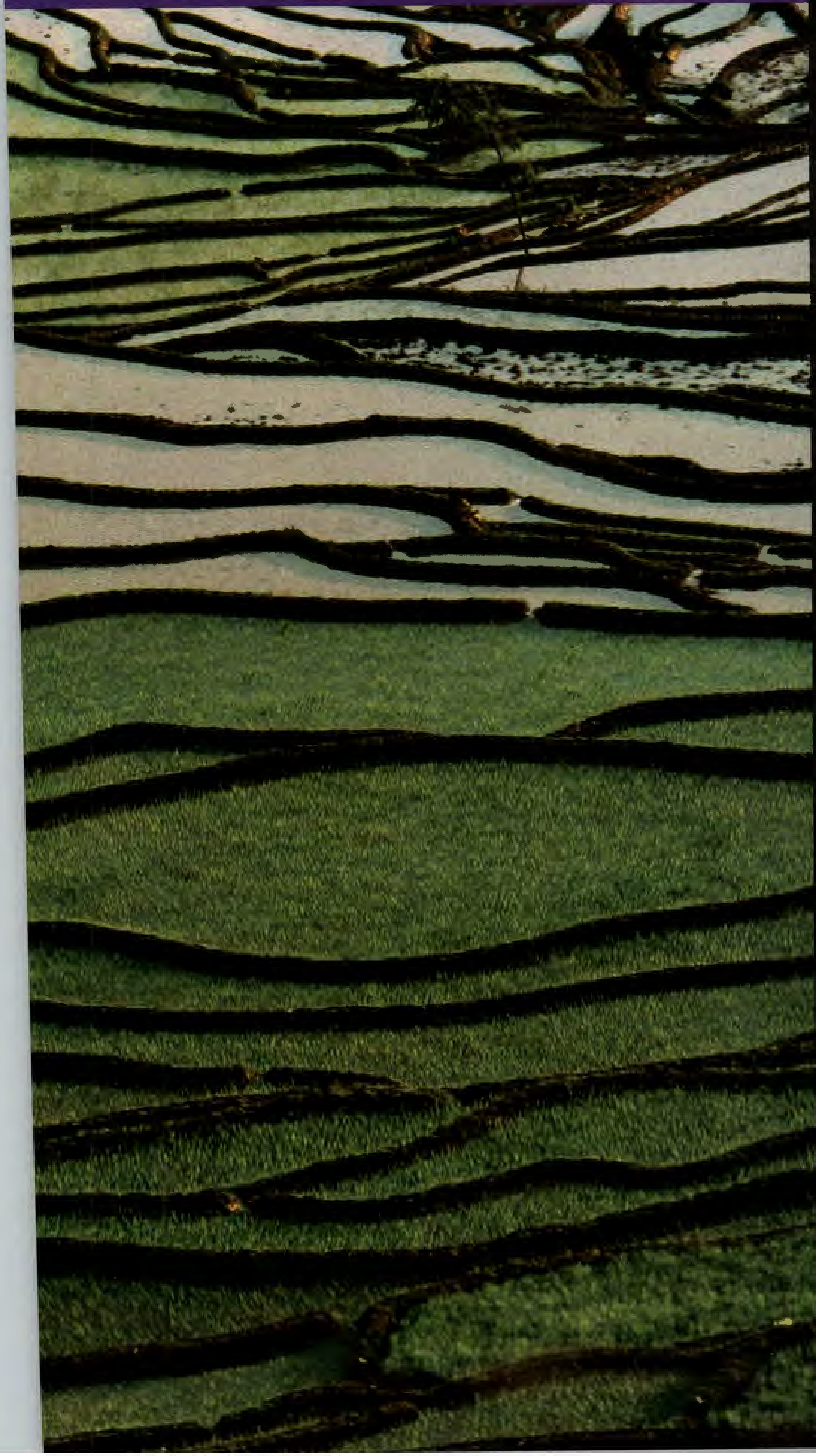
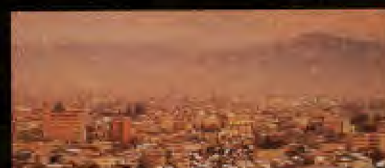
WATER, AIR, AND LAND

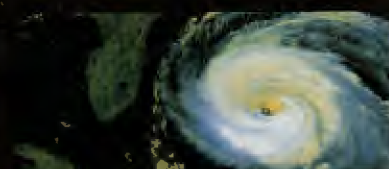
UNIT 4



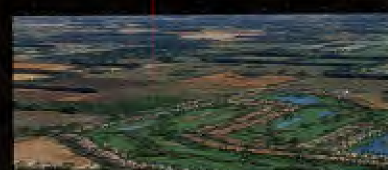
CHAPTER 11
Water



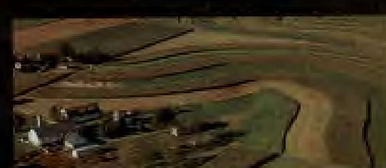
CHAPTER 12
Air



CHAPTER 13
Atmosphere and Climate Change



CHAPTER 14
Land



CHAPTER 15
Food and Agriculture

For thousands of years, humans have altered the environment to grow food. These rice paddies in China are built to trap water from the monsoon rains.

