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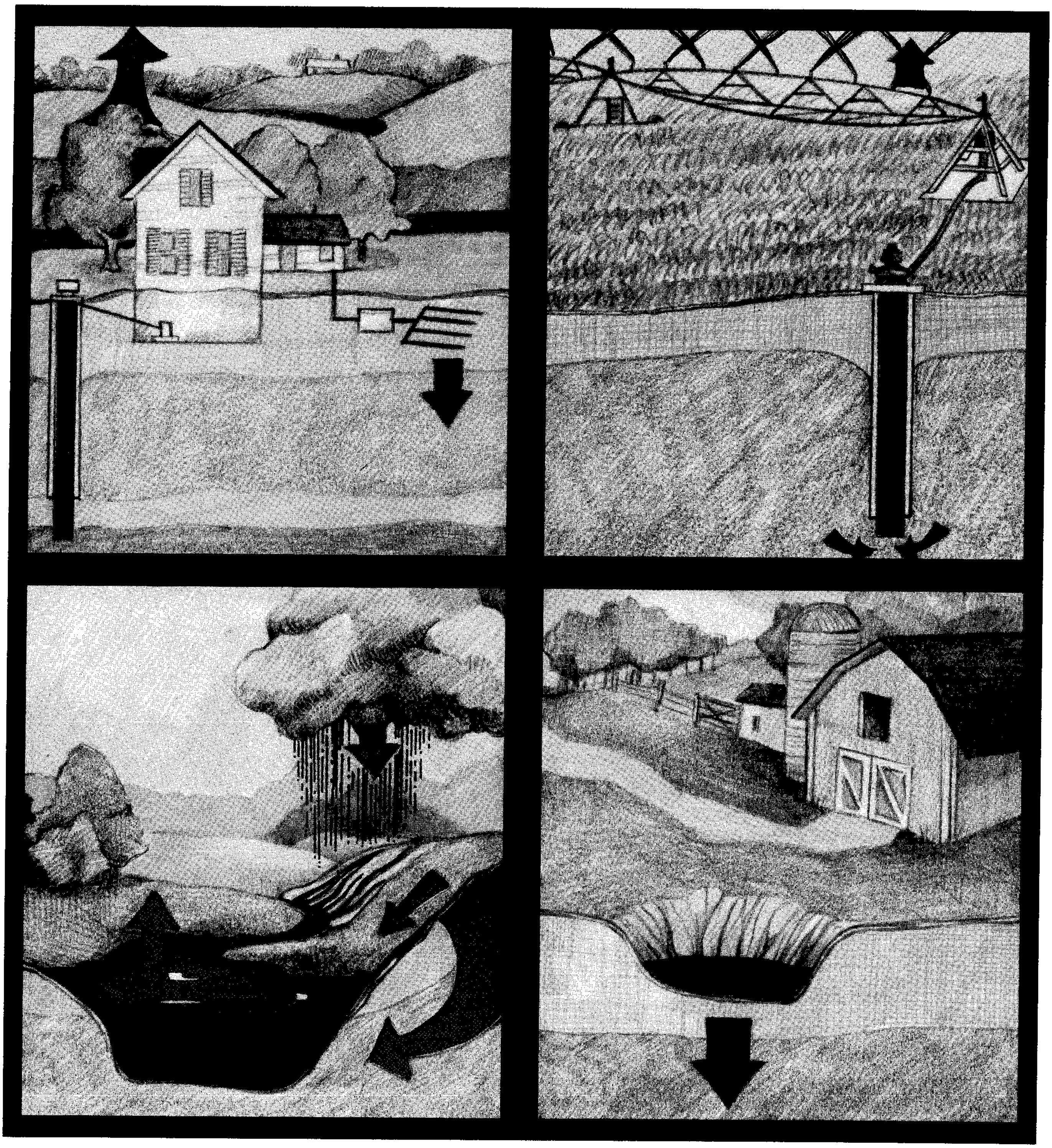
Georgia's Ground Water Resources



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Georgia's Ground Water Resources

Prepared by Anthony W. Tyson, Extension Engineer

Beneath the surface of the land lies a tremendous resource that many of us depend on for our very existence, yet often take for granted. This precious resource is ground water.

Georgia's ground water aquifers provide water for almost half of the state's population and about 90 percent of its rural residents. (Figure 1) It is also an important source of water for municipal supplies, industrial needs and agricultural uses.

Figure 1. Ground water provides drinking water for almost half of Georgia's population.

Georgia has an abundant supply of ground water in a complex system of underground aquifers throughout the state. Unlike some parts of the country which receive very little precipitation, Georgia's ground water is constantly being replenished by an abundance of rainfall.

Although some areas of the state have experienced problems with quantity and quality of ground water, these problems have not yet proven severe. However, it is inevitable that future growth will continue to place increasing demands on this precious resource. It is critical to the future of the state that we strive to better understand the nature of our ground water resources, to help to ensure that our activities don't irreparably damage our supplies.

WHAT IS GROUND WATER?

Georgia has a relatively abundant supply of both surface water and ground water. Fresh surface water includes the water in our streams, rivers, ponds and lakes. These sources make up the above-ground portion of our total fresh water supply. The part that lies below the earth's surface in saturated layers of sand, gravel or sedimentary rock, or in fractures in crystalline rock, is called ground water.

People tend to understand surface water much better than they do ground water. We can see surface water. We swim in it and fish in it. We can see that water levels decline during dry weather and rise when rainfall is plentiful. We can also see the effects of man-made pollution almost immediately.

On the other hand, ground water is hidden. It is deep in the ground and is shrouded in many misconceptions and myths. For instance, some people believe that ground water originates in some mystical, pristine place far removed from man's influence. The fact is: almost all ground water found in Georgia originates within the state's boundaries -- and many wells withdraw water which originates within a few hundred feet of the well. Many people also believe that ground water occurs in vast underground rivers or lakes. But with the exception of underground caverns and solution channels in some limestone aquifers, ground water almost always occurs in small pore spaces in layers of saturated sand, gravel or sedimentary rock or in cracks and fissures in crystalline rock.

