MS Earth's Fresh Water

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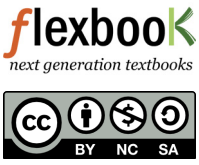

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CHAPTER 1 MS Earth's Fresh Water

CHAPTER OUTLINE

If you think of freshwater on Earth's surface, lakes and rivers might come to mind. But most of Earth's freshwater is frozen. Much of it occurs in glaciers, like the one pictured here. This massive sheet of ice is Portage Glacier in Alaska. It contains a huge amount of frozen water. Where else is frozen water found on Earth? Besides solid ice, in what other states does Earth's freshwater exist? And how does water change from one state to another? This chapter answers these and many other questions about Earth's freshwater.

1.1 Water on Earth

Lesson Objectives

- Describe water and where it occurs on Earth.
- Give an overview of the water cycle.

Vocabulary

- condensation
- evaporation
- freshwater
- infiltration
- precipitation
- runoff
- transpiration
- water
- water cycle

Introduction

Water is all around you — in pipes, in puddles, even in people. Water covers more than 70 percent of Earth's surface. That's a good thing, because all life on Earth depends on water. In fact, without water, life as we know it could not exist. Water is a very special substance. Do you know why?

What Is Water?

Water is a simple chemical compound. Each molecule of water contains two hydrogen atoms (H_2) and one oxygen atom (O). That's why the chemical formula for water is H_2O. If water is so simple, why is it special? Water is one of the few substances that exists on Earth in all three states of matter. Water occurs as a gas, a liquid and a solid. You drink liquid water and use it to shower. You breathe gaseous water vapor in the air. You may go ice skating on a pond covered with solid water — ice — in the winter.

Where Is Earth's Freshwater?

Earth is often called the "water planet." **Figure** 1.1 shows why. If astronauts see Earth from space, this is how it looks. Notice how blue the planet appears. That's because oceans cover much of Earth's surface. Water is also found

in the clouds that rise above the planet.

FIGURE 1.1

Take a look at this image. Do you think that Earth deserves the name "water planet"?

Most of Earth's water is salt water in the oceans. As **Figure** 1.2 shows, only 3 percent of Earth's water is fresh. **Freshwater** is water that contains little or no dissolved salt. Most freshwater is frozen in ice caps and glaciers. Glaciers cover the peaks of some tall mountains. For example, the Cascades Mountains in North America and the Alps Mountains in Europe are capped with ice. Ice caps cover vast areas of Antarctica and Greenland. Chunks of ice frequently break off ice caps. They form icebergs that float in the oceans.

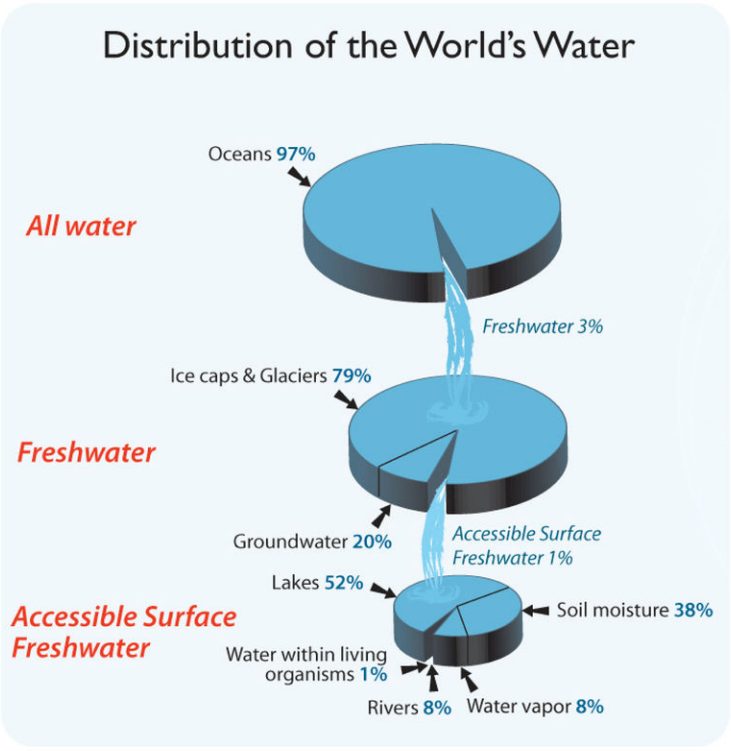

FIGURE 1.2

What percentage of Earth's surface freshwater is water vapor in the air?