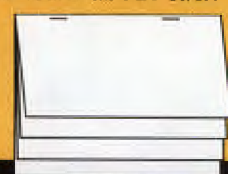
Water

CHAPTER 11

PRE-READING ACTIVITY

FOLDNOTES

Layered Book Before you read this chapter, create the **FoldNote** entitled "Layered Book" described in the Reading and Study Skills section of the Appendix. Label the tabs of the layered book with "Water Resources," "Water Use," "Water Management," and "Water Pollution." As you read the chapter, write information you learn about each category under the appropriate flap.



This composite photograph shows what an iceberg might look like if you could see the entire iceberg. Did you know that some countries are considering towing icebergs to their coasts and melting the ice to provide drinking water?

SECTION 1
Water Resources

The next time you drink a glass of water, think about where the water came from. Did you know that some of the water in your glass may have been part of a rainstorm that pounded the Earth long before life existed? Or that water may have been part of a dinosaur that lived millions of years ago. Some of the water we drink today has been around since water formed on Earth billions of years ago. Water is essential to life on Earth. Humans can survive for more than a month without food, but we can live for only a few days without water.

Two kinds of water are found on Earth. Fresh water—the water that people can drink—contains little salt. Salt water—the water in oceans—contains a higher concentration of dissolved salts. Most human uses for water, such as drinking and agriculture, require fresh water.

Objectives

- Describe the distribution of Earth's water resources.
- Explain why fresh water is one of Earth's limited resources.
- Describe the distribution of Earth's surface water.
- Describe the relationship between groundwater and surface water in a watershed.

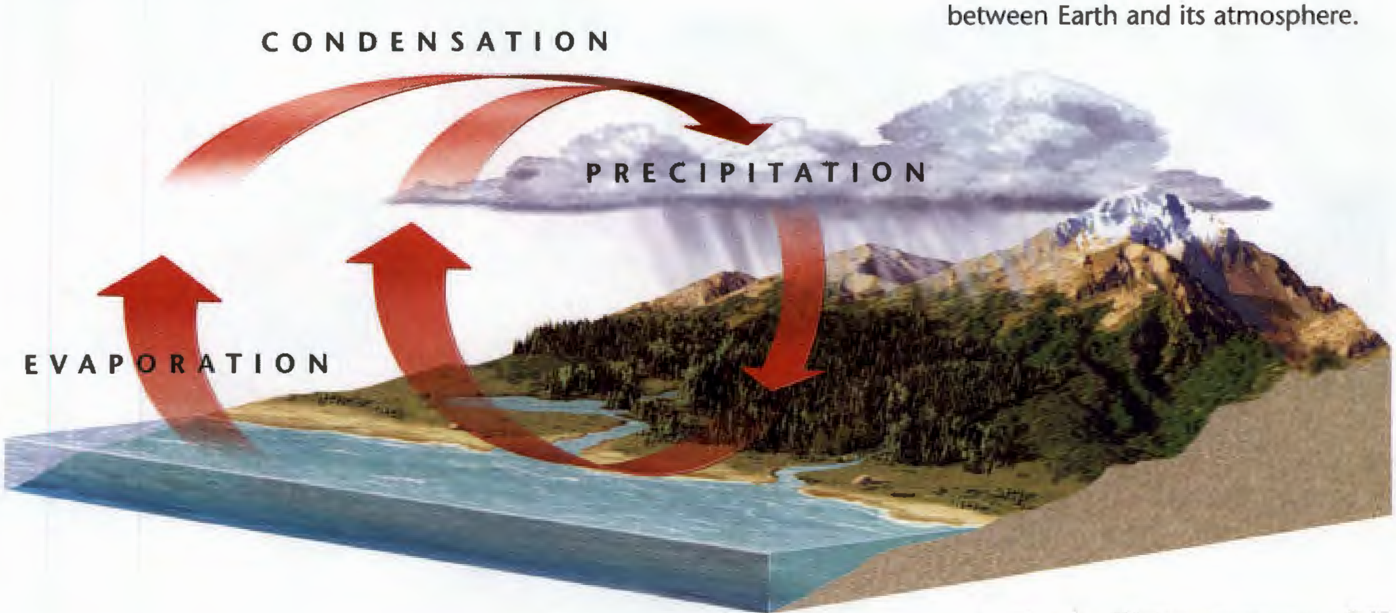
Key Terms

surface water
river system
watershed
groundwater
aquifer
porosity
permeability
recharge zone

