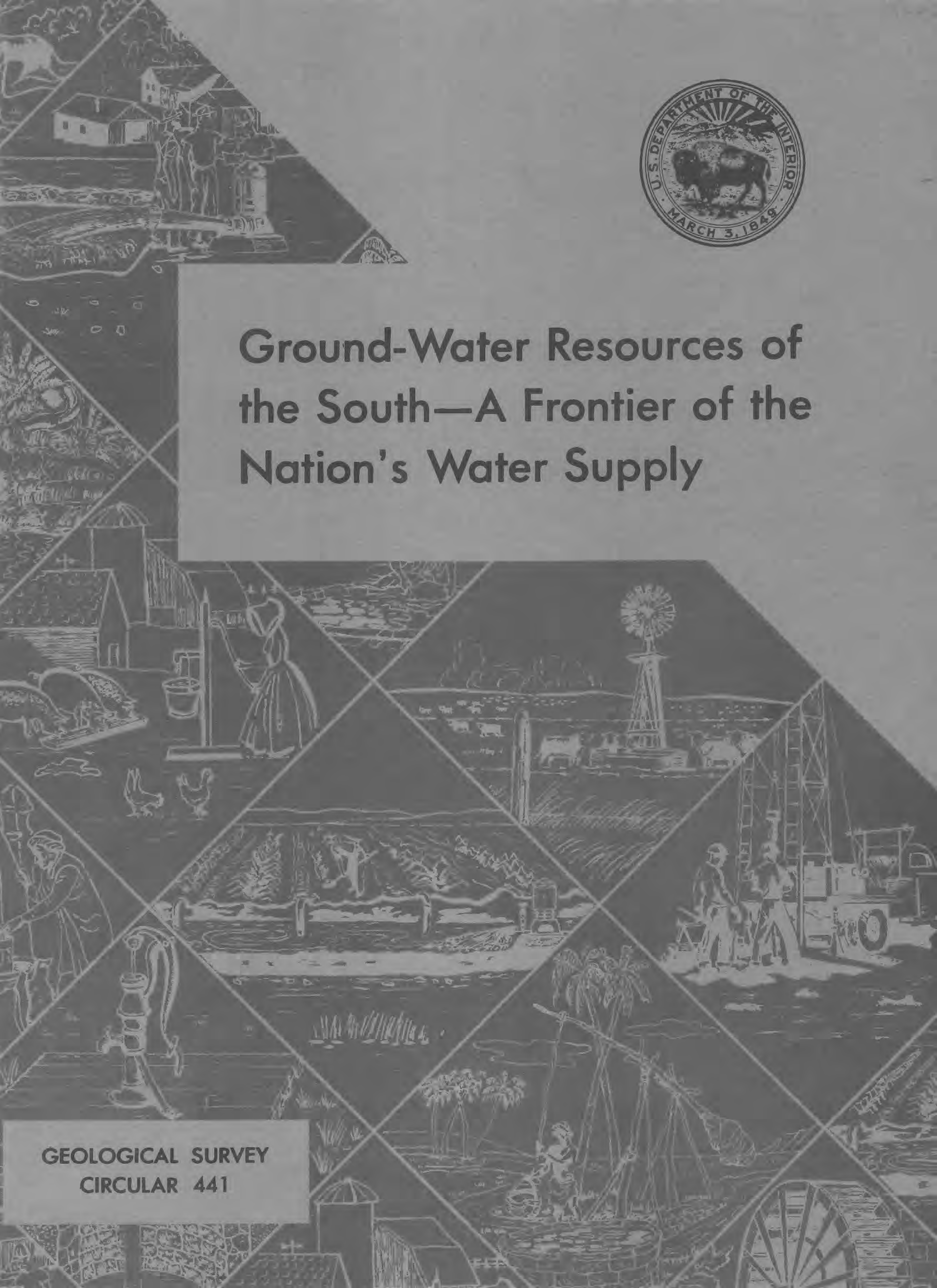
Ground-Water Resources of the South—A Frontier of the Nation's Water Supply



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Ground-Water Resources of the South—A Frontier of the Nation's Water Supply

