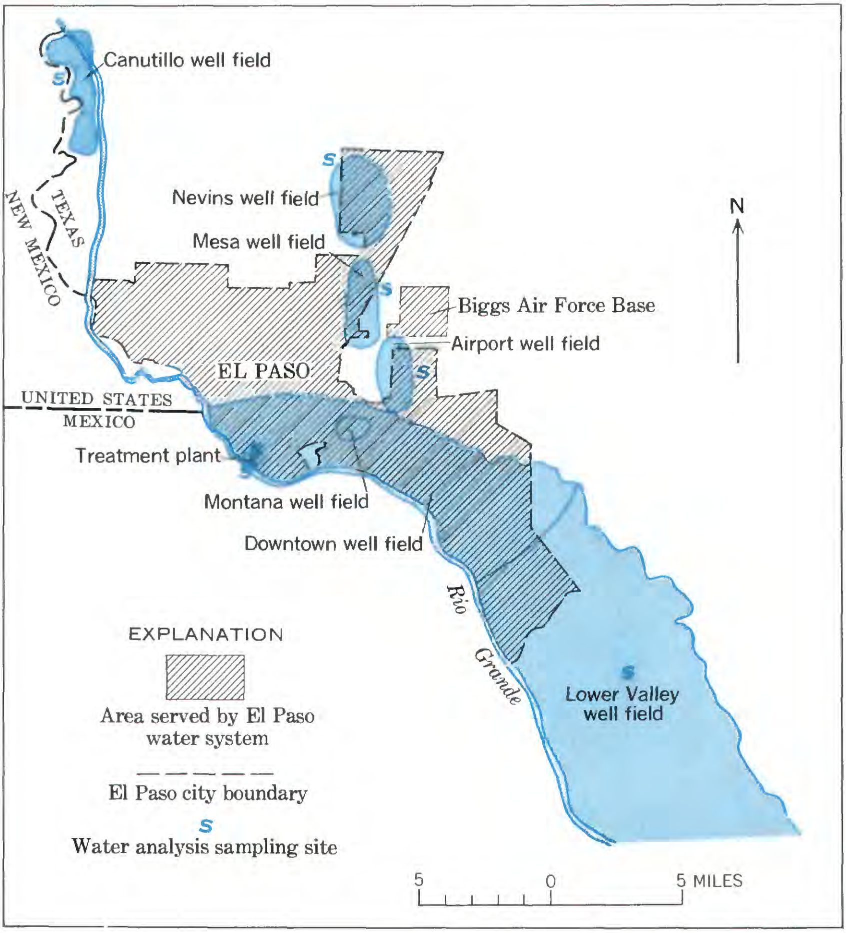

FIGURE 60.—Water supplies and areas served by El Paso, Tex., water system. (Approved by local municipal water officials, April 1963.)

FORT WORTH

(See fig. 61.)

Ownership: Municipal.

Other areas served (partially): Westover Hills, Edgecliff Village, White Settlement, and Westworth Village. In emergencies supplies Haltom City, Benbrook, and Arlington. About 10,000 people within Fort Worth city limits are served by private water companies.

Population served: Fort Worth, 356,268; total, about 360,000.

Sources and percentages of supply: A series of three lakes on West Fork Trinity River; Lake Worth, Eagle Mountain Lake, and Lake Bridgeport, 99.5 percent; three wells in the western part of the city, 0.5 percent.

Auxiliary and emergency supplies: Lake Benbrook, on Clear Fork Trinity River, is available for emergency supply.

Average amount of water used daily in system during 1962: 47 mgd (U.S. Public Health Service, 1962c).

Treatment:

North Holly treatment plant: Coagulation with alum and lime, sedimentation, rapid sand filtration, and chlorination.

South Holly treatment plant: Prechlorination, coagulation with alum and lime, sedimentation, rapid sand filtration, and chlorination.

Water is rechlorinated at most booster stations.

Rated capacity of treatment plants: North Holly treatment plant, 79 mgd; South Holly treatment plant, 50 mgd.

Raw-water storage, in million gallons: Lake Worth, 10,980; Eagle Mountain Lake, 59,540; Lake Bridgeport, 88,090; Lake Benbrook, 29,000.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 11 years.

Finished-water storage: Five ground reservoirs, 26 million gal; 12 elevated tanks, 13 million gal; clear wells, 21 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.3.

Regular determinations at North Holly treatment plant, October 1960–September 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	128	134	124	8.0	8.3	7.6	139	149	136	22	40	5
Finished water	129	135	115	8.1	8.2	7.8	144	153	139	0	0	0

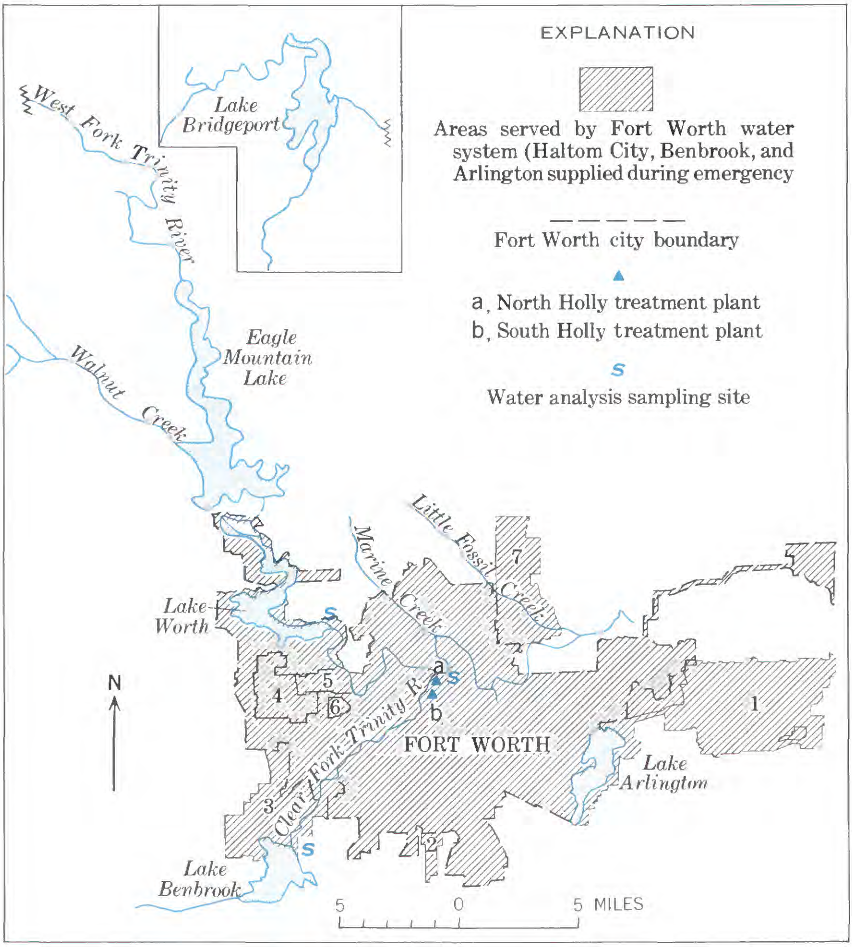

FIGURE 61.—Water supplies and areas served by Fort Worth, Tex., water system. (Approved by local municipal water officials, May 1963.) Areas served by Fort Worth water system: 1, Arlington; 2, Edgecliff Village; 3, Benbrook; 4, White Settlement; 5, Westworth Village; 6, Westover Hills; 7, Haltom City.

Analytical data—Fort Worth

	Lake Worth	North Holly treatment plant	Lake Benbrook
Percent of supply	99	99	----------
Date of collection	2-27-62	2-27-62	2-27-62
Type of water: R, raw; F, finished	R	F	R

Chemical analyses

[In parts per million]

	Lake Worth	North Holly treatment plant	Lake Benbrook
Silica (SiO_2)	5.8	4.2	4.6
Iron (Fe)	.05	.00	.00
Manganese (Mn)	.00	.00	.00
Calcium (Ca)	44	45	45
Magnesium (Mg)	8.4	8.4	6.1
Sodium (Na)	20	20	15
Potassium (K)	4.5	4.4	4.4
Bicarbonate (HCO_3)	153	146	143
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	20	24	26
Chloride (Cl)	32	34	20
Fluoride (F)	.3	.3	.4
Nitrate (NO_3)	.0	.0	.0
Dissolved solids (residue at 180° C)	228	228	209
Hardness as $CaCO_3$	144	147	137
Noncarbonate hardness as $CaCO_3$	19	27	20
Specific conductance (micromhos at 25° C)	387	394	348
pH	7.6	7.0	7.4
Color	----------	0	----------
Turbidity	----------	0	----------

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

	Lake Worth	North Holly treatment plant	Lake Benbrook
Beta activity	----------	21	----------
Radium (Ra)	----------	.4	----------
Uranium (U)	----------	1.4	----------

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Lake Worth	North Holly treatment plant	Lake Benbrook
Silver (Ag)	----------	ND	----------
Aluminum (Al)	----------	330	----------
Boron (B)	----------	110	----------
Barium (Ba)	----------	120	----------
Beryllium (Be)	----------	ND	----------
Cobalt (Co)	----------	ND	----------
Chromium (Cr)	----------	14	----------
Copper (Cu)	----------	4.3	----------
Iron (Fe)	----------	23	----------
Lithium (Li)	----------	2.0	----------
Manganese (Mn)	----------	<3.6	----------
Molybdenum (Mo)	----------	4.0	----------
Nickel (Ni)	----------	4.3	----------
Phosphorus (P)	----------	ND	----------
Lead (Pb)	----------	11	----------
Rubidium (Rb)	----------	ND	----------
Tin (Sn)	----------	ND	----------
Strontium (Sr)	----------	580	----------
Titanium (Ti)	----------	4.0	----------
Vanadium (V)	----------	ND	----------
Zinc (Zn)	----------	ND	----------

HOUSTON

(See fig. 62.)

Ownership: Municipal.

Population served: About 770,000 people were served by the municipal system as of January 1, 1961. Many private wells in areas annexed in recent years have not been taken over by the city.