The Water Cycle

Ground water makes up part of the earth's water cycle or hydrologic cycle, which is the continuous circulation of moisture and water on our planet. This cycle is in constant operation, moving water from the earth to the atmosphere by evaporation and back again to the earth's surface as precipitation, to produce stream flow and ground water flow.

Of the water that falls to the earth's surface in the form of rainfall, some runs off the surface, some evaporates back to the atmosphere and some infiltrates into the ground. Part of the water that moves into the ground is taken up by plant roots and re-enters the atmosphere through transpiration. The rest percolates deeper into the earth and becomes ground water. This process is called recharge.

On average, Georgia receives about 50 inches of rainfall per year. The U.S. Geological Survey has calculated that 35 of the 50 inches of annual precipitation will be returned directly to the atmosphere by evaporation and transpiration (Figure 2). About nine inches becomes surface runoff. In streams, rivers and lakes it provides an important source of water for the state. The remaining six inches infiltrates the soil and becomes ground water. This water may enter the aquifer system and, if not withdrawn by man, will move slowly and eventually discharge into streams or the ocean.

Aquifers

The word aquifer comes from the Latin words *aqua*, meaning water, and *ferre*, meaning to bear or carry. Thus an aquifer is a water-bearing geologic formation that can yield usable amounts of water. An aquifer may be a layer of gravel or sand, a layer of sandstone or limestone, or even a body of massive rock, such as granite, which has sizeable cracks and fissures.

An aquifer may be anywhere from a few feet to several hundred feet thick. It may lie just below the earth's surface or hundreds or even thousands of feet down.

Aquifer materials may be classified as consolidated or unconsolidated rock. Consolidated rock (often called bedrock) may consist of sandstone, limestone, granite or other rock. Unconsolidated rock consists of granular material such as sand, gravel and clay.

The quantity of water a rock can contain depends on the rock's porosity -- the total amount of spaces among the grains or in cracks that can fill with water (Figure 3). If water is to move through rock, the pores must be connected to one another. If the rock has a great many connected pore spaces big enough that water can move freely through them, it is permeable.

Aquifers consisting of sand or gravel contain relatively large interconnected spaces between particles and will generally yield sizeable quantities of water. On the other hand, clay may contain a considerable amount of

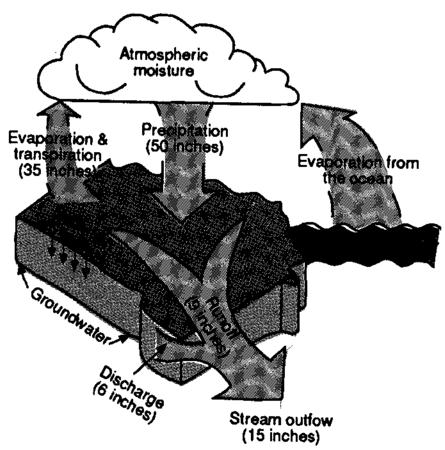

Figure 2. Water Cycle in Georgia

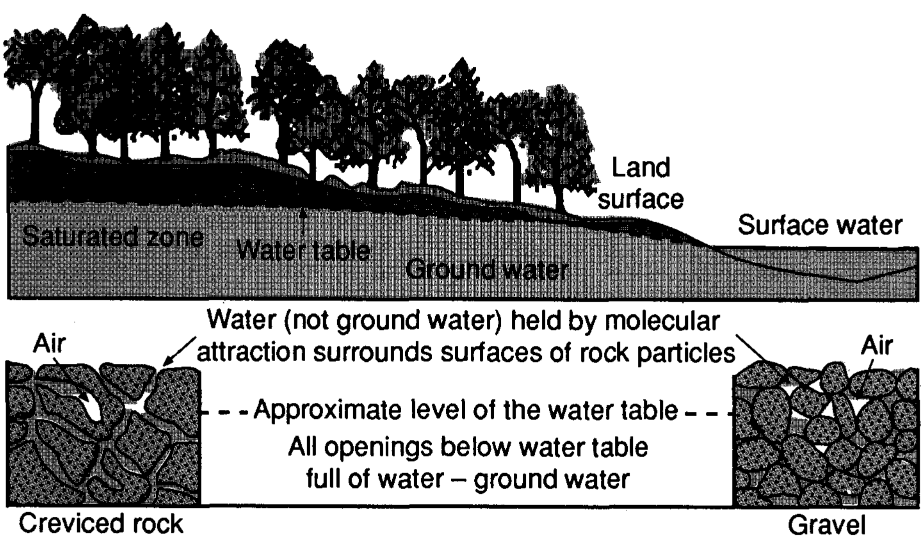

Figure 3. How Ground Water Occurs in Pore Spaces and in Cracks and Fissures in Rocks

water and yet the pore spaces are so small that water cannot move freely between them. Therefore, clay layers tend to impede water movement and are not productive aquifers. Some of the most productive aquifers in Georgia consist of sedimentary rocks such as limestone, dolomite and sandstone. These typically contain many solution channels and interconnected pores which hold water and allow it to move easily.

Crystalline rock, such as granite, contains very little pore space and has very low permeability. However, nearly all consolidated rock formations of this type are broken by cracks, fractures or faults, which may enlarge over time. These cracks tend to hold water and, when intercepted by a well, will often yield usable quantities of water.

In many areas there may be multiple aquifers stacked on top of one another. These distinct layers of water-bearing material are often separated by impermeable layers of clay or rock which prevent water from moving readily from one aquifer to another (Figure 4). These impermeable layers are called confining layers or confining beds. An aquifer which does not have a confining layer above it is said to be unconfined (Figure 5). The upper surface of the saturated zone in such an aquifer is referred to as the water table. These aquifers occur in almost all areas of the state and are commonly called water table aquifers or surficial aquifers. In water table aquifers, water may move readily from surface sources such as streams and rivers to ground water and vice-versa. The water level in these aquifers fluctuates readily with changes in weather patterns. An aquifer lying beneath a confining layer is commonly called a confined or artesian aquifer (Figure 6).

