Section 1

The Active River

Terms to Learn

erosion
water cycle
tributary
drainage basin
divide
channel
load

What You'll Do

- Illustrate the water cycle.
- Describe a drainage basin.
- Explain the major factors that affect the rate of stream erosion.
- Identify the stages of river development.

You are probably familiar with the Grand Canyon, shown in **Figure 1.** But did you know that about 6 million years ago, the area now known as the Grand Canyon was nearly as flat as a pancake? The Colorado River cut down into the rock and formed the Grand Canyon over millions of years by washing billions of tons of soil and rock from its riverbed. This process is a type of *erosion*. **Erosion** is the removal and transport of surface material, such as rock and soil. Rivers are not the only agents of erosion. Wind, rain, ice, and snow can cause erosion as well.

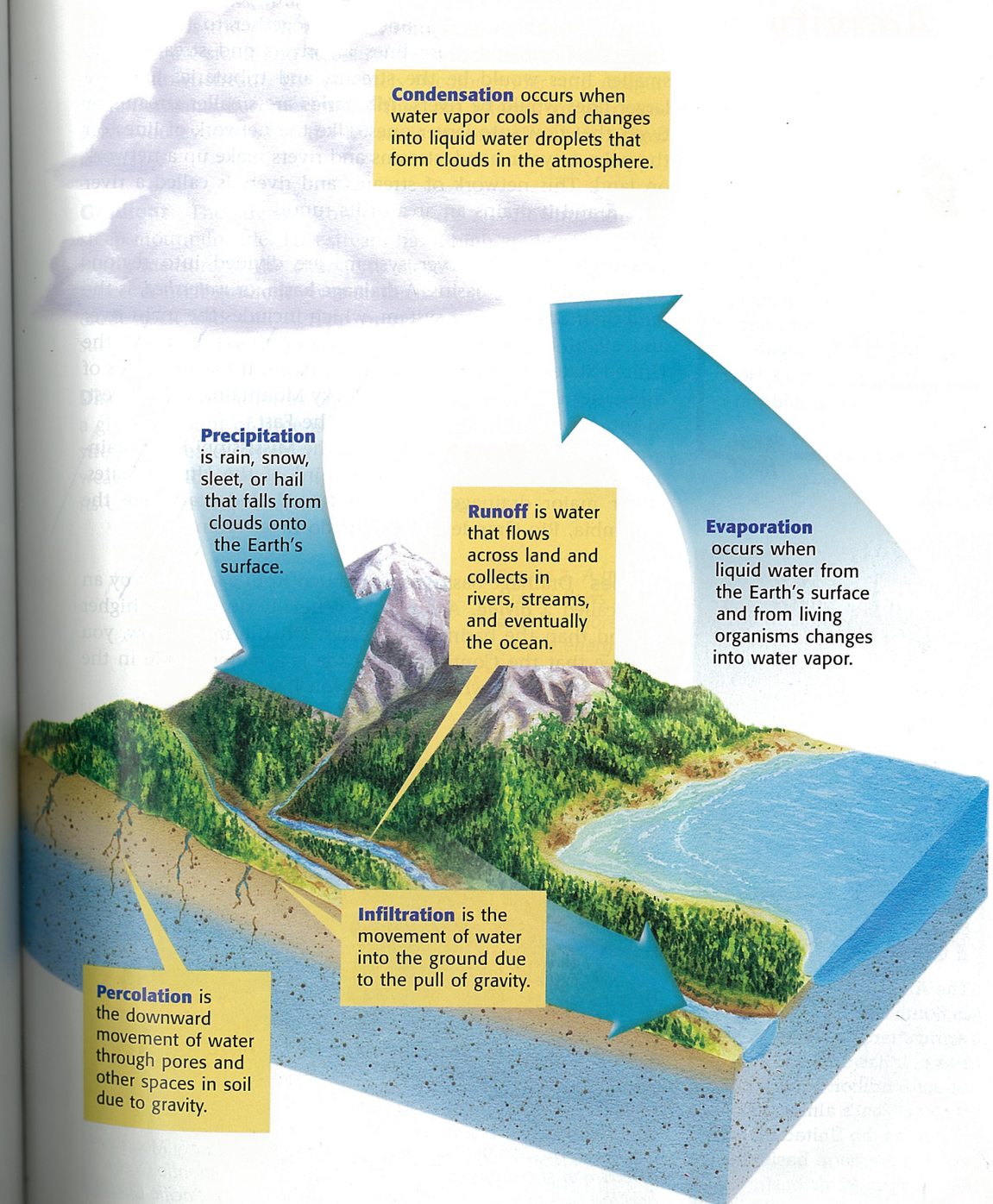
Because of erosion caused by water, the Grand Canyon is now about 1.6 km deep and 446 km long. In this section, you will learn about stream development, river systems, and the different factors that affect the rate of stream erosion.