By P. E. LaMoreaux

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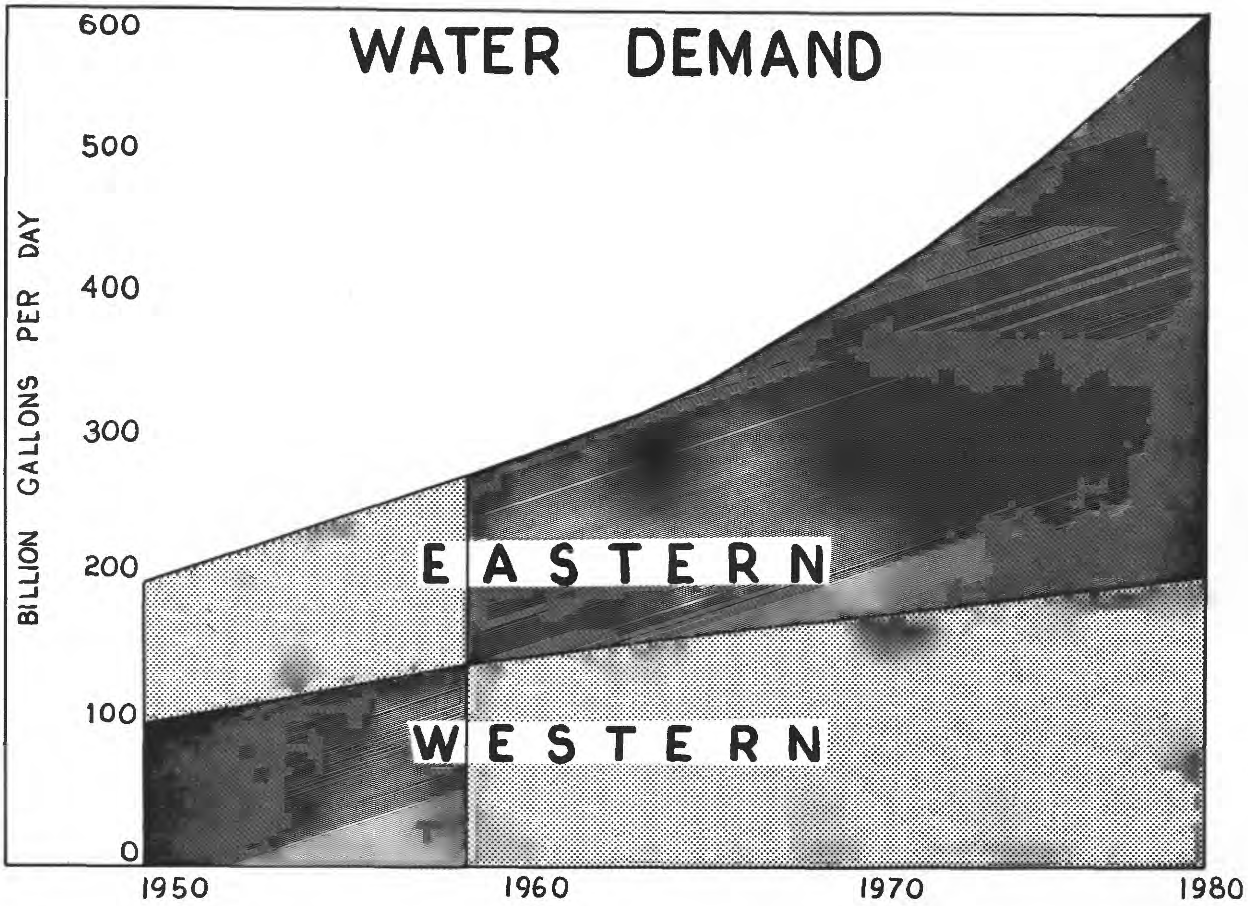
By P. E. LaMoreaux

Up to a few centuries ago, practically all of Man's needs for water were supplied from streams and springs. As bands or tribes of people grew, Man was forced to move farther from these surface sources of water in search of food, clothing, and other useful materials that would allow him to live more comfortably in a very competitive world. He solved his new water problems at first by scooping out shallow dug wells; then, guided by his experience, he dug, and later drilled, deeper and deeper wells. There is some record of wells being dug as early as 6,000 years ago, and very substantial information that the ancient Egyptians and Romans, more than 3,000 years ago, learned that a well bored deep into the sandstone beds beneath the oases of the Libyan Desert would flow fresh water. At about the same time the Persians learned that by tunneling or digging inclined wells known as "kanats" into the stream deposits known as alluvial fans, they could obtain large quantities of water. Remnants of the work of these ancients in their search for water are historic monuments to the capabilities of Man to satisfy his water needs.

This quest for water was a very great challenge to early man for he was delving into a completely mysterious unknown. That this mystery was important to him is indicated by the number of references to water in the Bible and other ancient writings, and by the amount of time the early philosophers devoted to the discussion of this subject. The solution of some of Man's water problems, and especially those related to the development of ground water, permitted civilization to spread and gave Man greater latitude in selecting his homesite, in carrying out the development of his new environment, and in improving his techniques for doing things.

The challenge that faced the ancients in locating water, however, was no greater than that faced by the generations that followed. We know from the record that Man's experience did not keep pace with water needs. Evidence of this is the rise and fall of civilizations along the Tigris, the Euphrates, and the Nile and in other parts of the world. Even today Man, with all his technology and scientific "knowhow," is having considerable trouble with water problems he has not been able to solve—problems related to the appraisal of supplies, and their development, protection, and management. Our world today is faced with a rapidly expanding population for which the term "explosive" is already becoming hackneyed but is none the less appropriate. It is forecast that the population of the United States will be slightly more than 200,000,000 by 1970 and 230,000,000 by 1975. The population is both growing, and shifting, as parts of our country grow more rapidly than others. In addition, our population is moving rapidly to metropolitan areas, and forecasters suggest that by 1970 about 70 percent and by 1975 about 90 percent of our population will be concentrated in urban areas. Therefore, we no less than the ancients are faced with complex water problems, for our millions must have food, water, clothing, proper sanitation facilities, and a great variety of materials if we are to maintain and continue to improve our living standards. As shown in figure 1, it is estimated that by 1980 our Nation will need 600 billion gallons of water a day, and that a large part of the increase over the 200 billion used at present will have to come from Eastern United States. (U.S. Senate Select Committee on National Water Resources, 1960, fig. 2). The need to develop water supplies of this magnitude must have a very profound influence on the water-resources programs that we devise for the future, and a large resource of water, such as that existing in parts of the South, becomes tremendously significant to the welfare of our Nation when it is placed in this perspective.



