6.3 Water Beneath the Surface

Reading Focus

Key Concepts

- Where is groundwater and how does it move?
- How do springs form?
- What are some environmental threats to groundwater supplies?
- How and where do most caverns form?
- What landforms are common in an area of karst topography?

Vocabulary

- zone of saturation
- groundwater
- water table
- porosity
- permeability
- aquifer
- spring
- geyser
- well
- artesian well
- cavern
- travertine
- karst topography
- sinkhole

Reading Strategy

Previewing Copy the table below. Before you read the section, rewrite the green topic headings as how, why, and what questions. As you read, write an answer to each question.

Question	Answer
How does water move underground?	

The ground beneath your feet isn't as solid as you might think. It includes countless tiny pore spaces between grains of soil and sediment. It also contains narrow joints and fractures in bedrock. Together these spaces add up to an immense volume of tiny openings where water collects underground and moves.

Underground water in wells and springs provides water for cities, crops, livestock, and industry. In the United States, it is the drinking water for more than 50 percent of the population. It also provides 40 percent of the irrigation water and more than 25 percent of industry's needs.

Distribution and Movement of Water Underground

When rain falls, some of the water runs off, some evaporates, and the rest soaks into the ground to become subsurface water. The amount of water that ends up underground in an area depends on the steepness of slopes, the nature of surface materials, the intensity of rainfall, and the type and amount of vegetation.

Distribution Some of the water soaks into the ground, but it does not travel far. Molecular attraction holds it in place as a surface film on soil particles. This near-surface zone is called the belt of soil moisture. Roots, voids left by decayed roots, and animal and worm burrows crisscross this zone. These features help rainwater seep into soil.

Section 6.3

1 FOCUS

Section Objectives

6.11 **Describe** the location and movement of groundwater.
6.12 **Describe** the formation of a spring.
6.13 **Explain** environmental threats to water supplies.
6.14 **Describe** the formation of caverns.
6.15 **Describe** landforms in karst areas.

Reading Focus

Build Vocabulary L2

Paraphrase Students may find terms such as *porosity*, *permeability*, *aquifer*, and *artesian* unfamiliar. Encourage students to create their own definitions for these terms to help them remember their meaning.

Reading Strategy L2

Sample answers

Question	Answer
How does water move underground?	by twisting and turning through interconnected small openings
How does a spring form?	when the water table intersects the ground surface
What is a well?	a hole bored into the zone of saturation
What are some environmental problems associated with groundwater?	overuse and contamination
What kind of terrain do Karst areas have?	irregular terrain with many sinkholes

2 INSTRUCT

Distribution and Movement of Water Underground

Build Science Skills L2

Inferring After students read p. 171, ask: **On sloping land, which would likely result in more groundwater: a quick thunderstorm or the same volume of water from a longer, gentle rain? Why?** *(the gentle rain because the water would have more time to soak into the ground rather than run off the land)* **Logical**

Teacher Demo

Water Table **L2**

Purpose Students visually see the boundary between the zone of saturation and the zone of aeration.

Materials large clear plastic cup; clean, dry sand; water

Procedure Fill the cup about two-thirds full with the clean sand. Slowly pour the water on top of the sand and allow it to filter down to the bottom. Add enough water so that the cup is approximately half full of water.

Expected Outcome Students should be able to clearly see the separation between the sand that contains water and the sand that does not have water in its pore space. Identify this boundary for them as the water table. Students can then infer what would happen to the water table in times of drought or excessive rainfall.

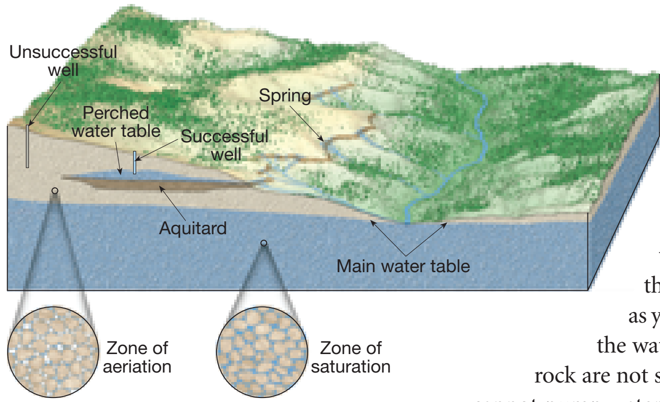


Figure 14 This diagram shows the relative positions of many features associated with subsurface water. **Applying Concepts** ***What is the source of the spring in the center of the illustration?***

