INTRODUCTION

This book has been written to help Alabama's citizens learn about one of our most important natural resources – **ground water**. Water beneath the earth's surface, or ground water, quenches our thirst, supports our crops and livestock, waters our lawns, and supplies industry throughout Alabama. If used wisely, ground water resources will never run out. However, lack of planning and careless actions can cause shortages or contamination of ground water. The better we understand this valuable resource, the better we will be able to protect and manage it for our benefit and the benefit of future generations.

Words printed in bold type in the text are defined in the glossary.

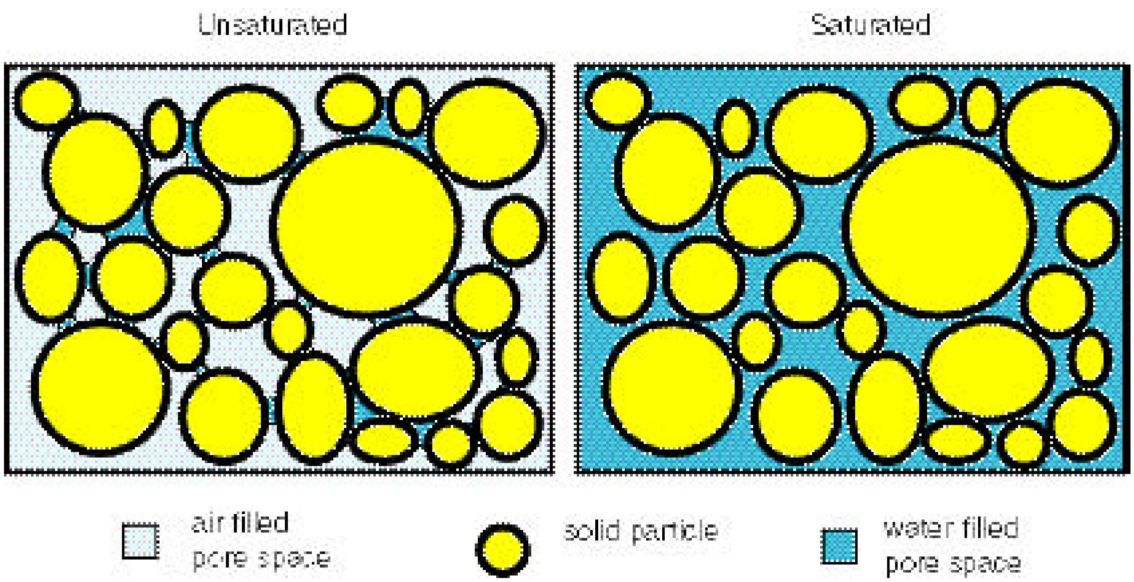
Ground water facts, indicated by the water drop symbol, appear at various points in the text.

Alabama has enough ground water to cover the entire state to a depth of about 50 feet.

WHAT IS GROUND WATER?

When rain falls on the ground, some runs off into rivers or streams and some soaks into the ground and partially or fully fills the open spaces between **soil** particles. These open spaces are called pores. Some of the water that enters the shallower soil will partially fill the pores spaces. It is held by capillary forces in the **unsaturated zone**. Capillary forces are caused by surface tension. These forces hold very small amounts of fluids in the pore spaces. If more water enters the soil than can be held by capillary forces, it will continue to flow downward until it reaches a depth where all of the pore spaces are filled with water. The soil in this zone is said to be saturated. The top of this **saturated zone** is called the **water table** and water in the saturated zone is ground water.

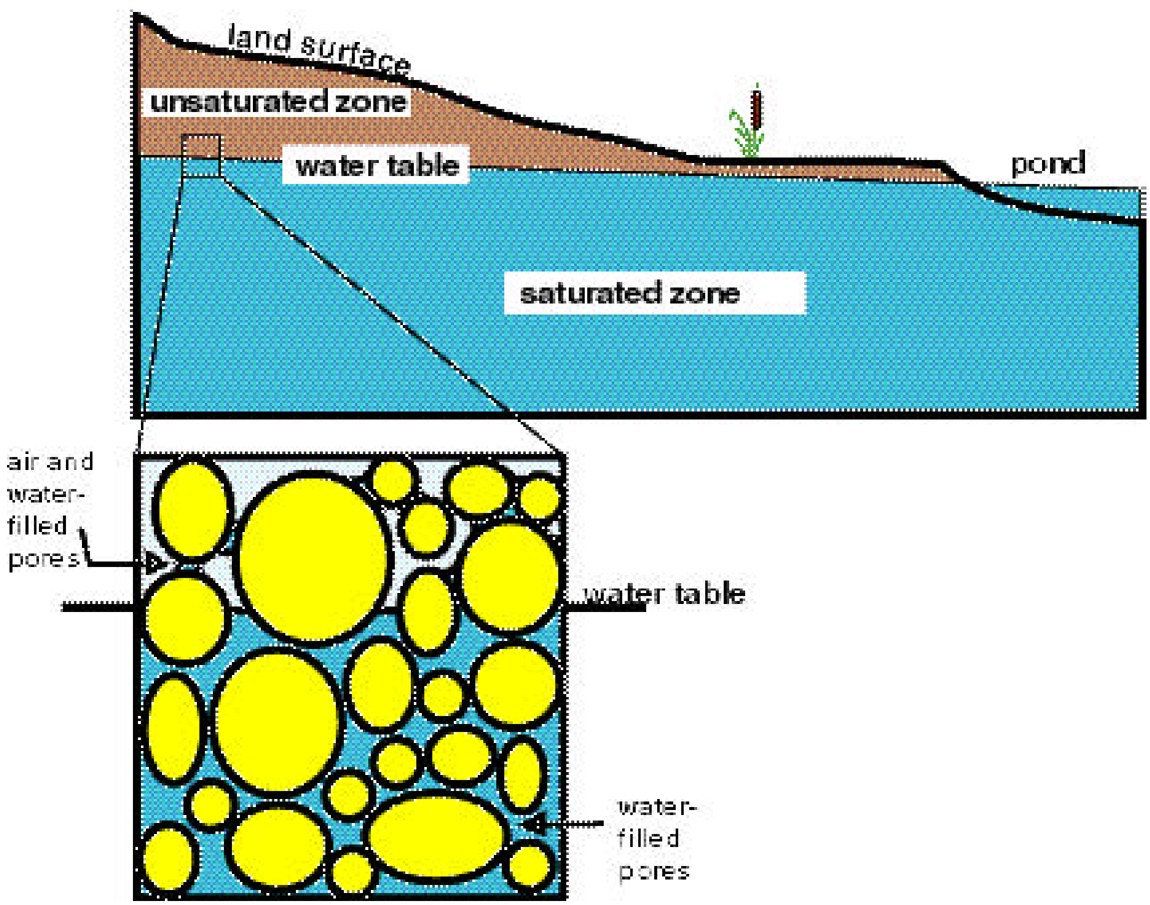
Ground water forms a fairly continuous mass of primarily fresh water that underlies the land surface. It may be only a few inches beneath the surface or hundreds of feet deep. Where the water table meets the land surface, ground water **discharges** such as **springs** may occur. Water may also seep out slowly to form **wetlands**, swamps or marshes, which are important ecologically. It also contributes to the flow of many streams. Nationally, 40% of the base flow of streams comes from ground water.

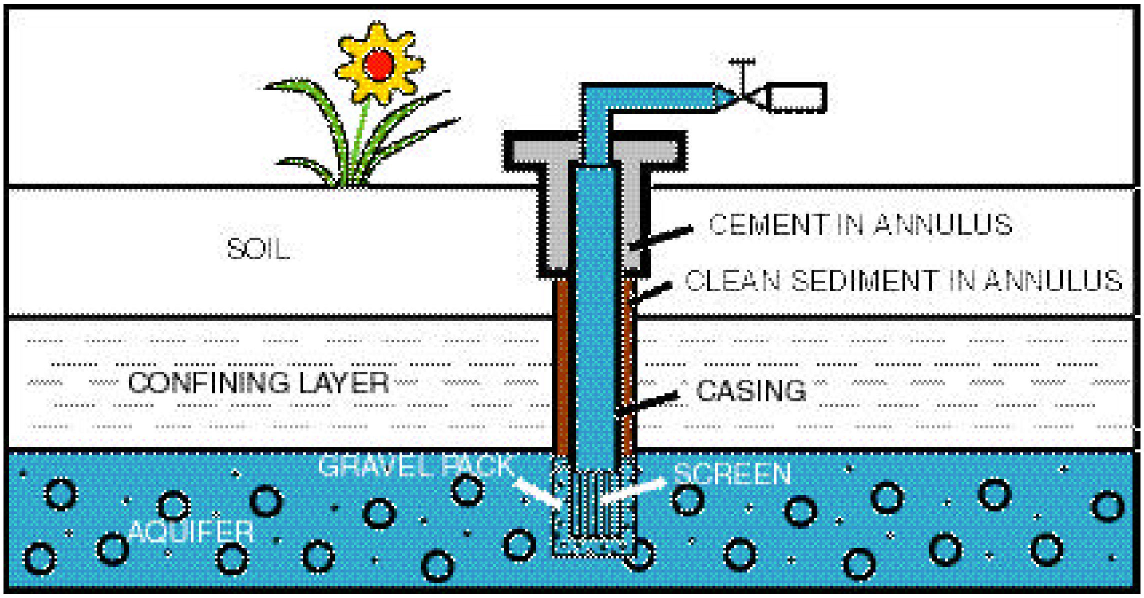


A film of water clings to each particle in the unsaturated zone even when it may seem dry. However, this residual water cannot be obtained through pumping of a well as in the saturated zone.

Many of us drink ground water every day. Turn on the faucet in Dothan, Greenville, Ozark, Selma, or Montgomery, to name a few cities, and you are probably drinking ground water. Eighty percent of the **public water systems** in this state depend on ground water for at least part of their water supply. Public water systems in Alabama withdraw more ground water than any other category of use, about 220 million gallons per day (gpd). Many rural Alabamians obtain water from private **wells**. In fact, nearly one in ten Alabamians get their drinking water from more than 100,000 private wells.