Only a tiny fraction of Earth's freshwater is in the liquid state. Most liquid freshwater is under the ground in layers of rock. Of freshwater on the surface, the majority occurs in lakes and soil. What percentage of freshwater on the surface is found in living things?

The Water Cycle

Did you ever wonder where the water in your glass came from or where it's been? The next time you take a drink of water, think about this. Each water molecule has probably been around for billions of years. That's because Earth's water is constantly recycled.

How Water Is Recycled

Water is recycled through the water cycle. The **water cycle** is the movement of water through the oceans, atmosphere, land, and living things. The water cycle is powered by energy from the sun. **Figure** 1.3 diagrams the water cycle.

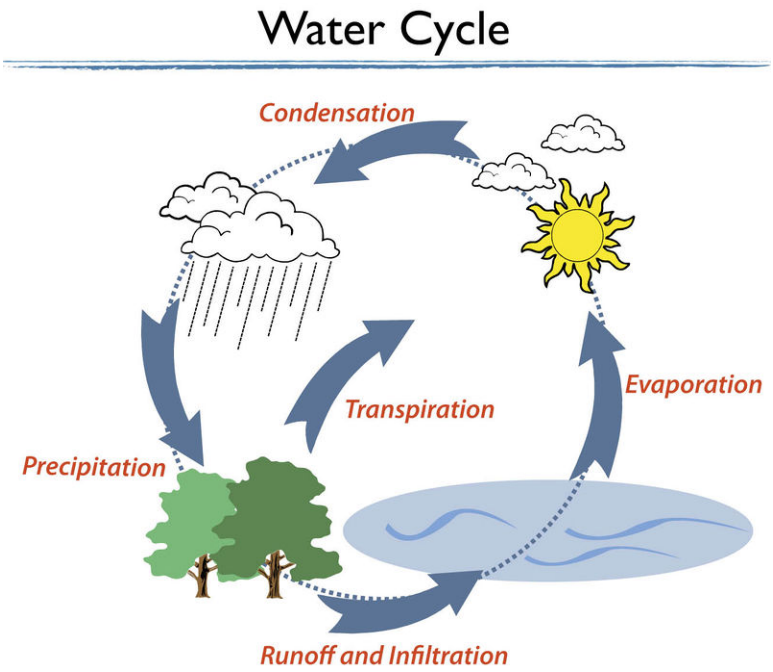

FIGURE 1.3
The water cycle has no beginning or end. Water just keeps moving along.

Processes in the Water Cycle

Water keeps changing state as it goes through the water cycle. This means that it can be a solid, liquid, or gas. How does water change state? How does it keep moving through the cycle? As **Figure** 1.3 shows, several processes are involved.

- **Evaporation** changes liquid water to water vapor. Energy from the sun causes water to evaporate. Most evaporation is from the oceans because they cover so much area. The water vapor rises into the atmosphere.
- **Transpiration** is like evaporation because it changes liquid water to water vapor. In transpiration, plants release water vapor through their leaves. This water vapor rises into the atmosphere.
- **Condensation** changes water vapor to liquid water. As air rises higher into the atmosphere, it cools. Cool air can hold less water vapor than warm air. So some of the water vapor condenses into water droplets. Water droplets may form clouds.

- **Precipitation** is water that falls from clouds to Earth's surface. Water droplets in clouds fall to Earth when they become too large to stay aloft. The water falls as rain if the air is warm. If the air is cold, the water may freeze and fall as snow, sleet, or hail. Most precipitation falls into the oceans. Some falls on land.
- **Runoff** is precipitation that flows over the surface of the land. This water may travel to a river, lake, or ocean. Runoff may pick up fertilizer and other pollutants and deliver them to the water body where it ends up. In this way, runoff may pollute bodies of water.
- **Infiltration** is the process by which water soaks into the ground. Some of the water may seep deep underground. Some may stay in the soil, where plants can absorb it with their roots.

In all these ways, water keeps cycling. The water cycle repeats over and over again. Who knows? Maybe a water molecule that you drink today once quenched the thirst of a dinosaur.

Lesson Summary

- Water is a simple chemical compound. It exists on Earth in all three states of matter: liquid, gas, and solid. As a gas, water is called water vapor. As a solid, water is called ice.
- Oceans of salt water cover much of Earth's surface. Freshwater is water that contains little or no salt. Most of Earth's freshwater is frozen in ice caps and glaciers.
- Earth's water is constantly recycled through the water cycle. Water keeps changing state as it goes through the cycle. The water cycle includes processes such as evaporation, condensation, and precipitation.