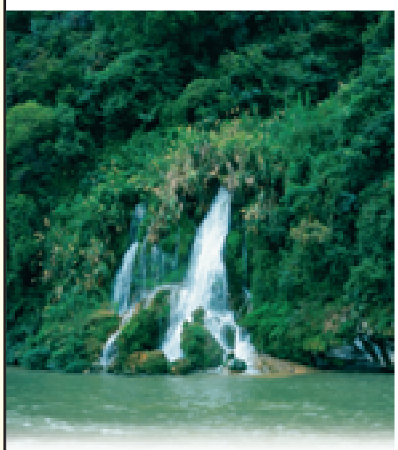
Much of the water in soil seeps downward until it reaches the zone of saturation. The zone of saturation is the area where water fills all of the open spaces in sediment and rock. Groundwater is the water within this zone. The upper limit of the zone of saturation is the **water table,** as you can see in Figure 14. The area above the water table where the soil, sediment, and rock are not saturated is the zone of aeration. Wells cannot pump water from this zone. The water clings too tightly to the rocks and soil. Only below the water table—where water pressure is great enough to allow water to enter wells—can water be pumped.

Movement The flow and storage of groundwater vary depending on the subsurface material. The amount of groundwater that can be stored depends on porosity. **Porosity** is the percentage of the total volume of rock or sediment that consists of pore spaces. Spaces between sedimentary particles form pore spaces. Joints, faults, and cavities also are formed by the dissolving of soluble rocks such as limestone.

Rock or sediment may be very porous and still block water's movement. The **permeability** of a material is its ability to release a fluid. **Groundwater moves by twisting and turning through interconnected small openings. The groundwater moves more slowly when the pore spaces are smaller.** If the spaces between particles are too small, water cannot move at all. For example, clay has high porosity. But clay is impermeable because its pore spaces are so small that water can't move through them.

Impermeable layers that get in the way or prevent water movement are aquitards. Larger particles, such as sand, have larger pore spaces. Water moves through them easily. Permeable rock layers or sediments that transmit groundwater freely are **aquifers.** Aquifers are important because they are the source of well water.

Figure 15 A spring flows from a valley wall into a stream.



Springs

A spring forms whenever the water table intersects the ground surface. A **spring** is a flow of groundwater that emerges naturally at the ground surface, as shown in Figure 15. Springs form when an aquitard blocks downward movement of groundwater and forces it to move laterally.

Customize for English Language Learners

Have students work in pairs to think of ways that groundwater can be conserved. Examples include shutting off the faucet when brushing your teeth, taking shorter showers, and running the dishwasher only when full. Strengthen discussion skills by having students share their examples with the class.

Hot Springs A hot spring is 6°C to 9°C warmer than the mean annual air temperature where the spring occurs. There are more than 1000 hot springs in the United States

Temperatures in deep mines and oil wells usually rise with an increase in depth at an average of 2°C per 100 meters. So when groundwater circulates at great depths, it becomes heated. If it rises to the surface, the water may emerge as a hot spring. This process heats many hot springs in the eastern United States. However, more than 95 percent of the hot springs in the United States are in the West. The source of heat for most of these hot springs is cooling igneous rock. In some places, hot acidic groundwater mixes with minerals from adjacent rock to form thick, bubbling mineral springs called mudpots.

Geysers A **geyser** is an intermittent hot spring or fountain in which a column of water shoots up with great force at various intervals. Geysers often shoot up columns of water 30 to 60 meters. After the jet of water stops, a column of steam rushes out—usually with a thundering roar. Perhaps the most famous geyser in the world is Old Faithful in Yellowstone National Park. It erupts about once each hour.

Geysers occur where extensive underground chambers exist within hot igneous rocks. Follow the formation of a geyser in Figure 16. As relatively cool groundwater enters the chambers, the surrounding rock heats it. The weight of the overlying water creates great pressure at the bottom of the chamber. This pressure prevents the water from boiling at the normal surface temperature of 100°C. However, the heat makes the water expand, and it forces some of the water out at the surface. This loss of water reduces the pressure in the chamber. The boiling point drops. Some of the water deep within the chamber then turns to steam and makes the geyser erupt. Following the eruption, cool groundwater again seeps into the chamber. Then the cycle begins again.