Wells are not just holes in the ground. Proper well construction keeps soil and sediment out of water that is pumped from the well. It also keeps contaminants from the surface from entering the well. The well bore in a properly constructed well may be lined with casing made of metal or plastic. Where water enters the well a special casing called a screen is used. The screen is slotted to admit water inside the casing, and it is surrounded by gravel. The gravel lets in water but keeps sediment out. The cement in the upper part of the annulus, the part of the bore hole outside the casing, protects the





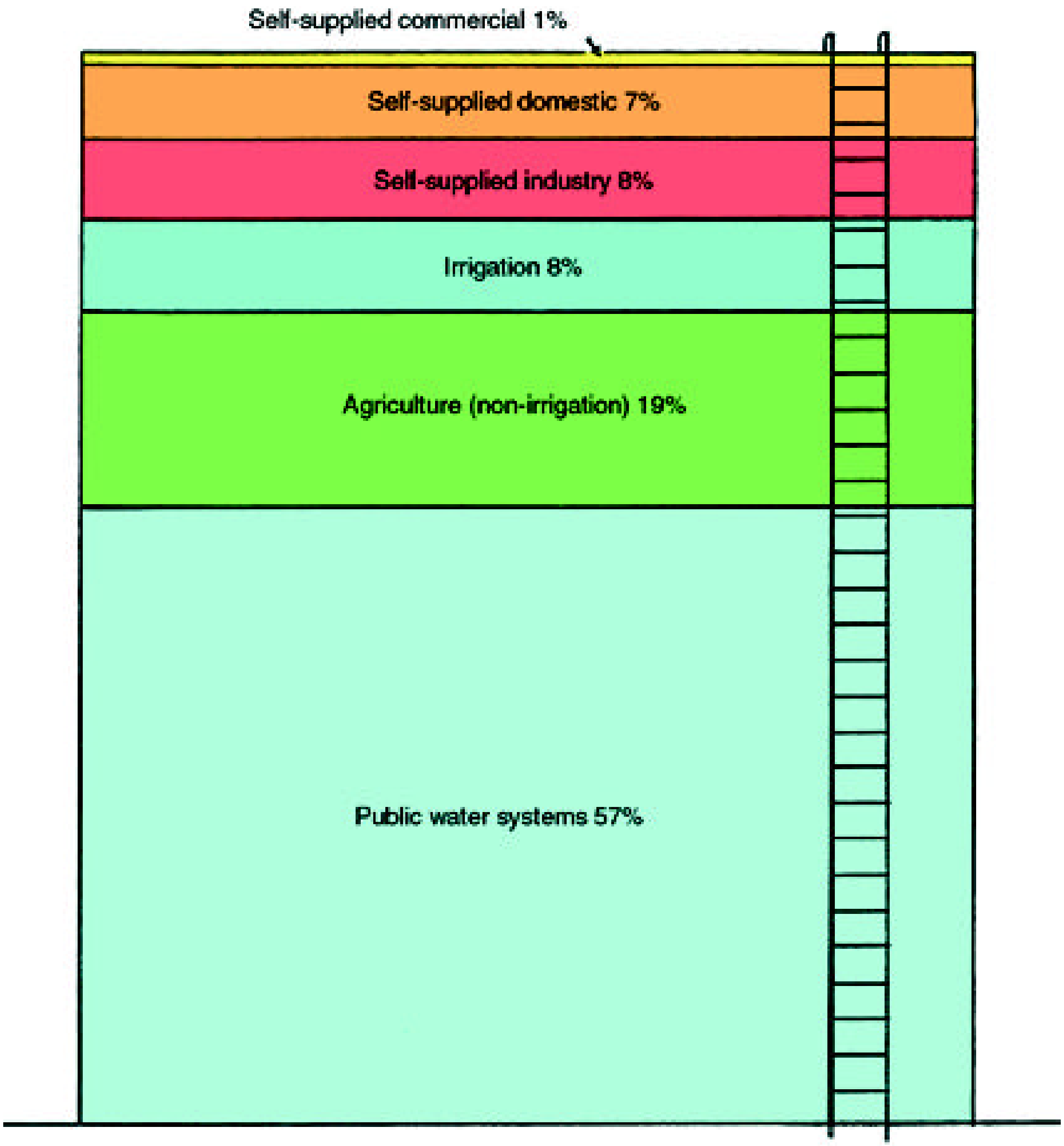
Cross section of a properly constructed well

subsurface from contamination that could enter the well bore. The rest of the annulus is filled with clean sand.

Why do so many of us depend upon ground water for our drinking water? Many times ground water may be the most economical source because it is so readily available in many areas of our state. Also, ground water usually requires less treatment than surface water. Although both surface water and ground water have to be chlorinated for public water supplies, surface water must also be treated to settle out soil particles which are carried along in streams and rivers.

What does all this water cost? A gallon of water, delivered to your house by a public water system, costs less than half a cent in most places in Alabama. You can buy water for as little as 0.08 cents per gallon (about 12 gallons per penny) from some Alabama public water systems, which makes it one of the world's best bargains. Nationally, tap water costs about 0.2 cents per gallon. A gallon of water in the grocery store costs at least 50 cents, more than 100 times as much as tap water in most parts of our state.

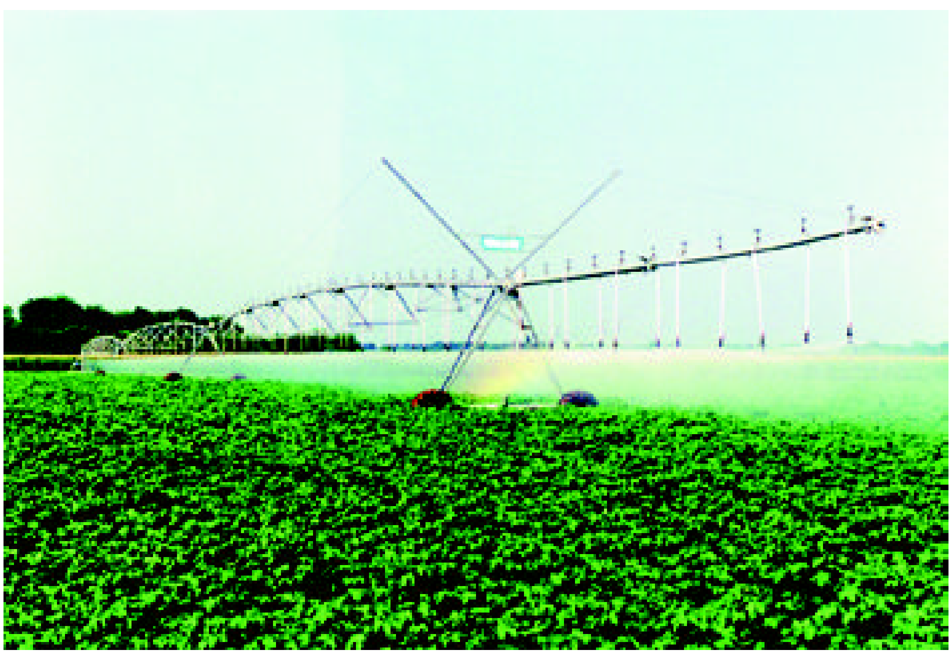
Drinking water is not the only important use of ground water.



How does Alabama use ground water?

Ground water is also used in agriculture, one of Alabama's most important industries. Agriculture uses about 100 million gallons of ground water every day, or more than 9,000 gallons per year for each person living in our state. This accounts for about one fourth of the total statewide ground water use. Alabamians use a total of about 400 million gallons of ground water per day, or about 146 billion gallons annually.

Brahan Spring, Huntsville's Big Spring, discharges from the base of a limestone bluff.



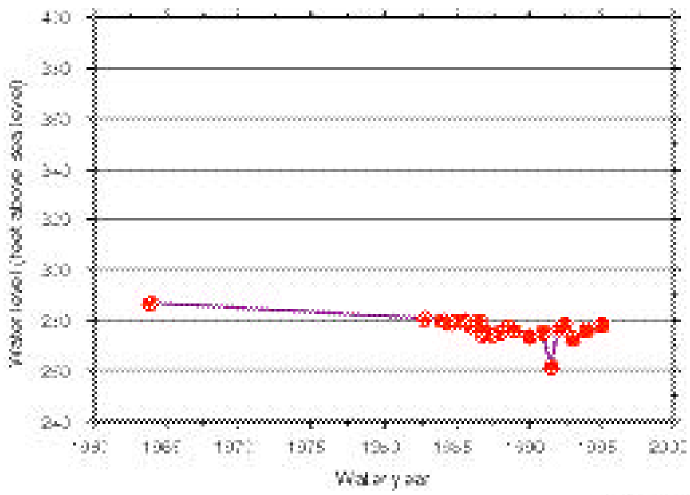
Center pivot irrigation system

Alabama's ground water reserves are estimated at about 533 trillion gallons, or enough to last 3,300 years at the present rate of consumption. Ground water is a renewable resource that is constantly replenished by rainfall. Alabama is a relatively wet states. More than 55 inches of rain fall each year. Considering these facts, it seems that conserving our ground water supply would not be a concern, but the numbers do not tell the whole story.

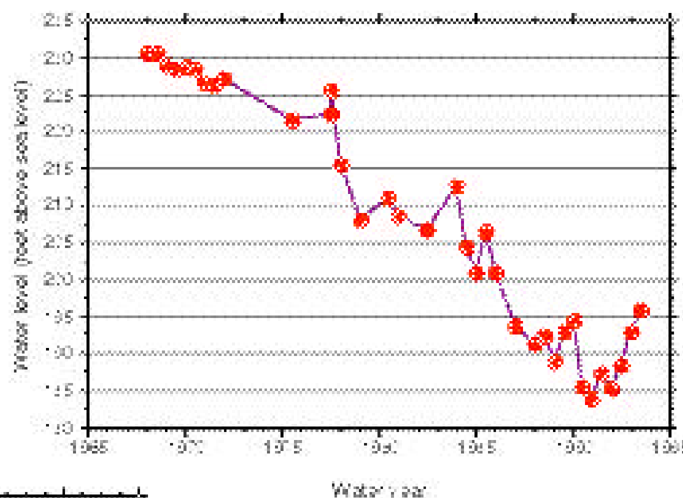
Ground water, while plentiful, is not evenly distributed throughout the state. In some places the water is shallow and abundant; in other places it is deeper and harder to find. When found, ground water can be difficult to extract in the quantities needed and may differ in quality from place to place. So even though a statewide shortage is unlikely, local shortages may occur in some areas where the demand is great, causing serious problems.

Hydrographs are graphs that show water levels over time. Some hydrographs record water levels in rivers or reservoirs, and other hydrographs record water levels in wells. In a stable situation, that is, one with no long term trends, water levels do not change. An example of a stable situation is shown in the hydrograph of the Dale County well shown on the next page. If more water is pumped than can be naturally replenished, then water levels decline over time, as shown in the Barbour County hydrograph. The hydrograph from a Houston County well shows that water levels in wells may change with the seasons. All of these are real examples. There are even some wells in which water levels are rising!

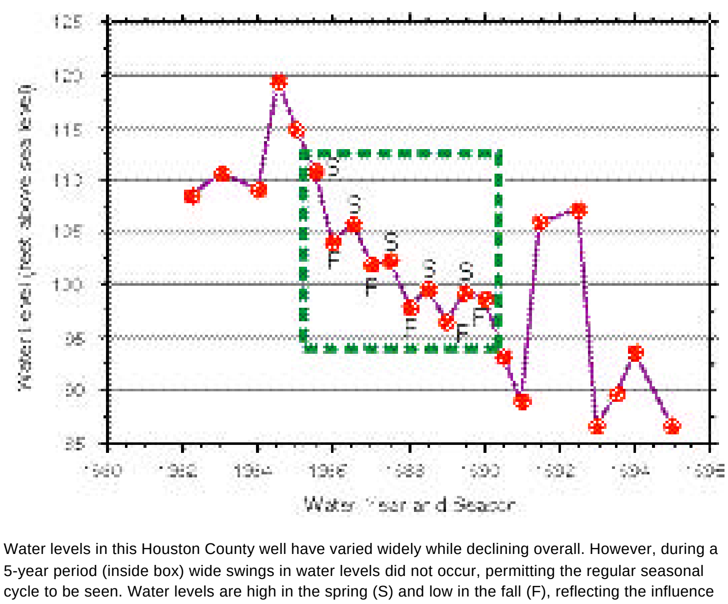
Ground water availability varies from region to region and is controlled primarily by the kinds of rocks, sediments, and soils that contain the water. To understand the differences in water availability between different areas, we must first understand how ground water moves from one area to another, as well as the rock, sediment, and soil properties that control water movement, storage, and availability.