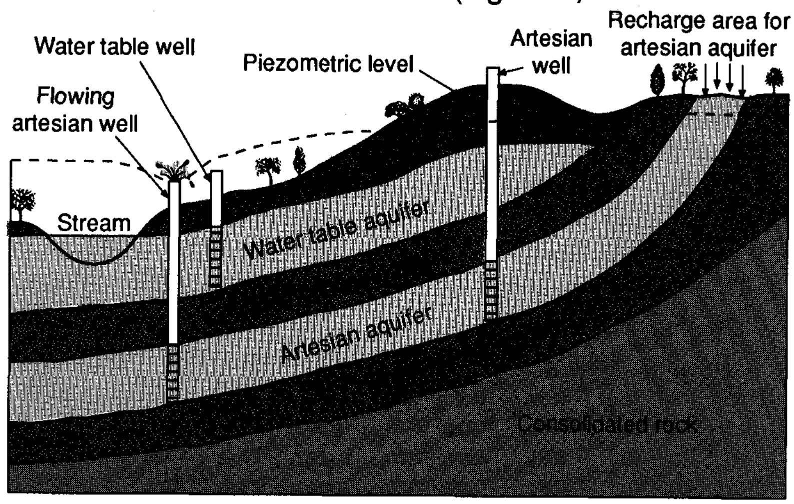

Figure 4. Occurrence of Aquifers Separated by Confining Beds (Reprinted from Johnson, 1966)

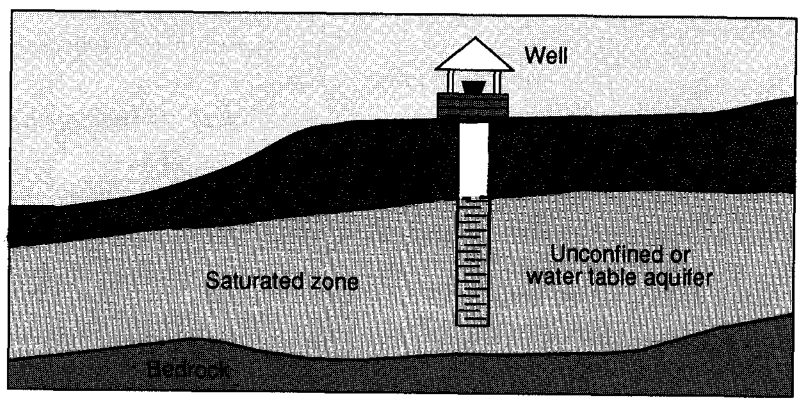

Figure 5. Unconfined or Water Table Aquifer

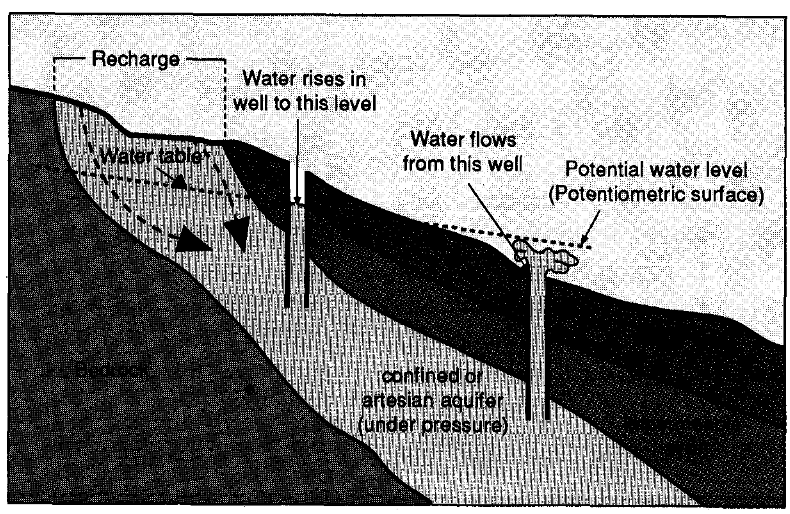

Figure 6. Confined or Artesian Aquifer

As the water flows beneath the confining layer it is essentially trapped by the impermeable layer above it. Consequently, the water in the aquifer may be confined under pressure. When a well is drilled into such an aquifer, this artesian pressure will cause the water level in the well to rise above the point where the well intercepted the aquifer. The level to which water will rise into tightly cased wells from artesian aquifers is called the potentiometric surface. If a well is drilled in a low-lying area where the surface of the ground is lower than the potentiometric surface, water will flow from the well under its own pressure. Such a well is known as a flowing artesian well.

Since artesian aquifers are overlain by confining layers, recharge to the aquifer can only occur in places where the confining layer leaks, is absent, or where the aquifer is exposed at the ground surface (Figure 4). These areas are known as outcrop areas or recharge areas.

Ground Water Movement

Ground water is always moving by the force of gravity from recharge areas to discharge areas. Contrary to popular belief, ground water movement is generally very slow, typically only a few feet per year. However, in more permeable zones, such as solution channels in limestone or fractures in crystalline rock, it may move as fast as several feet per day.

The force of gravity moves water toward areas of lower elevation. Ground water, particularly from the water table aquifers, typically discharges into streams, lakes and wetlands. Where the water table intercepts the ground surface, water can discharge, forming a spring (Figure 7).

Water in the confined aquifers of the southern part of the state generally moves in a southerly direction and eventually discharges into the Atlantic ocean or Gulf of Mexico. Where an upper confining layer is breached, particularly along river beds, the confined aquifers may discharge into the river, particularly during low-flow conditions in the river. Conversely, when river levels are high, water may flow from the river into the aquifer, thus contributing to recharge into the aquifer. Several places like this exist in South Georgia.

MAJOR AQUIFERS OF GEORGIA

Geologically, Georgia is divided into four major physiographic provinces, including the Valley and Ridge and Appalachian Plateau (treated as one province), the Blue Ridge, Piedmont and Coastal Plain (Figure 8). Because of differing geologic features and landforms in each of the provinces, there are substantial differences in ground water conditions from one part of the state to another. These features affect ground water quantity and quality.