Reading Checkpoint *What is a geyser?*

Geyser Eruption Cycle

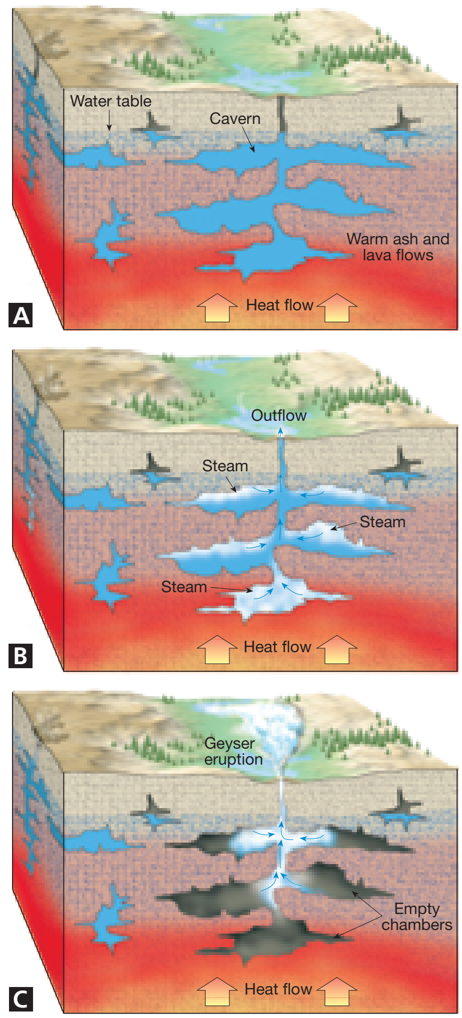


Figure 16 **A** Groundwater enters underground caverns and fractures in hot igneous rock where it is heated to near its boiling point. **B** Heating causes the water to expand, with some being forced out at the surface. The loss of water reduces the pressure on the remaining water, thus reducing its boiling temperature. Some of the water flashes to steam. **C** The rapidly expanding steam forces the hot water out of the chambers to produce a geyser. The empty chambers fill again, and the cycle starts anew.

Springs

Build Reading Literacy L1

Refer to **p. 502D** in **Chapter 18**, which provides the guidelines for visualizing.

Visualize Have students keep their books closed. Tell them to listen carefully while you read the section on geysers. Ask students to describe how they visualize what is occurring under ground at a geyser. Invite students to work in pairs to discuss how they visualized the process.
Visual

Use Visuals L1

Figure 16 Have the students study the diagram showing the geyser eruption cycle. Ask: **What heats the groundwater in the underground caverns?** *(hot igneous rock)* **What happens to the water when it is heated?** *(The water expands. Some water is forced to the surface; some turns to steam.)* **How is a geyser produced?** *(Expanding steam forces the hot water out of the chambers.)*
Visual, Verbal

Facts and Figures

Yellowstone National Park is home to approximately two thirds of the geysers on Earth. Included in these is one of the most famous geysers, Old Faithful. Despite its name, Old Faithful can be rather unpredictable. It usually erupts every 76 minutes but it can range from 35 minutes to 2 hours. The time between eruptions depends upon the length of the previous eruption.

Old Faithful can shoot up water to 60 m. This is not the largest geyser, however. Steamboat Geyser, also located in Yellowstone, is the largest geyser in the world. It can shoot water 90 m into the air.

Answer to . . .

Figure 14 *The source of the spring is the higher water table within the zone of aeration.*

Reading Checkpoint *A geyser is an intermittent hot spring or fountain in which a column of water shoots up at various intervals.*

Wells

Use Visuals L1

Figure 17 Ask students to compare the wells in both diagrams in Figure 17. Ask: **As you can see in the diagrams, two of the wells went dry as a result of heavy pumping and one well stayed productive. What rule of well digging can you deduce from this example?** *(When digging a well, be sure to sink it well below the average water table.)* **Visual, Logical**

Use Community Resources L2

Invite a hydrologist or water conservationist to speak to the class on ways to conserve the use of groundwater. The Soil and Water Conservation Society can provide a list of local chapters and resources. To prepare for the presentation, have students research current positions on water conservation. They can develop a list of questions to ask the speaker. **Interpersonal, Verbal**

Go Online NSTA SciLinks

Download a worksheet on aquifers for students to complete, and find additional teacher support from NSTA SciLinks.

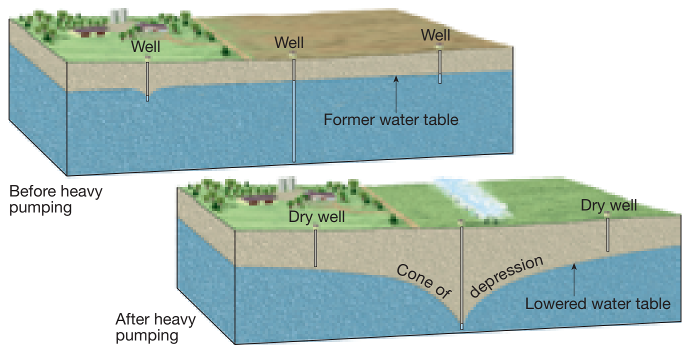


Figure 17 A cone of depression in the water table often forms around a pumping well. If heavy pumping lowers the water table, some wells may be left dry.