Water levels in this Dale County well have been stable since the well was drilled in 1964.



Water levels in this Barbour County well have been declining steadily since 1968 and continued decline is likely.



Water levels in this Houston County well have varied widely while declining overall. However, during a 5-year period (inside box) wide swings in water levels did not occur, permitting the regular seasonal cycle to be seen. Water levels are high in the spring (S) and low in the fall (F), reflecting the influence of spring rains and summer droughts.

Hydrographs show changes in water levels over time. These three hydrographs illustrate some of the water level changes that have been observed in wells in Alabama.

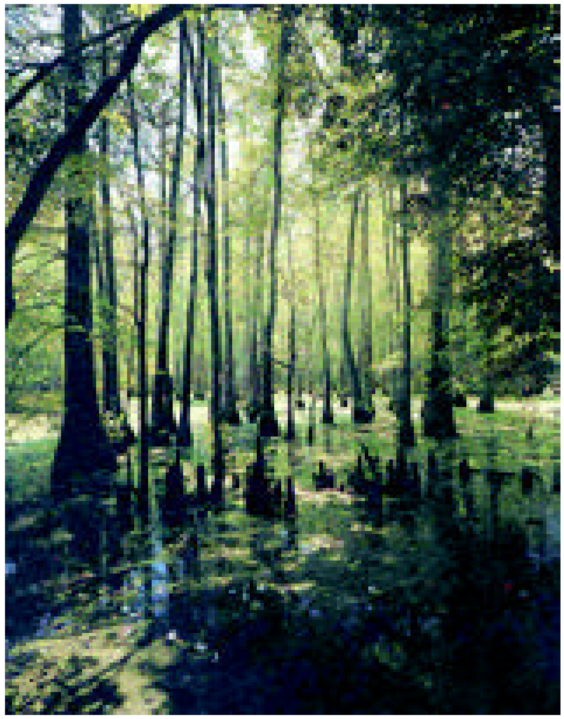
WHAT IS GROUND WATER MADE OF?

Water is composed of hydrogen and oxygen – two atoms of hydrogen for every atom of oxygen. But naturally occurring water is never pure H_2O. Water contains dissolved or suspended materials, both natural and anthropogenic (caused by human activity), that may be harmful, helpful, or not have any effect. Some natural water constituents, like fluoride, are helpful in small amounts but harmful where they are too concentrated. Iron causes no problems at low **concentrations** but at high concentrations may result in an unpleasant taste and staining of clothes and household fixtures.

Ground water commonly contains more mineral matter than surface water. This is because ground water moves slowly through the subsurface and has more time to react with minerals with which it comes in contact. The natural minerals in some ground water taste good, which is one reason bottled spring water is so popular.

Ground water is also likely to vary less in quality over time than surface water. Ground water moves slowly and it changes slowly. Natural factors affecting ground water quality include the amount of time the water has been underground, the composition of the rocks through which the water has moved, and local conditions underground.

Few natural water quality problems affect ground water in Alabama. Problems of local significance in some areas include excessive **hardness**, high concentrations of iron, chlorides and dissolved solids, and low pH (high acidity). All of these factors can make water unsuitable for some uses. As mentioned, too much iron in water stains fabric and fixtures, whereas high chloride concentrations and low pH can corrode fixtures.



Wetlands, such as this gum swamp in Greene County, occur when the water table meets the land surface. They provide natural filters and serve to protect the water quality of streams.

The effects of human activity on ground water quality are commonly less severe than on surface water. This is because most sources of anthropogenic contamination are located at the Earth's surface. Also, underground layers of clay and other natural materials help keep **contaminants** out of ground water. These earth materials act as natural filters, retaining contaminants and passing cleaner water on to other sediment or rock units.

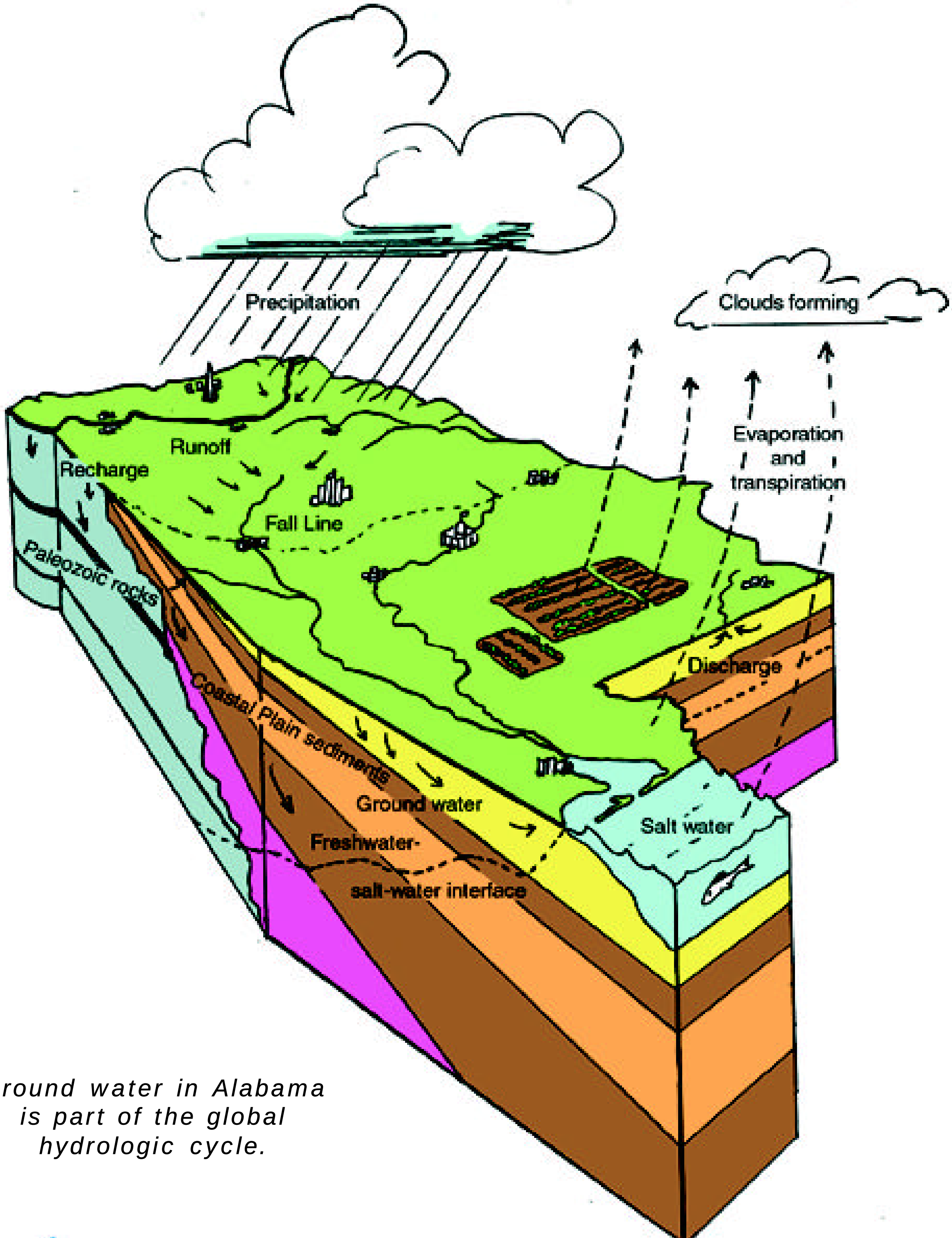
Although there are many instances in which ground water has been contaminated through surface activities, these effects are generally localized. Most ground water in Alabama is free of significant anthropogenic contaminants.

THE HYDROLOGIC CYCLE

The waters on the surface of the earth and beneath the earth are not separate. They are connected by soil and rock pore spaces and fractures. Water constantly moves from one zone to the other. This movement is part of a global pathway called the **hydrologic cycle**, which can be visualized as a series of banks that store and continuously transfer water. The oceans are the largest bank, containing about 97 percent of the Earth's water. The other banks, though much smaller, are also important. These include the atmosphere, glaciers and ice sheets, rivers, lakes and streams, soil moisture, and ground water.

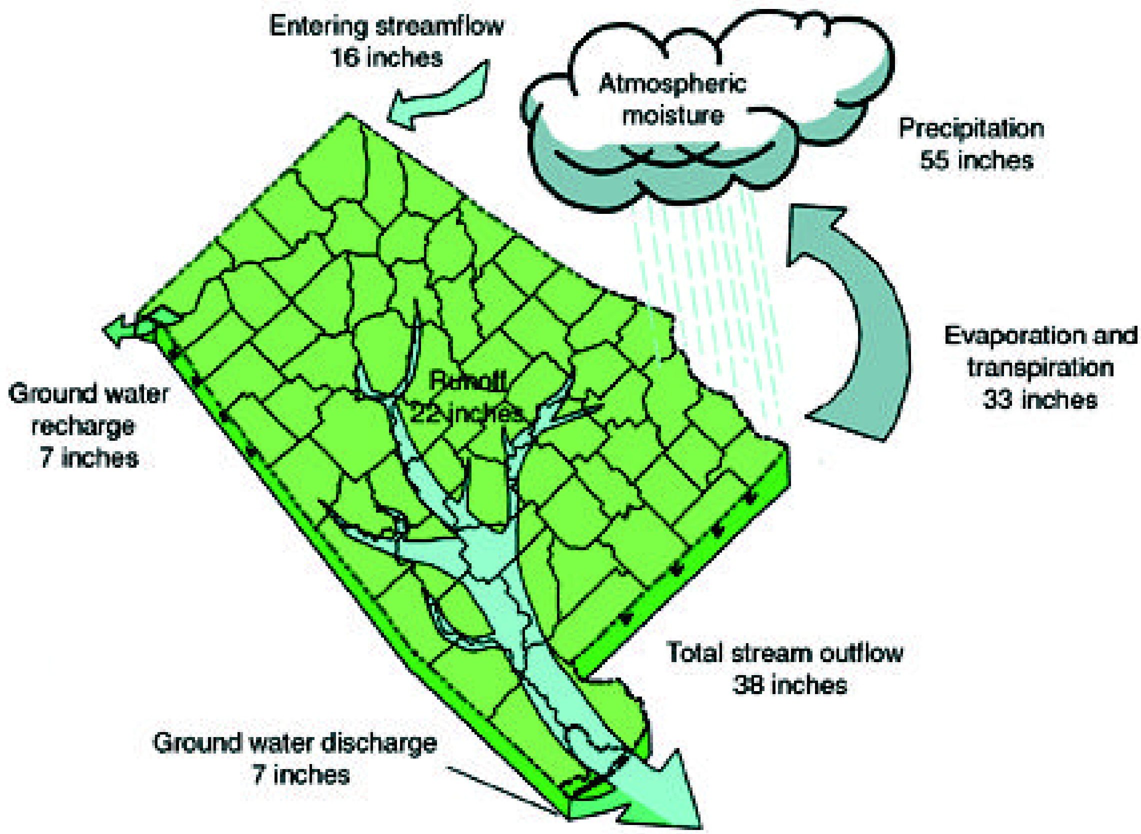
The hydrologic cycle goes on forever, and involves all water on and in the earth and in the atmosphere.

