WATER IN GEORGIA

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Report based mainly on work accomplished cooperatively with the Georgia Department of Mines, Mining, and Geology, with the Georgia Highway Department and with other Federal agencies

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Introduction

A Tourist's View of Water in Georgia

Tourists who passed through many south Georgia towns during August 1954 were puzzled by the frequent appearance of farm trucks loaded with water tanks and water barrels. Had they been traveling through parts of the arid Western States, such sights would not have been unusual, but they did not expect to see them in humid Georgia. Their amazement at such unusual conditions was a normal reaction to the severity of Georgia's 1954 drought. The statewide loss from crop failure alone during 1954 was estimated at 75 million dollars.

Newspaper headlines such as SOUTH GEORGIA RIVERS, STREAMS TERRIBLY LOW and GEORGIA RIVERS LOWEST SINCE '25! featured the drought of 1954. If a tourist's impression of water in Georgia had been formed solely by what he saw on the highways and read in the newspapers during the summer of 1954, it would have been an entirely false one. The 1954 drought was a rare event, as the tourist might have surmised from the headline that implied it was the most severe water shortage since 1925. During normal years, Georgia has abundant water supplies and even during the severe drought water was readily available underground, at little cost, at many of the farms where water was hauled by truck.

If the tourist stopped overnight in one of Georgia's cities he found little evidence of drought conditions. Excellent water was, as usual, freely available at a turn of a faucet. If he had been perplexed at the sight of some farmers hauling water, he understandably may have wondered how the city supply seemed normal while farm supplies were nil.

The tourist's speculations underscore the complexity of the water situation in Georgia. An understanding of it requires a much more complete knowledge of the variable nature of water in Georgia than can be gained by one or two chance observations or by reading a score of water-news items. Water varies with time and place in response to natural controls. A thorough study of water in Georgia must start with rainfall—the primary source of it all.

Georgia's Water Environment

The Hydrologic Cycle

At one time or another almost everyone has been forced to take shelter from a downpour of rain. While waiting for the rain to stop, you may observe many of nature's water controls in action. During the first few minutes of intense rain, much of the rainfall soaks into the ground. If the intense fall continues, small puddles of rainwater form in ground depressions and, if the rain is prolonged, the puddles grow and begin to drain over the ground.

After the rain stops, you may notice that small field ditches are flowing, that weeds and brush are dripping wet, and that the soil is soft, perhaps muddy (fig. 1). Nature's controls are working, unseen, on that part of the rain that soaked into the ground. The soil will keep some water, for a while, to satisfy the demand for soil moisture. If the soil moisture is already high, as it may be during winter, some unseen water will move slowly downward through the soil layer and underlying material. Eventually, under conditions that exist in much of Georgia, the downward-moving water will reach a zone of rock that is saturated with water. The top of this zone is the local water table. Water can be recaptured from the zone of saturation by wells dug or drilled into it.

FIGURE 1.—How rain reaches the water table.

The total rainfall is apportioned by natural controls as follows:

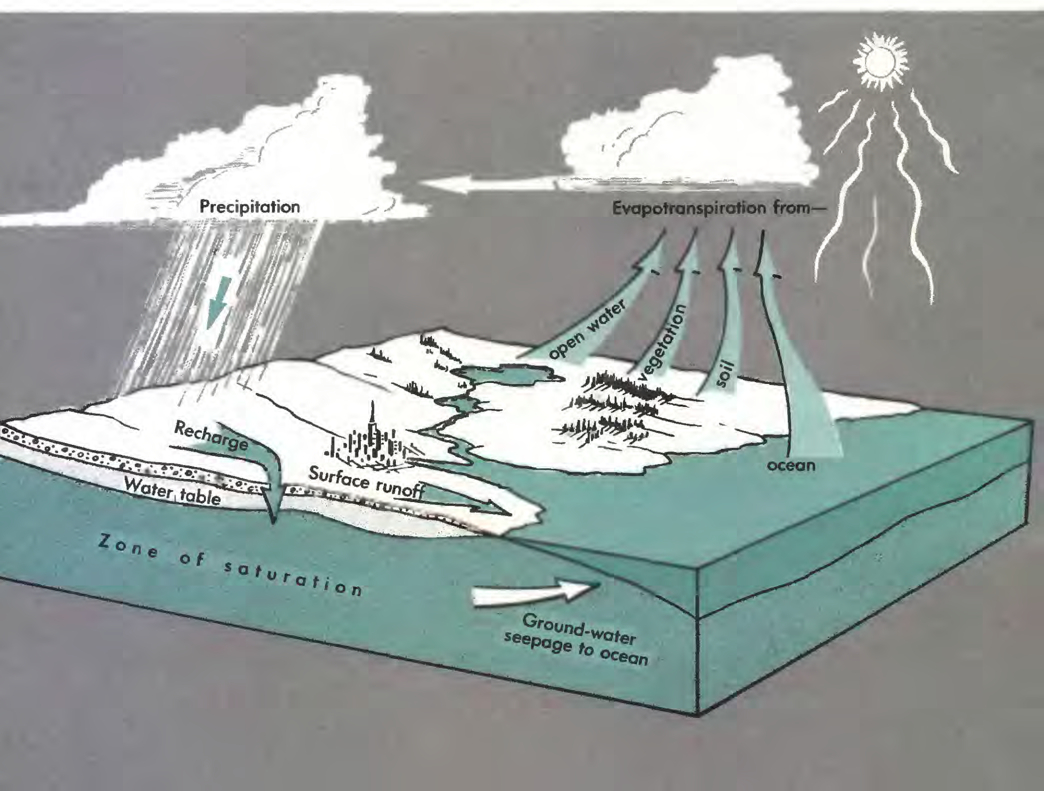
1. Water temporarily held on vegetation and on top of ground. This water eventually returns to the atmosphere by evaporation.
2. Water that runs off over the ground and eventually reaches the streams that drain the area.
3. Water that soaks into the soil, some to be used later by plants, some to evaporate from the soil, and some to travel downward to reach the local water table.

The relative amounts of water in each of the foregoing portions vary with location, season, and the amount and intensity of rain. On the average, about 70 percent of annual rainfall in Georgia is returned to the atmosphere and about 30 percent eventually flows into the ocean. In general, the latter portion is the water that can be managed for man's benefit.

Water follows an endless cycle from the ocean to the sky, to the land, and back again to the ocean. This phenomenon is called the hydrologic cycle. As shown in figure 2, the sun furnishes powers for this huge cycle by evaporating water from the sea and setting up atmospheric currents that result from unequal heating of the earth's surface. Acting with forces caused by the rotation of the earth, the unequal heating causes winds that carry the salt-free vapor over the land, where it is cooled and falls as rain or snow.

Part of the water returned to the atmosphere from soil moisture is used by vegetation. The transfer of water from soil to plants to air, called "transpiration," involves a tremendous volume of water. A single acre of corn transpires more than 3,000 gallons of water per day. A large oak tree transpires 40,000 gallons of water per year—roughly

FIGURE 2.—The hydrologic cycle.



equal to the annual amount of water used per person in a modern Georgia city. When we visualize the thousands of acres of farm crops and the millions of trees in the State we can understand how the total yearly transpiration exceeds the total yearly water use by industry and people.

Evaporation from inland water surfaces, such as rivers, swamps, and lakes, is another way that nature returns water to the atmosphere. Artificial lakes and ponds for storing water increase the natural water loss which occurs through evaporation. Thus, each reservoir we build pays an "evaporation toll" in return for the benefits obtained.

Rainfall

Rainfall is the primary source of all Georgia's water. The water in Lake Lanier and the water flowing from Albany's artesian wells come from rain. The lake water

FIGURE 3.—Average annual precipitation, in inches, in Georgia. (Adapted from map prepared by the U.S. Weather Bureau in the Weekly Weather and Crop Bulletin.)

FIGURE 4.—Map showing locations of the Fall Line in Georgia.

may have reached the earth as rain only a short time ago; the artesian waters may be rain water that has moved underground for years. Variations in the flow of streams and in the water levels of wells reflect variations in rainfall.

Rainfall in Georgia averages about 50 inches a year; it is generous, but it is not uniformly distributed by season or location. The Augusta area annually receives about 43 inches—a small area in the mountains of northeastern Georgia receives nearly twice that amount. Average annual rainfall in Georgia (fig. 3) varies between these two extremes. Most of Georgia's rainfall comes from warm moist air masses that formed over the Gulf of Mexico. Lesser amounts of rainfall come from air masses that formed over the Atlantic Ocean. Average annual rainfall decreases with distance from the Gulf of Mexico and the Atlantic Ocean up to the Fall Line. The Fall Line is the discernible geologic break between the "hard rock" hills of the Piedmont and the more easily eroded rock of the coastal plain (fig. 4). The Fall Line, which parallels the eastern seaboard, is marked by steep cliffs, waterfalls, and rapids.

Average annual rainfall increases north of the Fall Line because the moist air is forced to rise, and it precipitates moisture as it passes over the mountains.

There are seasonal variations, too—more rain falls in winter, early spring, and mid-summer than in May and June or in the usually dry months of October and November.

Average annual rainfall data, shown on figure 3, are useful for measuring the variation of rainfall in any specific year. Actually, the annual rainfall at a given point varies widely between extremes of drought and excess. The uneven time distribution of rainfall causes a water-supply problem. Rainfall may not occur during critical periods of the growing season, yet may be excessive during winter months of the same year. An obvious solution of the problem is storage of excess winter rain in reservoirs, for use in the dry summer.

FIGURE 5.—Average annual runoff, in inches, in Georgia.

Runoff

The water that collects in streams and flows to the sea is called "runoff." If no change occurs in the amount of water stored above and below ground, runoff is the difference between rainfall and the amount of water evaporated and transpired. Thus, runoff is a residual; it varies more from year to year than does the annual rainfall. Streams may be extremely low or completely dry during severe droughts, or may overflow their banks when heavy rains occur. Figure 5 shows the average annual runoff in Georgia in terms of its equivalent in inches of water on the area drained. Some similarity may be noted between the average annual runoff map and the average annual rainfall map. However, there are some marked differences between the two such as, for example, the "mound" of high annual runoff in west central Georgia where an annual runoff of 25 inches occurs in an area where annual rainfall is about 50 inches. The difference, 25 inches, is attributed to evapotranspiration (evaporation plus transpiration). Elsewhere in the State, annual evapotranspiration appears to vary from about 30 to 42 inches. The significantly lower evapotranspiration in the small area of west central Georgia is caused by the porous nature of the soil, which permits a high rate of rainfall intake. The water taken into the soil rapidly moves downward to the local water table and is protected from evaporation. Water thus stored is slowly released to sustain the local streams.

The records of flow of two nearby streams during the 1954 drought show some interesting differences. The June to November 1954 daily flows of Whitewater Creek above the U.S. Geological Survey stream gage near Butler and of Flint River above the gage near Griffin (figs. 6 and 7), show that, although the two drainage areas received about the same rainfall, the flow of Whitewater Creek varied only slightly, but the flow of Flint River varied widely. Flint River was much more sensitive to rainfall than was Whitewater Creek. The long-term monthly average flows show

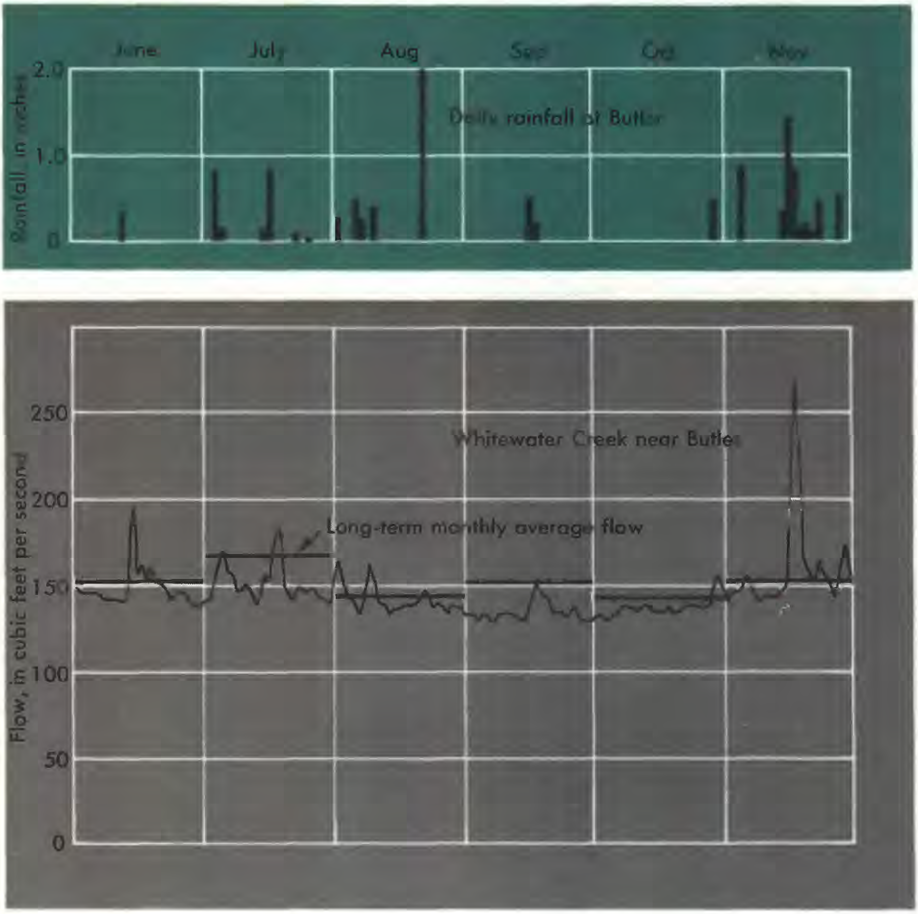


FIGURE 6.—Variation of rainfall and streamflow, Whitewater Creek near Butler, June to November 1954.

further that Flint River is sensitive to rainfall but that Whitewater Creek remains quite uniform.

All other natural controls on runoff being equal, a larger drainage area produces more flow than a smaller one. It might be concluded that Whitewater Creek has a large drainage area and Flint River a small one, but the fact is that Flint River above Griffin gage has an area of 272 square miles, roughly three times the area of Whitewater Creek above Butler, which is 93 square miles. Yet, Whitewater Creek maintains higher average flows in September and October than the Flint River. In the severe drought year of

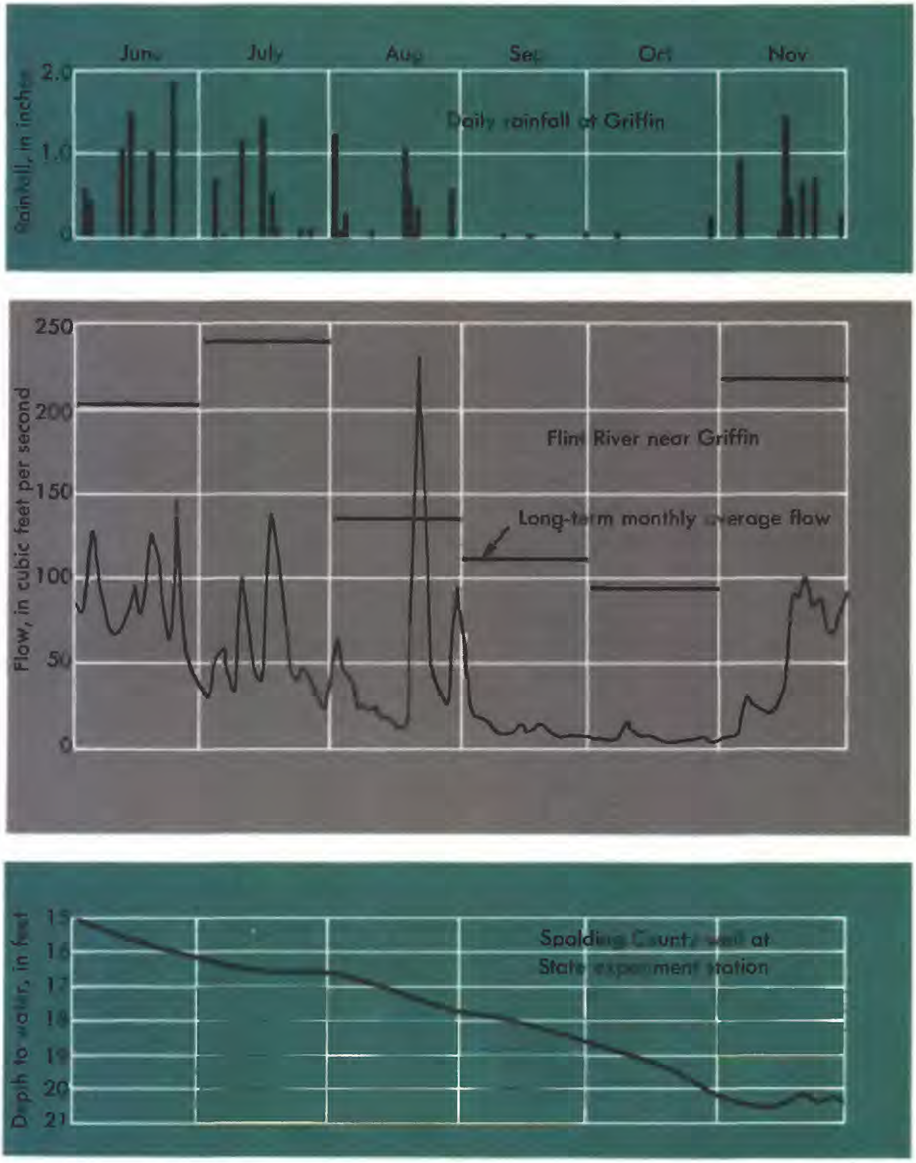


FIGURE 7.—Variation of rainfall, streamflow, and water levels in Flint River basin above Griffin, June to November 1954.

1954, Whitewater Creek maintained flows near the averages for those months while the Flint River flows dropped to only 5 to 10 percent of the averages.

Why does Whitewater Creek show such amazing yield of runoff in comparison with the Flint River? It is because of the different geologic formations on which the two drainage areas lie. Flint River drains from an area of soils formed from crystalline rocks; these are very dense rocks that have only a moderate capacity to soak up water. The sensitivity to rain and the low yield of Flint River above Griffin gage are related to the impermeable soil of its drainage area. The opposite extreme—a sandy, porous soil that readily lets water enter and travel downward—explains Whitewater Creek's abundant yield and steadiness of flow. The soil readily passes rain through to the local water table underlying the drainage area. The entrenched channel of Whitewater Creek receives seepage from the water table along the Creek's course, and this nearly steady contribution of ground water makes the flow of Whitewater Creek almost ideally uniform.

We have compared these two streams because the comparison illustrates an important hydrologic principle: the soil cover and geology of an area determine the amount of each rainstorm that will either run off or seep into the ground. Runoff reaches a stream in two ways: it may flow over the ground surface, or it may travel underground through soil layers and finally seep into a stream through the zone of saturation beneath the water table. The day-to-day flow of any stream is therefore a mixture of direct runoff and seepage flow, or base flow, as it is called. After a long rainless period, the flow of a stream may be entirely base flow.