AN IMPORTANT SOURCE OF WATER FOR THE NATION

Precipitation throughout most of the South exceeds 40 inches a year, as compared with the national average of 30 inches, and in much of the Southeast it exceeds 50 inches. From figure 2 one can see that the South is one of the areas of the United States most blessed with rainfall, the ultimate source of ground water. Accompanying this large potential source of usable water are favorable geologic conditions for replenishment and storage of water underground. In fact, no other large area of the United States and few other places in the world meet so favorably the requisite conditions for optimum supplies of ground water as does the southern Atlantic and Gulf Coastal Plain and the Mississippi Embayment. Let us refer to figure 3 and table 1 for an overall look at the geology and its relation to the availability of water.

The South can be divided into three areas: The first is the Blue Ridge and Piedmont, the oldest geologically and that having the smallest ground-water potential. It is an area underlain by igneous and metamorphic rocks from which wells will yield only limited water for rural, domestic, and small municipal and industrial uses. The second area, the Appalachian Ridge and Valley and the Appalachian Plateau, is underlain predominantly by relatively compact consolidated shale, sandstone, and limestone. The water available from these rocks varies greatly in quantity; it ranges from very small water supplies from wells in shale to very large supplies, measured in millions of gallons per day, from wells and springs in cavernous limestone.

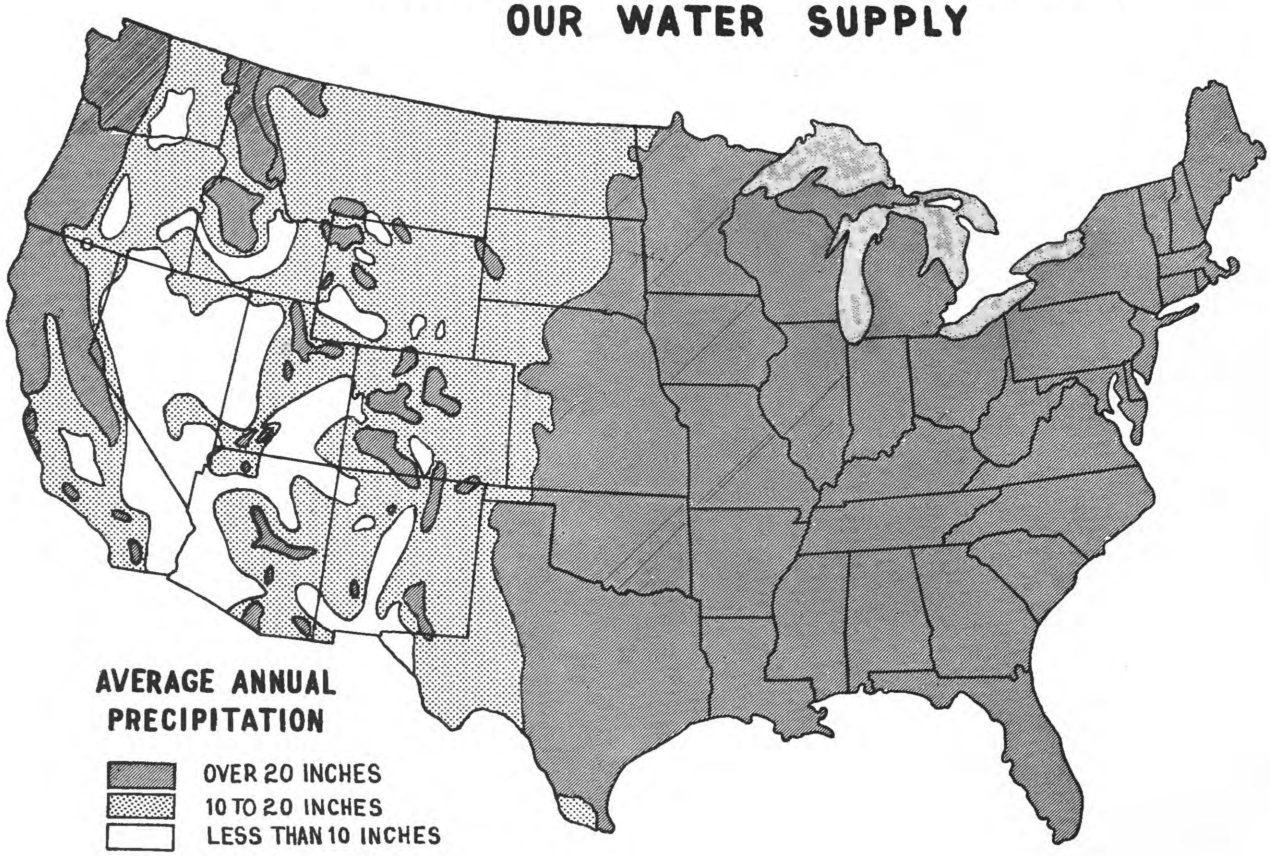
The third area, the Atlantic and Gulf Coastal Plain, is underlain by tremendous volumes of relatively unconsolidated sediments capable of producing many billions of gallons of water per day. It is about this "sleeping giant" among our Nation's water sources that I would like to make some remarks here.