Q & A

Q *I have heard people say that supplies of groundwater can be located using a forked stick. Can this actually be done?*

A What you describe is a practice called "water dowsing." In the classic method, a person holding a forked stick walks back and forth over an area. When water is detected, the bottom of the "Y" is supposed to be attracted downward.

Geologists and engineers are extremely doubtful, to say the least. Case histories and demonstrations may seem convincing, but when dowsing is exposed to scientific scrutiny, it fails. Most "successful" examples of water dowsing occur in places where water would be hard to miss. In a region of adequate rainfall and favorable geology, it is difficult to drill and *not* find water!

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For: Links on aquifers
Visit: www.SciLinks.org
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Wells

A **well** is a hole bored into the zone of saturation. Irrigation for agriculture is by far the single greatest use of well water in the United States—more than 65 percent of groundwater used annually. Industrial uses of groundwater rank a distant second, followed by the amount used by homes.

The level of the water table may change considerably during a year. The level can drop during the dry season and rise following periods of rain. To ensure a continuous water supply, a well must penetrate far below the water table. The water table around the well drops whenever a substantial amount of water is withdrawn from a well. This effect is called drawdown, and it decreases with an increase in distance from the well. The result of a drawdown is a cone of depression in the water table. This cone of depression is shown in Figure 17. For most small domestic wells, the cone of depression is tiny. However, when wells are used for irrigation or industry, a very wide and steep cone of depression can result.

Water must be pumped out of most wells. However, water rises on its own in some wells, sometimes overflowing the surface. An **artesian well** is any formation in which groundwater rises on its own under pressure. For such a situation to occur, two conditions must exist. First, water must be in an aquifer that is tilted so that one end is exposed at the surface, where it can receive water. Second, there must be aquitards both above and below the aquifer to stop the water from escaping. The pressure created by the weight of the water above forces the water to rise when a well taps the aquifer.

Reading Checkpoint ***How does an artesian well differ from most wells?***

Environmental Problems Associated with Groundwater

As with many valuable natural resources, groundwater is being threatened at an increasing rate. **Overuse and contamination threatens groundwater supplies in some areas.**

Treating Groundwater as a Nonrenewable Resource

Groundwater seems like an endlessly renewable resource. However, supplies are finite. In some regions, the amount of water available to recharge an aquifer is much less than the amount being withdrawn.

The High Plains provides one example of severe groundwater depletion. In some parts of the region, intense irrigation has gone on for a long time. Even if pumping were to stop now, it could take thousands of years for the groundwater to be fully replenished.

The ground may sink when water is pumped from wells faster than natural processes can replace it. As water is withdrawn, the ground subsides because the weight of the overburden packs relatively loose sediment grains more tightly together.

This type of subsidence is extreme in the San Joaquin Valley of California, as shown in Figure 18. Land subsidence due to groundwater withdrawal for irrigation began there in the mid-1920s. It exceeded eight meters by 1970. During a drought in 1976 and 1977, heavy groundwater pumping led the ground to sink even more. Land subsidence affected more than 13,400 square kilometers of irrigable land—one half the entire valley.

Groundwater Contamination The pollution of groundwater is a serious matter, particularly in areas where aquifers provide much of the water supply. Common sources of groundwater pollution are sewage from septic tanks, farm wastes, and inadequate or broken sewers.

If sewage water that is contaminated with bacteria enters the groundwater system, it may become purified through natural processes. The harmful bacteria can be mechanically filtered by the sediment through which the water passes, destroyed by chemical oxidation, and/or assimilated by other organisms. For purification to occur, however, the aquifer must be of the correct composition.

For example, extremely permeable aquifers have such large openings that contaminated groundwater may travel long distances without being cleansed. In this case, the water flows too quickly and is not in contact with the surrounding material long enough for purification to occur. This is the problem at Well 1 in Figure 19A.

Reading Checkpoint *What are some common sources of groundwater pollution?*

Figure 18 The marks on the utility pole indicate the level of the surrounding land in years past. Between 1925 and 1975 this part of the San Joaquin Valley sank almost 9 meters because of the withdrawal of groundwater and the resulting compaction of sediments.