Figure 7 illustrates also the close relation of ground water to surface water. The water level of Spalding County Well (in the Flint River drainage) steadily declined during the 1954 drought. Part of the decline represented the drainage of ground water to the Flint River for sustaining the base flow of the stream.

Average annual runoff, as shown in figure 5, is an excellent index to the water-potential of Georgia; it has a characteristic monthly distribution and it varies with rainfall and with the seasonal demands of vegetation. Although monthly rainfall is roughly uniform, the amount of runoff declines as the amount of evapotranspiration increases. At the end of the growing season, the relation is reversed and the runoff increases as the evapotranspiration decreases; runoff reaches a high in winter. The normal variation in monthly runoff—low streamflow in summer and high flow in winter—calls for reservoir storage of the winter flows to supplement summer flows whenever the latter are inadequate to meet demands.

To water users and water planners, the minimum flow of a stream is more important than its average flow. Most important of all is the frequency of low-flow conditions. A community may endure infrequent water shortages, but refuse to tolerate annual shortages. To obtain information on the flows, the U.S. Geological Survey maintains continuous records of many of the rivers in the State.

Although large municipal and industrial supplies are pumped from the rivers, many smaller supplies depend on ground water. Towns of a few thousand people usually have one or more drilled wells, and many small industries in these towns have privately developed well fields. The rural population depends on springs and dug and drilled wells. Most of these springs and wells furnish water during droughts, although some have gone dry or failed to supply sufficient water. The most probable time for a well to fail is during a summer drought when demand is highest. The water level gradually falls and the well yields less water than formerly. When wet-weather conditions return, the water level recovers and the wells once again supply the quantity of water needed.

Quality of Water

Just knowing that water is available and how much is needed does not provide a complete picture of our water resources. Other characteristics of water must be considered in the selection of a water supply. The development of cities, the establishment and expansion of industries, and the productive yield of farms have been limited at some places by the quality, as well as by the quantity, of available water. The chemical composition of water and its sediment characteristics and bacterial contamination, if any, all affect its suitability for use.

Water approaches chemical purity only as a vapor or as rain. Even then, nitrogen, oxygen, and carbon dioxide, as well as minute particles of industrial wastes and ocean salts, are carried by rain drops.

Water is dynamic; not only does it move, but the material that it carries in solution and suspension changes constantly. Given sufficient time and proper conditions, most materials known can be dissolved in water. The length of time required for solution depends on the material and on the water. For example, large amounts of sugar will dissolve in water in a relatively short time, but bits of limestone or commercial fertilizer on the farmer's field would take weeks or months. Quartz sand would require thousands of years for solution.

The capacity of water to dissolve materials is enhanced by the presence of other materials and by temperature changes. If the sugared water is heated, the sugar will dissolve more quickly. Iodine is barely soluble in distilled water. The addition of potassium iodine to this water, however, will increase the solubility of the iodine severalfold.

The quality of water is determined partly by the type of soil or rock on which the rain falls. As the water drains away or seeps into the ground, it dissolves some minerals which then travel in solution. When the water evaporates, the salts remain behind. Only pure water returns to the atmosphere. The result is a temporary concentration of salts on or near the soil surface. Flushing of these salts by heavy rainfall may carry them to nearby streams and alter the quality of water considerably during the periods of runoff.

The sand, silt, and clay carried in suspension by surface streams are collectively called "sediment." The amount of sediment carried into a stream is governed by several factors, such as the amount of material available, the slope of the runoff area, and the intensity of rainfall. When any one governing factor is altered, the sediment load of the stream is altered.

The amount of sediment a stream can carry is limited, and a change in stream course may cause the deposition of material. The shifting sand bars that plagued the Mississippi steamboat pilots are examples of such deposition.

The size of the sediment particle is also an important factor in determining the load a stream can transport. The larger the particles, the greater the force or velocity required to hold them in suspension. Thus, at the head of a reservoir, where velocity of the stream is lowered, the larger particles of gravel and sand are deposited first. Finer materials are carried farther into the reservoir. Some of the finest material, clay for example, may remain in suspension for days before settling, or may pass through the reservoir without settling. Paradoxically, a sediment-free stream flowing from a reservoir may create problems. If its velocity is sufficient, the clear water may erode streambed and banks for a considerable distance downstream from the reservoir—or to the point where the stream's load of sediments is more nearly in equilibrium with its capacity to carry sediment. Deposits of sediment gradually build up in reservoirs and reduce the storage capacity. For municipal and for many industrial uses, sediment in the water must be removed.

Streams provide a favorable environment for many kinds of bacterial and microscopic life. Some bacteria in streams are harmless, but others, such as those that come from human wastes, cause serious epidemics. Typhoid fever, dysentery, and cholera are only a few of the water-borne diseases that once plagued America. About 1850, scientists in Europe showed conclusively that these dreaded diseases were mainly water-borne; by about 1900 most large cities in the United States were treating water supplies to prevent transmission of disease via the city water. However, the struggle to make water supplies safe from disease has been long and difficult. Only continued vigilance ensures safe water supplies and prevents the outbreak of water-borne diseases.

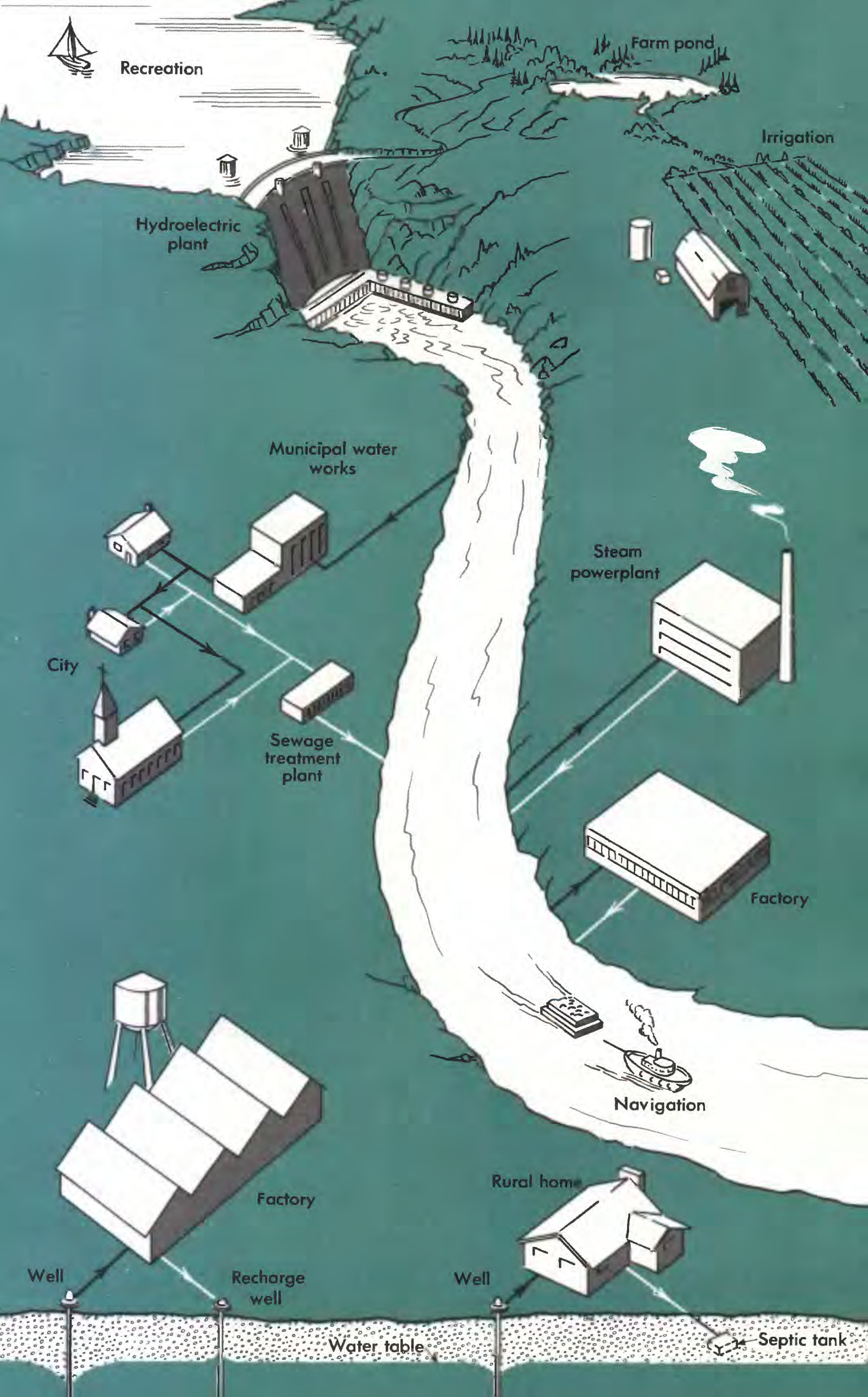
How Water Is Used in Georgia

Withdrawal and Consumptive Use

Most of the water that Georgia receives as rain is used in some way (fig. 8). A large quantity is absorbed by forests, pastures, and farm crops. About one-third of the average annual rainfall flows out of the State in the rivers—after much use has been made of it. Even the water that evaporates from land and water surfaces and the water that discharges from aquifers under the ocean may not have completely escaped use, although in all probability most of it was never used.

The average daily withdrawal use of water in Georgia is shown in figure 9: nearly 44 billion gallons. Use by the State's 42 hydroelectric plants far exceeded all other uses. Industry is the second largest user of water. In addition to water from sources developed by private capital, industry uses between 30 and 50 percent of the water furnished by city water systems. The water for farm supplies, irrigation, and city supplies is but a small fraction of the total used in Georgia.

FIGURE 8 (opposite page).—The many uses of water.



Recreation
Farm pond
Irrigation
Hydroelectric plant
Municipal water works
Steam powerplant
City
Sewage treatment plant
Factory
Navigation
Rural home
Factory
Well
Recharge well
Well
Water table
Septic tank

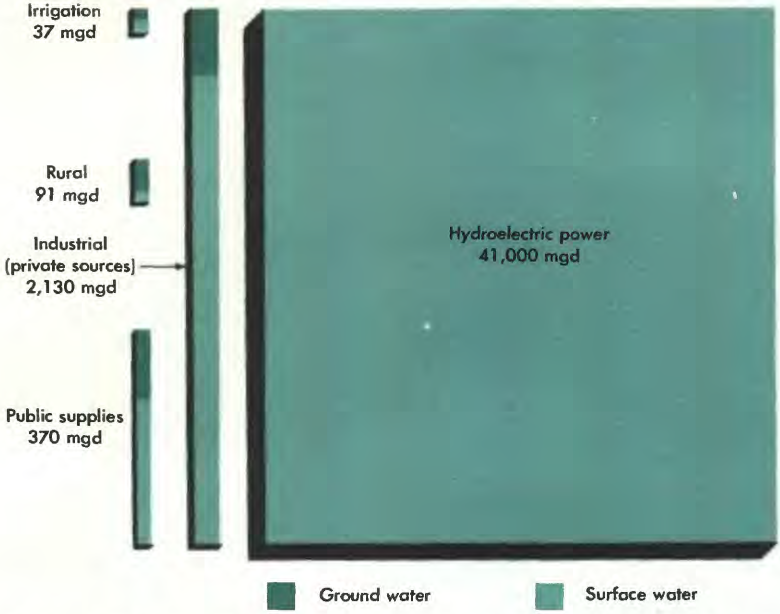


Figure 9.—Average daily withdrawal water use, in million gallons per day, in Georgia, 1960.

Many uses of Georgia's water are not portrayed in figure 9. Navigation, recreation, waste disposal, and conservation of fish and wildlife all require water, but measuring these uses in terms of gallons per day is almost impossible. The water uses shown in figure 9 are termed "withdrawal" uses. The other uses are nonwithdrawal; that is, the water is not withdrawn but is used in the stream or lake where it occurs.

Much of Georgia's industrial use of water is for cooling. Of the 2,130 mgd (million gallons per day) withdrawn from private sources by industry, 1,720 mgd was used to cool condensers at steam powerplants. The total use of water at steam and hydro plants to generate electricity was 98 percent of all withdrawal uses. Most of these withdrawals are returned to the source and are available for further use. Thus, the present use of water in Georgia has an insignificant effect on the quantity available.

Figure 10 shows where the major users of river water are located in relation to minimum supply. Note that only a few users of river water require more than the minimum daily flow expected, on the average, once in 20 years.

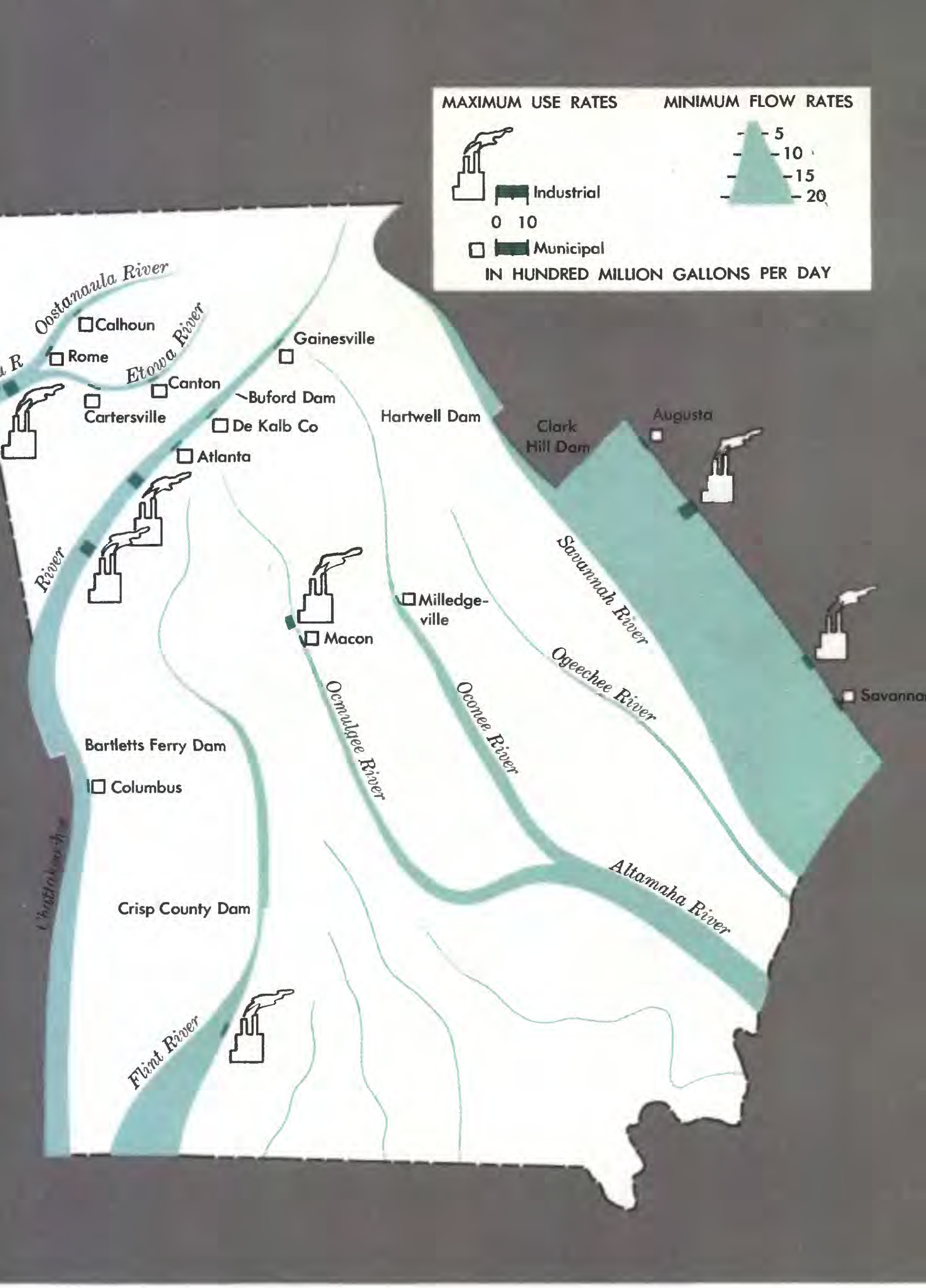


FIGURE 10.—Maximum rates of use of river water, in million gallons per day, in relation to minimum flow rate.

Fortunately, water is not destroyed in use. Most of the water used in homes and industries is discharged to rivers and streams by way of sewers and treatment plants, and becomes available for reuse downstream. Such uses are nonconsumptive. Our biggest use of water—to generate hydroelectric power—is entirely nonconsumptive. Thus, the total of our uses is not directly comparable to the supply available. In comparing the amount of water used with the supply, total use is of less significance than consumptive use. In consumptive use, water is evaporated, transpired by plants, or incorporated into a product and is no longer available for reuse. Only a small part of Georgia's water use is consumptive. Water used for irrigation, especially sprinkler irrigation, is largely "consumed" by evaporation and transpiration.

Although the sum of all withdrawal uses of water exceeds the average supply of 39,000 mgd by about 10 percent, consumptive use—the use that actually depletes the supply—equals less than one-half of one percent of the average supply. Does this mean, then, that we have plenty of water to meet our needs? Yes, it does—as far as totals and averages are concerned. We have seen, however, that the supply of water is not uniformly distributed with respect to time and place. Often our demands for water are greatest when the supply is at a minimum. For example, we draw heavily on our supplies to water lawns and gardens in the summer and early fall when streams and ground-water levels are apt to be low. On the other hand, during winter months when water is abundant, much of it escapes before we can use it. We have plenty of water, but not always when and where we want it. We must devise ways of distributing water so it will serve us best.

Water for Cities and Towns

To most of us, the water we use means first and foremost the water that is piped into our homes—the water we use for drinking, cooling, washing, flushing the toilet, and watering the lawn. Individually, we use between 20 and 80 gallons of water per day for these purposes. It takes 20 to 40 gallons of water to take a shower or a tub-bath, 5 to 10 gallons to flush the toilet. The average family of five uses 250 gallons of water per day. In a year, this amounts to almost 100,000 gallons, enough to fill a fair-sized swimming pool.

Two out of every three Georgia families get their water from a public supply system. The public system not only furnishes water for our homes, but also water for fighting fires and washing streets, for business establishments and for some industries. About half the water distributed by the average public supply system is delivered to homes; the rest provides for public, commercial, and industrial needs.

Altogether, Georgia public supply systems furnished an average of 370 mgd in 1960—161 gallons per person served. This quantity is not large compared to most other water uses in Georgia, or compared to the 10,000 gallons-per-person available. However, we usually rate the need for an adequate and unfailing supply of pure water for our communities above all other needs.

The water requirements of a community vary from month to month, day to day, and even from hour to hour. The number of showers we take, the number of times we water the lawn, the working hours in factories, and the number of fires are only a few of the many factors which cause water demands to fluctuate. As might be expected, we use more water in summer than in winter. In most Georgia communities, the maximum amount of water used in any one day in a year is about 50 percent greater than average daily demand. Peak demands during part of a day are at a much higher rate. Water-supply systems must, of course, be capable of meeting maximum as well as average needs. Where they are not, water pressure becomes low and cities are sometimes forced to prohibit watering lawns or washing cars during the hours of peak demand. Such "shortages" are usually caused by the limitations of the water-supply system rather than by an inadequate source of supply.