A few years ago the Geological Society of America authorized a Symposium on Sedimentary Volumes (Murray and others, 1952). The Gulf Coastal Plain was chosen as the logical area for study because of the wealth

Table 1.—*Availability of ground water*

Areas	Water use (excluding water power) in millions of gallons per day and percent of total from ground-water sources		Availability of ground water
	Total (millions of gallons per day)	Ground water (percent of total)	
A. Atlantic and Gulf Coastal Plain area.	32,000	25	Abundant water supplies in sand and limestone. Large potential. Salt-water encroachment a factor near coast.
B. Southern Great Plains areas	21,000	45	Abundant supplies in sand and gravel, but replenishment low, especially in southern part—large demands result in mining of the water.
C. Appalachian Mountain and Piedmont area.	8,000	50	Small but reliable supplies for domestic and limited municipal and industrial use. Potential good for limited demands.
D. Rocky Mountains, northern Great Plains, and northern Pacific Coast area.	28,000	12	Generally small supplies adequate only for domestic and stock use. Quality very poor in places. Potential not great.
E. Unglaciated central plateaus and lowlands.	26,000	10	Bedrock generally yields meager supplies, often of poor quality. Large supplies of hard water from limestone locally. Valley alluvium yields moderate and locally large supplies of variable quality. Potential not great.
F–1. Basin and Range	41,000	42	Productive valley alluvium, but recharge low in many places. Large developments may "mine" the water. Substantial potential with judicious management.
F–2. Columbia Plateau	24,000	7	Productive lava rocks throughout province. Locally, recharge is generous. Potential still great with proper management, especially in eastern part (Snake River Plain), which contains one of largest unused ground-water supplies in the Nation.
G. Glaciated area of the East and Midwest.	57,000	10	Glaciated area, many local deposits of productive and amply recharged sand and gravel. Bedrock variable but highly productive in relatively few places. Substantial potential for future.
U.S. total (rounded)	240,000	20	

PRECIPITATION IS THE SOURCE OF OUR WATER SUPPLY

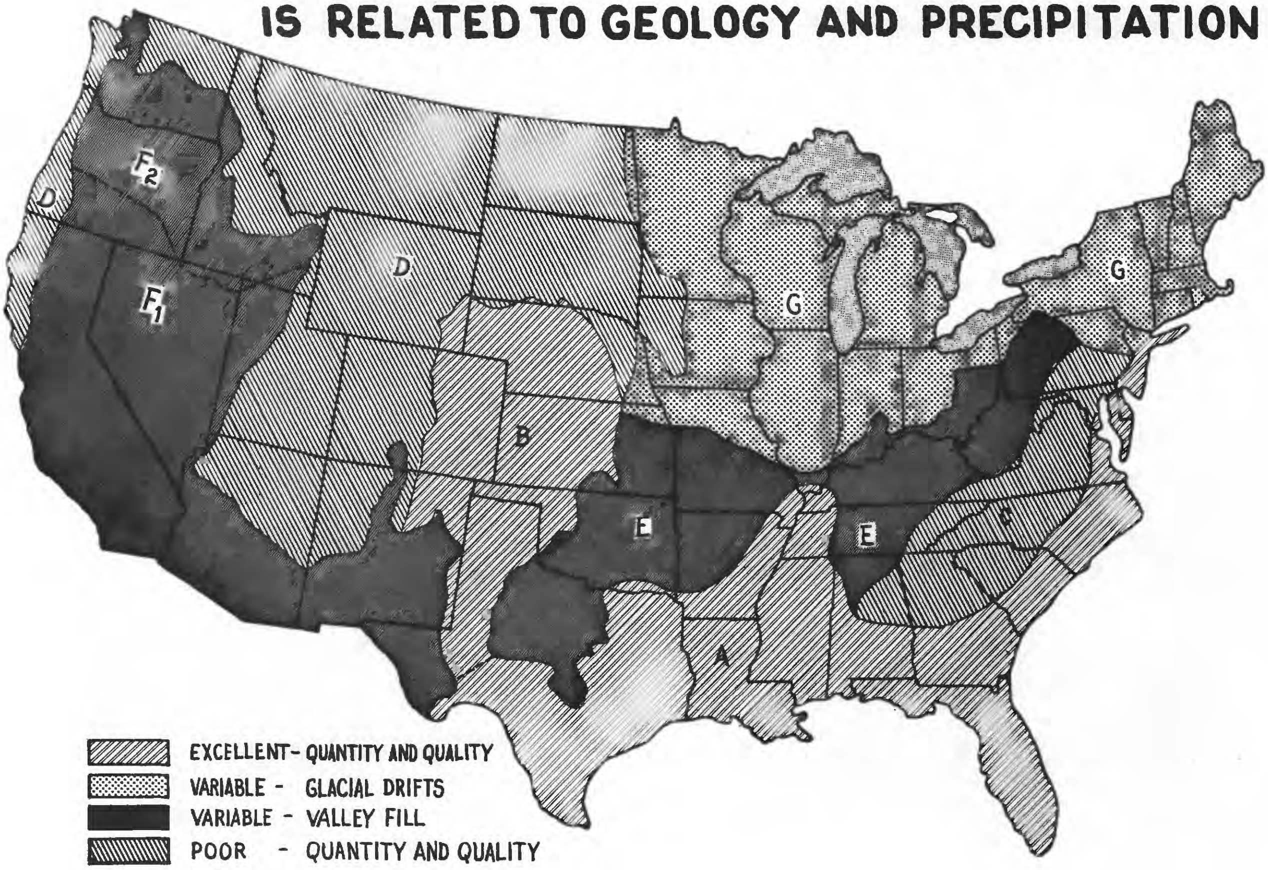


of information from thousands of oil test holes and from surface geologic mapping. The results of this work were extremely valuable to geologists in the petroleum industry and educational field; however, its full implication has not been and still is not generally appreciated in the field of water resources.