Water evaporates from the surfaces of the oceans and other water bodies and enters the atmosphere as water vapor, eventually falling back to Earth as precipitation, usually in the form of rain or snow. Some of the rainfall drains directly into streams and lakes as **runoff**, and eventually flows back to the ocean. The rest enters the soil. If the sun is hot enough and the air dry enough, much of the moisture in soil evaporates and returns to the atmosphere. If plants are growing in the soil, their roots will capture some or most of the water in that zone. Ultimately, much of this water will be returned to the air by plants through **transpiration**, a process whereby moisture absorbed by the plants evaporates directly into the atmosphere from plant surfaces. In Alabama, about 60 percent of precipitation is returned to the air by **evaporation** and transpiration, or **evapotranspiration**. Part of the water that enters the soil zone moves downward to the water table. Ground water may discharge as springs or seeps into streams, lakes, wetlands, or directly into the ocean, completing the cycle. The hydrologic cycle goes on forever, and involves all water on and in the earth and in the atmosphere.



Ground water in Alabama is part of the global hydrologic cycle.

The oceans contain about 97 percent of the Earth's water. Only 0.3 percent of the Earth's water is fresh water in lakes, rivers, and ***aquifers****. The other 2.7 percent is frozen in glaciers, is very deep salty ground water, or is located in water bodies not included above, such as salt water lakes.*



Precipitation=Evaporation and transpiration+Runoff
Ground water recharge and discharge are equal under stable conditions
Total stream outflow=Runoff+Entering streamflow

Balancing Alabama's water budget

Water moves very slowly through some parts of the hydrologic cycle. Some water stays in the ground for thousands of years and may penetrate miles below the surface. Precipitation that falls onto glaciers and ice sheets may also be trapped in ice for thousands of years.

Rates of ground water movement are variable and difficult to measure. Depending upon local hydrologic and geologic conditions, water can travel several miles underground in a few days, or it may take hundreds or even thousands of years to cover the same distance. The average rate of ground water movement in Alabama is about 1 inch per day. A drop of water moving at this rate would take 174 years to travel 1 mile.

WHAT ARE AQUIFERS?

Many people believe that ground water occurs primarily in underground lakes or rivers. Although underground lakes and rivers do exist, the vast majority of ground water is found in the tiny openings called pores that occur between the grains in rocks, soil, and sediment. Many rock formations are fractured, and large amounts of water can be contained in those fractures. Below the water table these openings are filled with water. Even in areas where the ground is dry, water-saturated material exists everywhere at some depth, usually from a few inches to a few hundred feet below the surface.

The upper part of the earth's crust is composed of soil and many different types of rocks. Some types of rocks are able to store and transmit water better than others. Rock, sediment, and soil units that contain significant amounts of producible ground water are called **aquifers** (from the Latin *aqua*, water, and *ferre*, to bring). Aquifers have two very important properties. The first is **porosity**, which is the amount, usually represented as percent, of open pore space in the aquifer. This represents the storage capacity of the aquifer. A good aquifer may contain 10 to 30 percent open space and therefore 90 to 70 percent rock, so its porosity is 10 to 30 percent. An equally important aquifer property is **permeability**.

Permeability is a measure of the interconnectedness of a pore or fracture system, and determines the ability of a rock unit to transmit fluids. Not all porous rocks are permeable. Impermeable rocks may contain significant amounts of water, but make poor aquifers because the water cannot move from pore to pore and be pumped to the surface. Permeability can be illustrated by the following example. An open pipe is totally permeable because its volume is all open space. If the pipe is filled with gravel, about 25 percent of the total volume of the pipe consists of interconnected pore

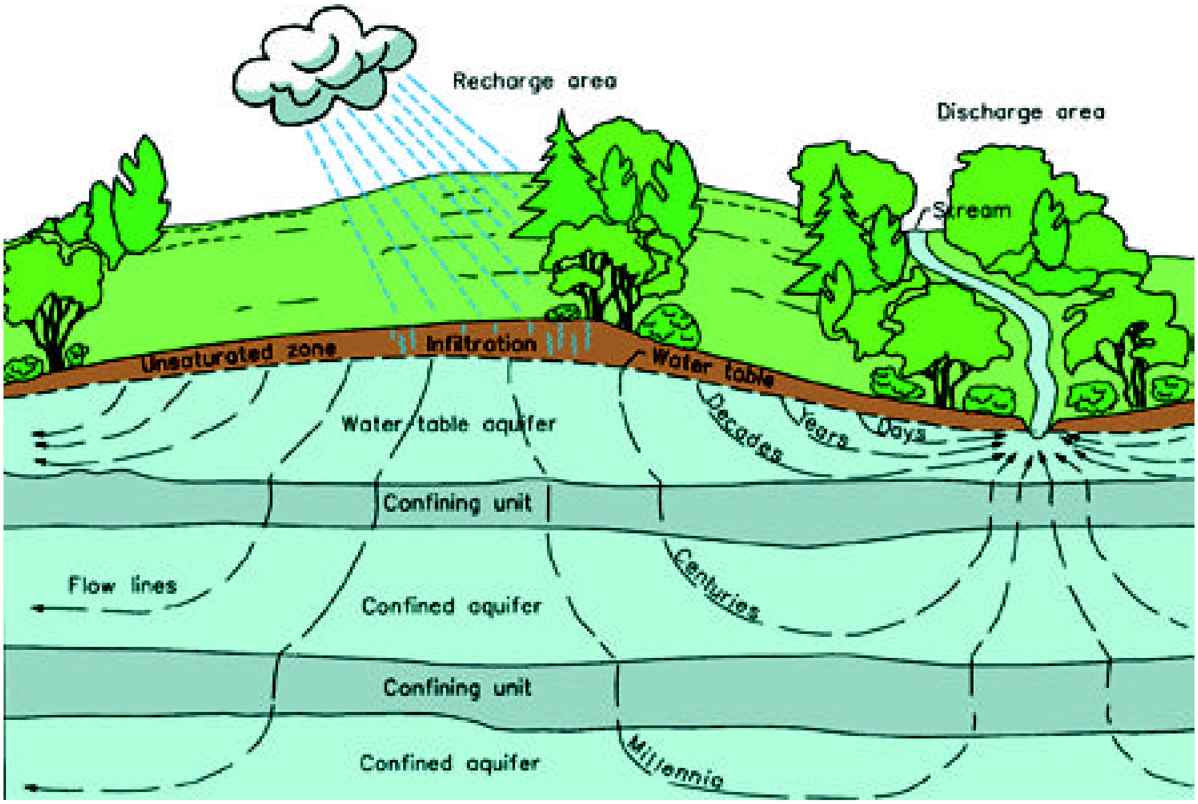
Even where the ground is dry, water-saturated material exists everywhere at some depth.

A pump test can reveal how much water an aquifer can yield to a well.

space and the pipe can still transmit water, though not as quickly as before, because its permeability has been reduced. If the pipe is filled with cement, very little or no water can pass through it, and its permeability is near zero. The porosity of the cement may not be much less than that of the gravel-packed pipe but the pores are not well connected. This illustrates why some rock formations, while having significant porosity, cannot transmit much water and do not make productive aquifers.

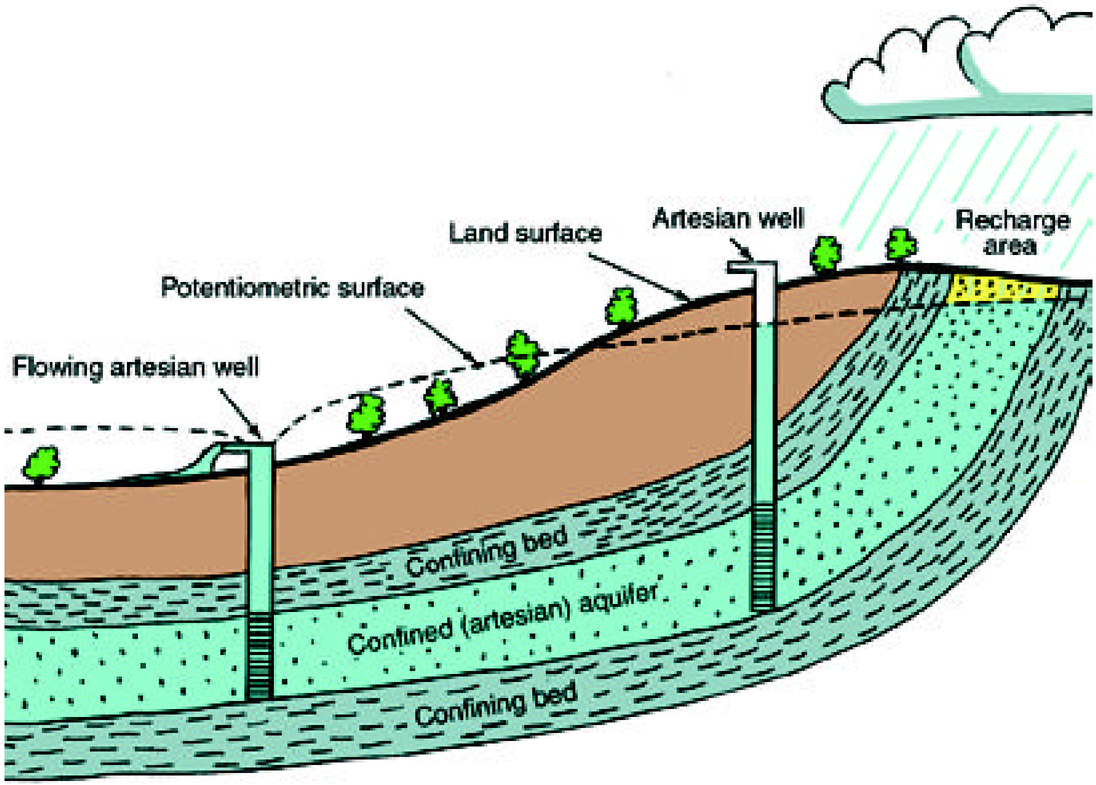
The porosity and permeability of aquifers tend to decrease with depth because pressure generated by the weight of the overlying rocks squeezes the pores and fractures shut. This compression of pore space usually does not occur at depths shallower than about 2,000 feet. Aquifers that produce sufficient quantities of water commonly occur at much shallower depths, so compression is not a factor in the siting of most water wells.