Three-fourths of all Georgia communities use well or spring water that constitutes 26 percent of the water withdrawn for public supplies. The other communities, in general the larger ones, obtain their water from streams and withdraw 74 percent of the total. In northern Georgia,

PUBLIC-WATER-SYSTEM PUMPAGE, IN MILLION GALLONS PER DAY
50
from streams
25
from wells
0
Dalton
Summerville
Colhoun
Rome
Cartersville
Cedartown
Atlanta
Carrollton
Toccoa
Gainesville
Gwinnett Co
Athens
De Kalb Co
Cobb Co
Monroe
Clayton Co
East Point
Newnan
Augusta
Griffin
Milledgeville
State Hospital
Sandersville
La Grange
East Thomaston
Macon
Columbus
Warner Robins
Dublin
Statesboro
Vidalia
Savannah
Americus
Cordele
Fitzgerald
Albany
Tifton
Douglas
Brunswick
Pelham
Moultrie
Waycross
Bainbridge
Thomasville
Valdosta

most supplies are obtained from streams, but on the Coastal Plain all supplies but one are from wells. This difference is quite understandable because, as we have seen, streamflow is more dependable in northern Georgia than in southern Georgia, and ground water is much more abundant in the Coastal Plain than in the northern part of the State.

Most of the approximately 450 public water-supply systems in Georgia are small—90 percent of them pumped less than a million gallons per day in 1960. The 10 percent that pumped more than a million gallons per day are shown on figure 11. These systems pumped over 80 percent of all water supplied by municipal plants. The pumpage rates shown are average—peak pumpage rates are often one and a half, or more, times the average.

Water for Waste Disposal

All of us dislike using streams for sewers. We would like to keep our streams pure and sparkling—free of pollution of all kinds. However, the transportation and dilution of wastes constitutes major and indispensible functions of streams. Most water used in city water systems is discharged to a stream as waste water. Untreated waste water is polluted. Completely treated waste water is as pure (except for an increase in salt content) as the city water supply. However, complete waste treatment is expensive and is not always necessary.

Every stream has a certain capacity to dispose of sewage and other wastes by natural processes. A stream, in effect, provides a natural sewage-treatment plant if the pollution load does not exceed the self-purification capacity of the stream. Problems begin when the pollution load is greater than the stream can handle. Good management of our streams to keep them clean, then, depends on keeping quantities of wastes below the self-purification powers of streams.

Man-made waste is either organic or inorganic. The organic wastes are a problem for they deplete oxygen in streams

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FIGURE 11 (opposite page).—Location of public water systems that supplied more than 1 million gallons per day in 1960.

during the natural self-purification process. The principal sources of organic wastes are: cities, canneries, packing houses, and pulp mills.

Oxygen dissolved in streams is a vital factor in the self-purification process by which a stream "treats" organic wastes. The micro-organisms that act on the wastes in a stream are of two general types: oxygen consuming (aerobic) and nonoxygen consuming (anaerobic). The nonoxygen-consuming type flourishes under stream conditions which we find objectionable and, because we are very much interested in keeping the aerobic organisms alive, we try to keep enough oxygen in the stream so they can thrive and work on the wastes and so fish can live. Proper regulation of waste disposal in a stream depends on a knowledge of the dissolved oxygen in the stream and the biochemical oxygen demand of the wastes. The dissolved oxygen should not fall below about 4 parts per million if fish are to be protected.

Inorganic wastes, such as acids, cyanides, brines and the like are directly toxic. In excess, they can kill life and make water unfit to drink. Inorganic wastes include also silt, mineral tailings, and other solids carried in suspension.

In 1958, the U.S. Public Health Service listed 262 sources of pollution in Georgia which "are of significance in water pollution control programs." Of these sources, 240 were municipal sewage systems, 10 were industrial plants and the remaining 12 were schools, hospitals, and military establishments. Not all these sources polluted streams; 185 of them applied some type of treatment before disposing of their wastes in streams. Treatments ranged from simple processes for removal of solids to processes that produced an effluent with no biochemical oxygen demand. Of the 77 sources of pollution in the State which applied no treatment, 69 were municipal, 6 were industrial. and 2 were institutional.

Between 1954 and 1956, several Georgia organizations sponsored public meetings throughout the State to collect information on local water problems. Among the many and varied problems cited by farmers and townspeople were those involving pollution of streams and lakes; many, but not all, of these problems were the result of waste disposal. Typical of some of the problems cited is one from Pierce County: "* * * Sewage entering the Alahaba River caused a fish kill which destroyed both game and rough fish; at the time of the kill, it was estimated that sewage constituted 30 percent of the flow of the river at the sewer outfall * * *"

Streams provide our communities and industries with easy and economical means of waste disposal, but such use should not unreasonably impair the value of the water for other uses. Pollution can and should be controlled. Most wastes can be treated. Some degree of purifying can be done at little cost, although complete purification can be very expensive. The basic question is: What degree of pollution control is necessary to protect public interests? The question is both economic and social. How much purification are we willing to pay for, through higher taxes and higher prices? To increase the value of streams for swimming and fishing, are we willing to pay a little more for a shirt or a can of peaches to cover the manufacturers' cost of waste treatment?

How Cities Purify Water

The water we draw from our taps must be clear, colorless, odorless, pleasant-tasting, fairly soft, and above all, safe to drink. It must be free of disease-producing bacteria, toxic salts, suspended solids, and organic matter. Moreover, its chemical composition should be such that it will not corrode or form scale in pipes and tanks and will not stain fabrics. For our safety, requirements for drinking water have been set forth by the U.S. Public Health Service and adopted by the Georgia State Board of Health.

Most urban water supplies require some treatment. The treatment removes substances occurring naturally or those resulting from man's activities. Well water is often chlorinated and sometimes softened or treated to remove iron, manganese, or carbon dioxide. Water from streams is always treated to remove impurities. Usually treatment involves settling the water in reservoirs, the addition of chemicals, filtration, and chlorination.

In Georgia, two-thirds of the public water supplies are treated. All the public supplies from streams receive some treatment, and sixty percent of the public supplies from wells receive chlorination. A few supplies are fluoridated. One hundred and twenty public supplies from wells receive no treatment whatsoever.

When we think of water purification, we think of a water-treatment plant. However, even before the water arrives at the plant, there are many ways in which it is purified by natural processes. Most well-water has been naturally purified by filtration through sand and gravel before it is pumped from the well. Water-treatment plants duplicate natural processes in producing pure water, but the treatment plant does in a few hours what Nature takes years or centuries to accomplish. Furthermore, chemical and mechanical aids are used in the treatment plant as additional safeguards.

Many cities store water behind dams in reservoirs to insure an adequate supply at all times. Reservoirs help the purification process. Most streams carry turbidity and sediment in suspension as long as the water is moving. When the water is ponded, all except the smallest sediment particles settle out quickly. Some bacteria adhere to sediment particles and settle with them. Others are destroyed by protozoa and die in the new environment. Some bacteria thrive in reservoirs, but few of these are harmful to man.

Sunlight acts on the water in the reservoir to destroy many bacteria, remove color, and stimulate algae growth. Some algae give water an odor and taste, but for the most part they do more good than harm.

Organic matter—human and industrial wastes and forest debris—decomposes in streams and reservoirs. Some of it imparts color, odor, and taste to the water. A carefully selected withdrawal point in a reservoir may minimize the amount of decomposition products pumped into a water-treatment system. Nevertheless, enough objectionable material gets into many systems to require specific treatment.

Taste and odors imparted to water by algae, decaying vegetation, dissolved gases, or by sewage and industrial pollution can be removed. Aerating the water by spraying it into the air is sufficient to remove many tastes and odors.

Specific treatment must be tailored to each individual taste or odor problem, for there is no single method that will solve all of them.

Many treatment plants soften water that is very hard. Lime and sodium carbonate and some natural minerals will remove calcium and magnesium, the principal hardness-producing elements in water. A few treatment plants completely soften a part of the water, and by mixing it with unsoftened water prior to distribution, obtain water of the desired hardness. Completely softened water is not desirable because it is corrosive to metal. Chemicals are added to make the finished water noncorrosive.

It is well to remember that although man himself has often contaminated water supplies, he is able in most cases to treat the water so that the supply is as safe as it was before contamination. However, complete removal of dissolved material which results from dumping wastes into streams is very costly and is not usually done.

Water for the Farm

A small but important proportion of our water demands are for domestic and livestock needs of rural people—those not served by public water supplies. In 1960, about 36 percent of Georgia's population obtained water from their own wells or from ponds and streams. Exclusive of irrigation water, the estimated average rural use was 91 mgd, about one-fourth as much as was furnished by public supply systems. Sixty-two million gallons per day was for domestic use (in homes) and 28 mgd was for livestock. About two-thirds of the water was taken from wells or springs and about one-third was taken from streams and ponds.

Generally, rural people do not use as much water in their homes as their city cousins, mainly because many rural homes still do not have running water. A rural family with running water uses about 50 gallons of water per person per day, but a family that relies on a hand pump, or perhaps bucket and rope, gets along with 10 to 20 gallons per person. In 1955, more than half of Georgia's rural families did not have running water in their homes.

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The quantity of water used by livestock varies widely depending on the age and kind of the animal and to some extent on the climate. Per-capita livestock needs are about as follows:

	Gallons per day
Horses and mules	10
Beef cattle	10
Milk cows	20
Hogs	3
Sheep	2
Goats	2
Chickens	.04
Turkeys	.06

The purity of water for domestic use in rural homes should equal that required for public supplies. Generally, Georgia rural well and spring supplies which are protected from contamination are of satisfactory quality.

Water for Irrigation

Irrigation is a recent development in Georgia. Before 1950 it was almost unknown, because the State normally has abundant rainfall for good crops. In rare years, droughts reduce yields and sometimes cause crop failure. Such occurred in 1954, when the drought caused crop losses in the State in excess of 75 million dollars.

Agricultural research has demonstrated that the way to fight droughts is to irrigate. And that is just what an increasing number of Georgia farmers have begun to do; in 1955, more than 600 installed irrigation systems. The total number of irrigated farms in the State was thus increased by more than 50 percent. So far, irrigation has been used mostly on tobacco and vegetables, but farmers are finding it can pay off for many other crops, including cotton, corn, and pasture. Furthermore, irrigation can increase crop yields, even in normal years.

No records of water use for irrigation in Georgia are available, but the quantity has been estimated from the number of acres irrigated and the usual rates of application. In 1960, Georgia farmers applied irrigation water to about 96,000 acres. Rates of application vary much for different types of crops, different types of soils, and different weather conditions. The average use of water for irrigation in 1960 was about 37 mgd.

Farmers do not, of course, apply irrigation water at a uniform rate throughout the year. Ordinarily, they irrigate only during dry periods of the growing season. Daily use during these periods is many times the average. The demand for irrigation water is often greatest when stream levels are seasonally low.

Georgia farmers pump about half of the water used for irrigation from streams and ponds, the other half from wells or springs. Many farmers obtain irrigation water from farm ponds that intercept surface runoff. Some farmers use ponds to store water pumped from wells. There were about 30,000 farm ponds in the State in 1955 and farmers were building new ones at the rate of 250 per month. Figure 12 shows the density of farm ponds as of 1954. Many, but not all, of these ponds are used to irrigate crops. Most of the ponds in the State have an average capacity of only 2 to 4 million gallons. Individually, such ponds are big enough to irrigate only about 7 to 15 acres, but collectively they provide water to irrigate thousands of acres.

The quality requirements of water for irrigation are not as high as for homes and factories. The suitability of water for irrigation depends on the chemical and physical composition of the water itself, the composition of the soil, drainage conditions, climate, quantity and frequency of application, and the salt tolerance of the crops. In Georgia, both surface and ground waters are, for the most part, of good quality for irrigation.

Irrigation use in Georgia is still small, but almost entirely consumptive. The water taken from a stream or well to irrigate crops is transpired from the plants or evaporated and thus is not available for additional uses. Furthermore, when water is stored in reservoirs or ponds, evaporation loss increases. The net evaporation loss from all farm ponds in Georgia in 1954 was computed to average 100 mgd. Although evaporation causes serious water losses from individual farm ponds, the total Statewide loss from pond evaporation is less than 1 percent of the average annual runoff.

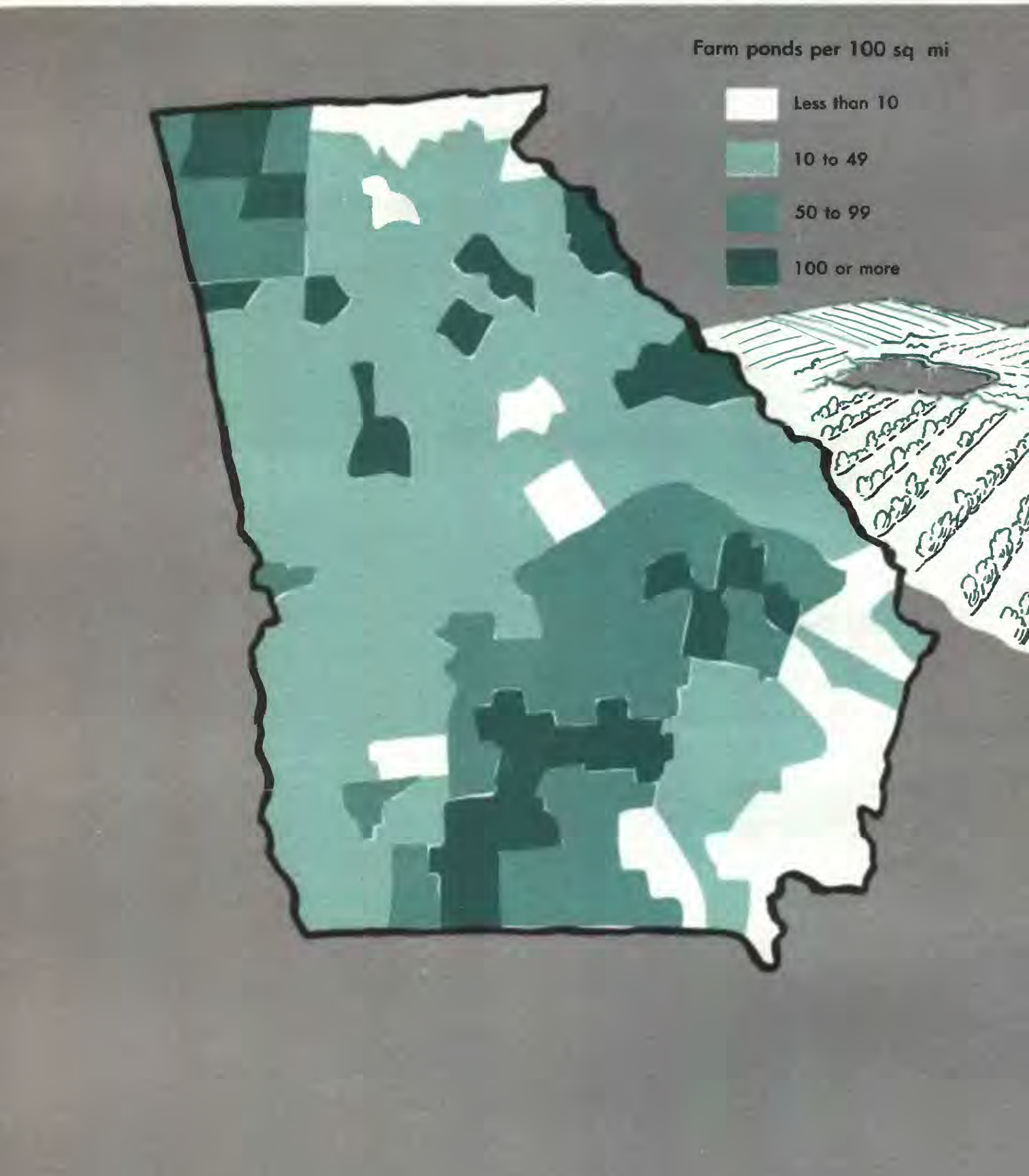


FIGURE 12.—Density of farm ponds in 1954.

Water for Industry

Georgia's industries use far more water than its homes and farms. Vast quantities of fresh and brackish water are required for generating steam, cooling, cleansing, use as a solvent, and for a host of other purposes. For example, it takes from 8 to 170 tons of water to manufacture a ton of textiles, and from 50 to 350 tons of water to make a ton of paper. Expressed another way, it takes 15 to 20 gallons of water to manufacture one bed sheet and about 13 gallons of water to manufacture the paper for one 50-page newspaper.

Total industrial use of water from sources other than public water systems was about 2,130 mgd in 1960. Of the total, about 1,720 mgd was used for cooling at steam powerplants. One plant, Hammond, uses Coosa River water at the rate of nearly a third of a billion gallons per day when operating at full capacity—enough water to supply eight cities the size of Atlanta. Not much data are available on water use by other individual industries.

The quality of water needed for industry is often as important as the quantity. The water-quality requirements of some industries are more exacting than those for drinking water. Especially high standards of quality are required in manufacture or processing of chemicals, textiles, plastics and food. Often these requirements must be met by treatment similar to that given to public water supplies.

On the other hand, water of inferior quality can be perfectly satisfactory for some industrial purposes. In 1960 about 20 percent of the water used by industry in Georgia was saline; that is, it contained more than 1,000 ppm (parts per million) of dissolved solids (usually brackish or sea water). Most of this water was used for condenser cooling. Much more of this low-quality water could be used if necessary.

Water for Power

The energy of falling water has been a source of power in Georgia since Oglethorpe's day. The first small grist mill in Georgia was built at the Salzburger settlement at Ebenezer in 1740; some 2,000 water-powered mills followed. After the early 1900's, the increasing availability of electric power and the increasing efficiency of gasoline engines made the numerous small water mills unnecessary, and most of them fell to ruins. However, about 200 such mills are still in operation.

Nowadays, water power usually means hydroelectric power. The force of falling water is converted to electrical energy, which is transmitted through wires to any place where it is needed. More than 40 billion gallons of water per day were used in 1960 to spin the generators in the State's 42 hydroelectric plants—more than 100 times the amount of water delivered by all Georgia's municipal supply systems. The combined capacity of these plants is more than 1 million kilowatts; generation of electricity in 1960 was more than 3 billion kilowatt-hours.

Georgia's hydroelectric plants are backed up by reservoirs having a total usable storage capacity of 2.25 trillion gallons. This volume is roughly equal to that of a lake 10 miles square and 110 feet deep—a large amount of water, but even so, only one-fifth the contents of Lake Mead formed by the mighty Hoover Dam on the Colorado River.

Reservoirs for storing or ponding water have a major role in power production. Storing water behind a dam not only provides operating "head" or pressure, but makes possible the generation of electricity as needed, rather than as nature sees fit to provide the water. The early settlers took advantage of waterfalls to supply the head needed to yield energy. Where waterfalls were not available, they built small dams to create the head. However, during dry seasons, power was severely limited by the small flows of the streams. (Power is the product of "head" multipled by "flow.") Millers needed more dependable power; they built dams at places where ponds would be formed that could supply stored water for tapping when the flow of streams was low. Typically, the mills operated during the day and drew down the ponds as required. Then, at night while the mills were idle, the ponds would refill. This process is known as "ponding"; it is still generally used at the great modern hydroelectric powerplants.