Figure 1 *The Grand Canyon is located in northwestern Arizona. It formed over millions of years as running water eroded rock and soil. In some places the canyon is 29 km wide.*

Water, Water Everywhere

Have you ever wondered how rivers keep flowing and where rivers get their water? The water cycle answers these and other questions. The **water cycle,** shown on the next page, is the continuous movement of water from water sources, such as lakes or oceans, into the air, onto land, into the ground, and back to the water sources.

The Water Cycle



Section 3

Water Underground

Terms to Learn

ground water
water table
aquifer
porosity
permeability
recharge zone
artesian spring

What You'll Do

- Identify and describe the location of a water table.
- Describe the characteristics of an aquifer.
- Explain how caves and sinkholes form as a result of erosion and deposition.

Although we can see surface water in streams and lakes, there is a lot of water flowing underground that we cannot see. The water located within the rocks below the Earth's surface is called **ground water.** Ground water not only is an important resource but also plays an important role in erosion and deposition.

Location of Ground Water

Surface water seeps underground into the soil and rock. Earth scientists divide this underground area into two zones. The upper zone, called the *zone of aeration,* usually is not completely filled with water. The rock and soil that make up this zone are filled with water only immediately after a rain. Farther down, the water accumulates in an area called the *zone of saturation.* Here the spaces between the rock particles are filled with water.

These two zones meet at an underground boundary known as the **water table,** as shown in **Figure 14.** The water table rises during wet seasons and drops during dry seasons. In wet regions the water table can be just beneath the soil's surface or at the surface. But in deserts the water table may be hundreds of meters underground.

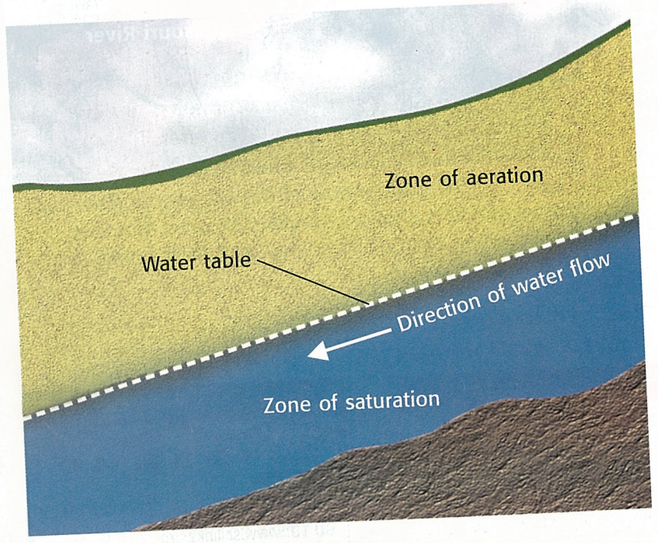


Figure 14 *The water table is the upper surface of the zone of saturation.*

Aquifers

Some types of rock can hold large quantities of water, while other types can hold little or no water. A rock layer that stores and allows the flow of ground water is called an **aquifer.**

To qualify as an aquifer, a rock layer must be *porous,* or contain open spaces. A rock's **porosity** is the amount of open space between individual rock particles. The rock layer must also allow water to pass freely through it, from one pore to another. If the pores are connected, ground water can flow through the rock layer. A rock's ability to let water pass through it is called **permeability.** A rock that tends to stop the flow of water is impermeable.

Aquifer Geology and Geography The best aquifers are usually formed of sandstone, limestone, or layers of sand and gravel. Some aquifers cover large underground areas and are an important source of water for cities and agriculture. The map in **Figure 15** shows the location of aquifers in the United States.