Another concept critical to the understanding of ground water availability and protection is that of **unconfined** and **confined aquifers**. Unconfined aquifers consist of an upper unsaturated portion above the water table and a lower saturated zone below the water table. Some aquifers are overlain and underlain by layers of significantly less permeable materials that restrict the flow of water



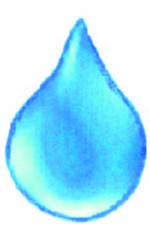
The time it takes ground water to travel from its point of recharge to point of discharge can be measured in days to years for shallow ground water, but may be centuries or millennia for deep ground water.

across the aquifer boundaries. These aquifers are called confined aquifers. The less permeable layers that impede water movement are called **confining units**. In Alabama, confining units are generally composed of clays, **shales,** and chalk. Confined aquifers are completely saturated with water. Because the space the water occupies in a confined aquifer is restricted by the confining layer, the water can be under considerable pressure. When a well is drilled into a confined aquifer the pressure forces the water in the well to rise above the top of the aquifer itself. If the pressure is great enough the water will actually flow from the well at the ground surface without having to be pumped. Such flowing wells are common in and near the flood plains of major streams in the southern half of the state, and are sometimes called **artesian wells**.



Recharge to a confined aquifer may occur far from the locations of wells producing water from that aquifer.

Also, it is important to note that where the confining unit is present confined aquifers cannot be locally replenished, or **recharged**, by rainwater filtering down from the surface. Infiltrating surface water can recharge confined aquifers only where the aquifer is exposed at the surface or where the confining unit is absent. Thus, the area of recharge for an aquifer may be a long distance from where water from that aquifer is produced. For example, the city of Dothan in Houston County pumps water from the Nanafalia **Formation**, a sandy geologic unit that, in that



Ground water moves at an average rate of an inch per day. At this rate it would take 174 years to travel one mile.

Flowing artesian well in Old Cahawba

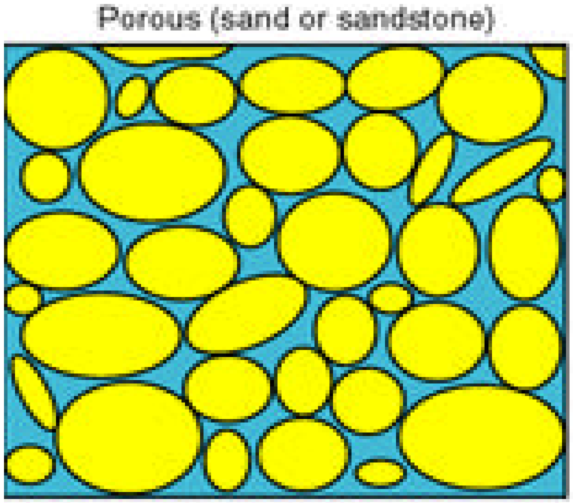
area, is a confined aquifer. The **recharge area** for the Nanafalia aquifer is where it crops out at the surface, more than 30 miles north of Dothan. It is important to understand this relationship because the water that future generations will rely on in Dothan can be affected by activities in the recharge area of the Nanafalia Formation, 30 miles away.

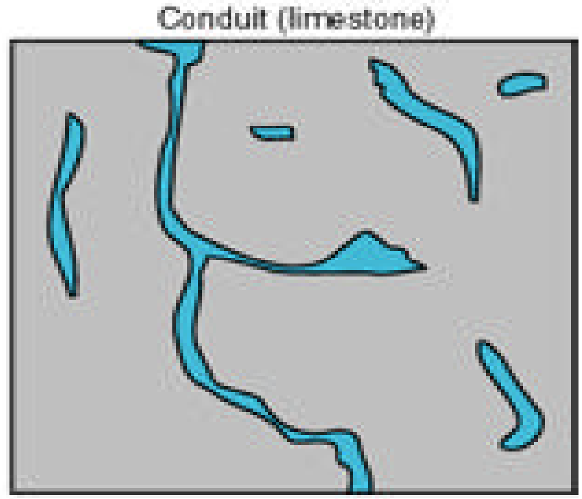
KINDS OF AQUIFERS

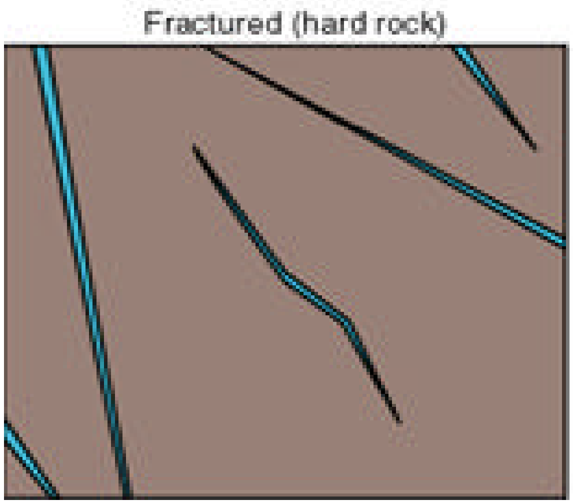
SAND OR SANDSTONE

Aquifers in Alabama can be grouped according to the way water flows through them. Aquifers transmit water by porous flow, conduit flow, fracture flow, or by a combination of these. Porous flow is typical of aquifers composed of **sand** or **sandstone**. These aquifers are made up of sand-sized particles of other rocks that were broken down by erosion, transported to their present location by wind or water, and deposited. Water is stored in and moves through the open spaces, or pores, between the individual sand grains. Sand bodies can range in size from a few square feet to thousands of square miles. Sand aquifers are often found along rivers and streams where they formed as the stream meandered back and forth across the floodplain. These aquifers, sometimes called watercourse aquifers, can supply significant amounts of water but are restricted to the floodplains of major rivers and thus are only of local importance. The towns of Saraland and Satsuma in Mobile County use ground water from sand aquifers deposited by the Mobile River. Sandstone is simply sand that has been hardened into rock by the heat and pressure caused by deep burial for extremely long periods of geologic time. Many sand bodies and some sandstone units are highly permeable, with porosity values that may exceed 25 percent. Typically, water moves slowly but steadily through sand and sandstone, making many sand and sandstone aquifers reliable sources of large amounts of ground water. Sand and sandstone aquifers are the most important aquifers in many parts of Alabama and generally produce large amounts of water. Because water moves slowly through the aquifer, there is

> **Water moves slowly but steadily through sand and sandstone, making many sandstone aquifers reliable sources of large amounts of ground water.**







The three kinds of aquifers have differing pore networks and therefore transmit water at different rates.

more time to respond if the ground water becomes contaminated. Also, sand and sandstone aquifers tend to filter out some contaminants as the water moves slowly through the pore spaces. Disadvantages include slow recharge if a sandstone aquifer becomes depleted, and the tendency of some sandstone aquifers to produce water containing too much iron, which can stain fixtures and fabric and give the water a bad taste.

One important sand aquifer in Alabama is the Eutaw Formation. Sands of the Eutaw produce fresh water from Aliceville to Eufaula.

LIMESTONE

A second way that water moves through an aquifer is by conduit flow. In conduit flow, water actually flows through underground channels, or conduits, in the rock. Conduit flow is commonly associated with carbonate rocks, such as **limestone** and **dolomite**. Most conduits are formed over thousands of years by dissolution, a chemical reaction between limestone and fresh water in which the limestone is dissolved. Sometimes, large volumes of rock can be dissolved, forming cavities and caves. Although cave formations can be fascinating and sometimes spectacular, most dissolution cavities in limestone aquifers are small, even microscopic. Most ground water in limestones occurs in these cavities and channels. Because these openings are irregular in shape and distribution, ground water flow can be unpredictable and extremely fast, sometimes up to several thousand feet per day through the larger channels.

Springs are common in limestone aquifers, discharging water where water filled channels meet the surface.

Stream pouring into a sinkhole, connecting surface water to ground water.

A total of nearly 90 million gallons of water each day flows from the three biggest springs in Alabama—Coldwater Spring (Anniston), Tuscumbia Spring (Tuscumbia), and Big Spring (Huntsville).

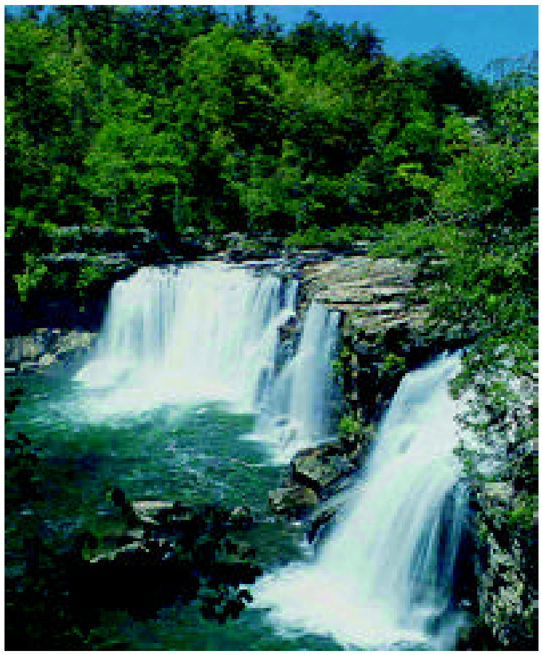
Caves are common features in limestone terrain. This cave is located in Madison County.

Limestone aquifers have several potential disadvantages. For example, **sinkholes** tend to occur in areas underlain by limestone. A sinkhole forms when the ground surface collapses into an underlying dissolution cavity. Sinkholes are like huge drains and water entering them is immediately introduced into the ground water system. If contaminated water enters a sinkhole connected to a channel or cavity system capable of transporting large volumes of water, ground water can become contaminated very quickly, leaving little time to take action to protect it. Also, the water table in limestone aquifers may fall rapidly in response to an increase in pumping or a decrease in precipitation. As a result, some wells in limestone aquifers may stop producing altogether during dry summer months or periods of over-pumping. Fortunately, most of these wells recover quickly when the fall rains come. Another potential disadvantage of many limestone aquifers is the hardness of the water. This means it contains large quantities of dissolved carbonate, and does not readily produce a lather with soap.

In spite of these disadvantages, limestone aquifers are important sources of ground water in many parts of Alabama. The Tuscumbia-Fort Payne aquifer in north Alabama, for example, serves more than 100,000 public water supply system customers, although it is prone to all the problems which characterize limestone aquifers.

FRACTURED ROCK

The third way aquifers transmit water is through fractures. Aquifers characterized by porous flow or conduit flow can also be fractured, which enhances the permeability of these aquifers. In nonporous and insoluble rocks, fractures may provide the only way in which fluids can be transmitted. Examples of such rocks include sandstone in which the pores have been filled by some secondary material; shales; and most igneous and metamorphic rocks such as granite and gneiss (pronounced "nice"). These rocks are very dense and contain few open spaces except for fractures. Typically, fractures are concentrated near the surface and are not distributed evenly over a large area.