Environmental Problems Associated with Groundwater

Integrate Health **L2**

Groundwater Contamination Arsenic contamination of groundwater is a common problem. Arsenic is a known carcinogen. It was once an ingredient in pesticides used on apple orchards. Many communities now are testing old apple orchards and finding that there are significant amounts of arsenic in their soil, which seeps into the groundwater. The Environmental Protection Agency (EPA) recently revised the standard for safe levels of arsenic in drinking water. Prior to January 22, 2001, the acceptable level was 50 parts per billion. Now public water systems must comply with the new acceptable level of 10 parts per billion by January 23, 2006. This will serve as a further level of protection of our groundwater resources. Ask students to research other types of groundwater contamination and steps that have been taken to prevent or eliminate it. Pairs of students can present short reports to the class.
Interpersonal, Verbal

Facts and Figures

Drilling a well can be a daunting task. Not only do you have to locate the source of water on your property and determine how much water is available, you have to estimate the amount of water that you, your family, and possibly your business will need. The following are estimates that can be used to determine the peak demand that will be placed on a well.

For a single family home, figure on 190 to 285 L of water a day per person. Maintenance of an average lawn and garden requires 190 to 3800 L per day. Farmers are faced with a more challenging estimate. For example, dairy cattle require 133 L per day per animal for drinking water. A goat requires 7.6 L per day; each pig requires 15.2 L, a horse 45.6 L per day. A flock of 100 chickens requires 19 to 38 L of drinking water per day and a flock of 100 turkeys needs 38 to 68 L per day.

Answer to . . .

Reading Checkpoint *In an artesian well, water rises on its own, instead of being pumped.*

Reading Checkpoint *Common sources of groundwater pollution are sewage from septic tanks, farm wastes, and inadequate or broken sewers.*

Build Science Skills

L2

Applying Concepts After reading the section on Groundwater Contamination, present the following problem to the class. **Imagine you are an environmental scientist and have been called in to solve a groundwater contamination problem. Some people have noticed that their well water has a funny smell and taste and they think that the contamination is coming from a farmer who lives upstream. The farmer insists that he is not contaminating the water supply and suggests instead that a large chemical factory farther upstream is to blame. How can you determine where the contamination is originating?** *(Answers will vary but students may recognize a few places to start. For example, they should suggest determining the type of contamination. Is the water supply being contaminated by fertilizer, for example? Identifying the contaminant will help in pinpointing the source. They also may recognize that by testing the groundwater upstream and downstream from the farmer, they may be able to identify if the contamination is occurring upstream or downstream of the farm.)* **Logical, Intrapersonal**

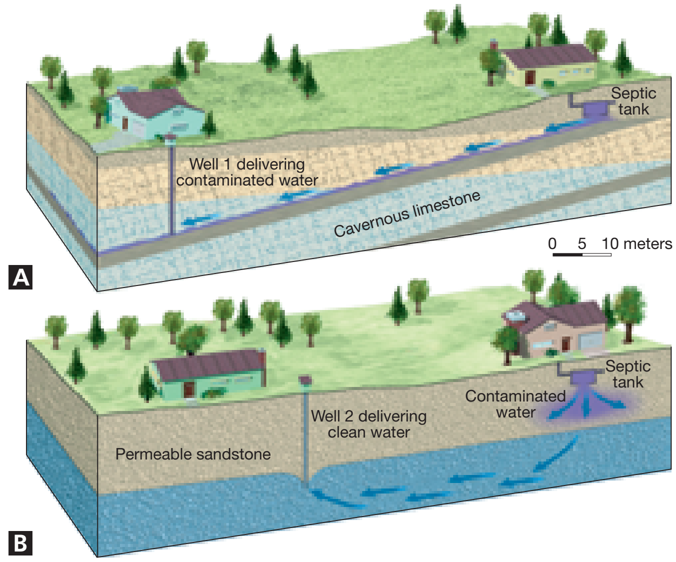

Figure 19 A Although the contaminated water has traveled more than 100 meters before reaching Well 1, the water moves too quickly through the cavernous limestone to be purified. **B** As the discharge from the septic tank percolates through the permeable sandstone, it is purified in a short distance.

Figure 20 Agricultural chemicals sprayed on farm fields can seep into soil and contaminate underground water supplies.

Figure 21 If landfills leak, harmful waste buried in them can escape into groundwater.

However, when the aquifer is composed of sand or permeable sandstone, the water can sometimes be purified after traveling only a few dozen meters through it. The openings between sand grains are large enough to permit water movement, yet the movement of the water is slow enough to allow enough time for its purification. This is the case at Well 2 in Figure 19B.

Other sources and types of contamination also threaten supplies, as you can see in Figures 20 and 21. These include fertilizers that are spread across the land, pesticides, and highway salt. In addition, chemicals and industrial materials—some hazardous—may leak from pipelines, storage tanks, landfills, and holding ponds. As rainwater oozes through the refuse, it may dissolve contaminants. If this material reaches the water table, it will mix with and contaminate groundwater. In coastal areas, heavy use can deplete aquifers, causing underground saltwater to enter wells.