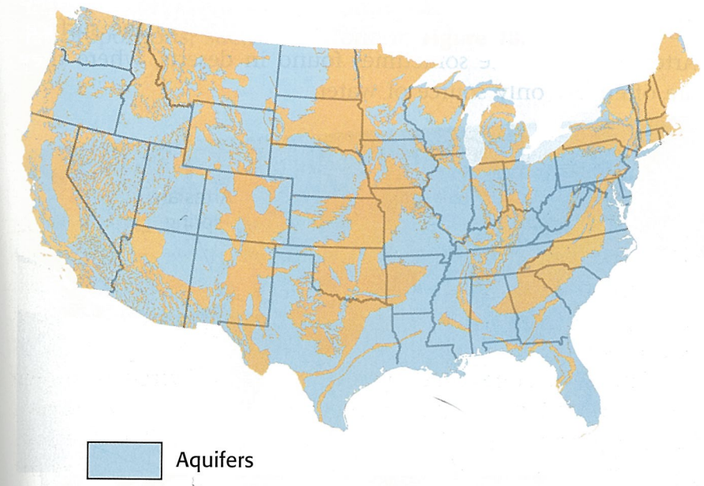


Figure 15 Aquifers in the Continental United States

Recharge Zones Like rivers, aquifers are dependent on the water cycle to maintain a constant flow of water. The ground surface where water enters an aquifer is called the **recharge zone.** The size of the recharge zone varies depending on how permeable rock is at the surface. In an area that contains a permeable rock layer, the water can seep down into the aquifer. In areas where the aquifer is confined on top by an impermeable rock layer, the recharge zone is restricted to areas where there is a permeable rock layer.

Springs and Wells

Ground-water movement is determined by the slope of the water table. Just like surface water, ground water tends to move downslope, toward lower elevations. If the water table reaches the Earth's surface, water will flow out from the ground, forming a *spring.* Springs are an important source of drinking water. Lakes form in low areas, where the water table is higher than the Earth's surface.

Quick Lab

Degree of Permeability

1. Obtain five **plastic-foam cups.**
2. Fill one cup halfway with **soil,** such as garden soil. Pack the soil.
3. Fill a second cup halfway with **sand.** Pack the sand.
4. Poke 5 to 7 holes in the bottom of each cup with a sharpened **pencil.**
5. Fill a third cup with **water.** Hold one of the remaining empty cups under the cup filled with soil. Pour the water into the top cup.
6. Allow the cup to drain for 45 seconds, and then put the cup aside (even if it is still draining). Put the cup filled with water aside.
7. Repeat steps 5 and 6 with the cup of sand. Compare the volumes of the two cups of water. The cup that allowed the most water to pass holds the more permeable sediment.

TRY at HOME

A mud pie the size of a house—where would you see something like that? Turn to page 294 to find out.

Artesian Springs A sloping layer of permeable rock sandwiched between two layers of impermeable rock is called an *artesian formation*. The permeable rock is an aquifer, and the top layer of the impermeable rock is called a *cap rock*, as shown in **Figure 16.** Artesian formations are the source of water for **artesian springs.** Artesian springs are springs that form where cracks occur naturally in the cap rock and the pressurized water in the aquifer flows through the cracks to the surface. Artesian springs are sometimes found in deserts, where they are often the only source of water.

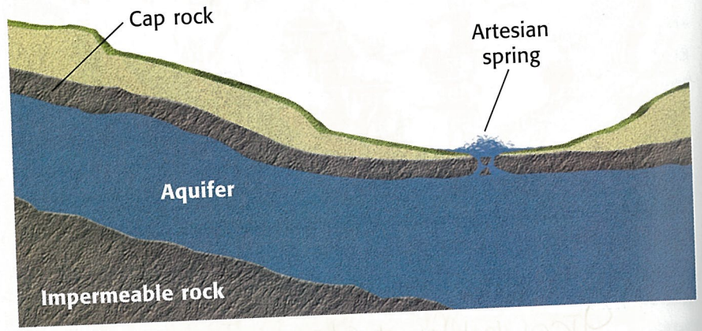


Figure 16 *Artesian springs form when water from an aquifer flows through cracks in the cap rock of an artesian formation.*

Wells A *well* is a human-made hole that is deeper than the level of the water table; therefore, wells fill with ground water, as shown in **Figure 17.** If a well is not deep enough, it will dry up when the water table falls below the bottom of the well. Also, if too many wells in an area remove ground water too rapidly, the water table will drop and all the wells will run dry.