As hydroelectric powerplants grew in number and size, the larger reservoirs could control seasonal variations in streamflow. The surplus flows of the winter and spring were "stored" in the reservoir to be released during the low-flow seasons of late summer and autumn. This process is known as "storage" operation, now a common procedure at many power reservoirs.

Modern hydroelectric-power development often calls for the coordinated operation of a number of reservoirs and powerplants within a river basin. Reservoirs on headwater streams are filled and emptied annually to "iron out" the wide seasonal fluctuations in flow. Power production at these reservoirs is relatively small. In contrast, the dams on the lower reaches of the main river generally provide the head for most of the power production of the system. They do not provide much seasonal storage because they are operated to maintain as much head as possible. Both the upstream and the downstream reservoirs are operated to provide daily pondage.

Steam-electric and hydroelectric powerplants are most efficient when they coordinate their operations. Power demand in any region is essentially a combination of a constant "base" load and daily "peak" loads. Steam-electric plants are best adapted to constant-output operation such as the "base" load. Hydroelectric plants work well in coordination with steam plants by taking care of the "peak" portion of the load. Of course, the relative shares of the total load that are taken by steam and hydro normally vary with the seasonal availability of water. During periods when water is abundant, hydroelectric powerplants may operate continuously. During dry seasons, however, the hydroelectric plants are normally operated intermittently, sometimes for only a few hours at a time.

The passage of water through a hydroelectric plant does not diminish the supply available. Except for the evaporation loss from reservoir surfaces, hydroelectric use is nonconsumptive. Regulation of the river by a powerplant does, of course, affect the pattern or distribution of flow. Water stored deep in a reservoir loses its dissolved oxygen. Removal of sediment during storage partly compensates for this quality deterioration.

Water for Navigation

Navigation on major rivers requires sufficient depth of water to float barges and towboats. The required depth of water can be maintained in two ways: by installing low dams and locks to make the river a canal, or by providing sufficient flow so that the water is always deep enough. The second method is apparently the most feasible in Georgia; it is used almost exclusively. It works well in conjunction with multi-purpose dams.

Projects completed in 1962 and 1963 will add considerably to the use of Georgia's rivers as waterways. At present (1964), the Savannah River has a 9-foot minimum depth as far as Augusta, and the Apalachicola and Flint Rivers have a 9-foot minimum depth to Bainbridge; the latter depth was made possible by the completion of Jim Woodruff Lock and Dam at the confluence of the Chattahoochee and Flint Rivers in 1957.

Construction was completed and the reservoirs filled to operating levels in 1963 on the Chattahoochee River to provide a 9-foot channel as far as Columbus. Navigation was made possible by the Walter F. George Lock and Dam at Fort Gaines and the Columbia Lock and Dam, in addition to the Jim Woodruff Lock and Dam. Regulation at Buford Dam on the upper Chattahoochee will help to maintain the flow requirements of this system.

The widening and deepening of the 199-mile channel between Savannah and Augusta, to its authorized dimensions of 9 feet deep by 90 feet wide, was finished in 1963. Clark Hill and Hartwell Dams upstream from Augusta regulate the flow of the Savannah River to provide 3,300 mgd or more for the enlarged channel. The amount of water needed is very large because the channel is a "flowing-water" channel rather than a "slack-water" channel, such as might be created with a series of dams and locks. Clark Hill was completed and the reservoir filled to operating levels in 1954, and Hartwell in 1962.

Thus, more than 500 miles of waterways are serving principal cities in Georgia. Waterborne transportation is available to all points along the Atlantic seaboard and the Gulf of Mexico.

Water for Recreation and Fish and Wildlife

Anyone who likes to swim, fish, hunt, sail, water ski, picnic, or just sit and admire the scenery can appreciate that water resources contribute much to our enjoyment of life. The use of water for these purposes cannot be measured in gallons, nor its value determined in dollars and cents. But as sources of pleasure and relaxation, lakes, ponds and streams are worth a great deal to us.

A study conducted jointly by the U.S. Fish and Wildlife Service and the State Game and Fish Commission shows that Georgia has more than 6 million acres of water and wetlands. Besides natural lakes and streams, this figure includes almost 90,000 acres of farm ponds and about 250,000 acres of reservoirs. Much of this water offers a variety of opportunities for recreation and wildlife—native and stocked fish, waterfowl and water animals, bathing and boating facilities, and scenery. An amazingly large number of Georgia farmers stock their ponds with fish. Reservoirs for storage of water for flood control, hydroelectric power, or navigation have tremendous recreational potential when they are intelligently planned and are made accessible to the public. Twenty hydroelectric-power dams in Georgia or on the State boundaries have created lakes that annually attract many thousands of vacationers and sportsmen. The Corps of Engineers set aside 14,000 acres adjacent to Jim Woodruff Reservoir and 3,500 acres adjacent to Lake Sidney Lanier for public recreation and game management. Two new reservoirs authorized and under construction give promise of providing more beaches, fishing places, and camp and picnic grounds.

Conflicts in Water Use

Some of the possible complications inherent in water use are: (1) If the irrigator withdraws too much water upstream, downstream water users will not have enough; (2) if water levels in the reservoir fluctuate too much as a result of regulation by the hydroelectric plant, recreation and wildlife will suffer; (3) if the plant stops all flow during "shutdown" periods downstream use will be affected—enough flow must be released at the plant to satisfy the needs of downstream users; (4) return water from a steam-electric plant can raise the temperature of the water in the river enough to injure the fish and reduce its value to downstream users; (5) inadequately treated sewage from the city will pollute the stream; (6) factory wastes can also pollute the stream; (7) heavy pumpage of ground water by one user may lower the water table and deprive others of water or, at least, increase their pumping costs; (8) ground-water supplies may become polluted if septic tanks are not properly constructed and adequately spaced.

Georgia water users have all these conflicts of interest. Some are of serious import, others are not. As our water use increases, the conflicts will multiply and become more acute. At present, the courts have the responsibility for settling disputes arising from these conflicts. However, the water laws on which the courts must base decisions are very general and have not been modified to fit the changing water situation. Additional regulatory legislation may be needed. Voluntary cooperation of water users and the general public to solve water problems can minimize the need for legal control.

Regional Occurrence of Water

How Water Shaped the State

Water shaped Georgia into its present physical form. Water attacks, erodes, and dissolves. It has carved and eroded Georgia for millions of years, and every time it rains, a little more of the State is carried to the seas as grains of sand or dissolved salts. The rock shapes resulting from this continual action of water make possible the division of the State into five major physiographic provinces or areas (fig. 13). Some rocks lie flat, like the pages of a book, one on top of the other. Other rocks are folded, as the pages will fold if they are pushed from the edge of the book toward the binding. Still other rocks are massive, broken, cracked, and without apparent layering. Each of these rocks react differently to the action of water.

The State has been subjected to the upheavals of the earth many times in the past millions of years. Oceans, sweeping across it, have eroded the land at one place and built it up at others. Water from the oceans and from the atmosphere has relentlessly and continuously modified the shape of the State.

In northwestern Georgia, the Cumberland Plateau section and the Valley and Ridge province are characterized by parallel valleys and ridges which are underlain by Paleozoic

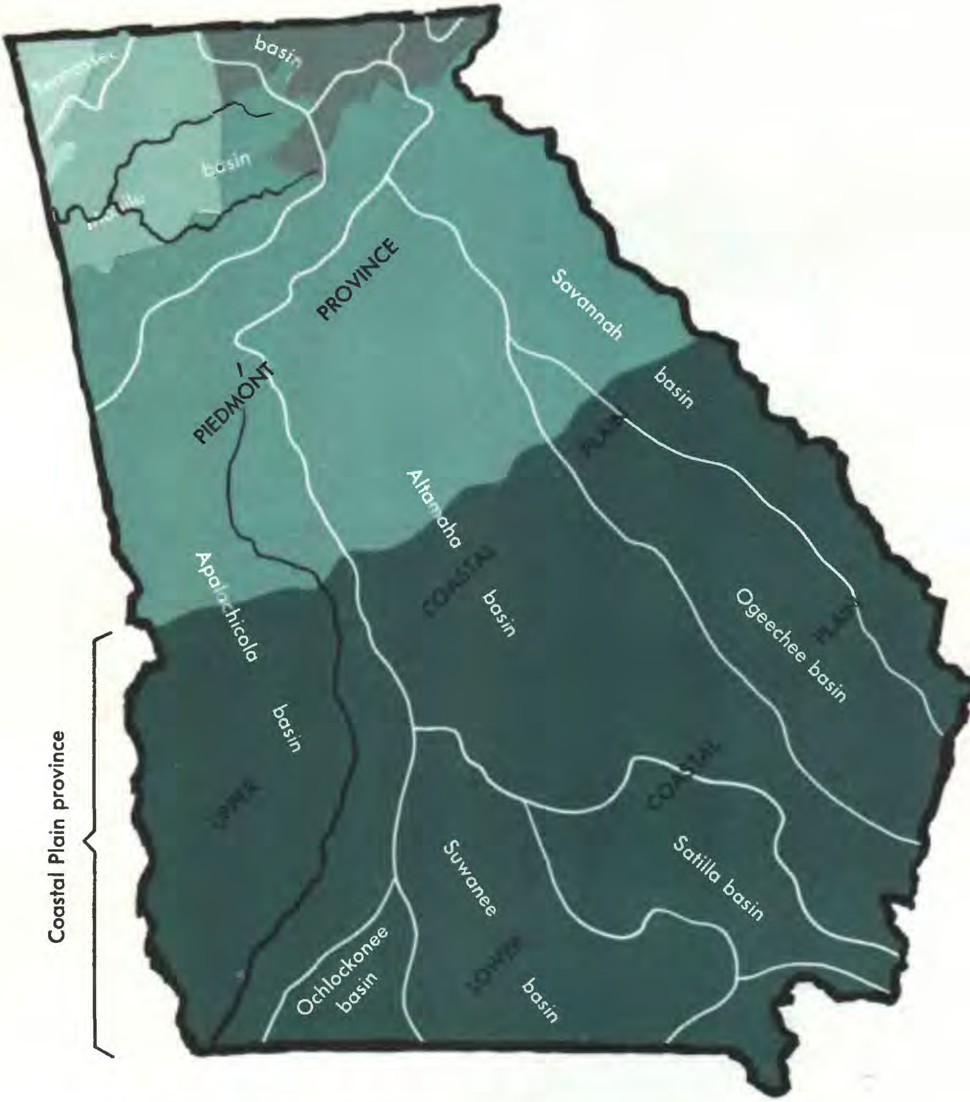
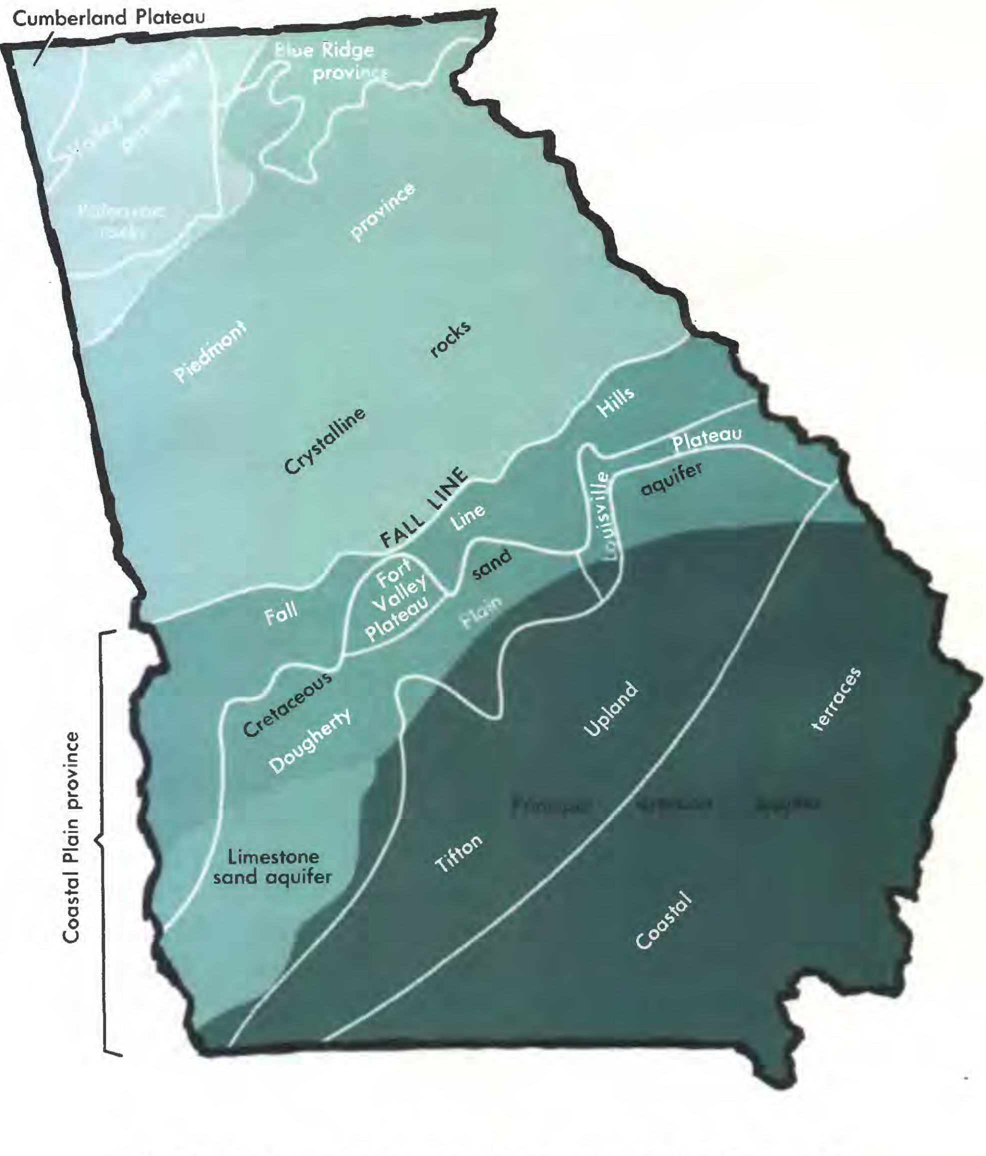


FIGURE 13.—Physiographic divisions of Georgia in relation to river basins (above) and ground-water areas (right).

sedimentary rocks, some nearly flat lying and some much folded. The Blue Ridge province is a mountainous area



underlain by very hard crystalline rocks. The Piedmont is a hilly, rolling area, a well-watered land where the ridgetops have a uniform level that slopes to the south. It is underlain by the same crystalline rocks as the Blue Ridge province.

The Coastal Plain is nearly flat everywhere. It is underlain by thick beds of sand and limestone, which were deposited only a short time ago (as geologists measure time) in an ocean whose shoreline was sometimes north of Macon.

Climatic conditions in all parts of Georgia are nearly alike, although north Georgia is slightly cooler and wetter than south Georgia. But geology, topography, and stream-channel development vary significantly with the location. However, several large areas are homogeneous with respect to the occurrence of water. A division of the State by physiographic areas, as in figure 13, is convenient for discussing the regional occurrence of water.

The Cumberland Plateau and the Valley and Ridge Province

The Cumberland Plateau section and the Valley and Ridge province grade one into the other; the rocks of the plateau lie almost flat, whereas those of the Valley and Ridge are folded. The latter province gets its name from the many long valleys and ridges that result from the erosion of the folded rocks that extend into Tennessee and Alabama.

Erosion is the process by which water, wind, and weather break down rocks; it works fastest on limestone which underlies most of the valleys. Not only is the limestone broken up by other rocks carried by moving water, but it is also dissolved by the water itself. This solution action has riddled the limestone with an extensive network of interconnected channels and caverns (fig. 14). Through these large openings the water moves as freely as it would through a city main. Solution action has also opened channels in some of the sandstone. However, these channels are very fine; water moves through them very slowly and in much smaller quantities.

Because the solution channels are interconnected under large areas, water can move long distances from its point of entry as rainfall. Water that falls as rain in Tennessee may flow underground and emerge in Georgia, and water that falls in Georgia may emerge in Alabama.

FIGURE 14.—Solution channels in limestone.

For water-supply purposes, the shale beds can be considered dry and impermeable, that is, incapable of allowing water to pass through. Because of their impermeability, they confine the water in sandstone or limestone above and below them and create artesian conditions. Artesian water is ground water that is under pressure and is confined between rocks of low permeability. Ground water that is not so confined is said to occur under water-table conditions. Figure 15 illustrates the occurrence of ground water under water-table conditions and under artesian conditions.

The Cumberland Plateau and the Valley and Ridge province might be thought of as "spring" provinces. Thousands of springs ranging in yield from 1 to 15,000 gpm (gallons per minute), flow from the caves and channels dissolved in the limestone. Much of the water in the streams comes from springs that line the valleys. For example, a large proportion of the water pumped from the rivers at Dalton and Ringold comes from springs a fews miles upstream.

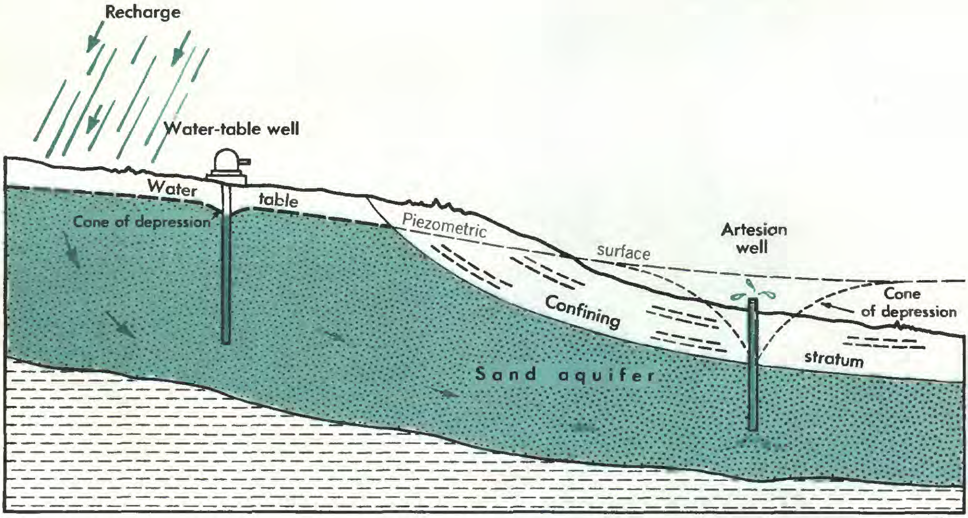


FIGURE 15.—Occurrence of ground water under water-table and under artesian conditions.

Springs, wells, and cisterns furnish water to the rural population. A good spring makes rural real estate more valuable. Nearly all the older houses in this region were built near springs, and the first industries were located at springs.