Sources and percentages of supply: San Jacinto River (Lake Houston), 25 percent; 153 wells, 75 percent. During 1960 pumpage from the San Jacinto River averaged 78 mgd, of which 25 mgd was treated and distributed through the municipal system. The remainder was furnished, untreated, to industrial users. About 80 percent of the ground water comes from 52 wells in 8 major well fields; the remainder is obtained from 6 large-capacity wells and about 95 smaller wells. The major well fields supply the following percentages of the total water supply for the city: Central well field, 3.0; South End field, 6.0; Northeast field, 9.2; East End field, 4.9; Meyerland field, 0.7; Heights field, 14.0; South Park field, 3.1; and Southwest field, 17.7.

Average amount of water used daily in system during 1962: 108 mgd (U.S. Public Health Service, 1962c).

Treatment:

San Jacinto purification plant: Prechlorination, coagulation with alum, addition of activated carbon, rapid sand filtration, and stabilization with lime.

Heights plant: Aeration and chlorination.

All other plants: Chlorination only.

Rated capacity of treatment plants: San Jacinto plant, 50 mgd; Central plant, 9 mgd; South End plant, 13.1 mgd; Northeast plant, 29.2 mgd; East End plant, 12.5 mgd; Meyerland plant, 3.5 mgd; Heights plant, 29.8 mgd; South Park plant, 5.2 mgd; and Southwest plant, 35.8 mgd.

Raw-water storage: Lake Houston, 52,000 million gal; no raw storage at well-field plants.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 1.3 years.

Finished-water storage: 60 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at San Jacinto purification plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	36	57	21	7.3	7.6	6.8	47	66	28	68	120	20
Finished water	30	36	25	8.7	8.2	7.8	68	79	54	5	5	0

Analytical data—Houston

	Heights well field	East End well field	South Park well field	South End well field	Meyerland well	Northeast well field	Southwest well field	Central well field	San Jacinto River	San Jacinto purification plant
Percent of supply	14	5	3	6	1	9	18	3	24	24
Depth of well (feet)	----	----	----	----	1,770	----	----	----	----	----
Date of collection	7-25-61	7-25-61	7-25-61	7-25-61	7-25-61	7-25-61	7-25-61	7-27-61	7-24-61	7-24-61
Type of water: R, raw; F, finished	F	F	F	F	F	F	F	F	R	F

Chemical analyses

[In parts per million]

	Heights well field	East End well field	South Park well field	South End well field	Meyerland well	Northeast well field	Southwest well field	Central well field	San Jacinto River	San Jacinto purification plant
Silica (SiO_2)	18	16	16	18	20	18	21	16	6.6	6.1
Iron (Fe)	.05	.06	.07	.11	.16	.06	.01	.19	.09	.03
Manganese (Mn)	.00	.00	.00	.00	.00	.00	.00	.00	.00	.15
Calcium (Ca)	26	4.0	6.0	19	23	21	26	14	9.5	21
Magnesium (Mg)	6.5	1.0	1.4	5.4	5.1	5.7	6.2	4.3	1.5	1.6
Sodium (Na)	111	177	161	100	87	106	86	143	11	11
Potassium (K)	2.4	.9	.8	1.9	1.8	2.2	1.9	1.9	2.0	1.8
Bicarbonate (HCO_3)	291	374	348	269	252	271	254	322	29	25
Carbonate (CO_3)	0	0	0	0	0	0	0	0	0	0
Sulfate (SO_4)	7.2	7.6	11	10	12	6.8	11	3.6	2.4	26
Chloride (Cl)	63	59	51	42	38	55	40	67	21	27
Fluoride (F)	.9	1.5	1.2	.7	.8	.8	.7	1.1	.3	.3
Nitrate (NO_3)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Dissolved solids (residue at 180° C)	378	456	420	333	316	348	318	415	117	129
Hardness as $CaCO_3$	92	14	21	70	78	76	90	52	30	59
Noncarbonate hardness as $CaCO_3$	0	0	0	0	0	0	0	0	6	38
Specific conductance (micromhos at 25°C)	641	750	695	553	520	584	533	697	127	196
pH	7.2	7.7	7.8	7.2	7.0	7.2	7.2	7.3	6.2	6.5
Color	0	0	0	0	0	0	0	0	80	0
Turbidity	0	0	0	0	0	0	0	0	22	0

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter. <, less than]

	Heights well field	East End well field	South Park well field	South End well field	Meyerland well	Northeast well field	Southwest well field	Central well field	San Jacinto River	San Jacinto purification plant
Beta activity	23	2.8	----	----	----	----	7.4	----	----	4.6
Radium (Ra)	1.3	.3	----	----	----	----	.8	----	----	<.1
Uranium (U)	3.6	.1	----	----	----	----	2.2	----	----	.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found. X, semiquantitative determinations in digit order shown]

Silver (Ag)	ND	ND	--	--	--	--	ND	--	<0.15	<0.14
Aluminum (Al)	21	42	--	--	--	--	13	--	380	800
Boron (B)	210	110	--	--	--	--	160	--	24	28
Barium (Ba)	340	70	--	--	--	--	380	--	57	120
Beryllium (Be)	ND	ND	--	--	--	--	ND	--	ND	ND
Cobalt (Co)	ND	ND	--	--	--	--	ND	--	ND	ND
Chromium (Cr)	1.2	ND	--	--	--	--	1.5	--	.65	.84
Copper (Cu)	2.9	1.8	--	--	--	--	2.0	--	2.9	4.3
Iron (Fe)	86	43	--	--	--	--	26	--	290	31
Lithium (Li)	28	18	--	--	--	--	19	--	.44	.91
Manganese (Mn)	11	<7	--	--	--	--	7.7	--	77	34
Molybdenum (Mo)	4.1	7.0	--	--	--	--	3.6	--	ND	ND
Nickel (Ni)	<6	ND	--	--	--	--	ND	--	3.3	4.5
Phosphorus (P)	ND	ND	--	--	--	--	ND	--	ND	ND
Lead (Pb)	ND	ND	--	--	--	--	ND	--	8.2	1.7
Rubidium (Rb)	ND	ND	--	--	--	--	ND	--	6.6	3.1
Tin (Sn)	ND	ND	--	--	--	--	ND	--	ND	ND
Strontium (Sr)	600	120	--	--	--	--	370	--	11	71
Titanium (Ti)	<6	<7	--	--	--	--	ND	--	35	1.4
Vanadium (V)	ND	ND	--	--	--	--	<15	--	<4.5	<4.3
Zinc (Zn)	ND	ND	--	--	--	--	ND	--	ND	ND
Ytterbium (Yb)	--	--	--	--	--	--	ND	--	X	X
Yttrium (Y)	--	--	--	--	--	--	ND	--	X	X
Zirconium (Zr)	--	--	--	--	--	--	ND	--	X	ND

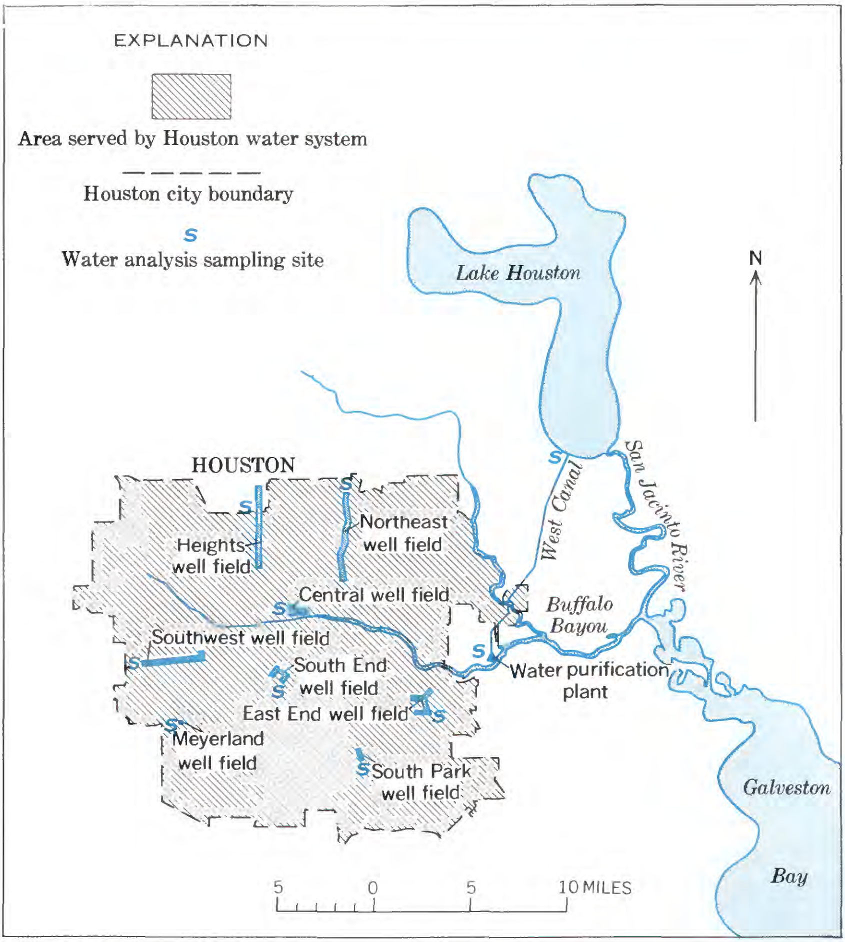

FIGURE 62.—Water supplies and areas served by Houston, Tex., water system. (Approved by local municipal water officials, April 1963.)

LUBBOCK

Ownership: Municipal.

Population served: Lubbock, 128,691; total, 133,000 (1961 estimate).

Sources and percentages of supply: Total of 141 wells. There are 81 wells in and adjacent to the city. The average depth of the wells is 135 feet, and the average yield is 110 gpm. Sixteen wells are in the Shallowater field about 14 miles northwest of the city; they have an average depth of 114 feet and an average yield of 235 gpm. Forty-four wells are in the "Sand Hills" area of Bailey and Lamb Counties approximately 60 miles northwest of the city. These wells have an average depth of 220 feet and an average yield of 530 gpm.

The wells are pumped in groups to ground-storage reservoirs; from these reservoirs, the water is pumped to a booster station, where it is pumped into the distribution system. The wells in and adjacent to the city furnish about 25 percent of the supply; the Shallowater field, 10 percent; and the Sand Hills, 65 percent.

Average amount of water used daily in system during 1962: 18 mgd (U.S. Public Health Service, 1962c).

Treatment: Chlorination.

Rated capacity of pumping plants: 47.4 mgd.

Finished-water storage: Eleven ground storage reservoirs and four elevated storage reservoirs have a combined capacity of 39 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 2.2.