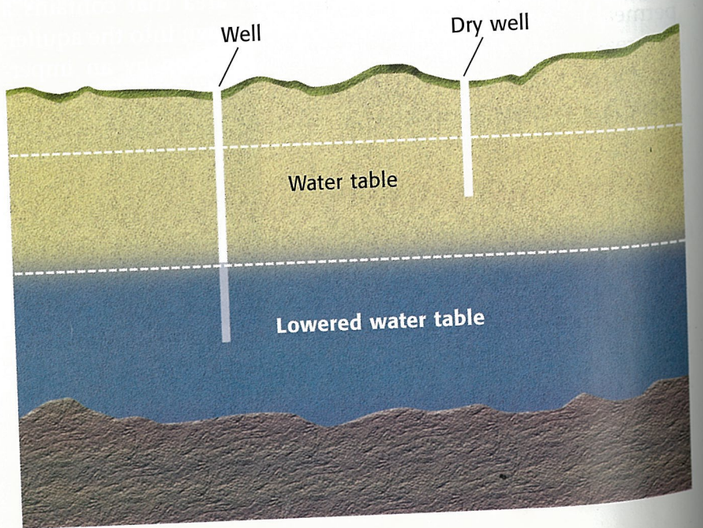


Figure 17 *A good well is drilled deep enough so that when the water table drops, the well still contains water.*

Self-Check

Why is it important that there is a layer of impermeable rock in an artesian formation? *(See page 726 to check your answer.)*

Underground Erosion and Deposition

Unlike a river, which erodes its banks when water moves over rock and soil, ground water erodes certain types of rock by dissolving the rock. Most of the world's caves formed over thousands of years as ground water dissolved limestone. Limestone, which is made of calcium carbonate, dissolves easily in water. As a result, caves form. Some caves reach spectacular proportions, such as the one in **Figure 18.**

Figure 18 *At Carlsbad Caverns, in New Mexico, underground passages and enormous "rooms" have been eroded below the surface of the Earth.*

Cave Formations While caves are formed by erosion, they also show signs of deposition. Water that drips from a crack in a cave's ceiling leaves behind deposits of calcium carbonate. These deposits of calcium carbonate are a type of limestone called *dripstone*. Water and dissolved limestone can drip downward into sharp, icicle-shaped dripstone features known as a stalactites. At the same time, water drops that fall to the cave's floor add to cone-shaped dripstone features known as stalagmites. If water drips long enough, the stalactites and stalagmites can reach each other and join, forming a dripstone column.

Environment CONNECTION

Most bat species live in caves. These night-flying mammals navigate by sound and can reach speeds of 95 km/h. Today scientists know that bats play an extremely important role in the environment. Bats are great consumers of insects, and many bat species pollinate plants and distribute seeds.

Sinkholes When the water table is lower than the level of a cave, the cave is no longer supported by the water underneath. The roof of the cave can then collapse, leaving a circular depression called a *sinkhole*. Surface streams can "disappear" into sinkholes and then flow through underground caves. Sinkholes often form lakes in areas where the water table is high. Central Florida is covered with hundreds of round sinkhole lakes. **Figure 19** shows how underground caves can affect a landscape.

Figure 19 *This city block shows the effects of a sinkhole in Winter Park, Florida.*

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REVIEW

1. What is the water table?
2. What is an aquifer?
3. What are some of the features formed by underground erosion and deposition?
4. **Analyzing Relationships** What is the relationship between the zone of aeration, the zone of saturation, and the water table?

Section 4

Using Water Wisely

Terms to Learn

point-source pollution
nonpoint-source pollution
sewage treatment plant
septic tank

What You'll Do

- Describe the stages of treatment for water at a sewage treatment plant.
- Compare a septic system with a sewage treatment plant.
- Explain how ground water can be both a renewable and a nonrenewable resource.

All living things need water to survive. But there is a limited amount of fresh water available on Earth. Only 3 percent of Earth's water is drinkable. And of the 3 percent that is drinkable, 75 percent is frozen in the polar icecaps. That's more than 100 times the volume of water found in the Earth's lakes and streams! This frozen water is not readily available for our use. Therefore, it is important that we use our water resources wisely.

Water Pollution

Surface water, such as rivers and lakes, and ground water are often polluted by waste from cities, factories, and farms. One type of pollution is called **point-source pollution** because it comes from one particular point, such as a sewer pipe or a factory drain. Fortunately, laws prohibit much of this type of pollution.

There is growing concern, however, about another type of pollution, called **nonpoint-source pollution.** This type of pollution, as shown in **Figure 20,** is much more difficult to control because it does not come from a single source. Most nonpoint-source pollution contaminates rivers and lakes by runoff. The main sources of nonpoint-source pollution are street gutters, fertilizers, eroded soils and silt from farming and logging, drainage from mines, and salts from irrigation.

As you know, ground water is an important source of fresh water. In fact, more than half of all household water in the United States comes from ground water. Farms use ground water for irrigation. Because ground water is supplied by water from the Earth's surface, ground water can become contaminated when surface water is polluted. And once polluted, ground water is very difficult to clean up.

Figure 20 *The runoff from this irrigation system could collect pesticides and other pollutants. The result would be nonpoint-source pollution.*