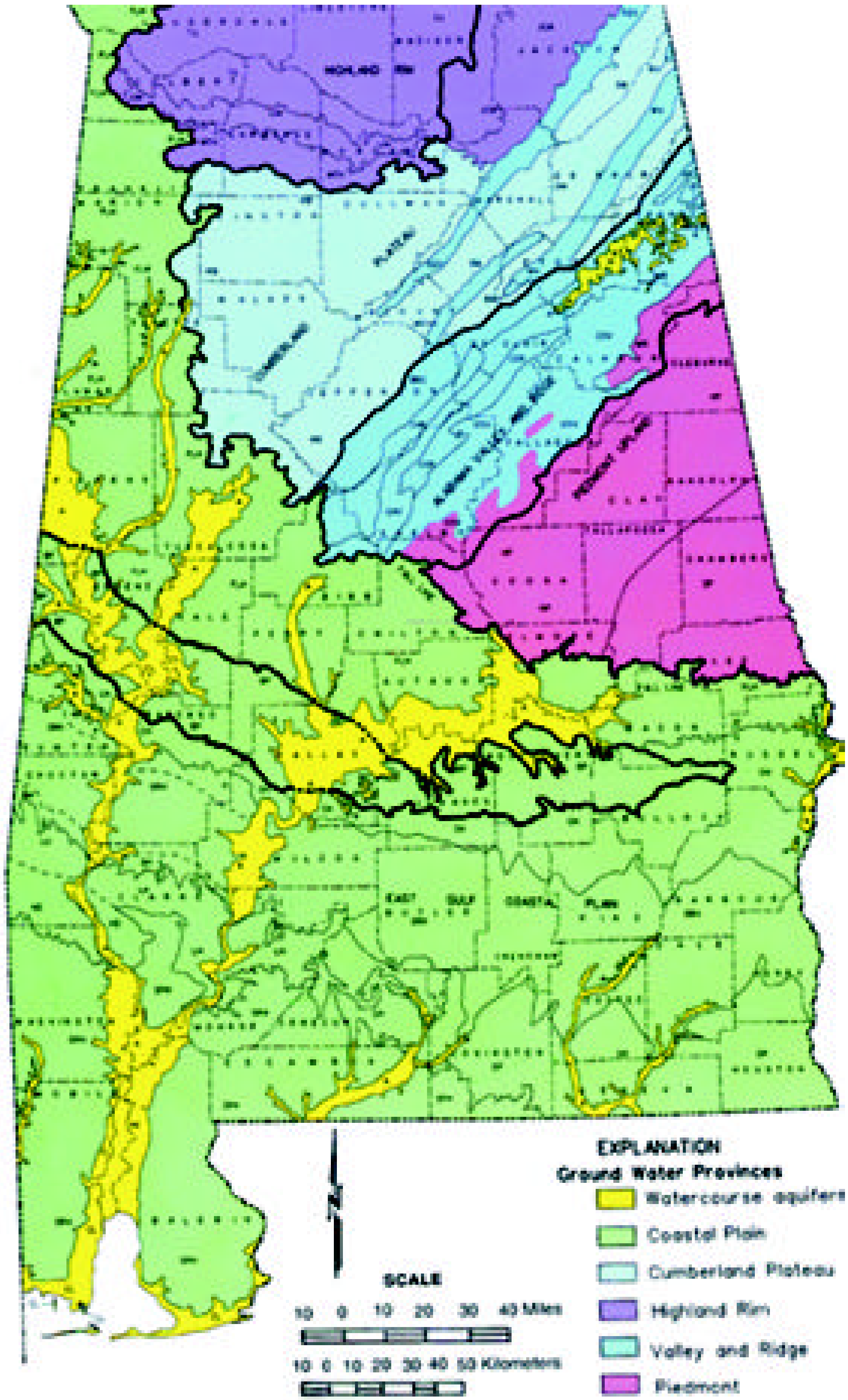
DeSoto Park is in an area of fractured rock

Fractures also may or may not be well connected, and fracture-dependent aquifers rarely contain enough water to make them reliable sources of water. They are typically used only when more suitable aquifers are not present. Small springs are common in fractured terrain wherever saturated permeable fracture systems intersect the land surface. In Alabama, fractured aquifers are most important in the Piedmont region (see next section), where hard granitic rocks, remnants of the core of the Appalachian Mountains, yield modest amounts of water from fracture systems. Fractured granites and granitic rocks are major aquifers in large parts of Coosa, Tallapoosa, and Chambers Counties, and smaller parts of several neighboring counties.

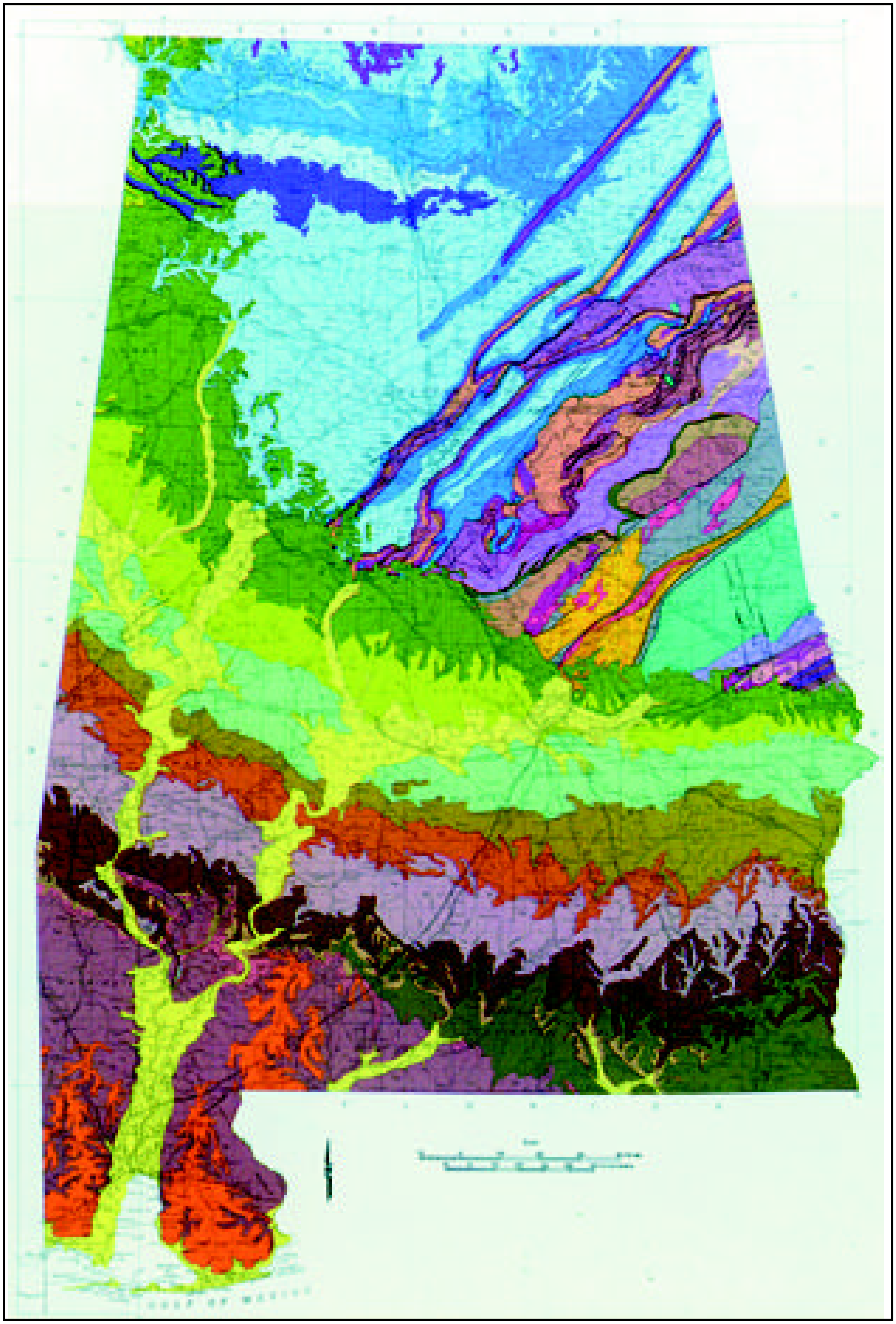
ALABAMA'S AQUIFERS

Alabama is divided into five **hydrogeologic provinces**: the Coastal Plain, Piedmont, Valley and Ridge, Cumberland Plateau, and Highland Rim. These hydrogeologic provinces are closely related to the physiographic provinces. The hydrogeologic provinces are defined on the basis of differences in water bearing properties of rocks, rock type, structural geology, and **physiography**. Such characteristics determine the types of aquifers in these areas.

The Coastal Plain province includes sediments such as sand, gravel, and clay, as well as chalk and some limestone deposited by seas that once covered the southern part of Alabama. Coastal plain sediments are relatively young compared with the rocks that make up the other provinces and are mostly unconsolidated, which means they have not been hardened into rocks. The other four provinces—the Piedmont, Valley and Ridge, Cumberland Plateau, and Highland Rim—are composed of much older sediments that have hardened into rocks. Also, the rocks in these provinces have all been structurally deformed to varying degrees by the forces that formed the Appalachian Mountains. The rocks of the Piedmont were strongly deformed to the point of recrystallization by the deformational pressures. This means that original mineralogy and texture of Piedmont rocks were funda-mentally changed by mountain building. The rocks of the Valley and Ridge, protected to some extent by the Piedmont, were highly folded and faulted. The rocks of the Cumberland Plateau and the Highland Rim were less affected. The intensity of the structural deformation influences the occurrence and quality of ground water in each province. The boundary between the soft rocks of the Coastal Plain province and the hard rocks of the other four provinces is called the **fall line**, because the change in rock durability fosters the formation of waterfalls along this line.



Ground water provinces are regions characterized by certain kinds of aquifers.



The geologic map shows that each part of the state is underlain by different rocks, which control the nature and distribution of aquifers.