Analytical data—Lubbock

	City well 62 in Northwest well field	Composite of wells in south part of Lubbock	Northeast well field	Composite of wells in Sand Hills well field	Well 102 in Shallowater well field
Percent of supply	7	4	13	65	10
Depth of well (feet)	135	135	135	220	114
Date of collection	2-14-62	2-14-62	2-14-62	2-14-62	2-14-62
Type of water: R, raw; F, finished	R	F	F	F	R

Chemical analyses

[In parts per million]

Silica (SiO_2)	55	56	53	53	43
Iron (Fe)	.00	.02	.02	.00	.00
Manganese (Mn)	.01	.00	.01	.00	.02
Calcium (Ca)	54	45	71	64	98
Magnesium (Mg)	49	58	62	14	120
Sodium (Na)	129	111	106	27	102
Potassium (K)	16	14	15	4.9	30
Bicarbonate (HCO_3)	364	342	324	296	357
Carbonate (CO_3)	0	0	0	0	0
Sulfate (SO_4)	189	160	237	23	572
Chloride (Cl)	92	108	115	10	64
Fluoride (F)	3.9	5.1	3.0	1.0	7.0
Nitrate (NO_3)	17	7.4	9.5	1.5	9.4
Dissolved solids (residue at 180° C)	794	741	861	350	1,220
Hardness as $CaCO_3$	336	351	432	217	738
Noncarbonate hardness as $CaCO_3$	38	70	166	0	446
Specific conductance (micromhos at 25° C)	1,200	1,150	1,220	524	1,660
pH	7.1	7.2	7.1	7.2	7.0
Color	0	0	0	0	0
Turbidity	0	0	0	0	0

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	-----------	-----------	35	7.4	130
Radium (Ra)	-----------	-----------	.1	.3	1.9
Uranium (U)	-----------	-----------	13	3.0	250

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	-----------	-----------	ND	<0.51	1.5
Aluminum (Al)	-----------	-----------	22	6.1	32
Boron (B)	-----------	-----------	590	120	500
Barium (Ba)	-----------	-----------	71	210	30
Beryllium (Be)	-----------	-----------	ND	ND	ND
Cobalt (Co)	-----------	-----------	ND	ND	ND
Chromium (Cr)	-----------	-----------	<1.1	<5.1	<1.5
Copper (Cu)	-----------	-----------	<1.1	13	15
Iron (Fe)	-----------	-----------	32	38	6,600
Lithium (Li)	-----------	-----------	78	14	96
Manganese (Mn)	-----------	-----------	<11	5.1	75
Molybdenum (Mo)	-----------	-----------	13	ND	68
Nickel (Ni)	-----------	-----------	ND	<5.1	<15
Phosphorus (P)	-----------	-----------	ND	ND	ND
Lead (Pb)	-----------	-----------	ND	ND	38
Rubidium (Rb)	-----------	-----------	ND	ND	ND
Tin (Sn)	-----------	-----------	ND	ND	ND
Strontium (Sr)	-----------	-----------	1,200	280	6,300
Titanium (Ti)	-----------	-----------	ND	<1.5	ND
Vanadium (V)	-----------	-----------	34	<15	74
Zinc (Zn)	-----------	-----------	ND	ND	ND

SAN ANTONIO

(See fig. 63.)

Ownership: Municipal and Bexar Metropolitan Water District.

Other areas served: Balcones Heights, Olmos Park, Terrell Hills, part of Alamo Heights, two water districts, and Brooks Air Force Base are served by the city system; Castle Hills is served by Bexar Metropolitan Water District.

Population served: San Antonio, 587,718; total, about 603,000.

Sources and percentages of supply: Fifty-nine city wells, about 85 percent; 18 wells of the Bexar Metropolitan Water District, about 15 percent. Twenty-five of the city wells are in the following six well fields (stations): Market Street, four wells about 900 feet deep; Mission, six wells about 1,300 feet deep; Artesia, five wells about 1,300 feet deep; 34th Street, three wells about 950 feet deep; Seale Road, three wells about 1,200 feet deep; Basin, four wells about 700 feet deep. Thirty-four wells are at various points throughout the city: the wells range in depth from 600 to 1,000 feet. The Bexar Metropolitan Water District wells are in eight pumping stations. (Sample for water analysis was collected at King Street Station.) Wells supplying the Castle Hills range in depth from 533 to 762 feet. Those supplying south and southwest San Antonio range in depth from 1,400 to 1,700 feet.

Average amount of water used daily in system during 1962: 81.7 mgd (U.S. Public Health Service, 1962c).

Treatment: Chlorination.

Rated capacity of pumping plants: City-owned plants, 365 mgd; Bexar Metropolitan plants, 35 mgd.

Finished-water storage: City system, 8 ground reservoirs, 22.8 million gal; and 12 elevated tanks, 21 million gal; Bexar Metropolitan Water District, ground and elevated storage, 5.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Analytical data—San Antonio

	4 wells, at Market Street Station	Wells of Bexar Metropolitan Water District	5 wells, Artesia Station	5 wells, Mission Station	4 wells, Basin Station	3 wells, 34th Street Station
Percent of supply						
Depth of well (feet)	900		1,300	1,300	700	950
Date of collection	2-8-62	2-8-62	2-8-62	2-8-62	2-8-62	2-8-62
Type of water: R, raw; F, finished	F	R	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	12	12	12	12	12	12
Iron (Fe)	.03	.02	.02	.01	.06	.02
Manganese (Mn)	.00	.00	.00	.00	.00	.00
Calcium (Ca)	62	64	62	65	70	63
Magnesium (Mg)	16	17	16	18	18	16
Sodium (Na)	7.9	8.7	7.6	10	7.2	6.6
Potassium (K)	1.1	1.0	.9	1.1	1.2	1.0
Bicarbonate (HCO_3)	242	236	238	237	252	241
Carbonate (CO_3)	0	0	0	0	0	0
Sulfate (SO_4)	15	25	19	32	31	15
Chloride (Cl)	14	17	13	18	13	14
Fluoride (F)	.3	.4	.3	.4	.3	.3
Nitrate (NO_3)	4.8	3.8	5.0	3.8	4.8	4.8
Dissolved solids (residue at 180° C)	265	278	265	292	298	260
Hardness as $CaCO_3$	220	230	220	236	248	223
Noncarbonate hardness as $CaCO_3$	22	36	25	42	42	26
Specific conductance (micromhos at 25° C)	447	461	446	486	492	445
pH	6.8	6.8	6.8	6.7	6.7	6.8
Color	0	0	0	0	0	0
Turbidity	0	0	0	0	0	0
Temperature °F		81	75	82	73	76

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	2.5					
Radium (Ra)	.3					
Uranium (U)	.3					

Spectrographic analyses

[In micrograms per liter. <, less then; ND, looked for but not found]

Silver (Ag)	ND					
Aluminum (Al)	8.5					
Boron (B)	57					
Barium (Ba)	69					
Beryllium (Be)	ND					
Cobalt (Co)	ND					
Chromium (Cr)	ND					
Copper (Cu)	25					
Iron (Fe)	9.3					
Lithium (Li)	1.5					
Manganese (Mn)	ND					
Molybdenum (Mo)	<1.2					
Nickel (Ni)	ND					
Phosphorus (P)	ND					
Lead (Pb)	ND					
Rubidium (Rb)	ND					
Tin (Sn)	ND					
Strontium (Sr)	400					
Titanium (Ti)	ND					
Vanadium (V)	<12					
Zinc (Zn)	ND					

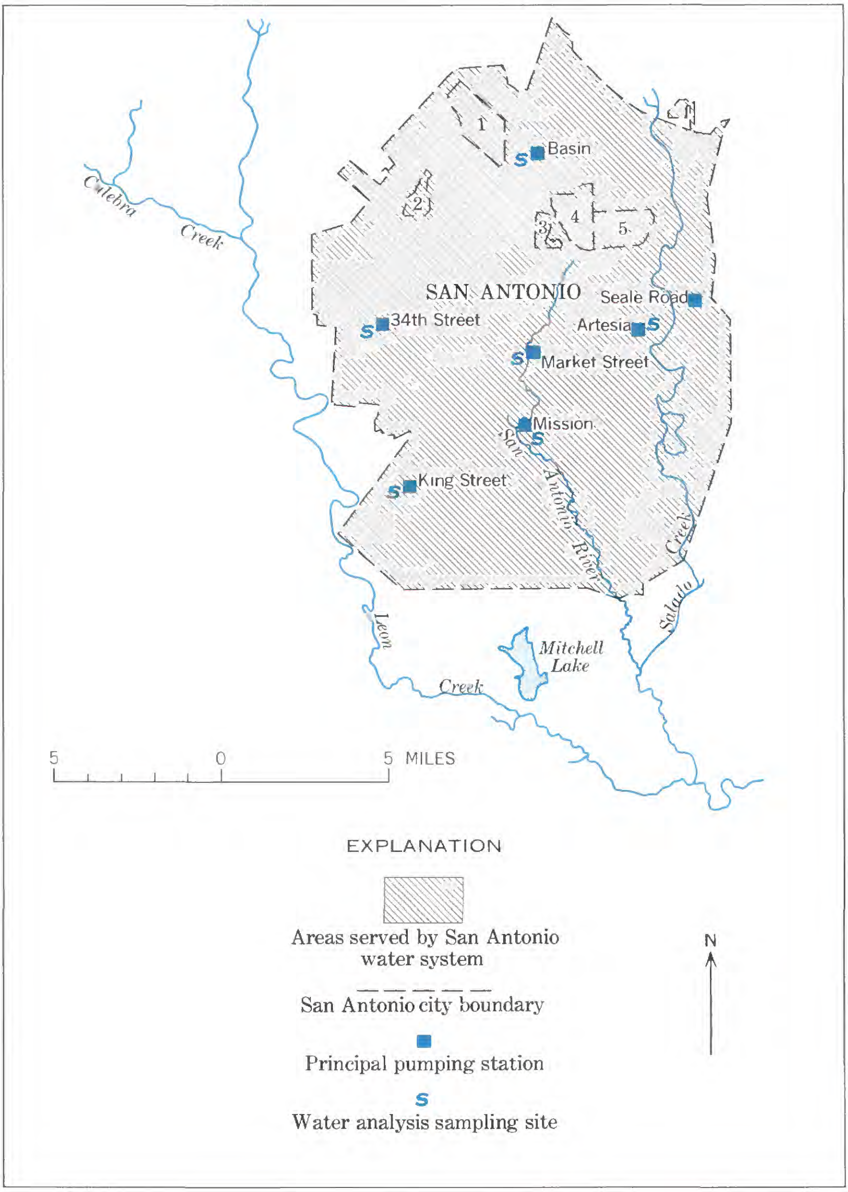

FIGURE 63.—Water supplies and areas served by San Antonio, Tex., water system. (Approved by local municipal water officials, June 1963). List of areas served: 1, Castle Hills; 2, Balcones Heights; 3, Olmos Park; 4, Alamo Heights; 5, Terrell Hills.