Lesson Review Questions

Recall

1. What is freshwater?
2. Where is most of Earth's freshwater found?
3. What process changes water from a liquid to a gas? From a gas to a liquid?
4. Define infiltration and runoff.

Apply Concepts

5. Describe the substance known as water.
6. Why does most precipitation fall into the oceans?

Think Critically

7. Apply lesson concepts to explain how a forest fire might affect the water cycle.
8. Explain why this statement is true: "The water you drink today may once have quenched the thirst of a dinosaur."
9. How does the sun drive the water cycle? What would happen to the water cycle if the sun decreased its intensity by half?

Points to Consider

As water moves through the water cycle, it spends some time on Earth's surface as freshwater.

- Where is freshwater found on Earth's surface?
- How do people use freshwater on Earth's surface?

1.2 Surface Water

Lesson Objectives

- Identify features of streams and rivers.
- Describe ponds and lakes and how they form.
- Explain why wetlands are important.
- State how floods occur.

Vocabulary

- flood
- lake
- pond
- river
- stream
- wetland

Introduction

Only a very small percentage of Earth's water is fresh, liquid water on the surface. But that tiny fraction of water is vital. It is needed by humans, plants, and many other living things. Liquid freshwater flows over Earth's surface in streams and rivers. It also forms ponds, lakes, and wetlands. People use freshwater for drinking, washing, and industry. They also use it for fun. How do you use freshwater for fun?

Streams and Rivers

Look at the pictures of flowing water in **Figure** 1.4. A waterfall tumbles down a mountainside. A brook babbles through a forest. A river slowly meanders through a broad valley. What do all these forms of flowing water have in common? They are all streams.

What Are Streams and Rivers?

A **stream** is a body of freshwater that flows downhill in a channel. The channel of a stream has a bottom, or bed, and sides called banks. Any size body of flowing water can be called a stream. Usually, though, a large stream is called a **river**.

FIGURE 1.4

All these forms of flowing water are streams.

Features of Streams and Rivers

All streams and rivers have several features in common. These features are shown in (**Figure** 1.5). The place where a stream or river starts is its source. The source might be a spring, where water flows out of the ground. Or the source might be water from melting snow on a mountain top. A single stream may have multiple sources. A stream or river probably ends when it flows into a body of water, such as a lake or an ocean. A stream ends at its mouth. As the water flows into the body of water, it slows down and drops the sediment it was carrying. The sediment may build up to form a delta.

Several other features of streams and rivers are also shown in **Figure** 1.5.

- Small streams often flow into bigger streams or rivers. The small streams are called tributaries. A river and all its tributaries make up a river system.
- At certain times of year, a stream or river may overflow its banks. The area of land that is flooded is called the floodplain. The floodplain may be very wide where the river flows over a nearly flat surface.
- A river flowing over a floodplain may wear away broad curves. These curves are called meanders.

River Basins and Divides

All of the land drained by a river system is called its basin, or watershed. One river system's basin is separated from another river system's basin by a divide. The divide is created by the highest points between the two river basins. Precipitation that falls within a river basin always flows toward that river. Precipitation that falls on the other side of the divide flows toward a different river.

Figure 1.6 shows the major river basins in the U.S. You can watch an animation of water flowing through a river basin at this link: http://trashfree.org/btw/graphics/watershed_anim.gif