Water table aquifers are present in each of the physiographic provinces. They are usually unconfined and are used for domestic and livestock supplies in most areas. Shallow wells tapping the water table aquifer are especially prevalent in rural areas where they are often used for domestic supply and livestock watering.

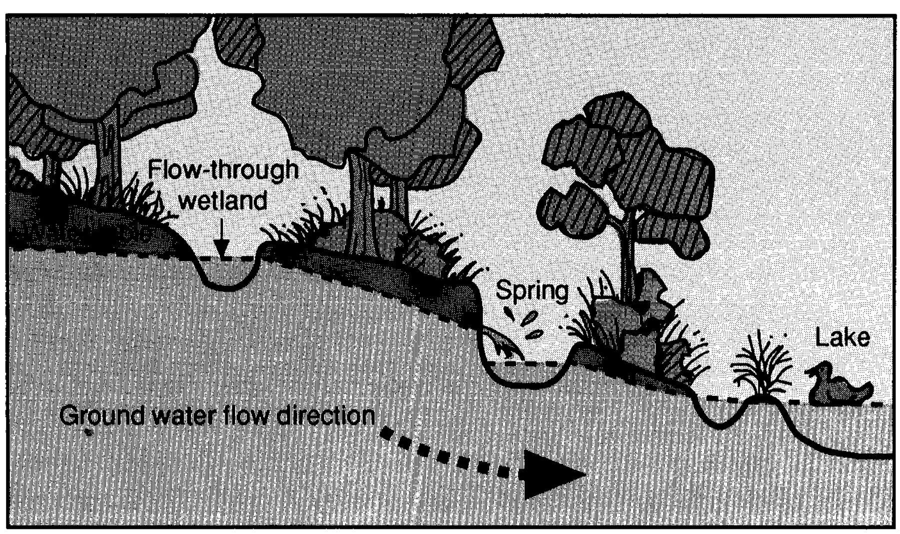

Figure 7. Ground Water Discharge into Surface Water

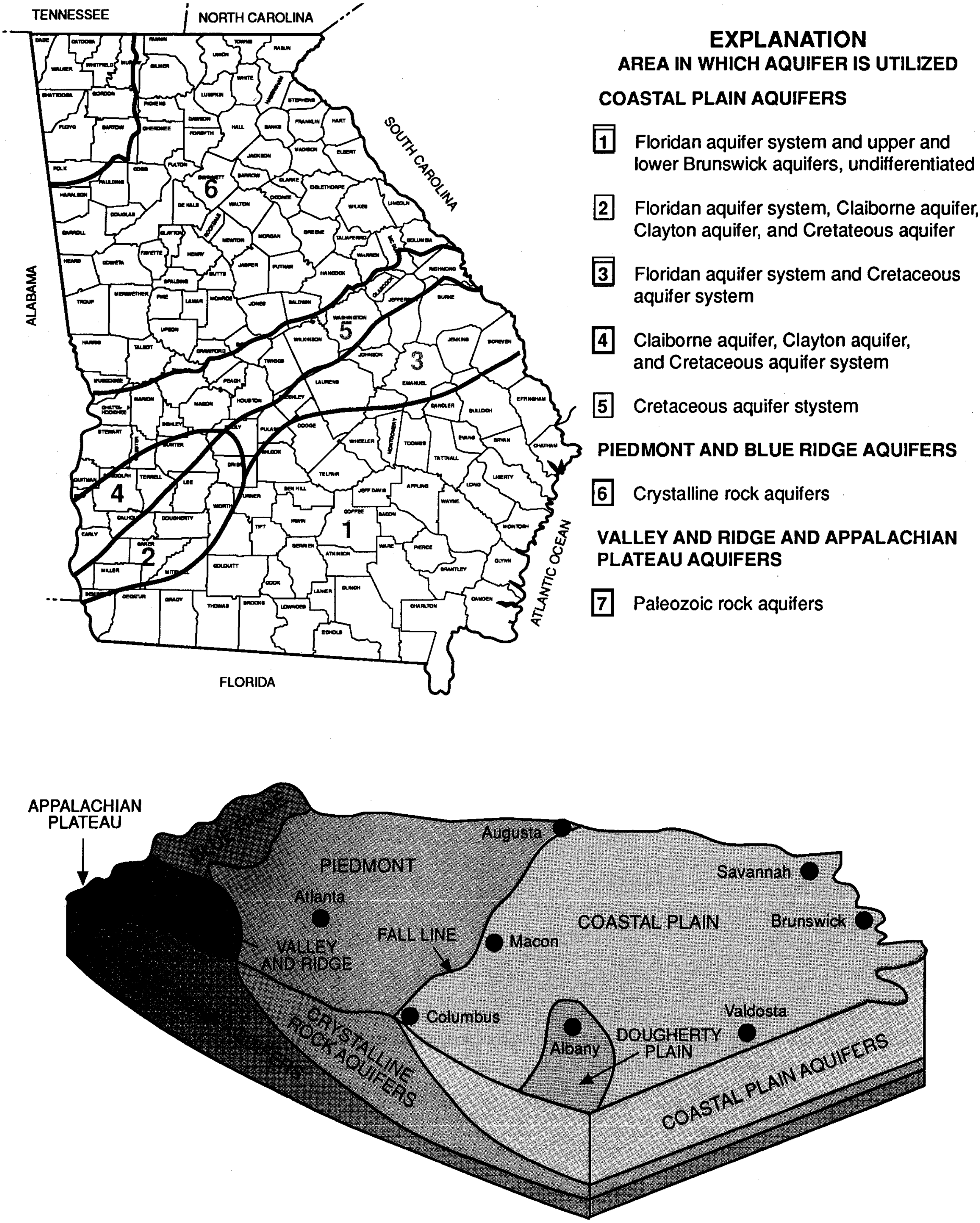

Figure 8. Areas of Major Aquifers and Block Diagram Showing Major Aquifers and Physiographic Provinces of Georgia. (From Peck, et. al., 1990)