UTAH

Salt Lake City

SALT LAKE CITY

(See fig. 64.)

Ownership: Municipal and Metropolitan Water District.

Population served: Salt Lake City, 189,454; about 83,000 in suburban areas; total, about 272,000.

Sources and percentages of supply: Big Cottonwood Creek, southeast of city, 30 percent of supply; Provo River impounded in Deer Creek Reservoir, northeast of Provo, 22 percent of supply; Parleys Creek impounded in Mountain Dell Reservoir, east of city, 14 percent of supply; many wells, both flowing and pumped, located throughout the city, 11 percent of supply; City Creek, north of city, 9 percent of supply; Little Cottonwood Creek southeast of city, 9 percent of supply; Third East Pumping Station, supplied by Murray Artesian Basin southeast of city, 3 percent of supply; and Emigration Tunnel, east of city, 2 percent of supply. Deer Creek Reservoir is used both as a regular and an auxiliary supply; during dry years this source supplies a greater proportion of the total supply than indicated above. Percentages shown above are representative of calendar year 1960.

Average amount of water used daily in system during 1962: 59.3 mgd (U.S. Public Health Service, 1962c).

Treatment:

Big Cottonwood Creek treatment plant: Prechlorination, coagulation, sedimentation, rapid sand filtration, and postchlorination.

Deer Creek Reservoir plant: Chlorination.

Little Cottonwood Creek treatment plant: Prechlorination, coagulation, sedimentation, rapid sand filtration and postchlorination.

City Creek treatment plant: Coagulation, sedimentation and chlorination.

Mountain Dell Reservoir plant: Addition of copper sulfate for algae control and chlorination.

Artesian well water is chlorinated; water obtained from most pumped wells is not treated.

Rated capacity of treatment plants: City Creek treatment plant, 15 mgd; Big Cottonwood Creek treatment plant, 32 mgd; Mountain Dell Reservoir plant, 31 mgd; Little Cottonwood Creek treatment plant, 100 mgd.

Raw-water storage, in million gallons: Twin Lakes Reservoir, 306; Lake Mary Reservoir, 242; Mountain Dell Reservoir, 1,100; Deer Creek Reservoir, 49,700.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 2.4 years.

735-717 O—64——23

Finished-water storage: The combined storage of finished water in various parts of Salt Lake City, both in reservoirs and steel or concrete tanks, totals 94.4 million gal. Two new reservoirs are proposed—one located near the State Capitol is to contain finished water from various sources; the other, a 5-million-gallon reservoir south of the terminal reservoirs, is to store water from the Little Cottonwood treatment plant.

Because of the need for intricate balancing of pressures, the finished water reservoirs are interlinked, and, thus, the supplies are mixed before reaching the consumer. As a result the composition of the water varies throughout much of the distribution system and changes considerably from time to time during the year. The analyses given are believed to show reasonably well the composition of the water from the major sources of supply.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.6.

Determinations at treatment plants, December 1960–November 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Regular determinations												
Big Cottonwood:												
Raw water	93	124	42	8.4	9.3	7.8	149	222	70	1.8	21	0.7
Finished water	------	117	41	------	9.5	7.6	------	218	70	.2	1.5	.0
Deer Creek Reservoir: Raw water	116	158	88	7.8	8.5	7.5	201	244	150	3.8	25	.2
Little Cottonwood: Raw water	51	64	36	7.8	8.5	7.4	95	108	66	2.0	44	1.0
City Creek:												
Raw water	168	188	139	8.5	8.8	8.1	209	246	176	.4	9.0	.3
Finished water	------	187	137	------	8.7	8.0	------	245	170	.2	1.3	.2
Parleys Creek at Mount Dell Reservoir: Raw water	176	202	152	8.1	9.0	7.6	240	268	210	------	4.5	1.0
Average monthly determinations												
Third East Pumping Station: Raw water	139	144	132	7.9	8.0	7.6	235	246	210	------	------	------

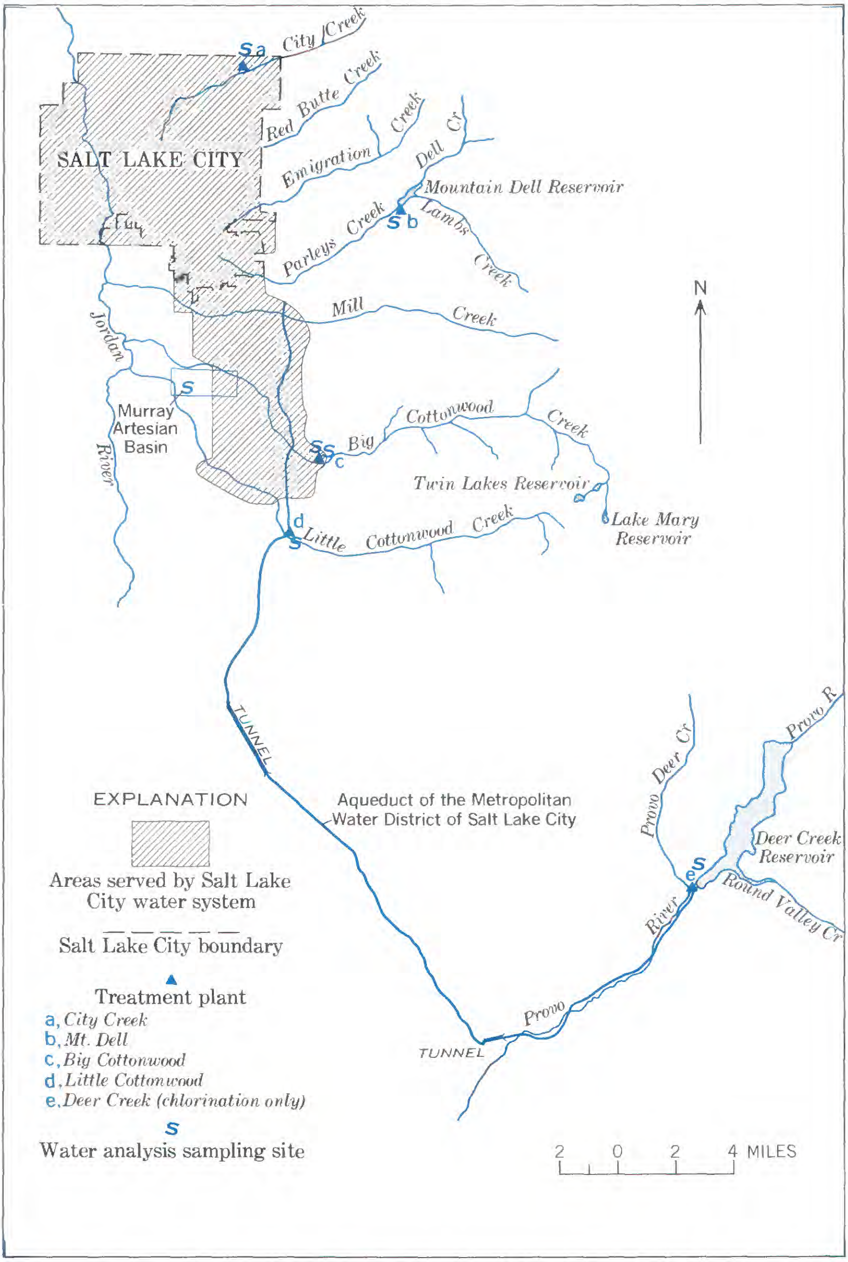

FIGURE 64.—Water supplies and areas served by Salt Lake City Utah water system. (Approved by local municipal water officials, December 1962).

Analytical data—Salt Lake City

	Deer Creek Reservoir	Little Cottonwood treatment plant	Big Cottonwood Creek	Big Cottonwood treatment plant		Mountain Dell treatment plant	City Creek treatment plant	Artesian wells, 3rd East Station
Percent of supply	24	11	33	----------	30	14	9	4
Date of collection	7-12-61	7-12-61	7-12-61	7-12-61	12-27-61	12-27-61	7-12-61	7-12-61
Type of water: R, raw; F, finished	R	F	R	F	F	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	6.7	6.2	5.6	----------	6.3	11	5.7	12
Iron (Fe)	.00	.00	.00	----------	.01	.06	.01	.00
Manganese (Mn)	.00	.01	.00	----------	.00	.18	.00	.00
Boron (B)	----------	.18	.13	----------	.01	.03	.13	.16
Calcium (Ca)	36	57	38	----------	44	87	52	63
Magnesium (Mg)	11	13	12	----------	15	14	15	20
Sodium (Na)	4.3	12	4.1	----------	5.5	22	4.3	28
Potassium (K)	1.0	2.3	1.0	----------	1.2	1.2	.5	2.1
Bicarbonate (HCO_3)	122	152	122	----------	144	288	218	200
Carbonate (CO_3)	0	0	0	----------	0	0	0	0
Sulfate (SO_4)	32	74	41	----------	52	41	11	72
Chloride (Cl)	7.0	13	7.0	----------	10	32	7.0	41
Fluoride (F)	.3	.5	.2	----------	.3	.1	.2	.5
Nitrate (NO_3)	.3	.3	.2	----------	.6	.2	.3	5.8
Phosphate (PO_4)	----------	.05	.00	----------	----------	----------	----------	.09
Dissolved solids (residue at 180° C)	159	256	170	----------	211	356	198	351
Hardness as $CaCO_3$	136	195	144	----------	172	274	192	239
Noncarbonate hardness as $CaCO_3$	36	70	44	----------	54	38	13	75
Specific conductance (micromhos at 25° C)	276	423	291	----------	357	587	362	578
pH	7.8	7.6	7.8	----------	7.9	8.2	8.2	7.8
Color	5	5	5	----------	----------	----------	5	5
Temperature °F	56	60	54	----------	39	34	65	64