The region is drained by a network of streams yielding generous supplies of water. Those in the northwest section drain northward into the Tennessee basin; the remainder drain westward into the Mobile basin. The streams generally flow in deep channels meandering in wide flood plains. Where they cut through the ridges in water gaps, they are shallow and swift and have many rapids. The steep slopes of northwest Georgia are ideal for the rapid runoff of storm water. Rivers rise quickly and often cause large volumes of angry flood water to spill over the banks into the valleys, as the residents of Rome well know.

The average annual runoff of streams ranges from 18 to 24 inches. That is, the water draining from the region in the course of a year is sufficient to cover the area to a depth of 18 to 24 inches. Average annual runoff from the State of Georgia as a whole is 14 inches. As elsewhere in Georgia, the yield of the streams varies greatly in time and place—from mere trickles to raging torrents. In the Valley and Ridge province, generally, the flow of streams is well sustained during dry weather because of the numerous springs which feed them. Streams draining the Cumberland Plateau have lower flow during dry weather because they are not fed by so many springs.

Water of the Valley and Ridge province is suitable for most uses, although removal of some constituents may be necessary for specific uses. Ground and surface waters in prolonged contact with the limestone rocks often contain relatively high amounts of calcium and magnesium carbonates which cause the water to be hard. Objectionable quantities of iron are found in ground water in some of the shale and sandstone. However, both of these conditions are easily remedied by minor treatment.

Blue Ridge (Mountain) Province

The Appalachian Mountains of the eastern United States extend southwestward from the State of Maine to the Blue Ridge province of Georgia. This province is the coolest and wettest part of the State. During the 1954 drought, when other parts of the State received as little as 45 percent of the average annual rainfall, the mountains received their full share. Average annual rainfall in the province ranges from 55 to more than 80 inches per year, the greatest amount falling in the higher altitudes. The annual average temperature is about 57°, 10° cooler than south Georgia.

The province contains thousands of acres of forest land, beautiful mountains and rivers, and state parks and national forests having a great potential for recreation. The area is not farmed extensively nor is it densely populated. The steepness of the topography makes the land more suitable for forests than for farms.

The Blue Ridge is drained by headwaters of four basins—the Tennessee, the Savannah, the Chattahoochee, and the Coosa. The rivers within the provinces are small and have small drainage basins, but they have the highest yields for their size in the State, almost 2 mgd per square mile of drainage area in some places. Their channels are steep and rocky, and water flows swiftly over many rapids and waterfalls.

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The combination of high yield and steep fall is ideal for water power. Eleven dams situated among the mountains provide hydroelectric power and flood control. Several of the larger dams have created beautiful lakes that provide a variety of recreational opportunities. Fishing and boating, plus the mountain scenery, have helped make the Blue Ridge one of the most popular recreation areas in the southeastern States.

High rainfall insures a continuous water supply. Steep topography encourages rapid runoff, but as long as the mountain slopes are tree covered, surface runoff is slowed down and erosion prevented. If the soil is in a porous condition, rainfall can infiltrate it and move deeper into the ground. Even though the vegetation consumes much of the water that falls, the soil and roots slow down the movement of the remaining water and make more of it available for man's use. A barren slope usually becomes hardpacked and sunbaked quickly; its permeability is thus lessened, and fast runoff causes erosion. Even though vegetation consumes much water, it helps to conserve some for man's use.

The Blue Ridge province is underlain by rocks that the geologist calls "crystalline." They consist of granite, slate, gneiss, and other dense, hard rocks. The mountains are high and steep and have nearly V-shaped valleys; they are covered with thick forests and soil. The decayed vegetation and the roots of the trees, which make the soil relatively permeable to the movement of water, allow more rainfall to seep downward to the rocks where it is stored in the zone of saturation.

A valley is the best place to drill a well in crystalline rocks in the Blue Ridge region. Water drains from the high to the low areas through cracks and open spaces in the rocks. Because it does, water is deep under the hills, and close to land surface in the valleys. The valley well will yield more water for a longer period of time than the hilltop well, and be less affected by a drought.

The crystalline rocks contain few open spaces, except in the cracks which extend downward to a depth of several hundred feet. The cracks in the existing rocks are open only to depths of 300 to 600 feet. At greater depths they are closed tight by the weight of the overlying rocks. The weathered zone has more open space for water storage, but it is relatively thin. The crystalline rocks are a good source of water supply during droughts because the cracks are full of water long after the weathered material has been drained. Openings vary in size and numbers from one rock to another, but none of the crystalline rocks are as permeable as the limestone of other parts of the State.

The few towns and industries in the mountains are small and do not use large amounts of water. Supplies are obtained in about equal amounts from rivers, springs, and wells. Rural household supplies are obtained from springs and wells, and livestock supplies from springs and rivers. The wells range in depth from 30 to 400 feet and yield from 1 to 130 gpm. The average drilled well yields less than 50 gpm, but if drilled in the proper place and to a sufficient depth, yields as high as 200 gpm may be obtained. The region contains many springs that yield less than 10 gpm and a few that yield much more.

The water resources of this region are not completely developed; much more use could be made of them. More springs could be developed for domestic supplies and some could supplement the main source of the towns. Wells could be drilled for community and industrial supplies, and more water could be taken from the rivers. Undeveloped supplies are adequate for all but the largest water-using industries.

The chemical quality of water in this region is good for most purposes. The river water is low in dissolved solids, most of the supplies containing less than 100 ppm. The ground water contains less than 100 ppm dissolved solids and, like the surface water, is classified as soft. Dissolved iron in the water at some places causes trouble, but it can be removed. The iron is present because it is dissolved from the rocks by the acid water of the region. When the water is exposed to air, the iron in solution is converted to its solid state, and causes red stains on enamel ware and white clothing.

Although this area may not be able to support many large water-using industries, it does have sufficient water resources to supply the needs of industries which do not use a great deal of water. Even though 10 gpm may appear to be a small quantity of water, if pumped continuously it represents enough water to satisfy the basic daily needs of more than 100 persons. A dug well or spring that yields only 1 gpm will provide water for the daily needs of at least 14 people if storage facilities are provided.

Piedmont Province

The Piedmont province is the most densely populated part of the State. About two-thirds of the State's population lives in this province, which contains about 40 percent of the State's area. The Piedmont was primarily an agricultural region for two centuries, but in the last half century the textile industry has expanded, and in recent years a completely diversified industrial expansion has begun. Airplanes, automobiles, aluminum products, steel pipe, plastics, food stuffs, pharmaceutical products, rubber and many other products have supplemented textiles. The industrial expansion was largely possible because of the availability of water and waterpower.

The Piedmont province is underlain by the same crystalline rocks as the Blue Ridge province, but it lacks the high relief of the Blue Ridge. It is an area of rolling plain, broken here and there by narrow stream valleys and prominent hills. The soil cover in the Piedmont is not as thick nor as capable of slowing the runoff as that of the Blue Ridge. In fact, where the Piedmont hills have steep slopes, runoff rates approach those that occur in the Blue Ridge province.

The Piedmont province includes parts of several drainage basins—the Savannah, Ogeechee, and Altamaha basins which drain into the Atlantic, and the Flint and Chattahoochee which drain to the Gulf of Mexico. Throughout most of the province the main streams flow southeastward, the direction of the general slope of the upland, and cross the underlying rock structure at right angles. In the northwest section of the province, the Chattahoochee and some streams in the Mobile basin tend to follow the direction of the underlying rock structure. The streams generally have moderate slopes interrupted by occasional rapids and waterfalls, and flow in well-defined channels within fairly narrow valleys—a situation which provides many ideal waterpower and reservoir sites.

The ridges between the major drainage systems are broad and rather sinuous. The cities, highways, railroads, and farmlands are concentrated on the ridges. For instance, the cities of Atlanta, Griffin, Fort Valley, and Cordele, connected by U.S. Highway 41, are situated on the ridge between the Apalachicola and Altamaha basins. Towns were established on the ridges along the old wagon trails and railroads because the ridges were well-drained routes that required a minimum number of bridges and were free of the danger of floods. However, these same ridges were the least promising for obtaining a water supply. Well fields must be located in adjoining lowland, or water must be pumped from streams in near or far-off valleys.

Where do people living in the Piedmont get their water? The answer depends on whether they live in a city, small town, or rural area. All the large cities and many of the smaller ones use purified river water. The Chattahoochee River system alone serves more than a million people, and the Savannah and Ocmulgee Rivers serve additional hundreds of thousands. Some of the smaller towns and all the rural population obtain water from wells and springs. Water for livestock is obtained from the rivers, ponds, wells, and springs. The rivers are the most important source of large water supplies; we might therefore classify the Piedmont as a "river" province.

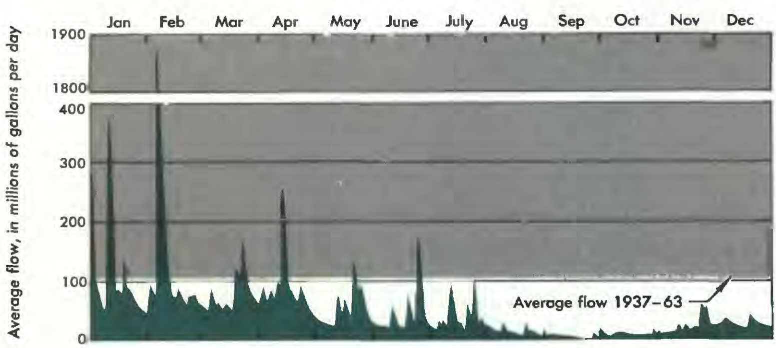
Rainfall along the northern margin of the province, the area of highest altitude, averages more than 50 inches annually. To the south and east, rainfall is less. The Augusta area receives less than any other part of the State, a little more than 42 inches annually, but more than falls on most of the rest of the United States.

The big rivers are the major source of water for the large cities, the water-using industries, and the hydroelectric and steam-electric plants in the region. They concentrate the flow from hundreds of miles of smaller streams in one channel where it can be drawn upon by the big water users.

The streams tributary to the big rivers are important sources of water supply in themselves. Generally, the flow of rivers is large in comparison to the amount of water needed for community supplies. The East Point water system, which serves about 70,000 people, withdraws an average of about 7 mgd from Sweetwater Creek. This withdrawal is equal to the average yield from only 9 square miles of the Sweetwater Creek watershed! The average flow of small- and medium-sized streams in the Piedmont ranges from 0.5 to 1.5 mgd per square mile.

Man finds the variability of rivers most difficult to cope with when he attempts to harness them for his use. Rivers seldom flow at their "average" rate; on most days of the year their flow is below average, and on a few days of the year it is far above average. The variation in average daily flow for Yellow River at a point near Snellville during a typical year is charted in figure 16. The wide range of flows on this small Piedmont stream is typical of streams which are not regulated by storage reservoirs. The average flow for the years 1937 to 1963 was 103 mgd as indicated in the figure. Note that the highest daily flow of the year is about 700 times the lowest daily flow. At the peak of the rise of February 7, the highest during the year, the momentary rate of flow (as opposed to the daily flow) reached 2,200 mgd. The range in stage during the year—from lowest to highest—was 11

FIGURE 16.—Variation in daily flow for Yellow River during a typical year.



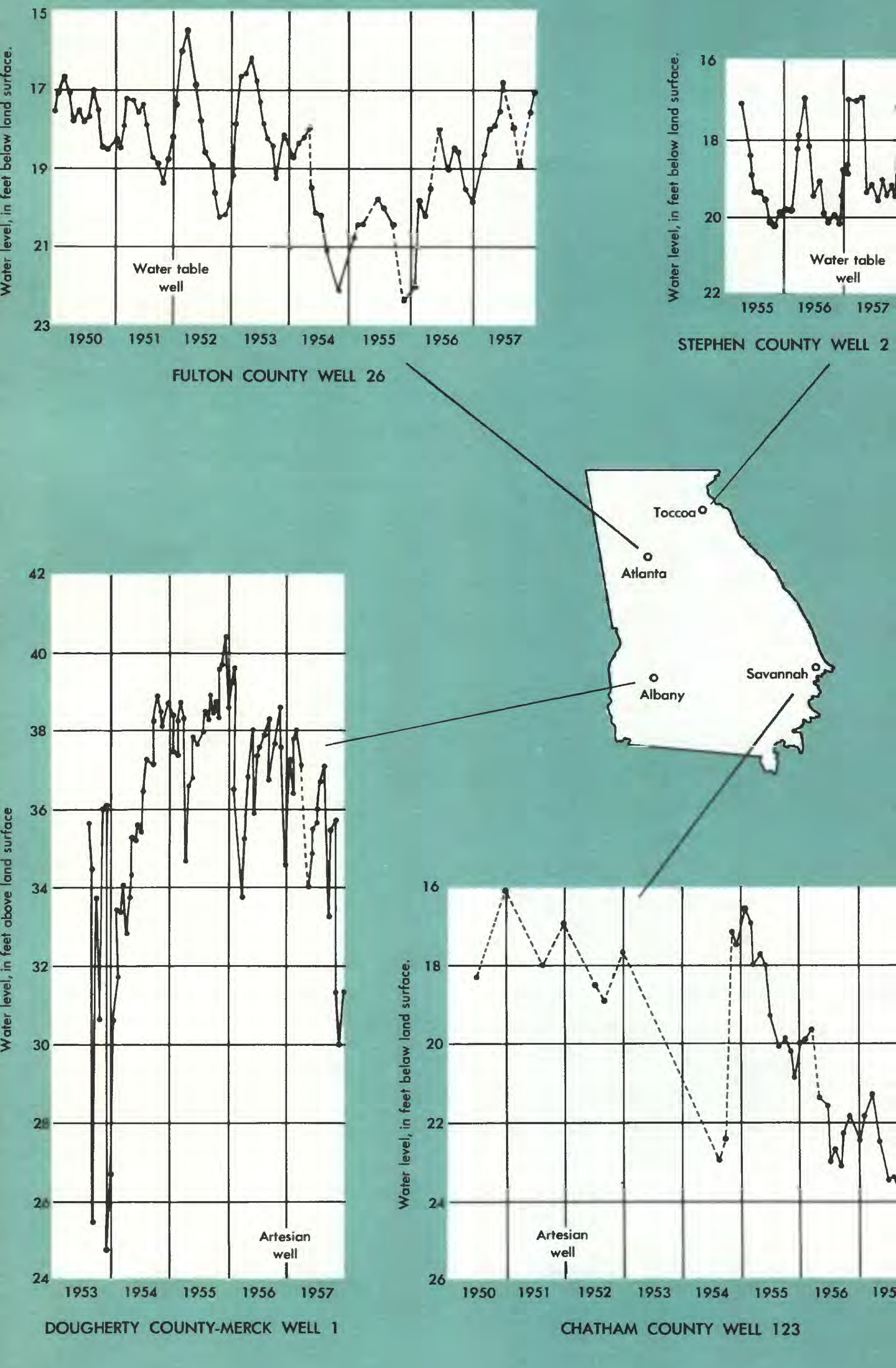
feet. It is expected that once in 20 years, on the average, this stream will discharge as little as 1 mgd and as much as 4,700 mgd. (A flow which is described as occurring once in 20 years may occur in any year or even in two years in succession. However, its chances of occurring in any particular year are 1 in 20.)

The minimum flow is more important to most water users than the average flow. The minimum flow of many streams in the Piedmont exceeds the maximum anticipated need. All the water needed can be obtained without building a storage reservoir. To use the "average" flow of a stream all the flow in excess of the average must be stored for later release when the natural flow is less than average. Some reservoirs store enough water that the streamflow can be almost fully used for hydroelectric-power production, municipal supplies, dilution of wastes, and other uses.

Ground water under both water-table and artesian conditions is a source of supply in some areas of the Piedmont. Under water-table conditions, as in most countries, water levels fluctuate with rainfall, evaporation, and vegetation use. As shown on figure 17, the water levels in Fulton County well 26 and Stephens County well 2 rose during the winter and spring and declined during the summer and fall. Note the low levels of the drought years of 1954 and 1955, and the subsequent recovery during 1956 and 1957, for Fulton County well 26.

The Dougherty and Chatham County well records shown in figure 17 are from artesian wells in the Coastal Plain. Artesian water levels fluctuate with ground-water pumpage and are not ordinarily affected by variations in local rainfall. Any apparent similarity of fluctuations in water-table wells and artesian wells during a drought is caused by the higher pumping rates in dry seasons. Artesian levels in Chatham County have declined steadily in recent years because of increased pumpage in the industrial areas. Pumpage in Dougherty County has varied over the years, and the water level has varied with it.

In the Piedmont province, both ground water and surface water have considerable variation in chemical quality. Most


Water level, in feet below land surface.
Water table well
1950 1951 1952 1953 1954 1955 1956 1957
FULTON COUNTY WELL 26
Water level, in feet below land surface.
Water table well
1955 1956 1957
STEPHEN COUNTY WELL 2
Toccoa
Atlanta
Albany
Savannah
Water level, in feet above land surface
Artesian well
1953 1954 1955 1956 1957
DOUGHERTY COUNTY-MERCK WELL 1
Water level, in feet below land surface.
Artesian well
1950 1951 1952 1953 1954 1955 1956
CHATHAM COUNTY WELL 123

of the water is low in dissolved solids and some is highly mineralized; other supplies contain large amounts of iron. Nearly all the ground water, despite these variations, is classifiable as soft.

Coastal Plain Province

Georgia's Coastal Plain is famous for many things. One is scenery, another is agriculture, and still another is industry. The picturesque city of Savannah, the beautiful Sea Islands, and the seemingly mysterious Okefenokee Swamp are visited by thousands of tourists every year. The residents are justifiably proud of their region. They are also proud of the tremendous increase in the industrialization of the region. All of these—the scenery, industries, and farms—are obvious things. They are a part of the landscape, and are impressive to the resident and visitor alike. The resource that makes the growing industrial might possible is one that is not so obvious at first; part of it remains hidden from human eyes until used. That resource is water. In addition to its large rivers, the region has a tremendous asset in its vast hidden ground-water resources. Southern Georgia has an extremely valuable water supply, one of the best in the Nation. Even brackish and salt water can be used. Plant McManus in Glynn County now uses an average of 26 mgd of brackish water to condense steam from its huge turbines.

Over three-fifths of Georgia lies in the Coastal Plain, and the people are concentrated in and around the Fall Line cities of Augusta, Macon, and Columbus and the coastal city of Savannah. Only the Fall Line cities, together with Savannah and Waynesboro, use river water for municipal supplies. Savannah uses river water only to supplement the main supply from the well fields.

The Coastal Plain contains the State's largest undeveloped water supplies. The region is like a great sponge, absorbing water almost everywhere. The river supplies have been

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FIGURE 17 (opposite page).—Variation of water levels in representative observation wells in Georgia. Line dashed where record not continuous.

barely utilized. The Savannah River alone pours more than 7 billion gallons per day into the ocean, and withdrawals from it are only a fraction of 1 percent. Additional billions of gallons flow into the ocean under the ground.