Geologically the Coastal Plain can be divided into a complex system of strata having definite physical character and traceable boundaries. Here, however, I'm going to show great restraint as a geologist and refrain from the details of stratigraphic names as I try to convey an idea of the volume and areal extent of this mass of material, most of which has a high porosity, 30 percent or more, and much of which is relatively permeable and capable of transmitting tremendous quantities of water.

The greatest bulk of the beds in the Coastal Plain consist of sand, clay, and gravel or a mixture of these materials; however, some notable exceptions are the chalk beds of Texas, Mississippi, and Alabama and the shell limestone beds of southern Georgia and Florida. Outcrops of these formations are represented by bands of color on the geologic map that simulate a huge lazy W extending from Texas up the Mississippi embayment, down across the eastern Gulf Coastal Plain, and northward along the Atlantic Coast. In general, each formation dips gently coastward and thickens into a great tabular wedge of sediments. As we travel toward the coast, succeeding outcrop patterns, or bands of color on the geologic map, represent the outcrops of successively younger formations, each resting on older beds like the pages of a book. If cut open like a pie, the wedge of Coastal Plain sediments would appear as a featheredge in its northern extremity, thickening seaward to the coast to a total of something less than half a mile in the Atlantic Coastal Plain north of South Carolina, to about 2 miles in southern Florida, and to an estimated thickness of perhaps as much as 40,000 feet in southern Louisiana. This estimate is based on seismic studies and projections of known geologic information, as the deepest oil test in the Coastal Plain, one of the 2 or 3 deepest wells in the world, had penetrated only the upper half of these formations at a depth of 22,570 feet (Butler, 1960). When