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity	----------	3.8	----------	1.8	6.9	21	1.2	3.6
Radium (Ra)	----------	<.1	----------	<.1	.1	<.1	<.1	.1
Uranium (U)	----------	.8	----------	.5	.5	.5	.8	2.8

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.42	<0.38	----------	<0.27	<0.30	<0.54	<0.40	<0.57
Aluminum (Al)	80	91	----------	260	280	75	28	91
Boron (B)	120	65	----------	24	21	49	44	68
Barium (Ba)	130	110	----------	87	78	120	56	140
Beryllium (Be)	ND	ND	----------	ND	ND	ND	ND	ND
Cobalt (Co)	ND	3.8	----------	ND	ND	ND	ND	ND
Chromium (Cr)	.93	3.0	----------	.68	3.3	ND	2.4	2.5
Copper (Cu)	12	6.1	----------	1.3	4.5	110	8.4	3.1
Iron (Fe)	80	80	----------	17	87	97	17	53
Lithium (Li)	13	12	----------	.92	1.2	3.0	.92	4.6
Manganese (Mn)	420	91	----------	<2.7	<3.0	290	<4.0	<5.7
Molybdenum (Mo)	2.4	2.0	----------	2.7	11	ND	1.8	68
Nickel (Ni)	18	11	----------	<2.7	7.2	<5.4	6.0	5.7
Phosphorus (P)	ND	ND	----------	ND	ND	ND	ND	ND
Lead (Pb)	9.7	<3.8	----------	3.3	6.0	12	5.6	62
Rubidium (Rb)	5.5	4.6	----------	ND	<3.0	ND	ND	ND
Tin (Sn)	ND	ND	----------	ND	ND	ND	ND	ND
Strontium (Sr)	220	280	----------	140	280	400	120	370
Titanium (Ti)	<4.2	ND	----------	<2.7	3.3	6.4	ND	49
Vanadium (V)	ND	<11	----------	ND	ND	ND	ND	ND
Zinc (Zn)	ND	ND	----------	<270	ND	ND	ND	ND

VIRGINIA

NORFOLK

(See fig. 65.)

Ownership: Municipal.

Other areas served: South Norfolk, Virginia Beach, and suburban areas. An unknown number of Army and Navy personnel are also served.

Population served: Norfolk, 276,897; total, about 375,000.

Sources of supply: Two systems of impounding reservoirs: Lake Smith system comprises a chain of reservoirs known as Lake Wright, Lake Taylor, Lake Whitehurst, Little Creek, Lake Lawson, Lake Smith, and North Landing Lake about 2 miles northeast of the city; Lake Prince system comprises Lake Prince on Exchange Creek and Lake Burnt Mills in Nansemond and Isle of Wight Counties, about 18 miles from the city.

Auxiliary and emergency supplies: Nottoway and Blackwater Rivers.

Average amount of water used daily in system during 1962: 41.9 mgd (U.S. Public Health Service, 1962c).

Treatment: Moores Bridges and 37th Street treatment plants—prechlorination, coagulation with alum and lime, activated carbon, addition of bleaching clay when needed, sedimentation, rapid sand filtration, postchlorination, adjustment of pH with lime, and fluoridation.

Rated capacity of treatment plants: Moores Bridges treatment plant, 40 mgd; 37th Street treatment plant, 24 mgd.

Raw-water storage: Lake Smith system, 1,800 million gal; Lake Prince, 3,700 million gal; Lake Burnt Mills, 3,400 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 212.

Finished-water storage: two ground tanks, 6 and 12 million gal; elevated tanks, 2 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Remarks: A 6,000-million-gallon reservoir on Western Branch of Nansemond River is to be completed in 1962. A new pumping station will be constructed at this reservoir to pump to existing lines. The Moores Bridges plant capacity will be increased from 24 mgd to 40 mgd.

Regular determinations at treatment plants, 1961:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Moores Bridges:												
Raw water	31	38	25	6.8	6.9	6.5	54	70	39	12	19	0.9
Finished water	40	49	30	8.2	8.4	8.0	84	99	61	.1	.4	------
37th Street:												
Raw water	26	42	6	6.7	7.1	5.9	40	51	24	4.8	10	3
Finished water	38	56	15	8.6	9.2	7.6	67	82	------	.2	1.2	0

Analytical data—Norfolk

	Lake Wright	Moores Bridges treatment plant	Lake Prince	Lake Burnt Mills	37th Street treatment plant
Percent of supply	62	62	38	----------	38
Date of collection	1-17-62	2-12-62	1-17-62	1-17-62	1-17-62
Type of of water: R, raw; F, finished	R	F	R	R	F

Chemical analyses

[In parts per million]

	Lake Wright	Moores Bridges treatment plant	Lake Prince	Lake Burnt Mills	37th Street treatment plant
Silica (SiO_2)	2.3	4.0	5.8	4.0	4.7
Iron (Fe)	.24	.02	.62	.84	.06
Manganese (Mn)	.02	.01	.00	.00	.00
Aluminum (Al)	.3	.2	.2	.3	.1
Lithium (Li)	.1	.0	.0	.0	.0
Calcium (Ca)	12	23	11	3.6	17
Magnesium (Mg)	4.9	3.3	1.6	1.4	1.7
Sodium (Na)	14	11	4.6	4.4	5.9
Potassium (K)	3.0	2.2	2.0	1.7	1.9
Bicarbonate (HCO_3)	29	36	29	13	28
Carbonate (CO_3)	0	0	0	0	0
Sulfate (SO_4)	29	34	10	5.6	17
Chloride (Cl)	22	20	9.0	8.5	14
Fluoride (F)	.1	.8	.1	.1	1.0
Nitrate (NO_3)	1.1	2.0	1.5	1.0	1.0
Phosphate (PO_4)	.1	.0	.0	.1	.0
Dissolved solids (residue at 180° C)	123	127	73	47	88
Hardness as $CaCO_3$	52	72	34	16	48
Noncarbonate hardness as $CaCO_3$	28	42	10	6	26
Specific conductance (micromhos at 25° C)	174	204	102	56	131
pH	6.7	8.0	6.9	6.7	8.2
Color	35	2	32	50	5

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

	Lake Wright	Moores Bridges treatment plant	Lake Prince	Lake Burnt Mills	37th Street treatment plant
Beta activity	----------	28	----------	----------	13
Radium (Ra)	----------	.2	----------	----------	<.1
Uranium (U)	----------	<.1	----------	----------	<.1

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Lake Wright	Moores Bridges treatment plant	Lake Prince	Lake Burnt Mills	37th Street treatment plant
Silver (Ag)	----------	<0.15	----------	----------	<0.10
Aluminum (Al)	----------	250	----------	----------	270
Boron (B)	----------	11	----------	----------	12
Barium (Ba)	----------	49	----------	----------	32
Beryllium (Be)	----------	ND	----------	----------	ND
Cobalt (Co)	----------	ND	----------	----------	ND
Chromium (Cr)	----------	5.2	----------	----------	1.3
Copper (Cu)	----------	4.4	----------	----------	3.7
Iron (Fe)	----------	25	----------	----------	150
Lithium (Li)	----------	.31	----------	----------	.27
Manganese (Mn)	----------	11	----------	----------	11
Molybdenum (Mo)	----------	ND	----------	----------	ND
Nickel (Ni)	----------	1.9	----------	----------	2.0
Phosphorus (P)	----------	ND	----------	----------	ND
Lead (Pb)	----------	3.7	----------	----------	5.5
Rubidium (Rb)	----------	5.0	----------	----------	4.0
Tin (Sn)	----------	ND	----------	----------	ND
Strontium (Sr)	----------	140	----------	----------	64
Titanium (Ti)	----------	5.2	----------	----------	3.5
Vanadium (V)	----------	ND	----------	----------	ND
Zinc (Zn)	----------	ND	----------	----------	ND

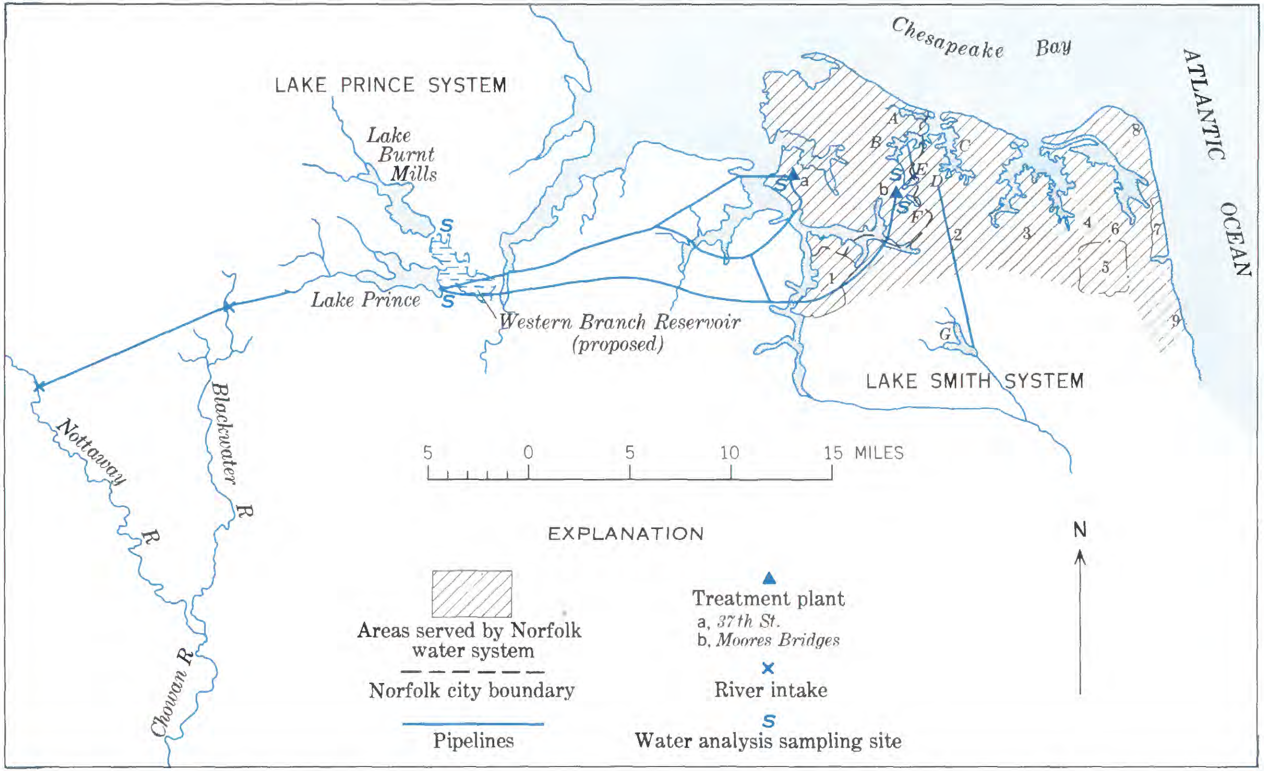

FIGURE 65.—Water supplies and areas served by Norfolk, Va., water system. (Approved by local municipal water officials, February 1963.) List of areas served: 1, South Norfolk; 2, Euclid; 3, Rosemont; 4, London Bridge; 5, U.S. Naval Reservation; 6, Oceana; 7, Virginia Beach; 8, Fort Story; 9, Dam Neck Mills (Coast Guard Station). Lake Smith System: *A*, Little Creek; *B*, Lake Whitehurst; *C*, Lake Smith; *D*, Lake Lawson; *E*, Lake Wright; *F*, Lake Taylor; *G*, North Landing Lake.