Yet in spite of these great rivers, the Coastal Plain is a ground-water or "drilled-well" province. Most supplies are obtained from wells, because ground water is obtainable everywhere at low cost, and the maintenance costs of well fields are much less than for the filter and treatment plants of a surface-water system. This cost factor is significant for a small town; furthermore, its nearly constant temperature and chemical composition make ground water ideal for industrial use.

Because of the great difference in the runoff characteristics of the streams, hydrologists differentiate between the upper Coastal Plain and the lower Coastal Plain (fig. 13). Streams in the upper Coastal Plain have relatively uniform flows and high yields because of small storm runoff and large ground-water inflow. The very small streams commonly have very little runoff because the permeable soil absorbs rainwater rapidly and the channels are not intrenched deeply enough to intercept much ground-water flow. The average annual runoff of the larger streams ranges from 12 to 28 inches. The streams are generally sluggish and flow in deep meandering low-banked, tree-choked channels bordered by wide swampy, densely wooded valleys. A few low-head water-power sites exist on larger streams but, because of the flat terrain and permeable soil, there are few reservoir sites.

The lower Coastal Plain generally has the least runoff of any part of Georgia. The average annual runoff ranges from 9 to 14 inches. The streams wander in wide swampy, heavily wooded valleys separated by very wide and very low, flat ridges. Swamp vegetation consumes large quantities of water and evaporation loss is high.

Water-bearing rock formations are called aquifers. There are three main aquifer systems in the Coastal Plain province: the Cretaceous sand aquifers, the limestone-sand aquifers, and the principal artesian (limestone) aquifer. The Cretaceous sand aquifiers and the limestone-sand aquifers are used mostly in the upper Coastal Plain; the principal artesian aquifer is in the lower Coastal Plain.

The Cretaceous sand aquifers are a blanket of sand and gravel that begins at the Fall Line and thicken to the south. Rainfall filters quickly into this sand blanket and recharges the sand aquifer with water. When the stream levels are high, water moves from the streams into the sands; when the stream levels are low, water feeds back from the sands into the streams.

The Cretaceous sand aquifers contain many different beds, some of which are beds of clay. The clay beds are the source of much of the Nation's kaolin (the raw material of the ceramics industry). Kaolin is quarried extensively in this part of Georgia. The kaolin industry uses large amounts of water in the processing of the clay.

The cities of Augusta, Columbus, Macon, and Waynesboro are the principal users of river supplies in the Coastal Plain. Of the four, only Waynesboro could develop ground water to supply all its needs. The other cities straddle the Fall Line, and neither the crystalline rocks of the Piedmont nor the Cretaceous sands of the Coastal Plain can supply their needs. However, ground water from either source could be used as an emergency or supplemental supply. All the other towns and the rural population have wells. In Quitman and Stewart Counties, town wells are about 1,100 feet deep, but eastward the water is closer to the land surface. Between Macon and Augusta, many wells which penetrate the Cretaceous sands flow at the land surface.

Artesian water was discovered in Georgia in the year 1881 on Hickory Level Plantation, some 20 miles west of Albany. Up to that time water had been obtained from dug wells and cisterns containing rainwater. These supplies were sometimes polluted. Artesian wells drilled at Albany in subsequent years provided an ample supply of unpolluted water, and thus were very beneficial to the economy of the area. They gave Albany its title of the "Artesian City."

Albany lies in the limestone-sand aquifer area, a triangular-shaped part of southwestern Georgia in the upper Coastal Plain. Most residents of southwestern Georgia are familiar with the lime sinks, caves, and underground rivers which are typical of the area. These features are formed by the solvent action of water on the limestone. When the limestone is dissolved, caverns and interconnected channels below land surface are left. If the cavern roof collapses, sink holes are created.

The Flint and Chattahoochee Rivers both flow from the Piedmont, across the Cretaceous sands and across the limestone-sand aquifer. Where the rivers cross the limestone, an interchange of water takes place between the stream and the ground through open channels in the limestone.

The region receives about 50 inches of rain distributed fairly evenly throughout the year. Much of this water either is transpired by plants or evaporates, but probably more water soaks into the ground through sands, sink holes, and solution channels here than anywhere else in the State. The Ocala Limestone, a part of the principal artesian aquifer, forms the surface rock in much of the Albany area, which is one of the important recharge areas for the Ocala Limestone. Water below the Ocala Limestone is under artesian pressure, and there are many flowing wells. Some wells in the Albany area no longer flow because pumping of water has lowered the artesian head below land surface.

Springs in the limestone maintain the low waterflow of the Flint and Chattahoochee Rivers. The flow of Radium Springs, the largest in Georgia, into the Flint River has varied from 18 to 87 mgd. During the 1954 drought, the minimum monthly yield of the Flint River was nearly twice as much at Bainbridge as at Albany. This large increase in flow was from springs issuing from the Ocala Limestone.

All municipal water supplies in this area are obtained from drilled wells. Although the rivers are not used for city supplies, they provide for important industrial uses, such as cooling, generating electric power, and waste removal. They also provide recreation for thousands of people.

The quality of ground water in this region is good enough for most purposes. The water from the Cretaceous sands is soft, but in some places contains objectionable amounts of dissolved iron. Water in the overlying limestones and sands is moderately hard and is lower in iron content. River water in the limestone area is harder than in most areas of Georgia, but is fairly soft in comparison to United States river water generally. Water obtained from aquifers below the Ocala is generally safe from surface pollution if wells are constructed properly. As has been explained, the surface limestone is open and contains many solution channels. Polluted water can move rapidly through these channels, and may be pumped back to the surface before the bacteria have been destroyed. Those who drink untreated water from such wells are risking disease.

In the western and northern parts of the limestone-sand area where the shallow water is in sand, the ground water should be unpolluted a short distance away from the immediate vicinity of septic tanks. Sand is the material commonly used in treatment plants to purify the water. In the ground, sand acts in the same way. Polluted water is purified by moving a short distance through a sand aquifer.

Most of the water used today in the Coastal Plain is obtained from a series of limestone beds that are riddled with interconnected openings and which are known collectively as the principal artesian aquifer. This aquifer underlies about two-thirds of the Coastal Plain, and about 70 percent of all ground water used in the State is pumped from it. The aquifer extends northeastward into South Carolina and southward into Florida, and furnishes water supplies to the entire region. At one time all the wells at the lower elevations along the coast and for many miles upstream in the river valleys were flowing wells. Today many of them have stopped flowing, especially near the industrial cities where heavy pumping has lowered the artesian pressure.

Other aquifers, both limestone and sand, overlie the principal artesian aquifer, but they do not yield such large quantities of water. Although the limestone and sand aquifers are very important sources of water for the rural population, they are seldom used by municipalities and industries, partly because of the uncertainty of the yield and partly because of the difficulty of developing wells in the sand.

The annual rainfall in this region of Georgia averages from 45 to 52 inches, but the runoff averages only 9 to 13 inches. The streams whose drainage areas lie entirely within the lower Coastal Plain have lower yields than those of any other part of Georgia. Rainfall drains slowly over the flat terrain and the part which does not sink into the ground is quickly evaporated or consumed by vegetation. Because most of the lower half of this area is covered by a blanket of sand left by the last invasion of the sea, much water disappears quickly into the ground and is protected against immediate loss.

Water for most uses in the lower Coastal Plain comes from drilled wells. Only Savannah takes water supply from a river, although all the cities use rivers for waste disposal. The river water is available for development at many cities, and it is only a question of time before more of it will be used.

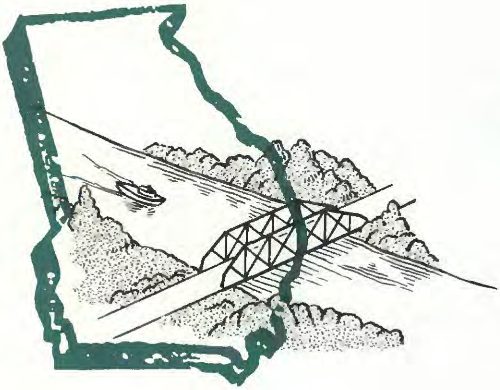
Ground water is inexpensive and is obtainable nearly everywhere in large quantities. The major supplies, however, are obtained from the principal artesian aquifer. Pumping has greatly changed the flow pattern of ground water in the artesian aquifer. Before water was pumped from this aquifer, the artesian pressure caused well water to rise to about 40 feet above sea level at Savannah, 65 feet at Brunswick, and more than 70 feet at Waycross. After the advent of well drilling, flowing wells became commonplace. Millions of gallons of water were wasted and the artesian pressure was reduced. Today, there are no flowing wells where once they were common. At one time, water in the aquifer flowed past Savannah toward the sea, but now it flows from the sea toward Savannah, because of the reduction of pressure in the artesian aquifer. Fortunately, water moves slowly, and there is time to determine the extent of the invasion of fresh water by sea water and the speed of its movement. Reducing the pumpage or changing the pattern of wells in the Savannah area can retard or prevent further salt-water invasion. In time, pumpage must be controlled in these areas or the artesian supplies will become too salty for use.

Greater use could be made of the shallow sand aquifers along the coast to lessen the draft on the principal artesian aquifer. Supplies for small industries, air conditioning, and household use could be obtained from the sands in many places, including the coastal islands. Water can be obtained from a simple sand-point driven well 10 to 30 feet deep. Water also may be pumped from the streams and purified.

The quality of water in the area of the principal artesian aquifer is generally good. The temperature of river water varies with the seasons; it is usually about the same as the mean monthly air temperature. The water of some rivers contain sediments; that of others is free of sediment but contains organic color. The temperature of ground water is nearly constant within any individual aquifer, but the kinds of dissolved solids vary with location. However, good quality ground water can be obtained everywhere. Ground water in the principal artesian aquifer itself is hard and contains some hydrogen sulfide gas (the rotten-egg smell), but this odor does not detract from its usefulness. Savannah has a problem of salt-water encroachment. A well at Valdosta found high-sulfate water, which is bitter to the taste. A well in Thomas County tapped brackish water at a depth of 1,635 feet in rocks below the principal artesian aquifer.

Water in the shallow sands is generally soft but contains sulfurous gas at some places. On some of the small coastal islands the sands contain brackish water, but on the larger islands the water is fresh. Many rural dwellers take water from these sands because they prefer a soft water and low pumping costs.

Aside from the few problem areas, the lower Coastal Plain contains billions of gallons of good quality water that, with or without treatment, can be useful in many ways for the further development of the State.



The Major Rivers of Georgia

A River and Its Environment

A river means many things besides a water supply to the people who live along its banks. Like the Savannah, it can be an opening to a continent. The history of sections of North America is the history of their rivers. The Ocmulgee and the Chattahoochee both determined the course of destiny for the cities along their banks. Indians, traders, and settlers moved up the rivers and used them not only as avenues of travel but as slender threads of communication with their own kind.

These rivers have a definite relationship with their environment. The "hills of Habersham" and the "valleys of Hall," like other hills and valleys, have their part in determining how much of the water from precipitation will find its way into the Chattahoochee basin, to be taken to the "lordly main from beyond the plain." The valley structures will resist erosion in some places, and in others submit to sculpturing by the river. The same soil that supports the peach orchards that decorate the hillsides like fragile clouds will capture varying amounts of rain water for its own uses and send the rest farther down valley. The underlying rocks, fragments of which sometimes shine in the streambeds, will receive or reject this water, according to their nature. Together, soil and rock will determine how much of the water will be returned to the surface, how much will move to another valley, or how much will be sent on directly into the ocean. The width of the ridges and valleys in the basin to some extent will influence human activities, which, in their turn, will control or consume the water or allow it to run off freely.

Because Georgia's major rivers drain more than one physiographic province, their flow characteristics reflect the influence of variable rainfall, topography, and rock structure. The effects of factors that control runoff in a tributary stream may be barely discernible in the flow of the big river into which it drains. The big river blends both the quantity and quality of flow from tributary streams that may differ significantly in flow characteristics.

The flow of big rivers varies from day to day but generally to a lesser degree than the flow of their tributaries. Big rivers of Georgia never go dry nor do they produce as high flood discharges on a per-square-mile basis as do the tributaries.

Big rivers require big dams if water-control projects are to be worthwhile. The size of the flood discharges in relation to the size of average flows gives a rough idea of the reservoir capacity required to store enough floodwater even to reduce partially flood damage caused by a big river. Projects to increase significantly the low flow of the big rivers also require large and costly reservoirs. Because big projects are expensive, they are built only after careful study shows that project benefits will exceed project costs.

The Savannah River

The Savannah, one of Georgia's largest rivers, begins near the northeast corner of the State where the Tugaloo and Seneca Rivers join. It flows about 300 miles southeastward along the State's eastern boundary to the sea. It drains an area of 10,600 square miles, 55 percent of which lies within Georgia. The Savannah's upper tributaries are typical mountain streams that have many rapids and deep gorges;

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in the Piedmont, the main stem of the river flows in a fairly deep channel of moderate slope and numerous rock shoals; in the Coastal Plain, the river sluggishly winds its way between the low banks to the sea.

The average runoff from the Savannah River basin is about 15 inches per year, a bit more than the State average of 14 inches. As in all rivers, the natural flow of the Savannah varies with time. Several reservoirs regulate the flow to provide a nearly constant discharge in the middle and lower river. Figure 10 shows how steady the flow is at Augusta. Even on the regulated Savannah, however, the relatively infrequent extreme flows vary a great deal from the average. At Augusta the minimum flow is about half the average flow and floods that had been about 220 times the average would be either fully controlled or reduced to the point where they would cause but little damage.

The rapid runoff in the Savannah River headwaters allows little time for contact between the water and the rocks of the area. This condition plus the absence of readily soluble rocks, results in water that is usually quite soft, clear, and low in mineral content. Some increase in concentration occurs as the water passes through the Piedmont and Coastal Plain provinces. Especially noticeable are the increases of color and sediment in the lower reaches of the stream produced by the clays of the Piedmont and upper Coastal Plain and the colored water of swampy coastal areas.

Although the properties of the water vary with time, only small variations appear in most of the constituents. Impoundment behind dams levels out the variations. Except for color and sediment removal, only minor treatment is required for most water uses. In the basin there are no known areas of gross contamination of the water supply by industrial or other wastes.

The flow of the Savannah River is regulated by a series of powerplants and reservoirs. Six powerplants on the Tugaloo and its tributary, the Tallulah, and one on the Seneca regulate the flows of these rivers. Clark Hill Dam on the main stem creates a great multi-purpose storage reservoir for flood control and hydroelectric power and, in conjunction with Stephens Creek Dam below it, controls the flow to provide navigation between Augusta and the ocean. The Augusta City Dam diverts water to the city power canal, and the new Savannah Bluff Lock and Dam creates a slack-water navigation pool. In 1963, construction was completed on Hartwell, a new multi-purpose dam 67 miles upstream from Clark Hill Dam. Hartwell Dam, when filled in 1962 impounded a reservoir almost as big as the one above Clark Hill. Even now, practically all the water flowing from the upper Savannah River basin is used for hydroelectric power, much of it several times over. Sixty percent of the average flow of the river at Augusta is required to maintain navigation in the river downstream.

Besides furnishing water for hydroelectric power and navigation, the Savannah River provides water for cities and industries. Augusta withdraws 10 mgd; Savannah withdraws about 30 mdg for industrial use; Urguhart, a steam powerplant on the South Carolina side of the river, uses 210 mgd for cooling; three smaller steam powerplants use a total of about 185 mgd; the Atomic Energy Commission's Savannah River Plant uses over 700 mgd for cooling. All these uses are considerably smaller than the minimum flow of the river. Furthermore, these users only "borrow" the water; they return almost all of it after use.

The Altamaha River

The Altamaha, the largest river lying wholly within Georgia, rises in the Piedmont province, crosses the Coastal Plain, and enters the ocean near St. Simons Island. The two principal rivers of the upper basin, the Ocmulgee and the Oconee, unite to form the Altamaha River. The length of the Altamaha from the mouth to its uppermost source, the headwaters of the Ocmulgee, is more than 400 miles. It drains 14,400 square miles—5,800 square miles of the Piedmont and 8,600 square miles of the Coastal Plain. In the Piedmont the Ocmulgee and the Oconee flow through narrow valleys in rather deep channels having shoals and rapids. In the Coastal Plain the rivers of the system meander from bluff to bluff in comparatively broad, shallow valleys.

The average annual runoff from the Altamaha basin is 12.5 inches, a little less than the average for the State. However, in terms of the average flow, the Altamaha is the largest river; at Doctortown the flow exceeds 8,000 mgd. Day to day flows on the Altamaha River system are not as uniform as on the Savannah or the Chattahoochee, and minimum flows of the Altamaha are lower than those of the Savannah. In the Piedmont the minimum flow is generally 3 to 5 percent of the average flow, but the South River, a tributary of the Ocmulgee, is an exception. It receives extra water from the Chattahoochee River by diversion through the Atlanta and De Kalb County water and sewer systems; the diversion causes an increase in the minimum flow to about 10 percent of the average. In the Coastal Plain, respective minimum flows of the Ocmulgee, Oconee, and Altamaha are 15, 9, and 11 percent of the average.

Waters of the Oconee and Ocmulgee Rivers are very similar in chemical composition. Lying entirely within the Piedmont and Coastal Plain provinces, these rivers contain waters having only slightly higher concentrations of minerals than those of the Savannah River. Color and sediment are more pronounced in the Altamaha than in the Savannah River. Industries and cities pollute the water at a few places, but not severely at present.

Two reservoirs regulate the flow of water in the Altamaha system: Jackson Lake formed by Lloyd Shoals Dam on the Ocmulgee River and Sinclair Lake formed by Sinclair Dam on the Oconee. The regulation by Lloyd Shoals has a marked effect on the day-to-day flow of the river for a short distance downstream. Lloyd Shoals uses 67 percent of the average available yearly flow to generate hydroelectric power; Sinclair uses 83 percent. In addition, there are several small "run-of-the-river" hydroelectric plants. Run-of-the-river plants depend on "as is" flows. The storage behind a run-of-the-river dam is too small to increase low riverflows appreciably.

The Altamaha River system drains a region that is basically agricultural; however, in recent years industrial growth, especially along the rivers, has had a marked effect on the region's economy. Cities such as Macon, Milledgeville, Dublin, and Jesup have attracted new industries and have grown in size and importance. The availability of water, both in rivers and in the ground, has been a major factor in this growth. The largest municipal user of river water is Macon: it withdraws about 20 mgd from the Ocmulgee. The largest industrial user of river water is Plant Arkwright near Macon: its average use is 180 mgd, more than the minimum riverflow of record and 15 percent of the average flow.

Shallow-draft vessels ply the Altamaha River between Doctortown and the ocean. Sixteen percent of the average flow is required to maintain a minimum depth of 3 feet for navigation on this section of the river.

The Chattahoochee River

The Chattahoochee is the longest river in Georgia—436 miles from its source in Union and Towns Counties to its junction with the Flint River. At Chattahoochee, Fla., the Chattahoochee River joins the Flint to form the Apalachicola River which flows into the Gulf of Mexico. The Chattahoochee's 8,340-square-mile drainage area, which includes part of southeastern Alabama, lies in three physiographic provinces, the Blue Ridge, the Piedmont, and the Coastal Plain. The course of the river is characterized by long straight reaches, deeply cut through the middle of the valley. Its upper reaches, above Gainesville, have the steep slopes of mountain streams; between Gainesville and West Point the slope is moderate and fairly uniform; in the vicinity of the Fall Line, between West Point and Columbus, the river falls steeply; and across the Coastal Plain to the river's mouth, the slope is gentle.