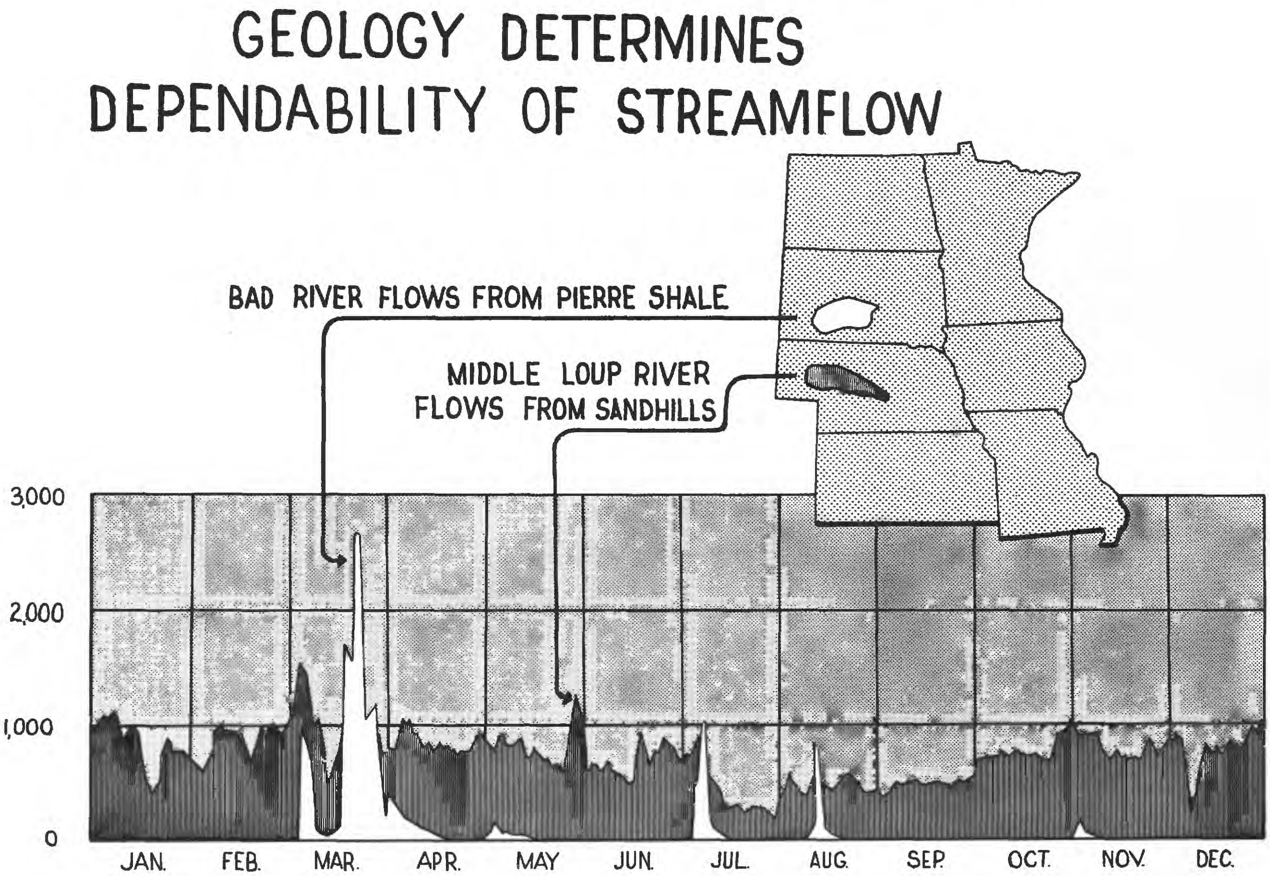
AVAILABILITY OF GROUND WATER IS RELATED TO GEOLOGY AND PRECIPITATION



totaled up, these formations in the Gulf and Atlantic Coastal Plain underlie an area between the Mexican border and the Georgia–South Carolina line of about 333,000 square miles (nearly one-tenth of the area of the U. S.), and the volume of these sediments is some 875,000 cubic miles (Murray and others, 1952). The alternation of permeable sands and limestones with relatively impermeable marls and clay create an immense artesian system in the Coastal Plain, simple in general design but complex in many details. The alternate layers of permeable and relatively impermeable beds and their gentle dips Coastward are ideally suited to the occurrence of artesian water. The most important aquifers are commonly the coarser grained sands or the limestones. The aquifers are separated by beds that are more clayey or limy, many of which are also very porous but relatively much less permeable. These less permeable beds are significant not only as confining beds for artesian conditions but also as sources of water, for it has been discovered that, as artesian pressures are reduced in the aquifers, water is squeezed out of the highly porous clays and marls, is added to the water available to wells.

We have described the receptacle—the general physical character of this water-storage facility; now let's have a more specific look at the "payload"—the part in which we as fresh-water explorers, producers, or managers are interested. Beneath the whole Coastal Plain the ground water occurs in three zones in downward succession: a shallow zone of unconfined water in the outcrop areas of the water-bearing beds; a zone of fresh artesian water below the point at which water becomes confined and commonly extending down to depths of as much as 2,000 feet; and a zone of salty artesian water in the lower aquifers, or in the downdip extremities of the same aquifers that yield fresh water inland.

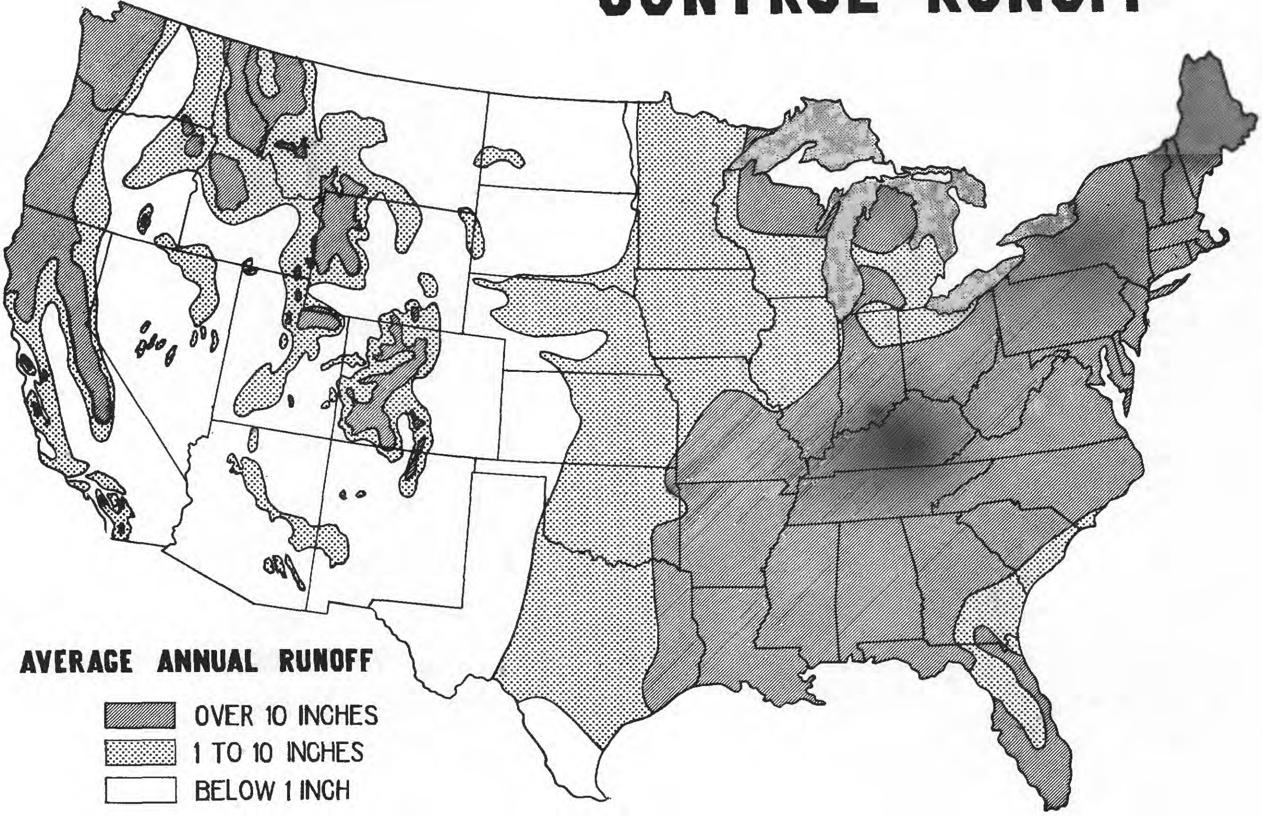
The shallow zone represents a volume of material nearly filled with water under water-table conditions. It extends throughout the Coastal Plain and contains fresh water everywhere except in a few places where the plain is narrow and is cut by channels connected with the sea. The relation of rainwater to geology is very intimate in this near-surface zone. Figure 4 illustrates this relationship