RICHMOND

(See fig. 66.)

Ownership: Municipal.

Population served: Richmond, 220,000; about 83,000 outside the city limits; total, 303,000.

Source of supply: James River.

Average amount of water used daily in system during 1962: 31.1 mgd (U.S. Public Health Service, 1962c).

Treatment: Douglasdale Road filtration plant—prechlorination, coagulation with alum, sedimentation, addition of activated carbon, rapid sand filtration, post-chlorination, ammoniation, adjustment of pH with lime, fluoridation, and addition of copper sulfate.

Rated capacity of treatment plant: Douglasdale Road filtration plant, 66 mgd.

Raw-water storage: 170 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 5.5.

Finished-water storage: 58 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.9.

Regular determinations at Douglasdale Road filtration plant, July 1959–June 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	41	66	19	7.1	7.4	6.8	------	------	------	44	274	10
Finished water	32	50	14	8.7	9.1	------	59	65	54	.1	.1	.1

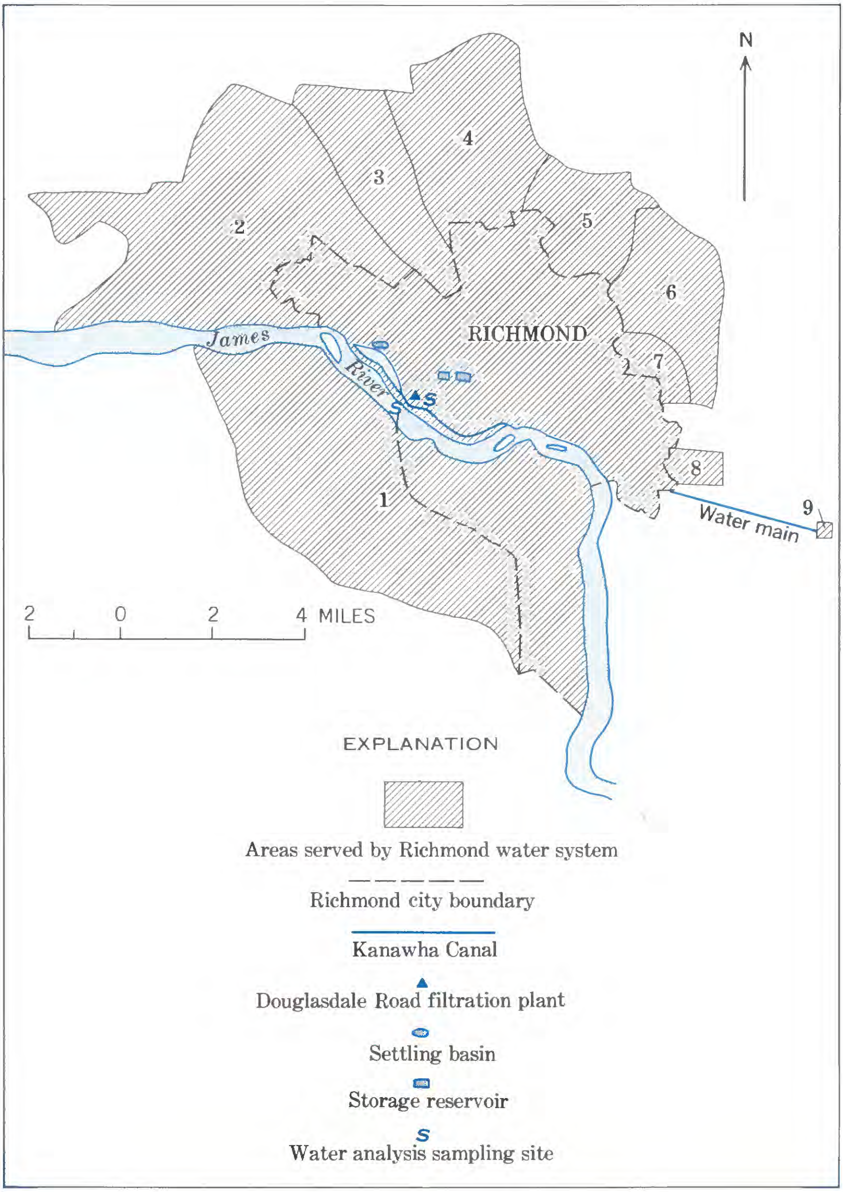

FIGURE 66.—Water supplies and areas served by Richmond, Va., water system. (Approved by local municipal water officials, February 1963.) Areas served by Richmond water system: 1, Contract area 1 (intermittently served); 2, Contract area A (Henrico Co. Sanitary District A); 3, Contract area 8; 4, Contract area 5 (Brookland, Sanitary District B); 5, Contract area 2; 6, Contract area 10; 7, Contract area 9; 8, Contract area 7; 9, Byrd Airport area.

Analytical data—Richmond

	James River	Douglasdale Road filtration plant		
Percent of supply	100	100		
Date of collection	1-16-62	1-16-62	(1)	(2)
Type of water: R, raw; F, finished	R	F	F	F

Chemical analyses

[In parts per million]

Silica (SiO_2)	9.5	8.9	6.5	5.0
Iron (Fe)	.01	.01	.07	.04
Manganese (Mn)	.01	.01	.31	.10
Aluminum (Al)	.0	.3		
Lithium (Li)	.0	.0		
Copper (Cu)			.16	.10
Calcium (Ca)	12	16	26	16
Magnesium (Mg)	2.5	2.9	5.6	2.0
Sodium (Na)	3.1	3.7		
Potassium (K)	1.0	1.3		
Phosphate (PO_4)	.1	.0		
Bicarbonate (HCO_3)	41	36	48	27
Carbonate (CO_3)	0	0	6	3
Sulfate (SO_4)	7.6	18	49	24
Chloride (Cl)	4.0	8.2	14	10
Fluoride (F)	.0	1.1	1.6	1.0
Nitrate (NO_3)	.8	1.1		
Dissolved solids (residue at 180° C)	70	85	153	79
Hardness as $CaCO_3$	40	54	73	49
Noncarbonate hardness as $CaCO_3$	6	25		
Specific conductance (micromhos at 25° C)	96	124		
pH	7.3	8.3	8.7	8.7
Color	5	2	5	1
Turbidity			0	0

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]

Beta activity		<6.0		
Radium (Ra)		<.1		
Uranium (U)		.2		

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)		<0.10		
Aluminum (Al)		140		
Boron (B)		11		
Barium (Ba)		26		
Beryllium (Be)		ND		
Cobalt (Co)		ND		
Chromium (Cr)		<.10		
Copper (Cu)		200		
Iron (Fe)		15		
Lithium (Li)		.42		
Manganese (Mn)		11		
Molybdenum (Mo)		ND		
Nickel (Ni)		<1.0		
Phosphorus (P)		ND		
Lead (Pb)		1.6		
Rubidium (Rb)		<1.0		
Tin (Sn)		ND		
Strontium (Sr)		18		
Titanium (Ti)		<.3		
Vanadium (V)		ND		
Zinc (Zn)		ND		

[1] Maximum value of constituents in quarterly composite of water analyses by the city of Richmond collected between July 1960 to June 1961.
[2] Minimum value of constituents in quarterly composite of water analyses by the city of Richmond collected between July 1960 to June 1961.

WASHINGTON

Seattle *Spokane* *Tacoma*

SEATTLE

(See fig. 67.)

Ownership: Municipal.
Other areas served: Kirkland, Houghton, Normandy Park, Tukwila, and 25 water districts.
Population served: Seattle, 557,087; total, about 734,739.
Source of supply: Cedar River and Tolt River.
Lowest mean discharge: Cedar River near Landsburg, Wash., for 30-day period in climatic water years (April 1–March 31) 1950–59: 102 mgd.
Average amount of water used daily in system during 1962: 103 mgd (U.S. Public Health Service, 1962c).
Treatment:

Lake Youngs purification plant: Ammoniation at first plant and chlorination at second plant, 1,000 feet down pipeline from first plant.

Secondary chlorination at all reservoirs, tanks, and standpipes in area served.

Rated capacity of treatment plants: Lake Youngs purification plant, 279 mgd.
Raw-water storage: Chester Morris Lake and Lake Youngs, 4,761 million gal.
Days of raw-water storage (storage, in million gal/average daily water used, in mgd): 46.
Finished-water storage: 385 million gal.
Days of finished-water storage (storage, in million gal/average daily water used in mgd): 3.7.

Regular determinations at Seattle Water Department Laboratory:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	26	39	18	7.4	7.6	7.0	20	30	14
Finished water	19	22	16	7.45	7.60	7.30	19	22	16

NOTE.—Raw-water analyses by U.S. Geol. Survey, July 1959 to June 1960; finished-water analyses by city of Seattle, two samples taken Oct. 25, 1960, and April 3, 1961.