An average of 17.5 inches of water runs off the Chattahoochee River basin each year; at Alaga, Ala., this runoff amounts to about 7,000 mgd. At Atlanta, the average flow is 1,600 mgd, about 13 times metropolitan Atlanta's municipal use.

The many uses of the Chattahoochee River have varying effects on the quality of its water. In general, the mineral content of the water is rather low in the headwater area and increases as it moves downstream. Originating as it does in the Blue Ridge province, the water is similar to that in the headwater section of the Savannah River. Variations in quality are small because of the mixing of waters in the reservoirs.

Industrial and municipal wastes enter at intervals throughout the entire reach of the river. Although pollution could become a serious threat to the suitability of the Chattahoochee as a water supply, there is, at present, sufficient flow to dilute wastes.

The lower reaches of the Chattahoochee, as well as the other streams of the Piedmont and Coastal Plain provinces, are fairly high in sediment content and color.

The waters of the Chattahoochee are gradually being brought under complete control. The upper part of the river is slightly regulated by several mills and powerplants. Buford Dam, completed in 1956 for flood control and hydroelectric power, regulates the flow of the river below it, and will greatly reduce floods at Atlanta; for example, the 50-year floodflow (flow recurring an average of once every 50 years) will be reduced 43 percent. Downstream from West Point a series of eight power dams regulate the flow. Multipurpose projects, such as the Jim Woodruff Dam at the junction of the Chattahoochee and Flint Rivers and the Walter F. George Lock and Dam regulate the river in the Coastal Plain.

The water supplied to almost one-fourth of the homes in Georgia comes from the main stem of the Chattahoochee River. In addition, homes in several communities obtain their water from the Chattahoochee's tributaries. Water systems in the Atlanta metropolitan area withdraw more than 80 mgd—a lot of water, but even so, only 5 percent of the average flow and 25 percent of the minimum flow (minimum maintained by release of water at Buford Dam) of the river at Atlanta.

By supplying cooling water for two major steam-electric plants, the Chattahoochee further adds to Georgia's supply of electricity. Plant Atkinson near Atlanta uses an average of 310 mgd, almost four times metropolitan Atlanta's use.

In 1958, Plant Yates, near Newnan, increased its maximum water use to more than 500 mgd. These plants annually generate enough electricity to provide for the needs of about 1½ million homes.

The Flint River

The Flint River rises just south of Atlanta and flows southward in a wide eastward arc to its junction with the Chattahoochee at the southwest corner of Georgia. It drains an area of 8,500 square miles, about a third in the Piedmont and two-thirds in the Coastal Plain. Like the other streams traversing these two provinces, the river slopes rather gently across the Piedmont, more steeply in the vicinity of the Fall Line, and very gently across the Coastal Plain. Throughout most of its reach, high banks generally confine the river in its channel through the rolling countryside. Swampy land borders the lower reach of the river, between Bainbridge and its mouth.

The annual runoff from the Flint River basin is higher than the average for the State—15.6 inches versus 14.0 inches. At Bainbridge, 30 miles above the mouth, its avearge flow is 5,500 mgd. As has been mentioned, numerous springs in the Coastal Plain contribute to the Flint River and sustain its flow there remarkably during dry seasons. The minimum flow of the river across the Coastal Plain is 22 percent of the average flow, but in the Piedmont, where there are fewer springs, the minimum flow is only 5 percent of the average.

Most of the Flint River is low in dissolved material. Appreciable concentrations occur in the headwater area near Atlanta but dilution by tributaries progressively reduces the concentrations downstream. Large volumes of hard water entering from Ichawaynochaway and Chickasawhatchee Creeks and from the many springs cause an increase in dissolved solids in the lower Flint River.

Two hydroelectric powerplants, one near Cordele and the other at Albany, regulate the flow of the river. Jim Woodruff Dam at the mouth uses 68 percent of the river's total runoff to generate electricity.

A steam-electric plant below Albany, Plant Mitchell, that uses about 8 percent of the average flow for cooling is the largest industrial user of the water. The largest municipal use of the river water is at Griffin where withdrawals from a tributary of Flint River average 4.3 mgd, much less than the average flow. However, at times during the drought of 1954, even though the entire flow of the tributary was pumped into the Griffin water mains, there was not enough water. Albany, the largest city in the basin, gets its water from wells; it discharges its wastes to the river.

Jim Woodruff Lock and Dam enables river boats and barges to navigate in a 9-foot channel up the Flint River as far as Bainbridge.

The Coosa River

The Coosa River is formed by the confluence of the Oostanaula and Etowah Rivers at Rome. The Etowah River rises in the mountains of north central Georgia, flows westward to Rome through rugged Piedmont terrain and across the folded rocks of the Valley and Ridge province. The Oostanaula River rises in the Blue Ridge Mountains and flows mostly along the folded rocks of the Valley and Ridge province. The characteristics of the two rivers differ considerably. In general, the Etowah River has flashier floods. The Oostanaula River floods tend to be lower but to move slower than those on the Etowah River. Below the confluence at Rome, the Coosa River has more of the characteristics of the Oostanaula River as it follows a wandering course through the Valley and Ridge province into Alabama, where it eventually enters the Gulf of Mexico in Mobile Bay. Of the Coosa River system's 10,300 square miles of drainage area, 4,400 square miles are in Georgia. Rapids and riffles characterize the upper reaches of the river system. Farther downstream in the Valley and Ridge province, the rivers generally meander in deep channels within wide flood plains.

The average annual runoff of that part of the Coosa basin that lies in Georgia is about 20 inches, highest of any of the major rivers in that State. At Rome, the Coosa River flows at an average rate of 4,000 mgd; 58 percent of this water comes from the Oostanaula River and the remaining 42 percent from the Etowah River. The dry-weather flow of the larger rivers in the Coosa system is also well sustained. For example, the minimum daily flow occurring once in 20 years on the average is 24 percent of the average flow in the Blue Ridge province and 14 percent in the Valley and Ridge province. In contrast, some rivers in the Coastal Plain have minimums that are less than 5 percent of the average.

Waters of the Coosa River basin are moderately hard, low in color, and high in sediment. The Etowah River water is much softer than the Oostanaula River water. Only minor treatment and the removal of the sediment are needed to make all the Coosa basin waters satisfactory for most uses.

Several factors affect the quality of the water in the Coosa River; most important probably is the varied geology of the headwater area. The concentration of dissolved solids in the Oostanaula River is, on the average, nearly twice that of the Etowah River; it results from solution of dolomite and limestone in the headwaters of the Oostanaula River. The concentration of salts below the confluence of the two rivers fluctuates because the proportion of the flow contributed by each stream varies.

Some wastes are discharged into the Coosa River system but, as is true of most rivers in Georgia, there is enough flow for adequate dilution.

Floods have been a more severe problem at Rome than at most river cities in Georgia. The frequency of damaging floods at Rome is high because the city is built on a low-lying flood plain and because the Etowah and Oostanaula come together there. Most other major Georgia cities are on reaches of streams where floodwaters do not concentrate so severely.

Allatoona Dam and Reservoir, a multi-purpose development on the Etowah, increases low flows and reduces floods. For instance, the minimum monthly flow of the Etowah at Rome to be expected once in 20 years has been increased about 25 percent by operation of the dam. As for floods, the Corps of Engineers estimates that if Allatoona had been in operation during the destructive floods of 1886 or 1919, maximum stages of the Etowah at Rome would have been reduced by about 5 feet.

Allatoona Dam uses practically all the flow of the Etowah River to generate electricity. Plant Hammond, a steam-electric plant on the Coosa, uses about 5 percent of the average flow near Rome for cooling. The city of Rome uses 7 mgd from the Oostanaula River, a fraction of a percent of the average flow and less than 2 percent of the minimum flow to be expected once in 10 years.

Enough Water?

The foregoing descriptions show that Georgia's major rivers provide plenty of good quality water for present use and, in most areas, enough for substantial increased use in the future. Urban water demands are generally not large in proportion to average or even minimum riverflows. Water use for cooling at steam-electric plants sometimes exceeds rare minimum flows, but is well below average flows. Continued expansion of steam-electric plants may require storage of the flow or, perhaps, more efficient cooling installations at the plants. Hydroelectric powerplants use practically all the flow at several points on the major rivers. However, all these uses have little effect on the quantity of water available. The same water may be used over and over at different points along a river. Water removed for irrigation does diminish the supply but, so far, irrigation withdrawals amount to only a small fraction of 1 percent of the flow. Even by 1970, irrigation withdrawals above hydroelectric dams will probably not reduce power production by more than 1 to 2 percent. Concentrations of municipal and industrial wastes, dissolved salts, or sediment constitute serious problems at some times and some locations, but the overall quality of water in the big rivers is good.

Water Problems in Georgia

Floods

Since the dawn of history man has had water problems of one kind or another. At some places he has had too much water and at others too little. Floods have ravaged civilizations throughout history. When more water reaches a river than its channel can hold, the excess must flow on the flood plain, and floods result. The flood plain and the river channel were made by the river. The river formed its flood plain from sediments carried by floodwaters. We will always have floods, for they are natural and cannot be wholly eliminated. Complete prevention of floods along the entire reach of our streams would be far too costly to attempt, but we have learned to control them to a certain degree with dams, levees, and channel improvements.

The idea persists that there were no floods prior to the cutting of the forests, but explorers and early settlers saw floods long before the forests were cut down. It is true that the amount and kind of vegetation on the land surface can and do affect the yield of streams, especially the low and medium flows and minor floods, but there is no proof that our use of the land has increased the severity or frequency of major floods.

Floods in Georgia, where there is little or no snow, are caused almost exclusively by heavy rainfall. The size of a flood depends on the rate, duration, and extent of rain, and also on the amount of rain which the soil can absorb. Most of the flood-producing rain in Georgia is associated with cyclonic storms which bring warm moist air over the State, principally from the Gulf of Mexico. The most severe floods on major rivers usually occur during the winter when a broad "front" between warm moist air and cool dry air stagnates and results in a few days of moderately intense rainfall over a wide area. Another type of storm, the short, violent local thunderstorm of summer, is a common cause of floods on very small streams but is rarely a cause of major floods on large rivers.

At average discharge, the river channel is far from full; on several days of each year the channel is about three-quarters full, and about twice a year the river flows bankful. Once every year or two, or perhaps once in several years, the river uses its flood plain. These generalizations may be modified for particular streams by many factors such as the climate, the topography, and the drainage pattern. Flood conditions may even vary at different points on the same stream. A flood in one section of a stream may be well contained within the channel at another section.

Georgia has not suffered from damaging floods to the extent that some other sections of the country have. On the Coastal Plain and Piedmont the cities, rail lines, and highways tend to favor the high ground between streams. Ridge cities, along the broad drainage divides, have few flood problems. Even so, many of the people of Georgia live, and much of Georgia farm land lies, on flood plains. The cities of Columbus, Macon, and Rome particularly have suffered from floods. Plans for future Georgia development must take these flood dangers into consideration.

Flood-control measures do not eliminate floods but they do provide a certain amount of protection from them. Major dams such as Buford on the Chattahoochee, Clark Hill on the Savannah, and Allatoona on the Etowah, the protective levees at Augusta, Rome, and Macon, and small upstream flood-retarding projects as in the Coosa River basin provide varying degrees of protection. The cost of this protection is the price we pay for occupying flood plains.

It is true that floods will always occur, but there need be no flood damage if we do not occupy the flood plains. Although cities, transportation lines, farms, and industries use the flood plains, they do so at the risk of flood damage. We can choose among the following alternatives: building on the flood plains and accepting the flood hazard, not using the flood plains at all, using them with flood-protection works, or adopting flood-zoning regulations. More and more communities in the United States are adopting flood zoning as a way of reducing flood damage. By "flood zoning" we mean local ordinances which regulate the use to which tracts in the flood plain will be put. Zoning might mean restriction of the use of the flood plain to agriculture or to municipal parks and playgrounds. Commercial enterprises which might be permitted are parking lots or factories and office buildings in which people and valuable records are accommodated only above the first floor.

Droughts

Here in Georgia, there were droughts in 1925 and 1941, but that of 1954 is generally considered the most severe in recent history. It was a major agricultural disaster. Municipalities and industries suffered less but, even so, 18 cities and towns had difficulty with water supply because streamflow dropped to very low levels. In southern Georgia, some streams were completely dry for the first time in memory. The 1954 drought was so damaging that it aroused widespread interest in measures to modify or prevent the effects of any future drought.

The basic cause of drought is simply lack of rainfall. In 1954, rainfall was deficient over the State by about 15 inches. It is chiefly in summer during the growing season that deficient rainfall causes drought. At other times of the year, seepage from the ground-water reservoir may keep stream levels high enough to meet needs. During the growing season, however, vegetation requires much moisture and only a small part of the rainfall runs off into streams. Evapotranspiration from plants tends to deplete any small surplus of water which might accumulate in the soil. Without rainfall in the summer, streamflow continually diminishes until a low point is reached in the fall.

For purposes of conservation, use, and control of water, the minimum flow of a river is a critical statistic. Municipal and industrial water supplies are designed on the basis of the minimum flow. If a lesser flow occurs than the design minimum, water use may have to be curtailed, irrigation may cease, and factories may be shut down; the whole economy of the town or region will be affected.

The severity of low-flow, or drought, conditions depends upon several factors. The quantity of flow is one factor; for example, it may still be sufficient for urban water supply long after it has become inadequate for waste-disposal, industrial, or power needs. The length of the low-flow periods is another important factor. A reservoir may suffice for a few days' deficiency, but may be inadequate for a shortage of several months. Another factor is the frequency of low-flow conditions. A community or industry may adapt itself to occasional water shortages in rare droughts, but may find conditions intolerable if the shortages occur too frequently. Thus, low flows must be defined in terms of the quantity of the flow, the duration of the low-flow period, and the frequency of recurrence. Hydrologic information to define these terms is obtained in Georgia by the U.S. Geological Survey through the continuous operation of a network of more than 100 streamflow stations and by making low-flow measurements at well over 1,000 sites throughout the State.

Data for the 1954 drought, collected by the Geological Survey in cooperation with the State of Georgia, indicate that the relative severity of the drought condition varied considerably over the State. Generalized areas were delineated in which the relative severity of the 1954 drought was indicated to be fairly uniform.[1] These generalized areas are shown on the map (fig. 18). The relative severity

[1] Thomson, M. T., and Carter, R. F., 1963, Effect of a severe drought (1954 on streamflow in Georgia: Georgia Geological Survey Bulletin 73.

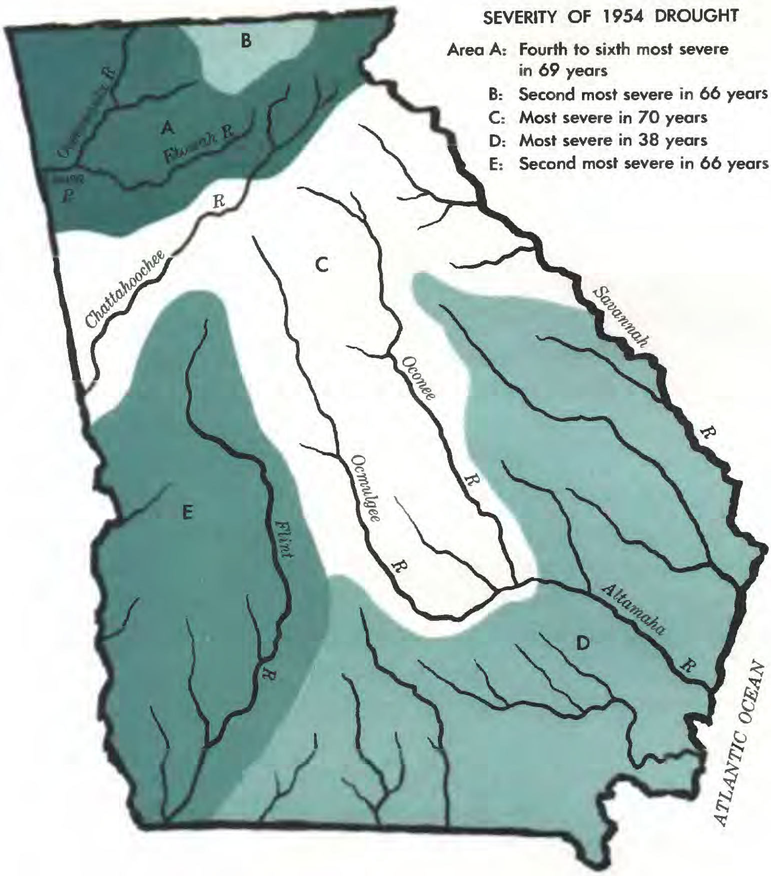

FIGURE 18.—Relative severity of the 1954 drought.

of the 1954 drought in each area ranges from the sixth most severe in 60 years to the most severe in 70 years. In the Coosa River basin (area A of fig. 18) the drought was the fourth to sixth most severe in 69 years. On the Tennessee River tributaries in northeast Georgia (area B), it was the second most severe in 66 years. In area C (the Savannah River basin from Toccoa to Augusta, the Altamaha River basin above the confluence of the Ocmulgee and Oconee Rivers, the Chattahoochee River basin from Norcross to West Point, and the Tallapoosa River basin), it was the most severe drought in 70 years. In area D (Savannah River basin below Augusta, Altamaha River basin below the confluence of the Ocmulgee and Oconee, and the Ogeechee, Satilla, Suwannee and Ochlockonee Rivers), the drought was the most severe in at least 38 years. In area E (Chattahoochee River basin below West Point, and Flint River basin), the 1954 drought was the second most severe in 66 years.

Even within these areas there is still a wide range of flow. In order to make reliable drought estimates for any practical purpose, such as locating a factory site, additional streamflow measurements at or near the site are needed.

There are ready, but not always easy, answers to the problem that a user faces of assuring an adequate supply of water during droughts. He may turn to an alternate source of supply—a larger stream or additional wells—or he may build dams to provide storage facilities to increase the dependable supply. Whatever measures taken to bolster the dependable supply of water are likely to be costly. It is, therefore, important that decisions be based on the best available hydrologic information about the possible sources of supply. If a stream is considered for additional development, its low-flow behavior most certainly needs to be taken into account. If a ground-water supply is considered, information about the yield of wells of a given size and spacing and about their long-term dependability should be sought. After considering all the hydrologic data, a community or industry can decide whether to accept the possibility of deficiency and can plan for the use of water on the basis of the minimum flow, or can arrange for additional water from some other source.

Legal Problems in Competition for Water

Competition for available water creates legal problems. Water rights have been of the utmost importance in the arid parts of the United States. Each State has water laws that control the priority of water use. Furthermore, the use of interstate waters is subject to legal control by interstate compacts or United States Court Decrees. Georgia's courts have settled many water cases although water laws are not always clearly defined.