by comparing the streamflow on a sand outcrop area with that on a clay or chalk outcrop. To carry this thought further, a study of streamflow records in the Coastal Plain, when plotted on a base map, can be used to delineate many of the major geologic boundaries. This concept of the close relation between precipitation, surface runoff, and water in the ground is important in evaluating the ground-water resources of the South, for if one looks at the map in figure 5 showing average annual runoff for the United States, practically all the Coastal Plain area east of Texas lies within the area of highest average runoff. That highly permeable beds crop out across this area, and further that their water appetite must be satisfied before streams will flow across them, is substantial evidence that these tremendous reservoirs not only are full but are rejecting recharge from rainfall. In addition, the water table in much of this area is near the ground surface and substantial amounts of water are being lost by evapotranspiration.

The second, or fresh-artesian-water zone—that part of the aquifer between the uppermost artesian confining beds and the salt-water zone below—also is present throughout the Coastal Plain except beneath a thin strip along the northern margin of each aquifer and locally along the outer margin of the Coastal Plain. This zone may consist of many different water-bearing beds aggregating many hundreds of feet of sediments. The deepest known fresh water in the Coastal Plain is obtained from a well 5,900 feet deep in Karnes County, Tex. Interpretation of electric logs from oil tests indicates that fresh water extends to depths of 5,000 feet in McMullen County, Tex., and to 3,500 feet just north of New Orleans, La., (Sundstrom, R.W., and Turcan, A. N., U.S. Geol. Survey, written communication, 1960). Pressure release resulting from withdrawal of water from wells in these systems is quite rapid and has been recorded over large distances—for example, as much as 60 miles in response to withdrawal of water in the Houston area of Texas. The actual movement of water at depths of several hundred feet and more in these aquifers may be quite slow, however, measured in feet per year or even in feet per century, in spite of the rapid transmission of pressure changes. This factor is of great practical importance. On

PRECIPITATION AND GEOLOGY CONTROL RUNOFF

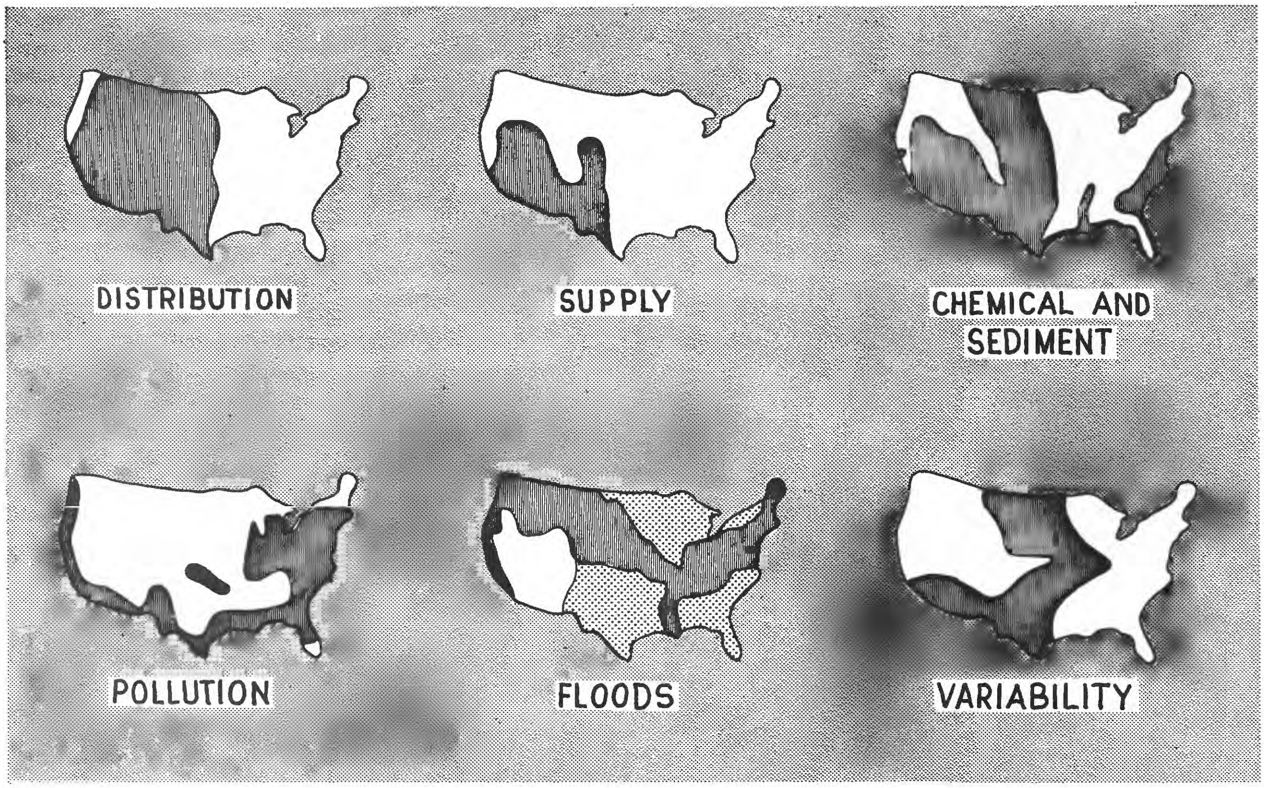


the one hand, it affords protection from immediate encroachment of salt water when artesian pressure is lowered, but on the other hand it retards the flushing out of salt water in the down-dip extensions of the aquifers by fresh water moving from outcrop areas.