Once the source of the problem has been identified and eliminated, the most common practice is to abandon the water supply. Abandoning the water supply allows the pollutants to flush out gradually. It's the least costly and easiest solution, but the aquifer must stay unused for years. To speed up this process, engineers sometimes pump out and treat polluted water. The aquifer then recharges naturally, or the treated water is pumped back in. This process can be risky, because there is no way to be sure that treatment has removed all the pollution. Prevention remains the most effective solution to groundwater contamination.

Some substances in groundwater are natural. Ions of substances (from adjacent rock) such as calcium and iron make some water "hard." Hard water forms scum with soap instead of suds. It can also deposit residue that clogs pipes. But hard water is generally not a health risk.

Facts and Figures

The Environmental Protection Agency (EPA) recognizes that groundwater needs to be treated as a nonrenewable resource. They have strict regulations on public water supplies but have no control over private wells and water sources. They do, however, have some suggestions for homeowners with private wells to ensure that this vital resource remains protected. They advise homeowners to

- periodically inspect exposed portions of the well for settling or damaged well casings.
- create a slope in the area around the well to drain runoff away from the well.
- have the well tested each year for bacteria and nitrates and other possible contaminants.
- avoid using pesticides, herbicides, fuels, and other contaminants near the well.
- inspect septic systems regularly.
- refrain from disposing of hazardous material in septic systems or abandoned wells.

Caverns

Figure 22 The dissolving action of groundwater creates caverns. These dripstone features are in Three Fingers Cave in New Mexico.

The most spectacular results of groundwater's ability to erode rock are limestone caverns. Soluble rocks, especially limestone, underlie millions of square kilometers of Earth's surface. Limestone is nearly insoluble in pure water. But water containing small quantities of carbonic acid dissolves it easily. Most natural water contains the weak acid because rainwater dissolves carbon dioxide from the air and decaying plants. Therefore, when groundwater comes in contact with limestone, the carbonic acid reacts with calcite in the rocks. Calcium bicarbonate forms. As groundwater carries away calcium carbonate in solution, it slowly erodes rock. A **cavern** is a naturally formed underground chamber, such as the one you see in Figure 22. There are thousands of caverns in the United States. Most are fairly small, but some have spectacular dimensions. Carlsbad Caverns in southeastern New Mexico is a famous example. One chamber has an area equivalent to 14 football fields, and it is high enough to fit the U.S. Capitol building inside it.

Erosion forms most caverns at or below the water table in the zone of saturation. Here, acidic groundwater follows lines of weakness in the rock, such as joints and bedding planes. As time passes, the dissolving process slowly creates cavities and enlarges them into caverns. Material the groundwater dissolves eventually flows into streams and then the ocean.

The features that produce the greatest curiosity for most cavern visitors are depositional stone formations. These formations give some caverns a wonderland appearance. They form from seemingly endless dripping of water over great spans of time. The calcium carbonate that is left behind produces the limestone we call **travertine.** These cave deposits are commonly called dripstone.

Although the formation of caverns takes place in the zone of saturation, the deposition of dripstone features is not possible until the caverns are above the water table in the zone of aeration. The formation of caverns in the zone of aeration commonly occurs as nearby streams cut their valleys deeper. As the elevation of the stream drops, the water table also lowers, leaving the caverns high and largely dry.

Caverns

Use Visuals L1

Figure 22 Challenge students to imagine themselves as the spelunker(cave explorer) in the photograph. Ask: **What temperature and overall climate would be in the Three Fingers Cave?** *(Climate would be cool and very damp.)*
Visual

Build Reading Literacy L2

Refer to **p. 474D** in **Chapter 17,** which provides guidelines for the monitor your understanding strategy.

Monitor Your Understanding Have students read the section on caverns. When students reach the end of that section, have them write the main ideas of that section. Have students ask themselves, "Did I have any trouble reading this section? If so, why?" Invite students to come up with their own strategies to improve their understanding of cavern formation and features. Have students use their own strategies as they continue reading.
Intrapersonal, Verbal

Customize for Inclusion Students

Hearing Impaired Reinforce the lesson's content by providing a variety of visual examples. Be sure to spend time on all the visual examples provided in the text. In addition, you may wish to provide a visual display of how limestone can be dissolved in a dilute acid. Place several drops of hydrochloric acid on a sample of limestone. Students will observe a bubbling action. Challenge students to imagine how this action could, over a long period of time, create an underground cavern.