MAP EXPLANATION

Quaternary System — Qal t — Alluvial, coastal and low terrace deposits

Coastal Plain Province

System	Series	Map unit	Description	Map unit	Description
Quaternary	Pleistocene	QTcl	Citronelle Formation		
Tertiary	Pliocene				
	Miocene	Tm	Miocene Series undifferentiated	Tre	Residuum
	Oligocene	To	Oligocene Series undifferentiated		
	Eocene	Tj	Jackson Group undifferentiated		
		Tc	Claiborne Group undifferentiated		
	Paleocene	Tw	Wilcox Group undifferentiated		
		Tmi	Midway Group undifferentiated		
Cretaceous	Upper	Ksu	Upper Selma Group undifferentiated		
		Ksl	Lower Selma Group undifferentiated		
		Ke	Eutaw Formation		
		Kt	Tuscaloosa Group undifferentiated		

System	Interior Low Plateaus Province		Appalachian Plateaus Province / Valley and Ridge Province	
Pennsylvanian			IPpv	Pottsville Formation
Mississippian	Mpb	Parkwood Formation and Bangor Lime-stone undifferenti-ated	Mu	Mississippian System undifferentiated
	Mhpm	Hartselle Sandstone and Pride Mountain Formation undiff-erentiated	Pzu	Paleozoic rocks undifferentiated
	Mt	Tuscumbia Limestone		
	Mfp	Fort Payne Chert		
Devonian / Silurian / Ordovician	DSOu	Devonian and Silurian Systems and Upper and Middle Ordovician Series undifferentiated (in places includes Newala Limestone)		
Ordovician / Cambrian			OЄk	Knox Group undifferentiated
Cambrian			Єum	Upper and Middle Cambrian Series undifferentiated
			Єl	Lower Cambrian Series undifferentiated

Piedmont Provinces

Erathem or System	Symbol	Unit
Pz		Hillabee Greenstone
Silurian?- Devonian	[illegible]	Talladega Group
Cambrian	hp	Heflin Phyllite
Cambrian-Ordovician	sm	Sylacauga Marble Group
Precambrian?-Cambrian	km	Kahatchee Mountain Group
Precambrian to Paleozoic	hf	Higgins Ferry Group
	pbm	Poe Bridge Mountain Group
	hc	Hatchet Creek Group
	mi	Mad Indian Group
	we	Wedowee Group
	em	Emuckfaw Group
	gr	Granitic rocks
	fgr	Foliated granitic rocks
	jg	Jacksons Gap Group
	dc	Dadeville Complex
	oc	Opelika Complex
	pm	Pine Mountain Group
	wc	Wacoochee Complex
	mgn	Motts Gneiss
	mm	Moffits Mill Schist
	uc	Uchee Complex
	mc	Mylonitic and cataclastic rocks

Intrusive Rocks

Mesozoic	[illegible]	Diabase dikes

Geologic contact

Fault

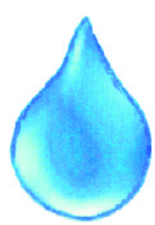
COASTAL PLAIN

The Coastal Plain is by far the largest and most populous hydrogeologic province in the state. The occurrence and availability of ground water in the Coastal Plain is quite high; some Coastal Plain wells can yield up to several thousand gallons per minute (gpm). Average production per well is higher than in any other province in Alabama. In most parts of the Coastal Plain, wells can be expected to yield more than 50 gpm. To put this in perspective, a well producing 7 to 10 gpm is adequate for most domestic purposes.

Ground water resources in the Coastal Plain are estimated at about 488 trillion gallons. Major ground water users include the cities of Dothan, Enterprise, Jackson (supplied by a spring), Montgomery (which also uses surface water), Prattville, Selma, and Troy. Residents of the Coastal Plain, while including only 44 percent of the state's population, account for approximately 63 percent of the total ground water use. The per capita use is high primarily because of agricultural use. More than 70 percent of Alabama's total agricultural water use occurs in the Coastal Plain.

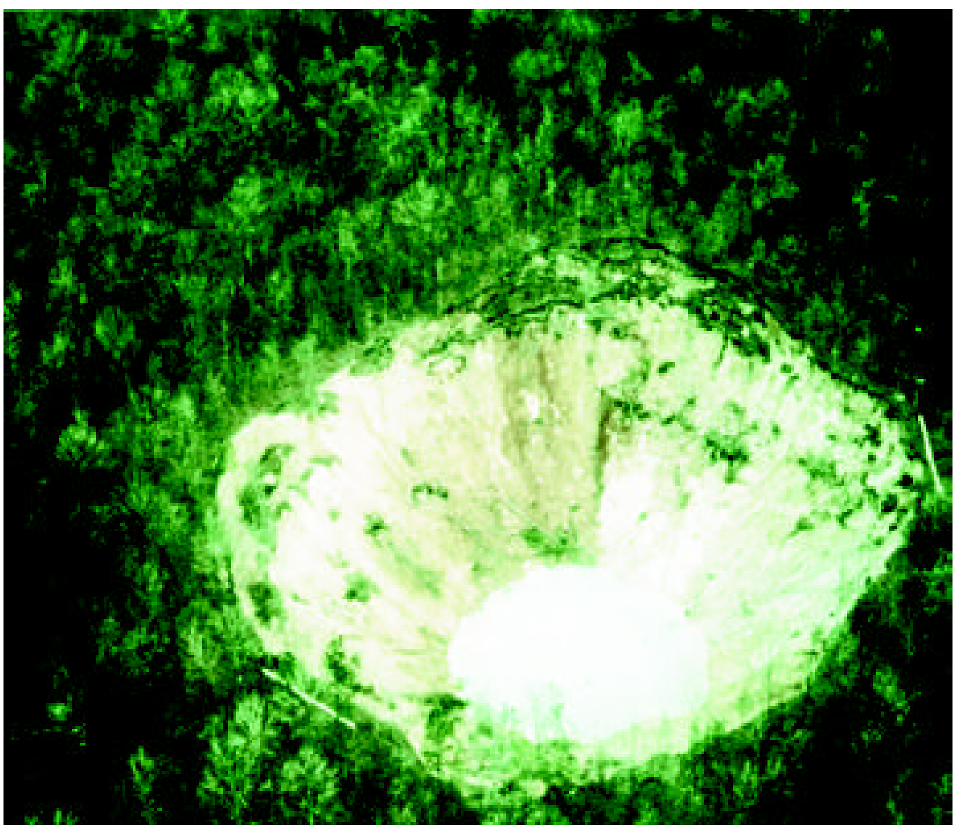
Although most areas in the Coastal Plain yield plenty of ground water, some areas do not. Near the northern limit of the Coastal Plain, **strata** (rock layers) are too thin to store large quantities of water, and major users have to augment their ground water supplies by developing other sources. The city of Tuscaloosa, for example, is located in the northern part of the Coastal Plain, and relies on Lake Tuscaloosa for its water because the ground water supplies there are insufficient to support the city.

Farther south in the Coastal Plain is a part of Alabama which has characteristic black, dense soils that are sticky when wet**.** This area is underlain by chalk, a variety of limestone, which is a poor aquifer.



Eighty percent of public water supply systems in Alabama have at least one ground water source.

Flowing wells can waste millions of gallons of water. The rust colored material on the pipe is due to the iron content of the water.



Sinkhole in Shelby County, 1972. Sinkholes are common in parts of the Alabama Coastal Plain where limestone is near the surface.

In many areas wells must penetrate the chalk and tap deeper aquifers to supply ground water. Because the deep aquifers are under high pressure, flowing wells are common. Although the deeper aquifers contain an abundant supply of water, flowing wells can waste millions of gallons of ground water, which can lead to long term depletion of these deeper aquifers.

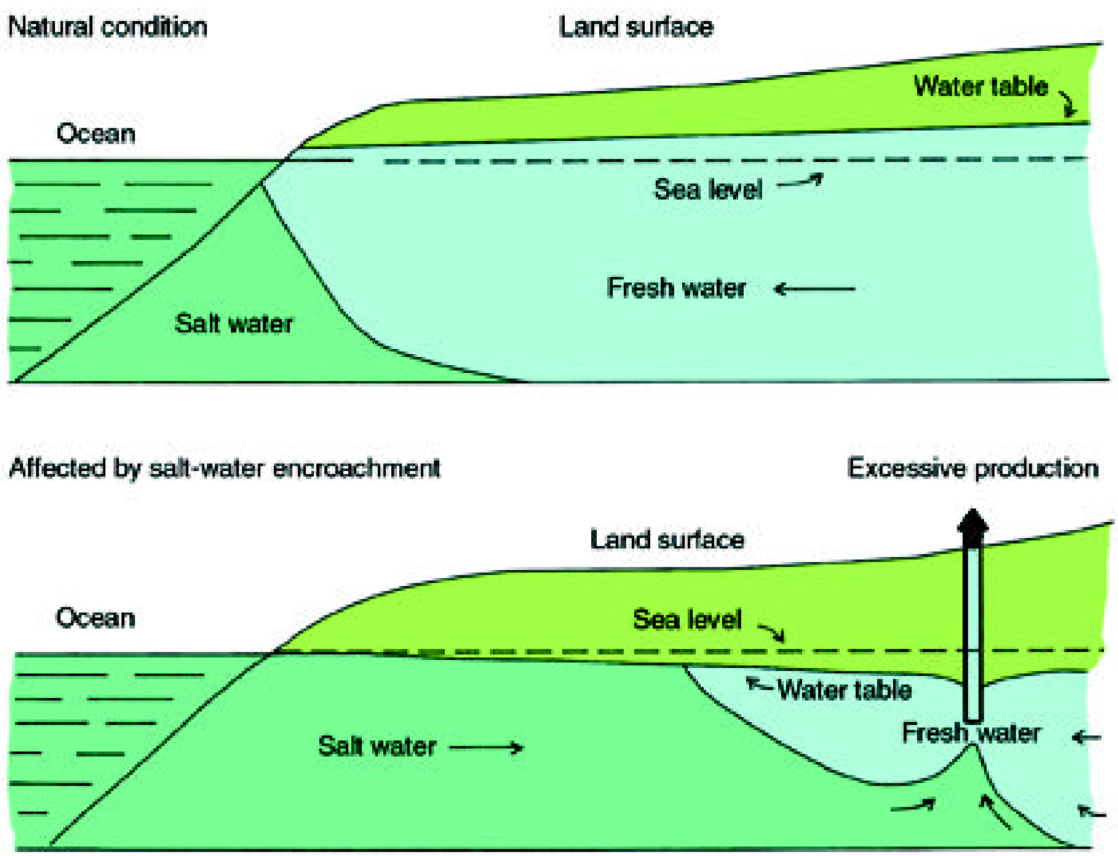
The Coastal Plain contains sporadic springs, most of which are found in the northern and southern parts of the region. In much of the Coastal Plain springs yielding between 10 and 100 gpm of water are moderately common. Rock types are interlayered sand, clay, and limestone, with many sand and limestone units capable of yielding water to springs.

Ground water from subsurface sand and limestone is the primary water source for the City of Dothan, and is an important source to people living in an area from Henry County to southern Choctaw County.

Flowing Well - Tuscaloosa County

Subsurface sands also supply ground water to communities in Escambia, Washington, Baldwin, and Mobile Counties. Ground water in the southern Coastal Plain is produced from wells ranging in depth from tens of feet to nearly 1,000 feet.

In some areas of the Coastal Plain located near the Gulf Coast, contamination of fresh ground water supplies by salt water is a problem. Salt water occurs at relatively shallow depths near the coast. Coastal freshwater aquifers can become contaminated if wells in these aquifers are pumped heavily, or **overpumped**, enough to draw salt water into the wells. Salt water contamination, or **salt water intrusion**, is a problem in southern Baldwin County and can affect any coastal area.