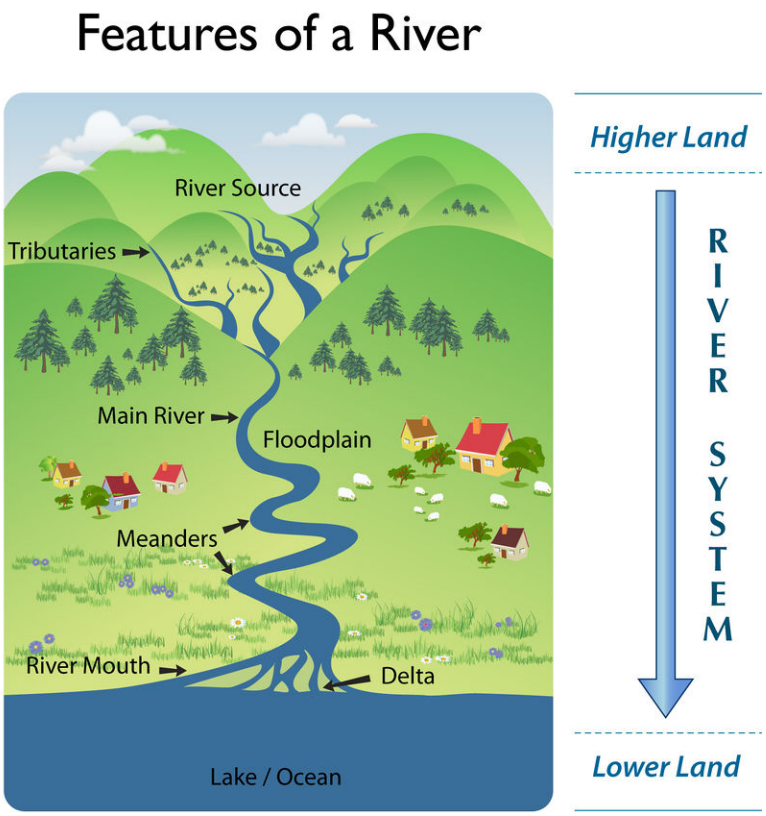

FIGURE 1.5

Water in a stream flows along the ground from higher to lower elevation. What force causes the water to keep flowing?

FIGURE 1.6

River basins in the U.S.

Ponds and Lakes

After a heavy rain, you may find puddles of water standing in low spots. The same principle explains why water collects in ponds and lakes. Water travels downhill, so a depression in the ground fills with standing water. A **pond** is a small body of standing water. A **lake** is a large body of standing water. Most lakes have freshwater, but a few

are salty. The Great Salt Lake in Utah is an example of a saltwater lake. The water in a large lake may be so deep that sunlight cannot penetrate all the way to the bottom. Without sunlight, water plants and algae cannot live on the bottom of the lake. That's because plants need sunlight for photosynthesis.

The largest lakes in the world are the Great Lakes. They lie between the U.S. and Canada, as shown in **Figure** 1.7. How great are they? They hold 22 percent of all the world's fresh surface water!

FIGURE 1.7

The Great Lakes of North America get their name from their great size.

Water in Ponds and Lakes

Ponds and lakes may get their water from several sources. Some falls directly into them as precipitation. Some enters as runoff and some from streams and rivers. Water leaves ponds and lakes through evaporation and also as outflow.

How Lakes Form

The depression that allows water to collect to form a lake may come about in a variety of ways. The Great Lakes, for example, are glacial lakes. A glacial lake forms when a glacier scrapes a large hole in the ground. When the glacier melts, the water fills the hole and forms a lake. Over time, water enters the lake from the sources mentioned above as well.

Other lakes are crater lakes or rift lakes, which are pictured in **Figure** 1.8. Crater lakes form when volcanic eruptions create craters that fill with water. Rift lakes form when movements of tectonic plates create low places that fill with water.

Wetlands

Some of Earth's freshwater is found in wetlands. A **wetland** is an area that is covered with water, or at least has very soggy soil, during all or part of the year. Certain species of plants thrive in wetlands, and they are rich ecosystems. Freshwater wetlands are usually found at the edges of steams, rivers, ponds, or lakes. Wetlands can also be found at the edges of seas.

This Russian lake formed in the crater created by a volcano.

The bold red lines on this map mark the rift between tectonic plates in East Africa. Fault movements created depressions that filled with water. This formed many rift lakes, from Lake Malawi in the south to Lake Turkana in the north.

FIGURE 1.8

Craters and rifts become lakes when they fill with water. Where does the water come from?

Types of Freshwater Wetlands

Not all wetlands are alike, as you can see from **Figure** 1.9. Wetlands vary in how wet they are and how much of the year they are soaked. Wetlands also vary in the kinds of plants that live in them. This depends mostly on the climate where the wetland is found. Types of wetlands include marshes, swamps, and bogs.

- A marsh is a wetland that is usually under water. It has grassy plants, such as cattails.
- A swamp is a wetland that may or may not be covered with water but is always soggy. It has shrubs or trees.
- A bog is a wetland that has soggy soil. It is generally covered with mosses.

Importance of Wetlands

People used to think that wetlands were useless. Many wetlands were filled in with rocks and soil to create lands that were then developed with roads, golf courses, and buildings. Now we know that wetlands are very important. Laws have been passed to help protect them. Why are wetlands so important?