The third, or salt-water, zone includes the deeper beds in the outer margin of the region, and this salt-water zone occupies more than nine-tenths of the aggregate volume of sediments in the Coastal Plain. Even so, if 1,000 feet is a fair average for the thickness of sediments in the fresh-water zone, there would be about 60,000 cubic miles of sediments containing fresh water in the Coastal Plain area of Texas, Louisiana, Mississippi, Arkansas, Missouri, Illinois, Kentucky, Tennessee, Alabama, and Georgia, and more than 800,000 cubic miles containing salt water. By further conversion we can estimate that there is 20,000 cubic miles of fresh water in storage in this same area, or enough fresh water to cover the 48 States to a depth of 35 feet.

Even though a large source of water supply is known to exist, it would not be of value to us unless its quality allowed its extensive use. From a quick review of many hundred analyses of water from wells spaced geographically over the Coastal Plain and tapping more than 100 different water-bearing beds it can be seen that, though the water varies greatly in quality, in general it may be classed as some of the best natural water in the Nation. In most places the water in the shallow water-table aquifers is low in dissolved mineral matter; however, in general it is slightly acid. Where fresh artesian water occurs in limestone, it is largely of the calcium bicarbonate type, the hardness ranging between 100 and 300 parts per million. Where the fresh artesian water occurs in sand, there is generally a gradual increase in mineral content with depth in each aquifer, the character of the water changing from chiefly calcium bicarbonate to chiefly sodium bicarbonate.

MAJOR WATER PROBLEMS



The temperature of water in the water-table aquifers is usually about 2° to 3°F above the average annual air temperature. The temperature of the water increases with depth, in most places at the rate of 1°F for each 60 to 90 feet of increase in depth.

WATER PROBLEMS

So far we have been looking at the good side of the ledger. We have seen that there is much rainfall in the South, and that the geology is highly favorable for its catchment and storage underground. We can say further that, whatever water problems the South has, they are not as grave as in some other parts of the country—as, for example, where the economy of whole sections of some western States is tied to a ground-water resource that is being depleted by pumping rates far in excess of replenishment.

However, there are symptoms that our sleeping giant may have ills which if not properly treated may develop into major problems. Let us take a brief look at these symptoms as depicted on figure 6, showing water problems of the Nation (U.S. Senate Select Committee on National Water Resources, 1960). The principal water problems shown for the South relate to surface water and specifically to floods and pollution. Indicated also are quality-of-water problems in coastal areas.

Not long ago we had our district representatives in each State list the ground-water problems and describe their magnitude and extent, and we requested that they project these into the next 20 and 40 years. The list developed was rather long and seemingly rather formless, but when it was plotted on a map certain patterns related to water use and geologic controls began to shape up. The problem areas were expansions of existing areas of overdraft, contamination by wastes, and salt-water intrusion in coastal areas, as related to existing or expected agricultural, industrial, and urban growth.

It should be noted, however, that the map showing problems for the Senate Select Committee report and the projection of ground-water problems point out the favorable position of the South. Granted, problems are impending, but many of them can be minimized by good engineering and geologic practices, based on sound hydrogeologic facts which will allow much fuller and more economical development of water.

SUMMARY

The South has a great water supply and at the same time has a grave responsibility to develop this resource to the maximum benefit to all. This is why we are meeting here, and why many other similar meetings are being held throughout the Nation. All agree as to the objective, but to attain it will require much more than just desire. Let me list the tasks that lie before us.

First, we must know all about our water resources—their source, occurrence, movement, quantity, and quality. In other words, we must know what our total water potential is before we can decide what can be done with it.

Second, we must delve deeper into the mysteries about water that are still held tenaciously by nature—the laws that control water movement, what happens to it while in storage, what energies drive or obstruct its movement through the earth's crust. We are now learning that some of the laws—such as Darcy's law upon which our quantitative ground-water studies are based—may have certain limitations not recognized heretofore, and that until we discover the answers to some of these unknowns we cannot solve certain critical problems related to waste disposal, salt-water encroachment, an even just plain water supply. This means that we must place more emphasis on basic research on water.

Third, our water developers and distributors must be able to meet the skyrocketing demand for water by more efficient methods of water withdrawal, treatment, and transmission. To do this they must understand and be guided by the results of water investigations.

Finally, we must recognize the extent to which development and use of water are tied to personal factors—the humanistic, the social, the economic situation of our Nation. To develop water fully, in the best interests of all, will require the utmost in unselfish and objective action by individuals, municipalities, industries, farmers, and water agencies of all types. Herein lies, of course, our most complex problem—a problem that can be solved only if there is adequate communication between those who know about water and the layman, educator, and legislator who are the final judges of what will and will not be done.

So now you have the challenge—not only are these huge supplies of water in the South of great value to you, but they are supplies that will have to satisfy a large percentage of the future agricultural, industrial, and municipal needs of our thirsty country. They are one of the last great frontiers of the Nation's fresh-water resources—deal with them judiciously.

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