Table 1.--Aquifer and Well Characteristics in Georgia (From Peck, et.al., 1990)

	Well Characteristics			
	Depth (ft)	Yield (gal/min)		
Aquifer name and description	Common Range	Common Range	May Exceed	Remarks
Upper Brunswick aquifer: Phosphatic and dolomitic quartz sand. Generally confined.	85-200	10-15	30	Not a major source of water in coastal Georgia, but considered a supplemental water supply to the Upper Floridan aquifer. Most wells are multiaquifer tapping both the Upper and Lower Brunswick aquifers and the Upper Floridan aquifer.
Lower Brunswick aquifer: Phosphatic and dolomitic quartz sand. Generally confined.	190-390	15-30	180	
Floridan aquifer system: Limestone, dolostone, and calcareous sand. Generally confined.	40-900	1,000-5,000	11,000	Supplies 50 percent of ground water in Georgia. The aquifer system is divided into the Upper and Lower Floridan aquifers. In the Brunswick area, the Upper Floridan aquifer includes two freshwater-bearing zones and the lower water-bearing zone. The lower Floridan aquifer is not considered a major aquifer because of high chloride concentrations. In the Brunswick area, the Lower Floridan aquifer consists of the brackish-water zone, the deep freshwater zone, and the Fernandina permeable zone.
Claiborne aquifer: Sand and sandy limestone. Generally confined.	20-450	150-600	1,500	Major source of water in southwestern Georgia. Supplies industrial and municipal users at Dougherty, Crisp and Dooly Counties and provides irrigation water north of Dougherty Plain. In east-central Georgia, the Claiborne aquifer is part of the Gordon aquifer system.
Clayton aquifer: Limestone and sand. Generally confined.	40-800	250-600	2,150	Major source of water in southwestern Georgia. Supplies industrial and municipal users at Albany and provides irrigation water northwest of Albany. Water-level declines exceed 100 ft at Albany.
Cretaceous aquifer system: Sand and gravel. Generally confined.	30-750	50-1,200	3,300	Major source of water in east-central Georgia. Supplies water for kaolin mining and processing. Includes Providence aquifer in southwestern Georgia and the Dublin and Midville aquifer systems in east-central Georgia. Water-level declines greater than 50 ft at kaolin mining centers and 100 ft near Albany.
Paleozoic rock aquifers: Sandstone, limestone, and dolostone; storage is in regolith and fractures and solution openings in rock. Generally unconfined.	15-2,100	1-50	3,500	Not laterally extensive. Limestone and dolostone aquifers most productive. Springs in limestone and dolostone aquifers discharge at rates of as much as 5,000 gal/min. Sinkholes can form in areas of intensive pumping.
Crystalline rock aquifers: Granite, gneiss, schist, and quartzite; storage is in fractures in rock and in regolith. Generally unconfined.	40-600	1-25	500	Not laterally extensive.

The most productive aquifers in Georgia are in the Coastal Plain Province in the southern part of the state. The Coastal Plain is underlain by alternating layers of sand, clay and limestone which get deeper and thicker to the southeast (Figure 8). In the Coastal Plain, aquifers generally are confined, except near their northern limits where they crop out or are near land surface. Principal aquifers of the Coastal Plain include the Upper Brunswick and Lower Brunswick aquifers, the Floridan aquifer system, the Claiborne and Clayton aquifers and the Cretaceous aquifer system.

The Piedmont and Blue Ridge provinces, which include most of the northern half of Georgia, are underlain by massive igneous and metamorphic rocks. These rocks have a very low permeability but may contain cracks and fractures which can yield usable quantities of water.

The Valley and Ridge and Appalachian Plateau provinces, in the northwestern corner of Georgia, are underlain by layers of sandstone, limestone, dolostone and shale of Paleozoic age. Wells tapping limestone and dolomite aquifers in this province can be very productive.

Upper and Lower Brunswick Aquifers

The Upper and Lower Brunswick aquifers, which are located primarily in the southeastern corner of the state, consist of phosphatic and dolomitic quartz sand. These aquifers are generally confined. At the present time these aquifers are not a major source of ground water but could become more so in the future in coastal Georgia, particularly if restrictions are placed on withdrawals from the Floridan aquifer. Currently, the Upper and Lower Brunswick aquifers are primarily used in multiaquifer wells that also tap the Upper Floridan aquifer.

Floridan Aquifer System

The Floridan aquifer system is one of the most productive ground water reservoirs in the United States. This system supplies about 50 percent of the ground water used in the state. It is used as a major water source throughout most of South Georgia.

The Floridan aquifer system consists primarily of limestone, dolostone and calcareous sand. It is generally confined, but is semiconfined to unconfined near its northern limit. Wells in this aquifer system are generally high-yielding and are extensively used for irrigation, municipal supplies, industry and private domestic supply.

Claiborne Aquifer

The Claiborne aquifer is an important source of water in part of southwestern Georgia. It is made up of sand and sandy limestone and is mostly confined. It supplies industrial and municipal users in Dougherty, Crisp and Dooly counties and provides irrigation water north of the Dougherty Plain. In East Central Georgia, this aquifer is referred to as the Gordon aquifer system.

Clayton Aquifer

The Clayton aquifer is another important source of water in southwestern Georgia. It is made up of sand and limestone and is generally confined. The majority of water pumped from this aquifer is used for public supply and irrigation. Due to increased pumping from this aquifer during the 1970s and '80s, water levels have trended downward, particularly in the Albany area. There is some concern now about overuse of this aquifer.

Cretaceous Aquifer System

The Cretaceous aquifer system is the deepest of the principle aquifers in South Georgia. It serves as a major source of water in the northern one-third of the Coastal Plain. The aquifer system consists of sand and gravel that locally contains layers of clay and silt which function as confining beds. These confining beds locally separate the aquifer system into two or more aquifers. In southwestern Georgia, the Providence aquifer is part of the Cretaceous system. In east central Georgia, this system is divided into three subsystems: the Dublin, Midville and Dublin-Midville aquifer systems.