- Wetlands have great biodiversity. They provide homes or breeding sites to a huge variety of species. Because so much wetland area has been lost, many of these species are endangered.
- Wetlands purify water. They filter sediments and toxins from runoff before it enters rivers, lakes, and oceans.
- Wetlands slow rushing water. During hurricanes and other extreme weather, wetlands reduce the risk of floods.

Although the rate has slowed, wetlands are still being destroyed today.

FIGURE 1.9
These are just three of many types of wetlands.

Floods

A **flood** occurs when so much water enters a stream or river that it overflows its banks. Flood waters from a river are shown in **Figure** 1.10. Like this flood, many floods are caused by very heavy rains. Floods may also occur when deep snow melts quickly in the spring.


Flooded River

FIGURE 1.10
A river in Indiana floods after very heavy rains. Some areas received almost a foot of rain in less than 24 hours!

Floods are a natural part of the water cycle, but they can cause a lot of damage. Farms and homes may be lost, and people may die. In 1939, millions of people died in a flood in China. Although freshwater is needed to grow crops and just to live, too much freshwater in the same place at once can be deadly.

Lesson Summary

- A stream is a body of water that flows downhill in a channel. A large stream is usually called a river.
- Standing freshwater forms ponds and lakes. Lakes are generally bigger than ponds. Lakes may form in several different ways.
- A wetland is an area that is wet for all or part of the year. Wetlands are home to certain types of plants.
- Wetlands are very important. They have great biodiversity. They purify water. They slow down rushing water and help prevent floods.
- Floods occur when so much water enters a stream or river that it overflows its banks. Floods may be caused by heavy rains or melting snow. They can cause a lot of damage and loss of life.

Lesson Review Questions

Recall

1. What are the source and mouth of a river?
2. Define tributary and river system.
3. How may water enter a pond or lake?
4. What is a wetland?
5. List three reasons why wetlands should be protected.

Apply Concepts

6. For each stream pictured in **Figure** 1.4, explain where it might be located on the map in **Figure** 1.5.

Think Critically

7. The Nile River in Egypt empties into the Mediterranean Sea. At the mouth of the river, there is a very large delta. Explain how the delta formed.
8. Compare and contrast glacial, crater, and rift lakes.

Points to Consider

- In the desert, water runs in channels after a storm. The channels are dry otherwise. Is this a stream?
- It may seem hard to believe, but most of Earth's freshwater is under our feet. It is stored below the surface of the ground.
  - How do you think water gets under the ground?
  - What happens to water after it goes under the ground? Is it trapped there forever?

1.3 Groundwater

Lesson Objectives

- Explain how water enters an aquifer.
- Explain how water leaves an aquifer.
- Define aquifer, and give an example.
- Define springs and geysers.
- State the purpose of wells and how they work.

Vocabulary

- aquifer
- groundwater
- spring
- water table
- well

Introduction

Rivers and lakes hold a lot of Earth's liquid freshwater. However, far more is hidden from sight. Where is it? It is stored under the ground. In fact, 20 times more of Earth's liquid freshwater is found below the surface than on the surface.

Groundwater

Freshwater below Earth's surface is called **groundwater**. The water infiltrates, or seeps down into, the ground from the surface. How does this happen? And where does the water go?

Porous and Impermeable Rock

Water infiltrates the ground because soil and rock are porous. Between the grains are pores, or tiny holes. Since water can move through this rock it is permeable. Eventually, the water reaches a layer of rock that is not porous and so is impermeable. Water stops moving downward when it reaches this layer of rock. Look at the diagram in **Figure** 1.11. It shows two layers of porous rock. The top layer is not saturated; it is not full of water. The next layer is saturated. The water in this layer has nowhere else to go. It cannot seep any deeper into the ground because the rock below it is impermeable.