Analytical data—Seattle

	Cedar River			Lake Youngs purification plant
Percent of supply	100			100
Date of collection	10-18-61	(1)	(2)	7-24-61
Type of water: R, raw; F, finished	R	F	F	F
Chemical analyses [In parts per million]				
Silica (SiO_2)	9.5	12	9.3	10
Iron (Fe)	.05	.22	.00	.00
Calcium (Ca)	7.0	11	5.5	6.5
Magnesium (Mg)	.3	1.3	.0	1.4
Sodium (Na)	1.9	1.8	1.3	1.6
Potassium (K)	.3	.5	.0	.1
Bicarbonate (HCO_3)	26	39	18	27
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	2.4	2.4	1.2	1.8
Chloride (Cl)	.5	2.0	.5	1.2
Fluoride (F)	.0	.2	.0	.1
Nitrate (NO_3)	.2	.6	.0	.1
Dissolved solids (residue at 180° C)	40	49	27	41
Hardness as $CaCO_3$	19	30	14	22
Noncarbonate hardness as $CaCO_3$	0	2	0	0
Specific conductance (micromhos at 25° C)	47	73	37	54
pH	7.4	7.6	7.0	7.5
Color	5	5	0	0
Temperature ° F	47	54	42	66
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]				
Beta activity				1.5
Radium (Ra)				<.1
Uranium (U)				<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]				
Silver (Ag)	0.05			<0.06
Aluminum (Al)	7.0			11
Boron (B)	7.0			8.3
Barium (Ba)	3.1			5.7
Beryllium (Be)	ND			ND
Cobalt (Co)	ND			ND
Chromium (Cr)	ND			.21
Copper (Cu)	1.1			25
Iron (Fe)	9.0			18
Lithium (Li)				<.06
Manganese (Mn)	2.6			4.5
Molybdenum (Mo)	ND			<.18
Nickel (Ni)	ND			1.1
Phosphorus (P)	ND			ND
Lead (Pb)	1.1			.8
Rubidium (Rb)				<.6
Tin (Sn)	ND			ND
Strontium (Sr)	2.6			8.3
Titanium (Ti)	.5			<.6
Vanadium (V)	ND			<1.8
Zinc (Zn)	ND			ND

[1] Maximum value of constituents in monthly analyses by the city of Seattle between July 1959 and June 1960.
[2] Minimum value of constituents in monthly analyses by the city of Seattle between July 1959 and June 1960.

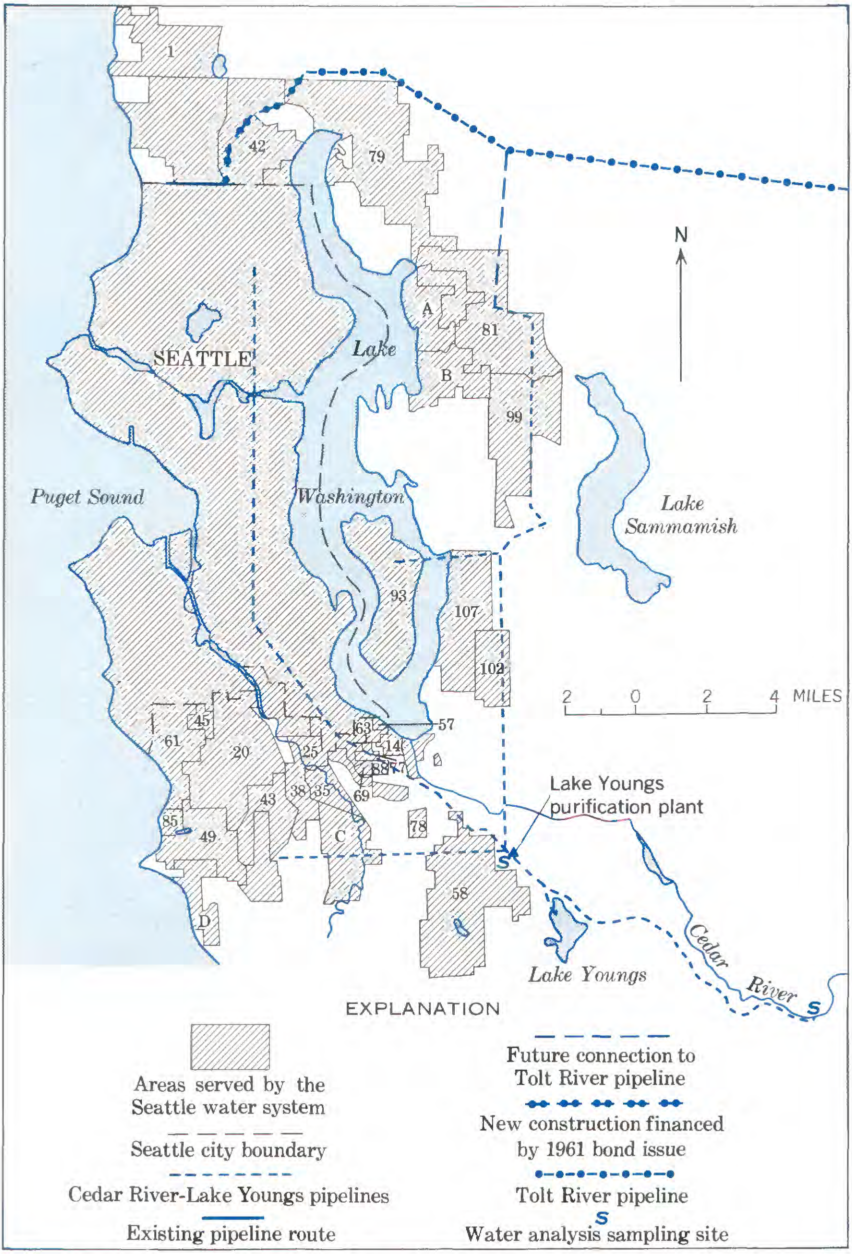

FIGURE 67.—Water supplies and areas served by Seattle, Wash., water system. (Approved by local municipal water officials, February 1963.) Water districts: 1, Yarrow; 14, Bryn Mawr; 20, Park; 25, Duwamish; 35, Foster; 38, Riverton Heights; 42, North City; 43, Riverton Heights; 45, White Center; 49, Burien; 57, unnamed; 58, Spring Glen; 61, White Center; 63, Lake Ridge; 69, Skyway; 77, unnamed; 78, Cedar River; 79, Kenmore; 81, Rose Hill; 85, Seahurst; 88, Skyway; 93, Mercer Island; 99, unnamed; 102, unnamed; 107, Factoria. Cities and towns: A, Kirkland; B, Houghton; C, Tukwila; D, Normandy Park.

SPOKANE

Owership: Municipal.

Population served: Spokane, 181,608; about 1,000 in minor housing developments adjacent to the city; total, about 182,600.

Sources and percentages of supply:

- Well Electric Pumping Station: Two wells, depth 45 feet, diameter 45 feet, dug 1921–25, 45 percent of supply.
- Parkwater Pumping Station: Eight wells, depth 140 feet, diameter 6 inches, dug 1948, 32 percent of supply.
- The following stations furnish 23 percent of supply:
  - Ray Street Pumping Station: Two wells, depth 75 feet, diameter 20 feet.
  - Hoffman Avenue Pumping Station: Two wells, depth 235 feet, diameter 5 feet.
  - Grace Avenue Pumping Station: One well, depth 124 feet, diameter 20 feet.
  - Baxter Pumping Station: Two wells, depth 126 feet, diameter 2 feet.
  - Nevada Street Pumping Station: One well, depth 122 feet, diameter 21 feet.
  - Central Avenue Pumping Station: One well, depth 272 feet, diameter 9 feet.

Average amount of water used daily in system during 1962: 68 mgd (U.S. Public Health Service, 1962c).

Treatment: Water chlorinated at all pumping stations.

Finished-water storage: 89.9 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 1.3.

Analytical data—Spokane

	Parkwater well 5	Electric well 2
Percent of supply	32	45
Depth of well (feet)	145	45
Diameter of well (inches)	72	----------------
Date drilled	1948	1921
Date of collection	7-26-61	7-26-61
Type of water: F, finished	F	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	12	12
Iron (Fe)	.00	.00
Calcium (Ca)	33	34
Magnesium (Mg)	16	16
Sodium (Na)	2.8	3.0
Potassium (K)	1.8	1.9
Bicarbonate (HCO_3)	166	168
Carbonate (CO_3)	0	0
Sulfate (SO_4)	15	14
Chloride (Cl)	1.5	2.0
Fluoride (F)	.1	.1
Nitrate (NO_3)	4.3	4.6
Dissolved solids (residue at 180° C)	162	162
Hardness as $CaCO_3$	150	150
Noncarbonate hardness as $CaCO_3$	14	13
Specific conductance (micromhos at 25° C)	292	294
pH	8.0	7.9
Color	0	0
Temperature °F	48	48
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than]		
Beta activity	----------------	3.1
Radium (Ra)	----------------	<.1
Uranium (U)	----------------	3.7
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	0.26	0.53
Aluminum (Al)	28	89
Boron (B)	13	25
Barium (Ba)	31	95
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	.62	9.5
Copper (Cu)	1.9	11
Iron (Fe)	12	15
Lithium (Li)	1.3	2.5
Manganese (Mn)	ND	<5.3
Molybdenum (Mo)	2.1	2.4
Nickel (Ni)	<2.6	<5.3
Phosphorus (P)	ND	ND
Lead (Pb)	<2.6	11
Rubidium (Rb)	ND	<5.3
Tin (Sn)	ND	ND
Strontium (Sr)	72	100
Titanium (Ti)	<2.6	ND
Vanadium (V)	ND	ND
Zinc (Zn)	ND	ND

TACOMA

Ownership: Municipal.

Population served: Total, 165,000.

Sources and percentages of supply: Green River impounded, 77 percent; wells, 23 percent (1960). Construction of Eagle Gorge Dam has resulted in the increased use of ground water. After construction activity ceases and the river quality returns to normal, about 94 percent of the supply will be obtained from the river and about 6 percent from wells.

Auxiliary and emergency supplies: Fourteen wells, ranging in depth from 74 to 788 feet; average yield from wells, 3,590 gpm.

Lowest mean discharge: Green River near Palmer, Wash., for 30-day period in climatic water years (April 1–March 31) 1951–59: 67.2 mgd.

Average amount of water used daily in system during 1962: 48.2 mgd (U.S. Public Health Service, 1962c).

Treatment: McMillan treatment plant—chlorination and ammoniation. Well 9A plant has a chlorinator on it. Other wells are pumped into the well pipe system, and the water is chlorinated before going into mains. All finished water resources have secondary chlorination facilities.