Paleozoic Rock Aquifers

The paleozoic rock aquifers are in the northwestern corner of the state within the Valley and Ridge and Appalachian Plateau provinces. This area is made up of a number of small aquifers, none of which is laterally extensive. These aquifers consist primarily of sandstone, limestone or dolostone. Well yields vary considerably, depending on the particular aquifer and location of the well.

Dolostone aquifers typically yield 5-50 gallons per minute (gal./min.), whereas limestone and sandstone aquifers typically yield 1-20 gal./min.; maximum reported yields from these aquifers are 3500 and 300 gal./min., respectively. Springs discharge from the limestone and dolostone aquifers at rates of as much as 5000 gal./min. Where the limestone and dolostone aquifers are near land surface, droughts or excessive pumping can contribute to the formation of sinkholes.

Crystalline Rock Aquifers

The Piedmont and Blue Ridge Provinces are underlain by bedrock consisting primarily of granite, gneiss, schist and quartzite. These rock formations make up the crystalline rock aquifers which are generally unconfined and not laterally extensive. These rocks tend to be impermeable, and thus where ground water is present it is stored in joints and fractures in the rock. Deep wells in this part of the state are usually drilled wells, and in order to yield usable quantities of water they must intercept fractures which hold water. Consequently, well yields tend to be unpredictable. Typical yields are 1 to 25 gal./min., but some wells have been reported to yield as much as 500 gal./min.

Presently, the crystalline rock aquifers are used primarily for private water supplies and livestock watering. It is commonly believed that ground water in this part of the state is not sufficient to supply such uses as municipal supplies and industry. Consequently, large water users in North Georgia have relied primarily on surface water. In recent years, however, systematic well-siting techniques have produced high-yielding wells (greater than 100 gal./min.) on a regular basis. Because surface water sources have been pushed to their limits in some areas, several studies are now under way to evaluate whether the use of ground water can be increased in this region, particularly for municipal supplies.

GROUND WATER USE AND WATER LEVEL TRENDS

According to USGS data (U.S. Geological Survey Water Supply Paper 2350), ground water withdrawals in Georgia amounted to about one billion gallons per day in 1985, which was about 48 percent of total water use in the state, excluding withdrawals for thermoelectric power generation (See Figure 9). Almost 90 percent of the ground water withdrawals were in the southern half of the state. (Figure 10).

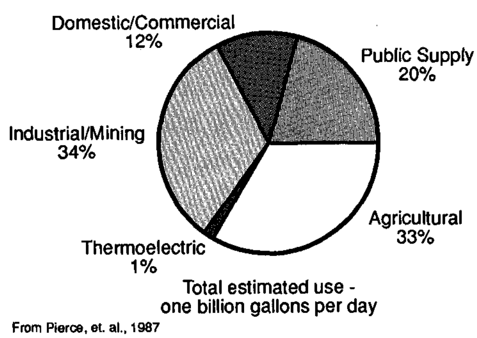

Figure 9. Ground Water Use in Georgia - USGS Data-1985

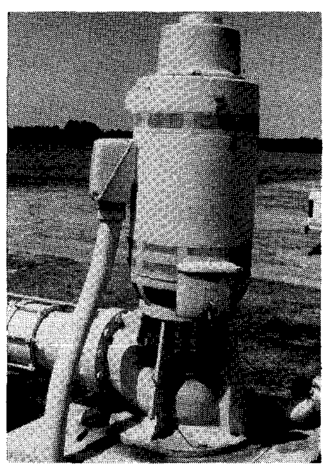

Figure 10. In the Coastal Plain, many large wells supply water for irrigation, industry and municipal supply.

Because of the increased use of ground water over the past few decades, there is increasing concern about declining ground water levels and whether water is being removed faster than it is being recharged.

Several factors cause ground water levels to fluctuate. These levels naturally rise and fall because of seasonal patterns of ground water recharge and storage. In Georgia, ground water levels tend to be highest in the spring and lowest in the fall (Figure 11). In late spring, summer and early fall, evaporation and transpiration by plants use up most of the water that would otherwise recharge the aquifer. At the same time, the aquifer is discharging water into streams, springs and wells. A seasonal decline in ground water levels results. In the late fall, winter and early spring, most plants are dormant and evaporation rates are low. Consequently, rains during this time of year tend to saturate the soil, stream levels rise, and ground water recharge occurs, resulting in water level increases.

Longer-term changes in ground water levels may occur because of climate and pumping changes. Less ground water recharge will occur during dry years than in wet years. Several years of below normal rainfall will typically result in a gradual decline in water levels. This actually occurred in Georgia during the 1980s when several years of drought caused water levels to decline in many areas. This general decline, with increases in pumping, caused water levels in some wells to drop below the pump inlet, requiring that the pump be lowered in the well. The sample hydrograph in Figure 11 shows record low water levels for this particular well in 1986 and 1988. These were both dry years in Georgia. However, the water level recovered in 1989 because of above normal rainfall and decreased pumping.

Ground water levels can also be affected by pumping from wells. When water is pumped from a well, the water level in the well is drawn down, forming a cone-shaped depression on the water surface (Figure 12). This cone of depression is maintained as long as the well is pumping but is usually localized and does not affect other wells in the area. However, when several high-capacity wells are pumping in the same vicinity, the cones of depression may overlap and cause a general lowering of the water level in an area. When this happens during a time of dry weather, the water level may drop to the point that shallower wells in the area go dry and the water level drops below the pump inlet in others. When this happens, even though the situation is usually temporary, it creates a great deal of concern about the use and allocation of our ground water resources.