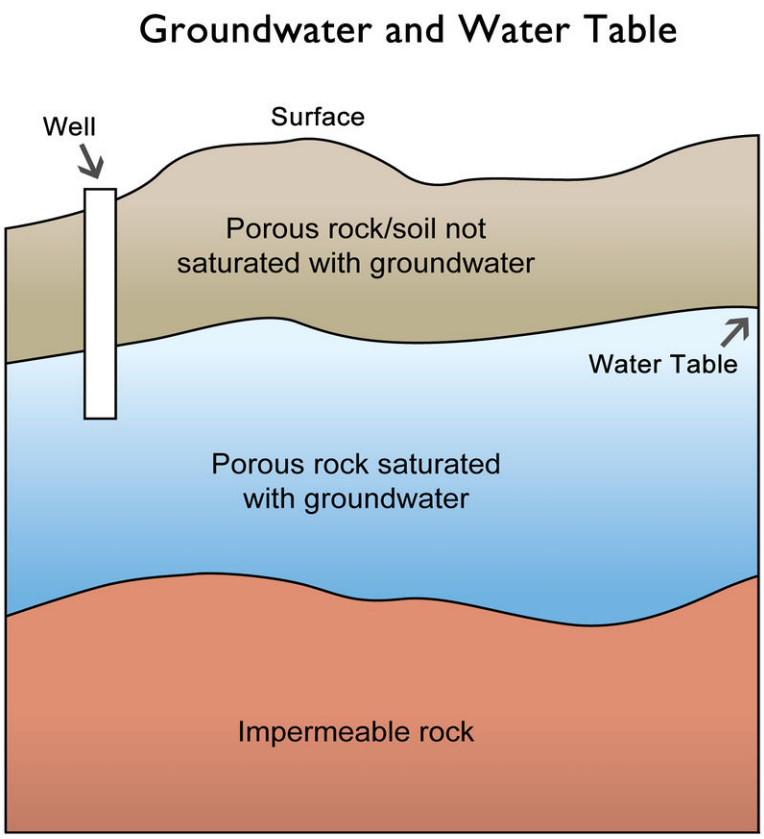

FIGURE 1.11

Water seeps into the ground through permeable material and stops when it reaches an impermeable rock. Predict the purpose of the well in the diagram.

The Water Table

The top of the saturated rock layer in **Figure** 1.11 is called the **water table**. The water table isn't like a real table. It doesn't remain firmly in one place. Instead, it rises or falls, depending on how much water seeps down from the surface. The water table is higher when there is a lot of rain and lower when the weather is dry.

Aquifer

An underground layer of rock that is saturated with groundwater is called an **aquifer**. A diagram of an aquifer is shown in **Figure** 1.12. Aquifers are generally found in porous rock, such as sandstone. Water infiltrates the aquifer from the surface. The water that enters the aquifer is called recharge.

Human Use of Aquifers

Most land areas have aquifers beneath them. Many aquifers are used by people for freshwater. The closer to the surface an aquifer is, the easier it is to get the water. However, an aquifer close to the surface is also more likely to become polluted. Pollutants can seep down through porous rock in recharge water. An aquifer that is used by people may not be recharged as quickly as its water is removed. The water table may lower and the aquifer may even run dry. If this happens, the ground above the aquifer may sink. This is likely to damage any homes or other structures built above the aquifer.

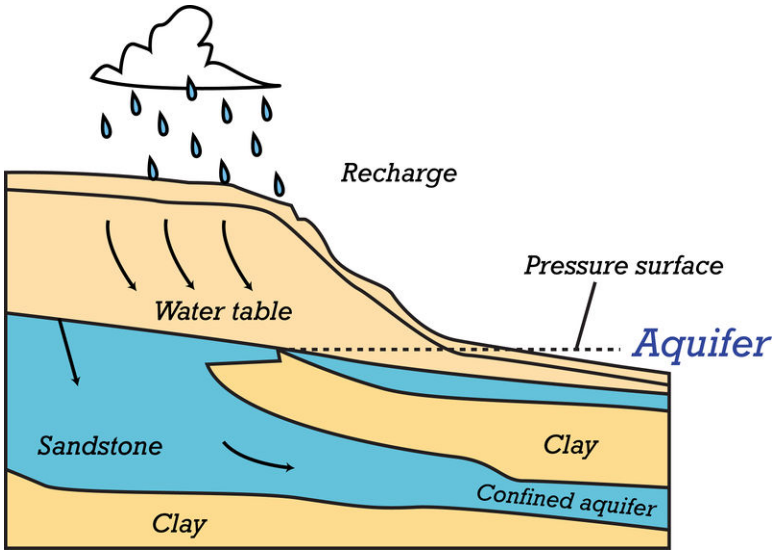

FIGURE 1.12

An aquifer is a layer of saturated porous rock. It lies below the water table. An impermeable layer, such as clay, is below the aquifer.

The Ogallala Aquifer

One of the biggest aquifers in the world is the Ogallala aquifer. As you can see from **Figure** 1.13, this aquifer lies beneath parts of eight U.S. states. It covers a total area of 451,000 square kilometers (174,000 square miles). In some places, it is less than a meter deep. In other places, it is hundreds of meters deep.