Section 6.3 (continued)

Karst Topography

Build Science Skills

L2

Inferring Describe for students the characteristics of "hard" water. Water containing a lot of dissolved minerals can impact the performance of soap and leave a residue behind on fixtures and shower curtains. Ask students if they think the water may be hard in a karst region, and if so, what mineral is most likely dissolved in the groundwater? *(The water is hard in a karst region due to the calcium dissolved in the water from the erosion of the limestone under ground.)*
Logical

Integrate Chemistry

L2

Acid Rain on Karst Topography
Explain to students that chemical and power plants release sulfur dioxide and nitrogen monoxide into the air. These chemicals combine with precipitation to become acid rain. Acid rain harms plants, animals, and soil. It also affects karst topography because limestone is vulnerable to the effects of acid. Have students research the effects of acid rain on karst topography. Ask each student to prepare a presentation that includes a graph or chart of data collected.
Verbal, Logical

Go Online NSTA SCILINKS

Download a worksheet on sinkholes for students to complete, and find additional teacher support from NSTA SciLinks.

Figure 23 Soda straw stalactites in Great Basin National Park's Lehman Caves.
Relating Cause and Effect
What part do these drops of water play in the formation of the stalactites?

Dripstone Features Perhaps the most familiar dripstone features are stalactites. Stalactites are icicle-like stone pendants that hang from the ceiling of a cavern. They form when water seeps through cracks in the cavern ceiling. When water reaches air in the cave, some of the dissolved carbon dioxide escapes from the drop and calcite begins to separate out. Deposition occurs as a ring around the edge of the water drops. As drops fall, each one leaves a tiny trace of calcite behind. This calcite creates a hollow limestone tube called a soda straw, as shown in Figure 23. Often the hollow tube becomes plugged or its supply of water increases. When a stalactite becomes plugged or the water supply increases, the water flows and deposits along the outside of the tube. As deposition continues, the stalactite takes on the more common conical shape.

Stalagmites are formations that develop on the floor of a cavern and reach up toward the ceiling. The water supplying the calcite for stalagmite growth falls from the ceiling and splatters over the surface of the cavern floor. As a result, stalagmites do not have a central tube. They are usually more massive and more rounded on their upper ends than stalactites. Given enough time, a downward-growing stalactite and an upward-growing stalagmite may join to form a column.

Reading Checkpoint *What is a dripstone deposit?*

Karst Topography

Many areas of the world have landscapes that have been shaped largely by the dissolving power of groundwater. These areas are said to have **karst topography.** This term comes from the *Krs* region of Slovenia, where such topography is strikingly developed. In the United States, karst landscapes occur in many areas that are underlain by limestone. These areas include parts of Kentucky, Tennessee, Alabama, southern Indiana, and central northern Florida.

Karst areas typically have irregular terrain, with many depressions called sinkholes. A **sinkhole** is a depression produced in a region where groundwater has removed soluble rock. In the limestone areas of Florida, Kentucky, and southern Indiana, there are tens of thousands of these depressions. They vary in depth from just a meter or two to more than 50 meters.

Go Online SCILINKS NSTA

For: Links on sinkholes
Visit: www.SciLinks.org
Web Code: cjn-2065

Sinkholes commonly form in one of two ways. Some develop gradually over many years without any physical disturbance to the rock. In these situations, downward-seeping rainwater containing carbon dioxide dissolves limestone below the soil. These depressions are fairly shallow and have gentle slopes. Sinkholes can also form suddenly when the roof of a cavern collapses. The depressions created in this way are steep-sided and deep. When they form in populated areas, they may be a serious geologic hazard, as shown in Figure 24.

In addition to a surface pockmarked by sinkholes, karst regions usually show a striking lack of surface drainage (streams). Following a rainfall, runoff is quickly funneled below ground through sinkholes. It then flows through caverns until it finally reaches the water table. Where streams do exist at the surface, their paths are usually short. The names of such streams often give a clue to their fate. In the Mammoth Cave area of Kentucky, for example, there is Sinking Creek, Little Sinking Creek, and Sinking Branch. Some sinkholes become plugged with clay and debris, creating small lakes or ponds.

Figure 24 This small sinkhole formed suddenly in 1991 when the roof of a cavern collapsed. It destroyed this home in Frostproof, Florida.

Section 6.3 Assessment

Reviewing Concepts

1. Where is groundwater located under the surface?
2. How does water move underground?
3. What are some environmental threats to groundwater supplies?
4. How and where do most caverns form?
5. What landforms are common in an area of karst topography?

Critical Thinking

6. **Comparing and Contrasting** What is the difference between stalactites and stalagmites?
7. **Analyzing Concepts** How is groundwater a nonrenewable resource?
8. **Analyzing Concepts** Explain why caverns form in the zone of saturation, while dripstone features form in the zone of aeration?

Writing in Science

Relating Cause and Effect Write a paragraph that connects these three concepts: land subsidence, extensive farming in dry regions, and water conservation.