The U. S. Geological Survey (USGS) has been monitoring ground water

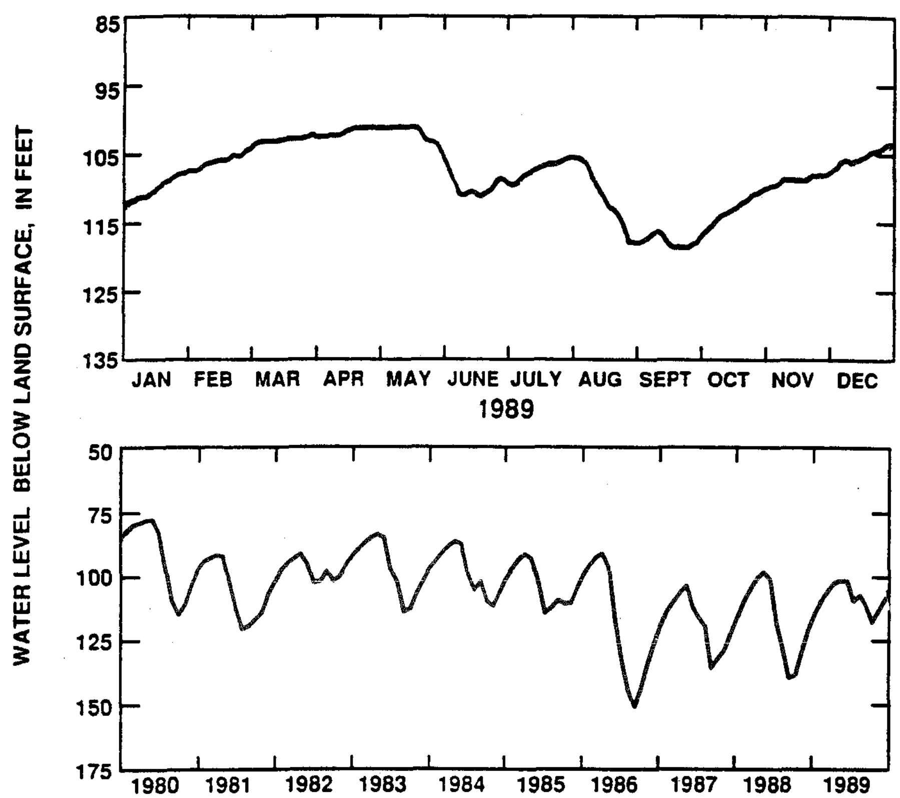

Figure 11. Hydrographs of Observation Well in Clayton Aquifer. Dougherty Co., GA.(From Peck, et.al., 1990)

levels in the United States for more than 100 years. Today they and the Georgia Geologic Survey monitor water levels in about 1,370 wells throughout Georgia; they use recorder instruments to continuously monitor 140 wells. A plot of water levels in a well over a period of time is called a hydrograph. Figure 11 is an example of a hydrograph from one of the test wells tapping the Clayton aquifer near Albany.

In Georgia, hydrographs from the statewide monitoring network show seasonal fluctuations in water levels -- many showed the effects of the droughts in 1986 and 1988. Some wells, particularly in the confined aquifers of South Georgia, showed a continual water-level decline throughout the 1980s. These declines were due to pumping from the aquifers and to decreased recharge during drought years. However, it is often hard to determine how much was due to increased pumping. In general, the water levels in most wells recovered somewhat during years with normal or above-normal precipitation.

Two areas where ground water levels are a primary concern are the Clayton aquifer in Southwest Georgia and the Floridan aquifer near Savannah and Brunswick.

The Clayton aquifer near Albany is heavily used for municipal supply and irrigation. It is a relatively small aquifer with a small recharge area, and pumping has produced significant water level declines, particularly near major pumping centers.

Near Savannah and Brunswick, ground water withdrawals from the Floridan aquifer for municipal and industrial uses have resulted in large cones of depression. Declining water levels in these areas have initiated concern over lateral encroachment of seawater in the Savannah area and upconing of salty water from deeper zones near Brunswick (Figure 13). However, from 1980 to 1989, chloride concentrations have remained relatively stable. Increased pumping in these areas could result in further encroachment of salt water into the aquifer.

These situations and other more localized problems are constantly being monitored by the USGS and the Georgia Department of Natural Resources. The state then uses this information in managing its ground water resources.

GROUND WATER QUALITY

Georgia's ground water is of good quality in most areas and is suitable for most uses. Concentrations of impurities in ground water generally do not exceed EPA's maximum contaminant levels for drinking water. There is no