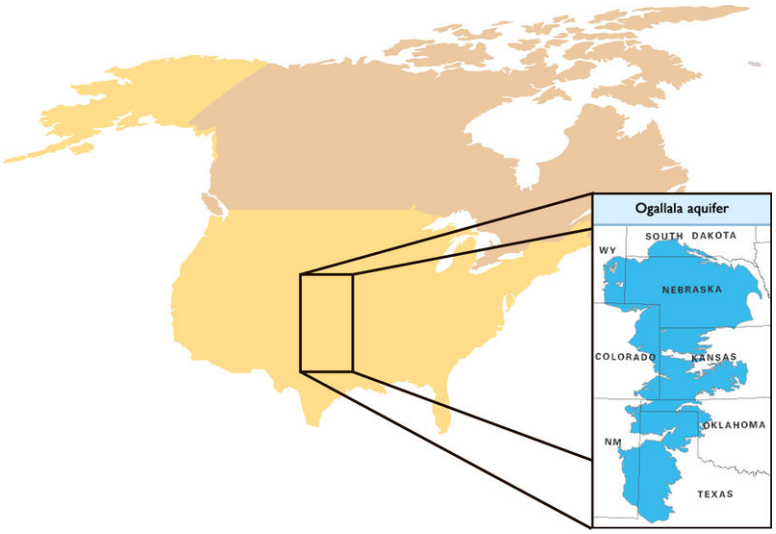

FIGURE 1.13

In this map, the area over the Ogallala aquifer is shaded in blue.

The Ogallala aquifer is an important source of freshwater in the American Midwest. This is a major farming area, and much of the water is used to irrigate crops. The water in this aquifer is being used up ten times faster than it is recharged. If this continues, what might happen to the Ogallala aquifer?

Springs and Geysers

The top of an aquifer may be high enough in some places to meet the surface of the ground. This often happens on a slope. The water flows out of the ground and creates a **spring**. A spring may be just a tiny trickle, or it may be a big gush of water. One of the largest springs in the world is Big Spring in Missouri, seen in **Figure** 1.14.

Big Spring (Missouri)

FIGURE 1.14

Big Spring is named for its large size. It releases more than 12,000 liters of water per second!

Water flowing out of the ground at a spring may flow downhill and enter a stream. That's what happens to the water that flows out of Big Spring in Missouri. If the water from a spring can't flow downhill, it may spread out to form a pond or lake instead. Lake George in New York State, which is pictured in **Figure** 1.15, is a spring-fed lake. The lake basin was carved by a glacier.

Lake George (New York State)

FIGURE 1.15

Lake George gets its water from a number of springs.

Mineral Springs and Hot Springs

Some springs have water that contains minerals. Groundwater dissolves minerals out of the rock as it seeps through the pores. The water in some springs is hot because it is heated by hot magma. Many hot springs are also mineral springs. That's because hot water can dissolve more minerals than cold water. Grand Prismatic Spring, shown in **Figure** 1.16, is a hot mineral spring. Dissolved minerals give its water a bright blue color. The edge of the spring is covered with thick orange mats of bacteria. The bacteria use the minerals in the hot water to make food.

Grand Prismatic Spring (Yellowstone National Park)

FIGURE 1.16

Grand Prismatic Spring in the Yellowstone National Park is the largest hot spring in the U.S. How can you tell from the photo that the water in this spring is hot?

Geysers

Heated groundwater may become trapped in spaces within rocks. Pressure builds up as more water seeps into the spaces. When the pressure becomes great enough, the water bursts out of the ground at a crack or weak spot. This is called a **geyser**. When the water erupts from the ground, the pressure is released. Then more water collects and the pressure builds up again. This leads to another eruption. Old Faithful is the best-known geyser in the world. You can see a picture of it in **Figure** 1.17. The geyser erupts faithfully every 90 minutes, day after day. During each eruption, it may release as much as 30,000 liters of water!

Wells

Most groundwater does not flow out of an aquifer as a spring or geyser. So to use the water that's stored in an aquifer people must go after it. How? They dig a well. A **well** is a hole that is dug or drilled through the ground down to an aquifer. This is illustrated in **Figure** 1.18.

People have depended on water from wells for thousands of years. To bring water to the surface takes energy because the force of gravity must be overcome. Today, many wells use electricity to pump water to the surface. However, in some places, water is still brought to the surface the old-fashioned way — with human labor. The well pictured in **Figure** 1.19 is an example of this type of well. A hand-cranked pulley is used to lift the bucket of water to the surface.