Overpumping in coastal regions may lead to contamination of wells by salt water (salt water intrusion).

PIEDMONT

Piedmont is a French word meaning foothills. The Alabama Piedmont is the southernmost exposure of a vast physiographic province that forms the foothills of the Appalachian Mountains and stretches all the way to Pennsylvania. The ancient crystalline rocks of the Piedmont are **igneous** and **metamorphic** rocks and are the most intensely deformed rocks in the state. Rocks in the Piedmont do not hold much water compared to the sands and limestones of the Coastal Plain. Most of the porosity in Piedmont aquifers is fracture related, although soil and weathered rock near the surface may exhibit porous flow. Water yields both from fractures and from the relatively thin layer of weathered material near the surface (known as **saprolite)** are typically low, highly variable, and difficult to predict. Generally, wells in the Piedmont yield enough water for domestic use, or sometimes for small communities, but not enough for a large town or for commercial use.

> **Water yields in the Piedmont are typically low, highly variable, and difficult to predict.**

Springs are more common in the Piedmont than in the Coastal Plain, but are not abundant. Typical Piedmont springs yield 10 to 100 gpm of water from fractured metamorphic and igneous rocks.

About 7 percent of Alabama's population lives in the Piedmont, accounting for 5 percent (less than 19 million gpd) of the state's ground water consumption. The hilly terrain is unsuitable for large scale agriculture, and only 3.5 percent of Alabama's agricultural water use takes place here. There are no large cities in the Piedmont except for Anniston, which uses water from Coldwater Spring, one of the largest springs in the state. Even though Anniston is in the Piedmont, Coldwater Spring is located in the Valley and Ridge province.

VALLEY AND RIDGE

The Valley and Ridge province is made up of folded and faulted **sedimentary rocks** (limestones and dolomites, sandstones, and shales), and marks the southern end of the Appalachian Mountains. Aquifers in the Valley and Ridge may be dominated by porous, conduit, or fracture controlled flow, depending on the rock type. Ground water is abundant in the Valley and Ridge, with limestone, dolomite, and sandstone aquifers capable of producing more than 100 gpm. A few wells can yield as much as 1,600 gpm.

The Valley and Ridge province is characterized by northeast-southwest trending ridges and valleys. Rocks that are resistant to erosion, such as sandstone and chert, form the ridges, whereas easily eroded rocks, such as limestone and dolomite, underlie the valleys. Generally, valleys are better places to locate wells than hill slopes because ground water tends to flow away from hill slopes into the valleys. Because most of the valleys are underlain by limestone and dolomite

Coldwater Spring, located in the Valley and Ridge province, supplies water to Anniston, located in the Piedmont province.

and therefore are prone to conduit flow, aquifers located in these areas are relatively susceptible to ground water contamination from the surface.

The Valley and Ridge accounts for 14 percent, or about 56 million gpd of the state's total ground water use. Eighteen percent of Alabama's population lives in the Valley and Ridge and, although the water use per person approaches the state average, agricultural water use is low (8 percent of the state total), because of the mountainous terrain.

The limestone aquifers in the Valley and Ridge feed many springs including Coldwater Spring, which has an average discharge of 31.2 million gpd. Few springs approach the flow rate of Coldwater Spring, but springs in the Valley and Ridge province typically yield 100 gpm or more of water from limestone, dolomite, and other rock types. Large springs are common in the Valley and Ridge because of conduit flow in limestone and dolomite aquifers.

Trussville, in Jefferson County, is the largest single consumer of ground water in the Valley and Ridge province. The cities of Attalla and Leeds also use ground water to ... r water

Contaminated water may enter the subsurface directly through sinkholes.

CUMBERLAND PLATEAU

The Cumberland Plateau in north central Alabama is underlain by relatively flat-lying rocks. The Pottsville Formation, which consists of interbedded sandstone and shale, is the major aquifer in the Cumberland Plateau, with the Bangor Limestone and the Hartselle Sandstone supplying significant amounts of ground water in some parts of the province. Water from the Pottsville contains enough iron in places to stain fixtures and affect the taste of the water, and water from the Bangor and to a lesser extent the Hartselle, is hard (see **hard water**). Individual wells in the province can yield as much as several hundred gallons per minute, but 20 gpm or less is typical. Springs in the Cumberland Plateau are moderately common, yielding 10 to 100 gpm of water from limestone, sandstone, and shale.

Ground water supplies in the Cumberland Plateau, although sufficient for smaller consumers, cannot sustain the needs of a major user.

The Cumberland Plateau contains 18 percent of Alabama's population and accounts for 12 percent of the state's total water consumption, 9 percent of the total ground water use, and 12 percent of the total agricultural water use. Ground water supplies in the Cumberland Plateau, although sufficient for smaller consumers, cannot sustain the needs of a major user. The towns of Eldridge in Walker County and Hodges in Franklin County depend on ground water to supply their needs.

Spring Source - Bridgeport, Alabama

HIGHLAND RIM

As is the case in many areas in Alabama, ground water is unevenly distributed in the Highland Rim. High capacity wells, producing from 100 to more than 1,000 gpm, occur in the limestones and dolomites of the Fort Payne-Tuscumbia aquifer system in the northern part of the Highland Rim, and in the Bangor Limestone in the southern part. The Hartselle Sandstone and several other aquifers of local importance supply minor amounts of ground water to the southern part of the province, mostly from wells producing 10 gpm or less.

The major aquifers in the Highland Rim province contain significant amounts of limestone. Caves and sinkholes are common, and contamination of ground water is a serious concern. Much of the ground water in the Highland Rim is hard and locally contains objectionable amounts of iron, carbon dioxide, or hydrogen sulfide.

Thirteen percent of Alabama's population lives in the Highland Rim, accounting for 12 percent of Alabama's total water use. Only 9 percent of the state's total ground water consumption occurs in the Highland Rim. Part of the reason for this is the Tennessee River system, which provides plentiful surface water

The Huntsville Lincoln Well is the largest diameter well (20 feet) in Alabama. It can pump up to 3200 gallons per minute.

to users throughout the province. Agricultural water use has increased dramatically in the past few years because the practice of irrigation is becoming more widespread in the area.

Springs in the Highland Rim are abundant and typically yield more than 100 gpm of water from limestone, chert, and other rock types. The Highland Rim includes two of Alabama’s three biggest springs. Tuscumbia Spring, also known as Big Spring, supplies water to the city of Tuscumbia. Large springs are common in the Highland Rim because of conduit flow in limestone and chert aquifers.

Huntsville is the largest ground water user in the Highland Rim, getting most of its water from two wells and Brahan Spring (Huntsville Big Spring). In addition, the Madison County Water Authority and the Limestone County Water Authority depend entirely on ground water for their water supply. Madison County has been a leader in the development of local ground water protection efforts.

Tuscumbia Spring, one of Alabama's largest, is located in limestone terrain.

GROUND WATER MYTHS

WATER WITCHING

Water witching (also called divining or dowsing) is an ancient method of finding ground water. The oldest detailed description of dowsing was published in 1556, but cave paintings at least 6,000 years old appear to show a dowser at work. But does it work? Alas, there is no hard evidence that supports the claims of any water dowser. In most parts of Alabama it would be difficult to drill a well and *not* find water. Dowsers in Alabama can easily build up excellent "success" rates, because in most of our state ground water is not that hard to find. In areas where water is more difficult to find, dowsers do no better than random drilling at locating usable quantities of water. The U.S. Geological Survey has two publications on dowsing. Both are listed in the reference

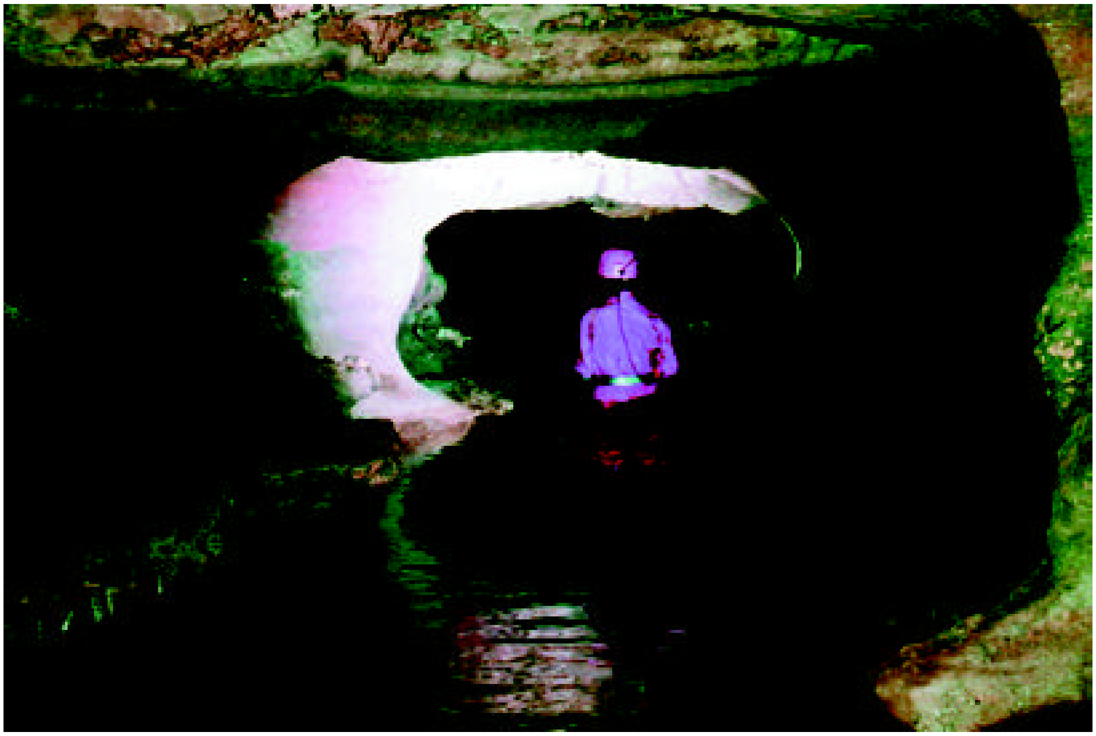
The Mount Carmel public water supply well in Pike County is the deepest in Alabama, at 2723 ft.

UNDERGROUND STREAMS AND LAKES

As mentioned earlier, underground lakes, rivers, and even waterfalls exist in Alabama. These features are almost always associated with caves.

It is important to remember that even in regions known for their caves, such as northwest Alabama or the southern Coastal Plain from Choctaw to Geneva Counties, more than 99 percent of the space underground is solid rock, not cave, and most ground water occurs in small cavities and fractures in that "solid" rock.

At least five caves in Jackson and Madison Counties contain underground rivers more than a mile long that are large enough for canoeing. No one knows exactly how long these rivers are, because they all completely fill the cave passages at some point. Such places remain largely unexplored because of the danger posed even to experienced cavers.



The beautiful cave formations and mysterious underground rivers form an eerie part of Alabama's natural environment. However, most underground water, even in cave country, is in holes too small to see. Bluff River Cave, Jackson County, Alabama.