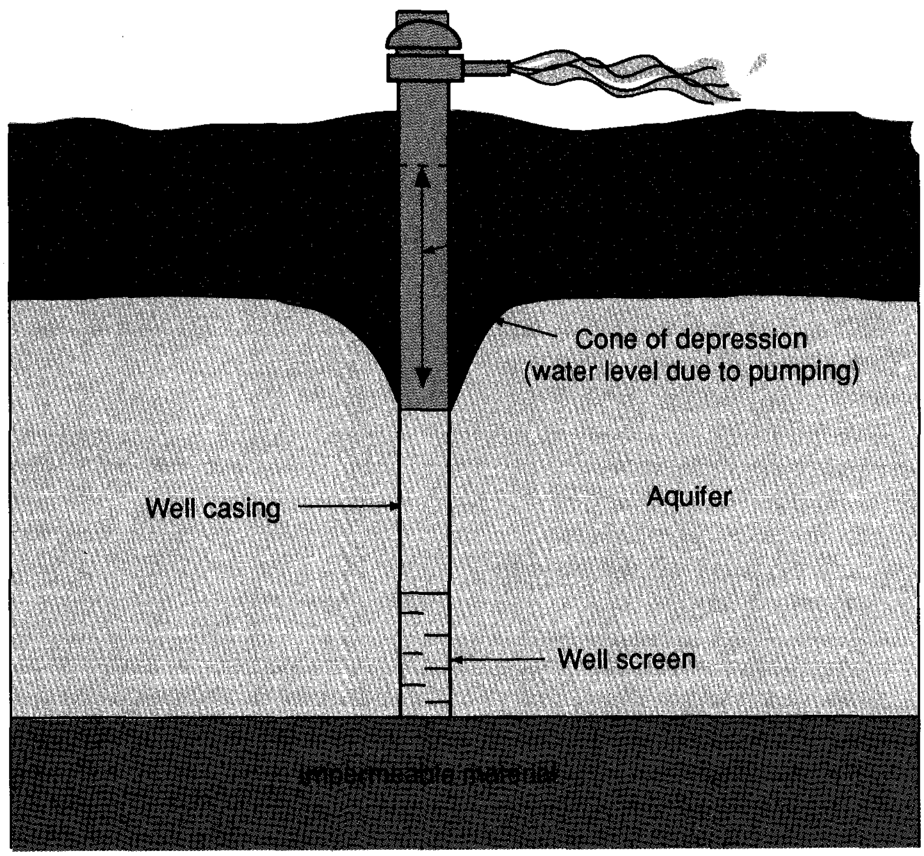

Figure 12. Cone of Depression Caused by Pumping

evidence of any significant deterioration of public drinking water supplies. Where human-related contamination has been detected, the effect has generally been local and has not caused widespread contamination of any of the aquifer systems. At present, salt water encroachment near the coast is probably the most significant threat to ground water quality in the state.

All ground waters in Georgia contain naturally occurring minerals in varying concentrations. It is not unusual for ground water to contain some minerals in high enough concentrations to cause problems with staining of plumbing fixtures and laundry, scale formation or objectionable tastes and odors.

Ground water throughout the state contains some iron and manganese, both of which cause stains and bitter taste at high concentrations. Hard water is fairly common, particularly from the limestone and dolostone aquifers of the Coastal Plain, Valley and Ridge and Appalachian Plateau provinces. Water from these aquifers typically contains higher levels of calcium and/or magnesium and generally have pH levels of 7.5 or higher.

Waters from the Crystalline Rock, Cretaceous and Water Table aquifer systems often have acidic water (pH below 7.0) due to the presence of dissolved carbon dioxide. These waters can be corrosive and may attack the metal components of household plumbing systems.

North of Valdosta, direct recharge of the Floridan aquifer by the Withlacoochee River has introduced significant levels of color and organic matter that, when combined with aquifer water, have produced hydrogen sulfide. Similar problems have been reported in other parts of Southwest Georgia where surface water may enter sinkholes and directly enter the aquifer. A few wells in Wheeler, Montgomery, Tift and Berrien Counties have been found to contain natural radioactivity which exceeded Georgia's drinking water standard.

As has been noted, declining water levels along the coast, particularly around Savannah and Brunswick, have led to quality problems, with elevated chloride levels detected in some wells due to some salt water encroachment into the aquifer (Figure 13). However, chloride levels did not significantly increase between 1980 and 1989.

Other water quality problems have been detected by various state agencies, but these have been relatively isolated and limited to small areas.

GROUND WATER PROTECTION

Protecting ground water from the effects of man's activities should be a major priority in order to preserve this valuable resource for future generations. Ground water, as a rule, moves very slowly. Once contaminated, an aquifer is very difficult (if not impossible) to clean up. It may take decades or even generations for nature to cleanse a contaminated aquifer.

Some potential sources of ground water contamination include:

- Septic tanks.
- Solid waste landfills.
- Leaking underground storage tanks.
- Municipal and industrial wastes.
- Animal wastes.
- Agricultural fertilizers and pesticides.

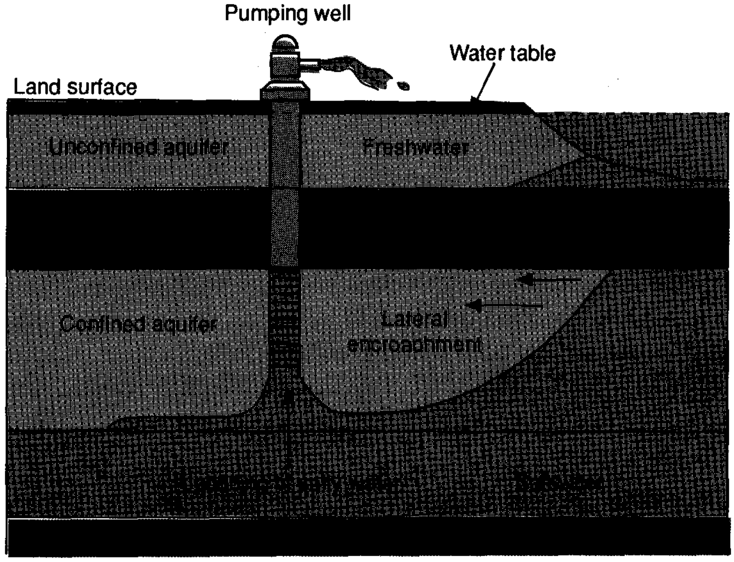

Figure 13. Two Aspects of Saltwater Encroachment

Any of these contamination sources can pollute ground water if not managed properly, but all are of special concern in those areas identified as major ground water recharge areas. In the future, these ground water recharge areas may warrant special protection in order to preserve the quality of Georgia's ground water.

Besides man's ability to create pollutants, his activities may also create situations which make contamination of ground water more likely. For instance, overpumping from wells in coastal areas may cause salt water encroachment. Overpumping may also cause sinkholes to form in some areas. These sinkholes may breach the confining layer above an aquifer and allow contaminants from the surface to enter the aquifer.

Wells, if not properly constructed, may allow water from the surface to carry contaminants into the aquifer, or they may allow water from a shallow, contaminated aquifer to mix with water in a deeper aquifer. Old, abandoned wells and agricultural drainage wells, if not filled, may also serve as conduits to allow surface contaminants to enter the aquifer. A particular risk is incurred when these old wells are used as disposal sites for household garbage, pesticide containers or other waste products.

Fortunately, at present there have not been any cases of widespread manmade contamination of any of the major aquifers in Georgia. Where contamination has been detected in wells it has typically been attributed to sources near the well site, often immediately adjacent to the well.

Georgia's ground water is one of her most precious resources and every effort should be made to preserve the integrity of this important commodity for now as well as future generation.

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