The right to use water on a priority basis may become a legal question in Georgia and other humid eastern States, and the lawmakers will have to enact water laws that clearly spell out priorities to use water. The conflicting points of view of the industrialists, the farmer, and the city dweller must all be reconciled. Will farmers have the right to pump water from rivers to irrigate crops when this might deprive the cities downstream of adequate water supplies? Will excessive pumpage from an artesian aquifer be allowed to cause saltwater invasion of the water supply of a nearby city? These are examples of the problems faced by legislators.

Savannah and Chatham County already face the problem of salt-water invasion. The city and county have adopted regulations to protect their ground-water supply from salt-water contamination, but neighboring counties in Georgia and South Carolina can permit unlimited well development and completely void all their precautions. Local ordinances cannot control the situation. State and interstate regulations are required for effective control.

The Problem of Water Quality

Water-pollution problems are becoming more and more complex. Cities and industries dispose of waste in the streams but, at the same time, want streams to be clear and clean. The technical problems involved in treating pollution are numerous and varied. City sewage requires a certain type of treatment, industrial waste another. Some treatments are bacterial, others chemical. No single treatment can be applied to all waste, and any treatment costs money.

The costs of treatment must be borne by the taxpayer and the consumer. Georgia's streams are not nearly as polluted as those of some States where much of the aquatic life has disappeared from the rivers. But if the people want cleaner streams, they must legislate and pay for them. The job is difficult and complex. It will require the cooperation of all cities, industries, lawmakers, and interested citizens.

Sometimes ground water is polluted, but not as often nor as seriously as is stream water. In highly settled areas like

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Atlanta, some shallow wells may be polluted. Chlorination is the simplest way to treat this water, but relatively few private systems are treated in Georgia.

In addition to chemicals and bacteria, certain physical properties affect the use of water. Sediment in streams, for instance, is so common that it has become an accepted part of Georgia life. Removal of such material is troublesome and costly. Proper land-use and water-control practices may do much to lessen this condition.

Another physical-quality problem occurs in both surface and ground water but is not as obvious as sediment. Increased water temperatures resulting from various uses may reduce the cooling potential of many water supplies and, in some instances, increase the ability of the water to dissolve material. This factor applies particularly where large volumes of heated water are returned to ground-water supplies.

Color in the water of many Georgia streams comes from dissolved or colloidal particles which are derived primarily from decomposition of vegetation. Studies are still being made to learn what these substances are. When ways are determined to remove the substances, more good water will be available for Georgia users.

Minor problems of chemical quality of ground water occur in various parts of the State. Dissolved iron is a problem in many places. Nearly all shallow water in sand and weathered rocks contains dissolved iron. When the water is exposed to air, chemical reactions take place in the water; the iron is converted to a solid form that stains clothes and enamelware red and deposits a red sludge in water heaters and boilers. Dissolved carbon dioxide creates problems because it corrodes iron pipes. The iron later precipitates from solution and causes red stains. Iron pipes rust through rather quickly and must be replaced.

At Valdosta, dissolved sulfate makes the water bitter and caused the abandonment of one city well. The cause and the extent of the high-sulfate water need to be determined so that the city can make long-range plans for its management and for use of water.

Cloudy water is a common problem for well and spring owners in limestone country. At times, usually following wet weather, cloudy or muddy water is pumped from wells and flows from springs. If this happens after every rain, a direct path between the land surface and the water source is probable, and the water supply would be much safer if it were chlorinated before use by humans. In the area surrounding Albany and along the rivers of northwest Georgia, known open connections exist between the land surface and the water table. Cloudiness in deep wells may indicate a local movement of sediment in the deep rocks and not an open connection with the land surface.

Atomic powerplants and reactors have a tremendous contamination potential. Numerous safeguards are built into such plants to prevent contamination. The location of atomic powerplants and reactors is very carefully studied to protect the environment against accidental contamination. Elaborate monitoring apparatus continually checks the waste cooling water coming from a plant to detect any sudden rise in radioactivity, which could mean serious trouble. A well-operated atomic powerplant or reactor has no more effect on a stream into which it discharges cooling water than does a conventional steam-electric plant, but continual vigilance is necessarily exercised to prevent accidental release of radioactivity.

Declining Water Levels

Most ground-water problems that have been minor in the past will become more important in future years, especially with respect to water rights. The many misconceptions about ground-water movement and about the relation of surface water to ground water need to be dispelled in order to have fair and equitable water laws.

Ground-water levels fluctuate up and down with the season and with variations in the amount of water pumped from wells. Normally, the water table is highest in the early spring and lowest in the fall. The aquifer is recharged by winter rains, which restore the water table to its normal level. If a dry winter occurs, the water table does not return to its normal high level, and decline during the following summer causes a drop to lower levels than the previous sum-

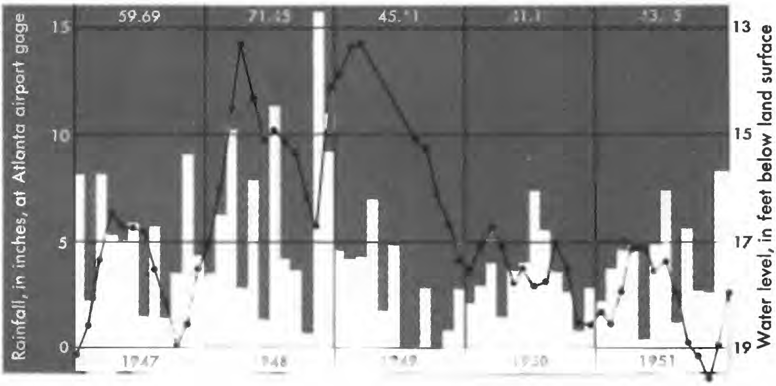


Figure 19.—Level of water in a water-table well in East Point, Ga., in relation to rainfall.

mer. The levels will rise during the following winter, but not as high as previously. Thus, deficient rainfall for several years in succession will cause the progressive lowering of the water table. During such periods, wells and springs become dry. When conditions are reversed and rainfall is greater than normal, the water table rises progressively, to the point that several years of excessive rainfall may bring the water table to land surface in the lowlands and may create swamps. Such a relation is shown in figure 19.

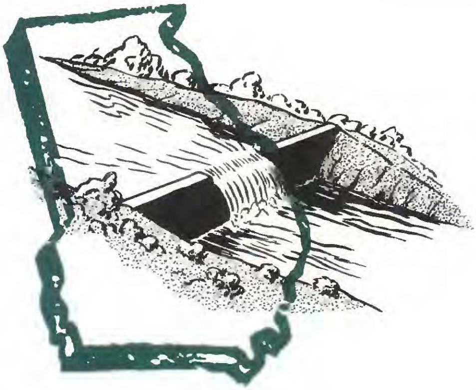
The overdevelopment of an aquifer takes place when recharge cannot keep pace with pumpage, as has happened in some of the cities of the Piedmont. Water is pumped from wells at a greater rate than it can flow through the rocks, the water table drops progressively, and, finally, the wells fail to yield water.

A parallel situation exists when the water-distribution system of an expanding city is overtaxed. The size of the mains limits the amount of water that will flow through them and the number of customers that can be served. When the capacity of the mains is exceeded, the customers who live farthest from the storage tank get water only when others are not using it. In rocks, the size of the cracks and their distribution limit the amount of water that will flow through them. If the capacity of the rocks to yield water is exceeded, the water table drops and the yield of individual wells decreases to the point where some wells dry up or yield water only when other wells are not pumping.

One of the most common problems of the rural dweller of the Piedmont is the fluctuating water table. This fluctuation is normal, but individual problems are created if the water table drops below the bottom of a well. Then the well owner is out of water and must take immediate action to obtain a supply. He must either deepen the existing well, drill a new well, or haul water from another place.

Wild-flowing wells in the coastal areas have caused a loss in pressure and waste of millions of gallons of water every day. Actually, the pumping of water by the cities is a kind of conservation measure, because by lowering the artesian head, the waste of water from wild-flowing wells has been reduced.

Heavy pumping from the principal artesian aquifer has caused a progressive lowering of the artesian head, or pressure, over a large area, and has decreased the flow from wells. Fifty years ago wells flowed at the land surface in all the coastal counties. At present, wells close to the centers of pumpage have stopped flowing completely. Not a single flowing well is left in Chatham County. There has been a serious loss of head at Brunswick and Savannah. Water levels have declined slightly at Albany and Valdosta. Though the ground-water situation is not nearly as critical in Georgia as it is in some of the Western States, it will bear watching and will need good management practices to prevent depletion of ground-water reserves.



Water—and Georgia's Future

Georgia is endowed with abundant high-quality water. The supply available to all users is so great during normal years that, when rare droughts occur, many water users are unprepared for such extreme conditions. These rare shortages could be remedied at low cost by storing surface water or, in the coastal plain, by developing additional groundwater supplies.

Georgia is divided into two major parts by the Fall Line. North of the Fall Line abundant water is available almost everywhere in streams, and small but dependable supplies can be taken from properly located wells. South of the Fall Line, the supply is abundant in large rivers, and the supply underground is phenomenal.

However, water needs are increasing in Georgia as elsewhere, and for the same reasons: increase of population and increase in manufacturing. The population of the State increased by 14.5 percent between 1950 and 1960 (fig. 20). And although Georgia is historically an agricultural State, its economy has gradually shifted since 1950 away from an agricultural toward an industrial base.

Several factors make industrial development natural for Georgia. It has ample supplies of water, fuel, and electric power. Construction costs are 11 percent lower than the national average. Time losses due to weather conditions are negligible. Many construction materials—clay, brick, cement, lumber—are produced locally. An ample supply of unskilled labor moves out of the rural areas into the cities, and Georgia's new system of vocational-technical schools will soon produce a larger supply of skilled workers.

Finally, Georgia's central location in the Southeast gives it access to a regional market which is steadily growing in population and buying power. Alabama, Tennessee, North Carolina, South Carolina, and Florida all increased in population in the last decade.

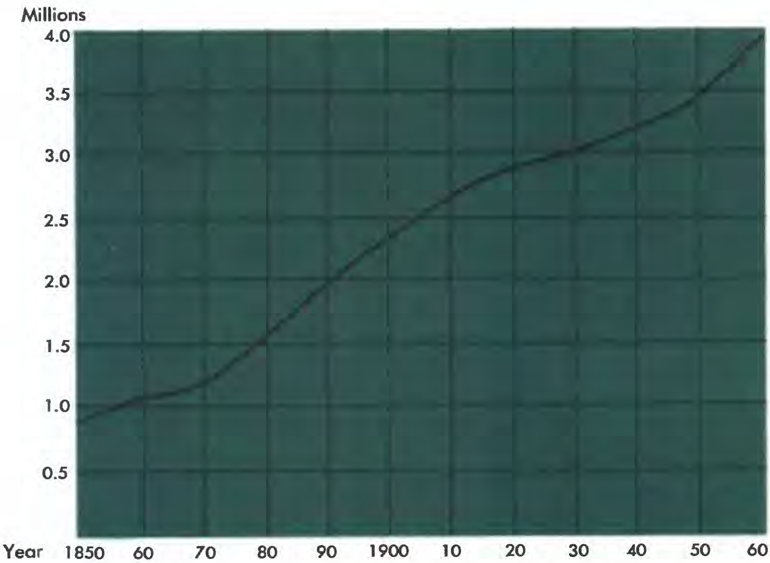


FIGURE 20.—Population trend in Georgia, 1850–1960.

From the beginning of its history, Georgia has been an agricultural state having diversified crops and a long growing season. The present emphasis on industry has meant no decrease in agricultural production. On the contrary, agricultural income has increased 46 percent over the last 10 years, while the national average has increased less than 19 percent. The chief products are cotton, tobacco, watermellons, peaches, pecans, peanuts, hogs, and broilers. Georgia leads the South in production of pulpwood.

As we have seen, modernization of agricultural methods demands more water for irrigation. Irrigation specialists of the U.S. Department of Agriculture estimate that about 10 percent of the present acreage in cotton, corn, and pasture, and about 50 percent of the present acreage in legumes, tobacco, and truck crops, could be irrigated economically. If irrigation were to reach this level, 1.3 million acres would be irrigated and average annual water use during a dry year would exhaust the flow of the streams. However, individual farm ponds filled during the nongrowing season would not noticeably deplete streamflow. Some conflicts between irrigators and other water users may develop during severe droughts unless surface-water storage is developed in advance of the drought. Farm ponds filled from the normal winter surplus runoff could largely alleviate conflicts.

The rural population in many Georgia counties is either static or declining—people are leaving the farms and moving to the city. It is estimated that the rural population depending on home water supplies will be about the same in 1970 as in 1955. However, by 1970, many more homes will have running water and additional water-using appliances; total rural water use, therefore, will probably increase as much as one-third.

Water requirements increase with industrial growth, and Georgia's industries are growing. In the 10-year period 1946–56, employment in manufacturing increased 33 percent and the production of electric energy increased 180 percent. The oldest and largest industry in Georgia is the textile industry. Other important industries are food processing, transportation equipment, lumber, apparel, pulp-paper, and chemicals. Three of these—food processing, pulp-paper, and chemicals—use large amounts of water. We can be reasonably certain that industrial demand for water will be much greater with each passing year.

Between 1945 and 1955, per-capita municipal water use in Georgia increased from 109 to 129 gpd. By 1970, municipal water use will be about 140 gpd. More homes will be equipped with extra bathrooms, automatic washers, air conditioners, and other water-using appliances. Too, much larger amounts of municipal water will be needed for nonresidential uses such as industry, commerce, and recreation.

Besides an increase in per-capita use, there will be a substantial increase in the population served by water-supply systems. Water mains will spread farther out into the suburbs and along the highways leading from the cities. And as mains are extended, prospective home builders will seek out lots with "city water." By 1970, urban water systems in Georgia will distribute an estimated average of 320 mgd, 44 percent more than in 1955, and in all probability maximum daily use will increase proportionately.

Atlanta's metropolitan area is one of the fastest growing areas in the southeast—between 1950 and 1958 the population increased 31 percent! Today, the total stands at more than 1 million, and the best estimate is that by 1970 it will exceed 1¼ millions. By 1970, the demand on the public water-supply systems serving the area will have climbed to an estimated 130 mgd. The demand for water by Atlanta's industries will increase too. If industrial use, not counting powerplant use, increases at the same rate as the expected increase in municipal use, it will reach 22 mgd by 1970.

The pumping rate of the Atlanta waterworks is a good index of the growth of water use. The graph of figure 21 shows the average rate of 5-year intervals since 1920, projected to 1970 by waterworks officials. Between 1940 and 1955, average withdrawals from the Chattahoochee River increased 60 percent because of two factors, a growing population and an increased per-capita use of water.

Other Georgia cities are growing too. It is estimated that between 1955 and 1970, the demand for water in Columbus will increase at least 50 percent. But even after this increase, total withdrawals will be equal to only about 10 percent of the minimum flow of the Chattahoochee River. Albany depends mainly on ground water, but if the level should decline greatly, water from the Flint River could be used to supplement ground-water supplies. Augusta is amply supplied by the Savannah River and has supplemental groundwater supplies. How do the largest uses of water in Rome compare with the supply? Municipal use is only 2 percent

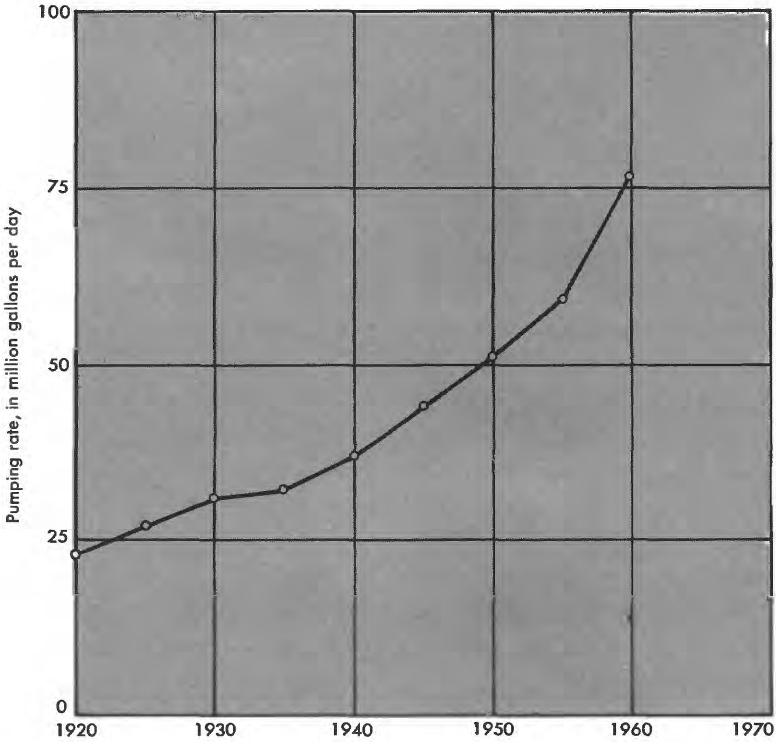
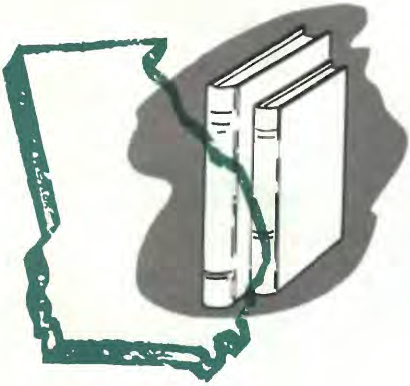


FIGURE 21.—Average rate of water use at Atlanta, 1920–60.

of the minimum daily flow of the Oostanaula River that might be expected once in 10 years. The largest industrial uses at Plant Hammond and the Rome Kraft plant on the Coosa River, are about 40 percent of the 10-year minimum. Several small tributaries around Rome are largely untapped sources of supply, as are several springs in the area. Savannah has water supplies available in the Savannah River for almost unlimited expansion. River water must be treated, hence it would be more expensive than ground water, but it is plentiful. The withdrawals must be made upstream because at Savannah the river is brackish. The source of Valdosta's water—the limestone aquifer— has not been fully developed, and much more water can be developed in this area. Valdosta has adequate ground-water reserves for the foreseeable future.

The fact that there are generally adequate water reserves in Georgia does not mean, however, that there will be no water problems in the future. Many water problems will continue to be acute, and new ones will arise. Until the planned flood-control projects are built, floods will continue to threaten many of Georgia's cities. The problem of salt-water encroachment will continue to be present. Water levels in certain aquifers will continue to decline. Pollution of streams will become more objectionable as the waste load increases with population and industry. Low streamflow during rare droughts will be inadequate to meet all demands unless storage is constructed to sustain low flows.

Georgia's water promises to be a continuing great asset. Industries that require large quantities of pure process water are sure to examine Georgia for possible new plant sites. As the demands for food, fiber, and wood for the Nation's expanding population become more difficult to supply, the good soil and abundant water of the coastal plain will be more fully exploited. Finally, by the year 2000 approximately, the latent hydropower, navigation, and recreation potential of Georgia's water will become fully developed.



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