Old Faithful Geyser (Yellowstone National Park)

FIGURE 1.17

Old Faithful in Yellowstone National Park is a geyser named for its regular cycle of eruptions.

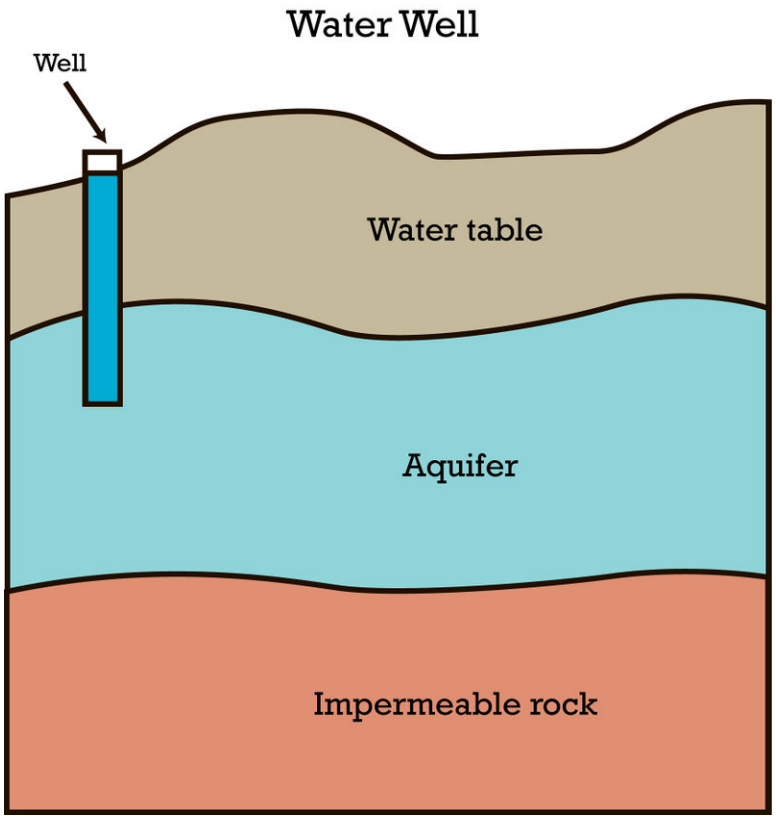

FIGURE 1.18

A well runs from the surface to a point below the water table. Why must a well go lower than the water table?

Lesson Summary

- Groundwater is freshwater below Earth's surface. It seeps down from the surface through pores in soil and rock. It keeps seeping downward until it reaches a layer of impermeable rock.
- An aquifer is an underground layer of rock that is saturated with groundwater. One of the biggest aquifers in

FIGURE 1.19
This old water well uses human muscle power to bring water to the surface.

the world is the Ogallala aquifer in the American Midwest.

- Water that flows out of the ground where an aquifer meets the surface is called a spring. Spring water may contain dissolved minerals. It may also be heated by magna in the crust. Heated groundwater that erupts from the ground under pressure is called a geyser.
- Many people get their freshwater from an aquifer. They obtain the water through a well. A well is a hole that is dug or drilled through the ground down to an aquifer.

Lesson Review Questions

Recall

1. Define groundwater.
2. Describe how water enters the ground.
3. What is the water table? What might cause it to rise or fall?
4. Define aquifer. Where does an aquifer get its water?
5. What is the purpose of a well?

Apply Concepts

6. Assume you live in a town that gets its water from an aquifer. The aquifer lies beneath the town. Apply lesson concepts to predict what may happen if water is pumped out of the aquifer faster than it is recharged. Then, write a letter to the editor of the town's newspaper. State what you think may happen. Argue for the need to use water wisely.

Think Critically

7. Compare and contrast springs and geysers.
8. LaShawna and her family went to Yellowstone National Park. They saw a spring called Green Dragon Spring.

Steam was rising off the water. When LaShawna saw the steam, she said that the water must contain a lot of minerals. Do you agree with LaShawna's statement? Why or why not?

Points to Consider

Freshwater is needed by many living things on Earth. However, most of Earth's water is not fresh. Instead, it is salt water in the oceans.

- What do you know about Earth's oceans? For example, how deep are they? And why is their water salty?
- Ocean water moves in waves, tides, and currents. Do you know what causes these ocean water movements?

1.4 References

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