3 ASSESS

Evaluate Understanding L2

To assess students' knowledge of section content, have them create a visual of the inside of a cavern. Encourage students to include as many features as possible.

Reteach L1

Use Figure 24 to discuss the hazards of living in a region with karst topography.

Writing in Science

Student paragraphs should accurately describe cause-and-effect relationships among land subsidence, extensive farming in dry regions, and water conservation.

Section 6.3 Assessment

1. in the zone of saturation
2. Groundwater moves by twisting and turning through interconnected small openings.
3. overuse and contamination
4. Most caverns form by erosion at or below the water table in the zone of saturation.
5. depressions and sinkholes
6. Stalactites are dripstone features that cling to the ceiling of a cavern. Stalagmites are dripstone features that build upward from a cavern floor.
7. Groundwater is becoming a nonrenewable resource in some areas due to overuse and contamination.
8. The deposition of dripstone is not possible until the caverns are above the water table.

Answer to . . .

Figure 23 *The water in each drop that drips down a stalactite contains dissolved minerals. Each water drop that evaporates leaves a small deposit at the end of the stalactite.*

Reading Checkpoint *A dripstone deposit is a rock deposit that forms as water containing dissolved minerals drips from cavern walls, leaving the minerals behind when the water evaporates.*

people and the ENVIRONMENT

The Ogallala Aquifer—How Long Will the Water Last? L2

Background

- Dry-land farming is a system of producing crops without irrigation in semi-arid regions. These regions often receive less than 50 cm of rainfall per year. Dry-land farmers usually rebuild soil moisture by allowing the land to be unplanted or mulched in alternate years.
- In May, 2003, the United States government provided $53 million to aid Western farmers and ranchers impacted by drought. About half of this funding went to farmers and ranchers in the High Plains. The funds helped implement technologies and practices to conserve water to relieve the long-term impact of drought on the region.

Teaching Tips

- Ask students to research dry-land farming and other methods that reduce agricultural dependence upon irrigation. Have them create a presentation with visuals that would educate people about these methods and the importance of finding a solution to the decline in the High Plains water table.
- Have students find out about regions in the world where there are large supplies of groundwater. Ask students to address these questions: What is the source of the groundwater? How is groundwater used by people in the region? How are they accessing it? Is the water table in danger of becoming low? If so, what are plans to help remedy the situation?

Visual

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The Ogallala Aquifer—How Long Will the Water Last?

The High Plains extend from the western Dakotas south to Texas. Despite being a land of little rain, this is one of the most important agricultural regions in the United States. The reason is a vast supply of groundwater that makes irrigation possible throughout most of the region. The source of most of this water is the Ogallala Formation, the largest aquifer in the United States.

Geologically, the Ogallala Formation consists of a number of sandy and gravelly rock layers. The sediments came from the erosion of the Rocky Mountains and were carried eastward by sluggish streams. Erosion has removed much of the formation from eastern Colorado, severing the Ogallala's connection to the Rockies.

Figure 25 The Ogallala Formation underlies about 450,000 square kilometers of the High Plains, making it the largest aquifer in the United States.

The Ogallala Formation, the largest aquifer in the United States, averages 60 meters thick. However, in some places it is as thick as 180 meters thick. Groundwater in the aquifer originally traveled downslope from the Rocky Mountains and from surface precipitation that soaked into the ground over thousands of years. Because of its high porosity and great size, the Ogallala Formation accumulated a large amount of groundwater—enough to fill Lake Huron! Today, with the connection between the aquifer and the Rockies gone (erosion has removed much of the formation in eastern Colorado), all of the Ogallala's recharge must come from the meager rainfall of the Plains.

In the late 1800s, people first started to use the Ogallala for irrigation. However, the capacity of pumps available at the time limited water withdrawal. Then in the 1920s, large-capacity irrigation pumps were invented. High Plains' farmers began tapping the Ogallala for irrigation. Today, there are nearly 170,000 wells irrigating more than 65,000 square kilometers of land.

The increase in irrigation has caused a drastic drop in the Ogallala's water table, especially in the High Plains. Declines in the water table of 3 to 15 meters are common. In places, however, the water table is now 60 meters below its original level.

Although the decline in the water table has slowed in parts of the southern High Plains, substantial pumping continues—often in excess of recharge. The future of irrigated farming here is clearly in jeopardy.

The southern High Plains will return sooner or later to dry-land farming. The transition will come sooner and with fewer ecological and economic crises if the agricultural industry is weaned gradually from its dependence on groundwater irrigation. If nothing is done until all the accessible water in the Ogallala aquifer has been removed, the transition will be ecologically dangerous and economically dreadful.*

*National Research Council. *Solid-Earth Sciences and Society.* Washington, DC: National Academy Press, 1993, p. 148.