Rated capacity of treatment plant: 72 mgd.

Raw-water storage: Eagle Gorge Dam will provide for public supply a minimum river flow of 71 mgd.

Finished-water storage: Reservoirs, 310 million gal; standpipes, 2.5 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): 6.5.

Regular determinations at McMillan plant:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	18	26	14	7.2	7.5	6.9	15	22	11	6	78	0.3
Finished water				7.2	8.0	6.6				0	3.5	0

NOTE.—Raw-water analyses by U.S. Geol. Survey, July 1959–July 1961, with exception of turbidity, which was determined by city of Tacoma, January 3–November 20, 1961; finished-water analyses by Bennetts Chemical Laboratories, May 2–November 29, 1961.

Analytical data—Tacoma

	Treatment plant	Treatment plant
Percent of supply		94
Date of collection	1-4-62	12-6-61
Type of water: F, finished	F	F

Chemical analyses
[In parts per million]

Silica (SiO_2)	13	13
Iron (Fe)	.04	.01
Calcium (Ca)	5.0	4.5
Magnesium (Mg)	.8	.9
Sodium (Na)	2.3	2.7
Potassium (K)	.1	.3
Bicarbonate (HCO_3)	18	18
Carbonate (CO_3)	0	0
Sulfate (SO_4)	3.8	2.8
Chloride (Cl)	2.8	2.8
Fluoride (F)	.1	.1
Nitrate (NO_3)	.3	.3
Dissolved solids (residue at 180° C)	41	40
Hardness at $CaCO_3$	16	14
Noncarbonate hardness as $CaCO_3$	0	0
Specific conductance (micromhos at 25° C)	47	43
pH	6.9	7.0
Color	5	5
Temperature °F	41	41

Radiochemical analyses
[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

Beta activity	23	
Radium (Ra)	.2	
Uranium (U)	.2	

Spectrographic analyses
[In micrograms per liter. <, less than; ND, looked for but not found]

Silver (Ag)	<0.05	
Aluminum (Al)	20	
Boron (B)	6.4	
Barium (Ba)	1.7	
Beryllium (Be)	ND	
Cobalt (Co)	ND	
Chromium (Cr)	<.05	
Copper (Cu)	4.7	
Iron (Fe)	35	
Lithium (Li)	<.05	
Manganese (Mn)	4.5	
Molybdenum (Mo)	ND	
Nickel (Ni)	ND	
Phosphorus (P)	ND	
Lead (Pb)	<.5	
Rubidium (Rb)	ND	
Tin (Sn)	ND	
Strontium (Sr)	2.6	
Titanium (Ti)	.9	
Vanadium (V)	<1.5	
Zinc (Zn)	ND	

WISCONSIN

MADISON

Ownership: Municipal.

Other areas served: Maple Bluff and Shorewood Hills; about 4,400 people outside of the city are served.

Population served: Madison, 126,706; total, about 135,000.

Sources and percentages of supply: Nineteen deep wells, four of which are chlorinated, fluoridated, and pumped as a group at the Main Pumping Station. These four wells furnish, on the average, about 25 percent of the total supply. The remaining 15 wells are chlorinated, fluoridated, and pumped as individual units. These 15 wells are scattered throughout the city and pumped into the distribution system; each well supplies mainly its surrounding area. Some wells are pumped only during periods of high demand, and some are not pumped during the winter.

Average amount of water used daily in system during 1962: 17 mgd (U.S. Public Health Service, 1962c).

Treatment:

Main Station group plant (Main Station, Dayton Street, Low Service Reservoir, and East Well): Chlorination and fluoridation as a group.

Individual wells: Chlorination and fluoridation at each individual well.

Rated capacity of pumping stations: Main station group plant, 5 mgd; Unit Well 6 plant, 3.2 mgd; Unit Well 11 plant, 3.2 mgd; Unit Well 12 plant, 3.9 mgd.

Raw-water storage: 3.3 million gal.

Days of raw-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Finished-water storage: About 9.4 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Remarks: The quality of the water from the various wells varies considerably.

Analytical data—Madison

	Main Station wells	Unit well 6	Unit well 11	Unit well 12
Percent of supply	25	25	25	25
Depth of well (feet)	734	751	752	986
Diameter of well (inches)		24		24
Date drilled		1938	1956	1957
Date of collection	8-1-61	8-1-61	8-1-61	8-1-6
Type of water: F, finished	F	F	F	F

Chemical analyses

[In parts per million]

	Main Station wells	Unit well 6	Unit well 11	Unit well 12
Silica (SiO_2)	10	14	12	11
Iron (Fe)	.26	.07	.07	.02
Manganese (Mn)	.04	.02	.04	.04
Calcium (Ca)	60	64	48	60
Magnesium (Mg)	33	36	39	32
Sodium (Na)	4.0	3.1	3.1	2.2
Potassium (K)	1.2	1.3	1.3	1.0
Bicarbonate (HCO_3)	335	360	340	335
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	18	18	7.6	10
Chloride (Cl)	4.0	4.0	2.0	1.0
Fluoride (F)	.8	1.2	.8	1.0
Nitrate (NO_3)	.1	3.6	.7	.2
Dissolved solids (residue at 180° C)	299	343	285	286
Hardness as $CaCO_3$	285	308	281	281
Noncarbonate hardness as $CaCO_3$	10	12	2	6
Specific conductance (micromhos at 25° C)	528	580	509	498
pH	7.6	7.6	7.8	7.6
Color	1	1	0	1
Temperature °F	54	52	50	52

Radiochemical analyses

[Beta activity and radium in picocuries per liter; uranium in micrograms per liter]

	Main Station wells	Unit well 6	Unit well 11	Unit well 12
Beta activity	28			
Radium (Ra)	1.0			
Uranium (U)	.5			

Spectrographic analyses

[In micrograms per liter. <, less than; ND, looked for but not found]

	Main Station wells	Unit well 6	Unit well 11	Unit well 12
Silver (Ag)	<0.5			
Aluminum (Al)	42			
Boron (B)	21			
Barium (Ba)	30			
Beryllium (Be)	ND			
Cobalt (Co)	ND			
Chromium (Cr)	5.8			
Copper (Cu)	3.6			
Iron (Fe)	330			
Lithium (Li)	.74			
Manganese (Mn)	48			
Molybdenum (Mo)	ND			
Nickel (Ni)	8.5			
Phosphorus (P)	ND			
Lead (Pb)	7.4			
Rubidium (Rb)	ND			
Tin (Sn)	ND			
Strontium (Sr)	48			
Titanium (Ti)	ND			
Vanadium (V)	ND			
Zinc (Zn)	ND			

MILWAUKEE

Ownership: Municipal.

Other areas served: Fox Point, Shorewood, West Allis, West Milwaukee, and Whitefish Bay; about 114,895 other people outside the city limits are served. (Fox Point and Whitefish Bay will soon have their own water plants.)

Population served: Milwaukee, 741,324; total, about 867,084.

Source of supply: Lake Michigan: the intake is about 5 miles north of Milwaukee Harbor.

Average amount of water used daily in system during 1962: 143 mgd (U.S. Public Health Service, 1962c).

Treatment:

Linnwood Avenue purification plant: Prechlorination, coagulation with alum sedimentation, rapid sand filtration, postchlorination, ammoniation, and fluoridation.

Howard Avenue purification plant: A new plant having a capacity of about 100 mgd is being built at Howard Avenue.

Rated capacity of treatment plants: Linnwood Avenue purification plant, 200 mgd.

Finished-water storage: 99 million gal.

Days of finished-water storage (storage, in million gal/average daily water used, in mgd): Less than 1.

Regular determinations at Linnwood Avenue purification plant, 1960:

	Alkalinity as $CaCO_3$ (ppm)			pH			Hardness as $CaCO_3$ (ppm)			Turbidity		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Raw water	108	120	101	8.1	8.7	7.6	131	138	128	3.7	38	0.1
Finished water	98	106	90	7.5	7.9	7.0	131	138	128	.0	.2	.0

Analytical data—Milwaukee

	Lake Michigan	Linnwood Avenue purification plant
Percent of supply	100	100
Date of collection	8-2-61	8-2-61
Type of water: R, raw; F, finished	R	F
Chemical analyses [In parts per million]		
Silica (SiO_2)	2.1	1.2
Iron (Fe)	.04	.01
Manganese (Mn)	.00	.00
Calcium (Ca)	35	35
Magnesium (Mg)	10	10
Sodium (Na)	4.1	4.1
Potassium (K)	1.0	1.0
Bicarbonate (HCO_3)	134	122
Carbonate (CO_3)	0	0
Sulfate (SO_4)	19	27
Chloride (Cl)	6.5	8.5
Fluoride (F)	.1	.7
Nitrate (NO_3)	.4	.3
Dissolved solids (residue at 180° C)	159	162
Hardness as $CaCO_3$	129	129
Noncarbonate hardness as $CaCO_3$	18	28
Specific conductance (micromhos at 25° C)	258	267
pH	8.0	7.2
Color	1	1
Temperature °F	68	68
Radiochemical analyses [Beta activity and radium in picocuries per liter; uranium in micrograms per liter; <, less than. Maximum beta activity data from U.S. Public Health Service, 1962]		
Beta activity		2.9
Maximum beta activity, raw water, July 1, 1961, to June 30, 1962	12	
Radium (Ra)		<.1
Uranium (U)		<.1
Spectrographic analyses [In micrograms per liter. <, less than; ND, looked for but not found]		
Silver (Ag)	<0.24	<0.25
Aluminum (Al)	38	150
Boron (B)	29	30
Barium (Ba)	36	37
Beryllium (Be)	ND	ND
Cobalt (Co)	ND	ND
Chromium (Cr)	3.6	35
Copper (Cu)	57	59
Iron (Fe)	26	18
Lithium (Li)	.43	.89
Manganese (Mn)	2.4	2.7
Molybdenum (Mo)	1.1	1.3
Nickel (Ni)	4.0	2.5
Phosphorus (P)	ND	ND
Lead (Pb)	26	4.0
Rubidium (Rb)	ND	ND
Tin (Sn)	ND	ND
Strontium (Sr)	81	100
Titanium (Ti)	<2.4	<2.5
Vanadium (V)	ND	ND
Zinc (Zn)	ND	ND

U.S. GOVERNMENT PRINTING OFFICE; 1964—O-735-717