The Water Cycle

The Earth is often called "the Water Planet" because it has an abundance of water in all forms: solid, liquid, and gas. Water is a renewable resource because it is circulated in the water cycle, as shown in **Figure 1.** In the water cycle, water molecules travel between the Earth's surface and the atmosphere. Water evaporates at the Earth's surface and leaves behind salts and other impurities. Water vapor, which is a gas, rises into the air. As water vapor rises through the atmosphere, the gas cools and condenses into drops of liquid water that form clouds. Eventually the water in clouds falls back to Earth and replenishes the Earth's fresh water. The oceans are an important part of the water cycle because almost all of Earth's water is in the oceans.

Figure 1 ▶ The water cycle is the continuous movement of water between Earth and its atmosphere.



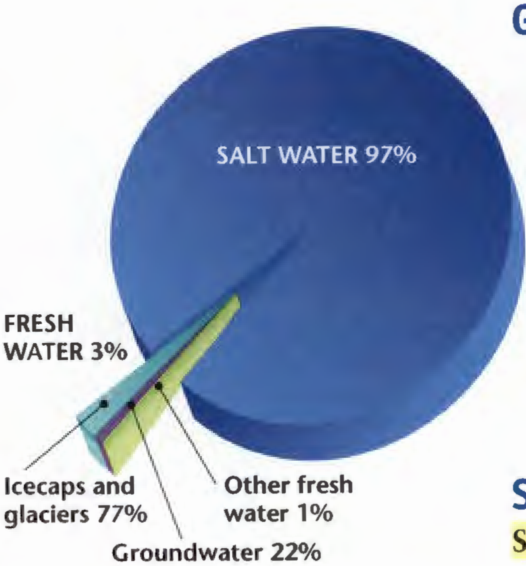


Figure 2 ▶ This pie graph shows the distribution of water on Earth. What percentage of the Earth's fresh water is in lakes and rivers?

Global Water Distribution

To understand why fresh water is such a limited resource you have to understand how little fresh water is found on Earth. Although 71 percent of the Earth's surface is covered with water, nearly 97 percent of Earth's water is salt water in oceans and seas. **Figure 2** illustrates this relationship. Of the fresh water on Earth, about 77 percent is frozen in glaciers and polar icecaps. Only a small percentage of the water on Earth is liquid fresh water that humans can use. The fresh water we use comes mainly from lakes and rivers and from a relatively narrow zone beneath the Earth's surface.

Surface Water

Surface water is fresh water on Earth's land surface. Surface water is found in lakes, rivers, streams, and wetlands. Although surface water makes up a small fraction of the fresh water on Earth, the distribution of surface water has played a vital role in the development of human societies. Throughout history, people have built cities, towns, and farms near reliable sources of surface water. Some of the oldest cities in the world were built near rivers. Today, most large cities depend on surface water for their water supplies. Rivers, lakes, and streams provide drinking water, water to grow crops, food such as fish and shellfish, power for industry, and a means of transportation by boat.

Figure 3 ▶ **Watersheds of the World** This map shows the Earth's major watersheds. The highlighted area of the satellite image below shows that the Mississippi River watershed covers almost half of the United States.

River Systems Have you ever wondered where all the water in a river comes from? Streams form as water from falling rain and melting snow drains from mountains, hills, plateaus, and plains. As streams flow downhill, they combine with other streams and form rivers. The more streams that run into a river, the larger the river becomes. As streams and rivers move across the land, they form a flowing network of water called a **river system.** If a river system is viewed from above, it can look like the roots of a tree that are feeding into a trunk. The Mississippi, the Amazon, and the Nile are enormous river systems because they collect the water that flows from vast areas of land. The Amazon River system is the largest river system in the world—it drains an area of land that is nearly the size of Europe.

Watersheds The area of land that is drained by a river is known as a **watershed.** The watershed of the Mississippi River is shown in the satellite image in **Figure 3.** Pollution anywhere in a watershed may end up polluting a river. The amount of water that enters a watershed varies throughout the year. Rapidly melting snow as well as spring and summer rains can dramatically increase the amount of water in a watershed. Other times of the year, the river system that drains a watershed may be reduced to a trickle. Communities that depend on rivers for water can be severely affected by these changes to the river system.

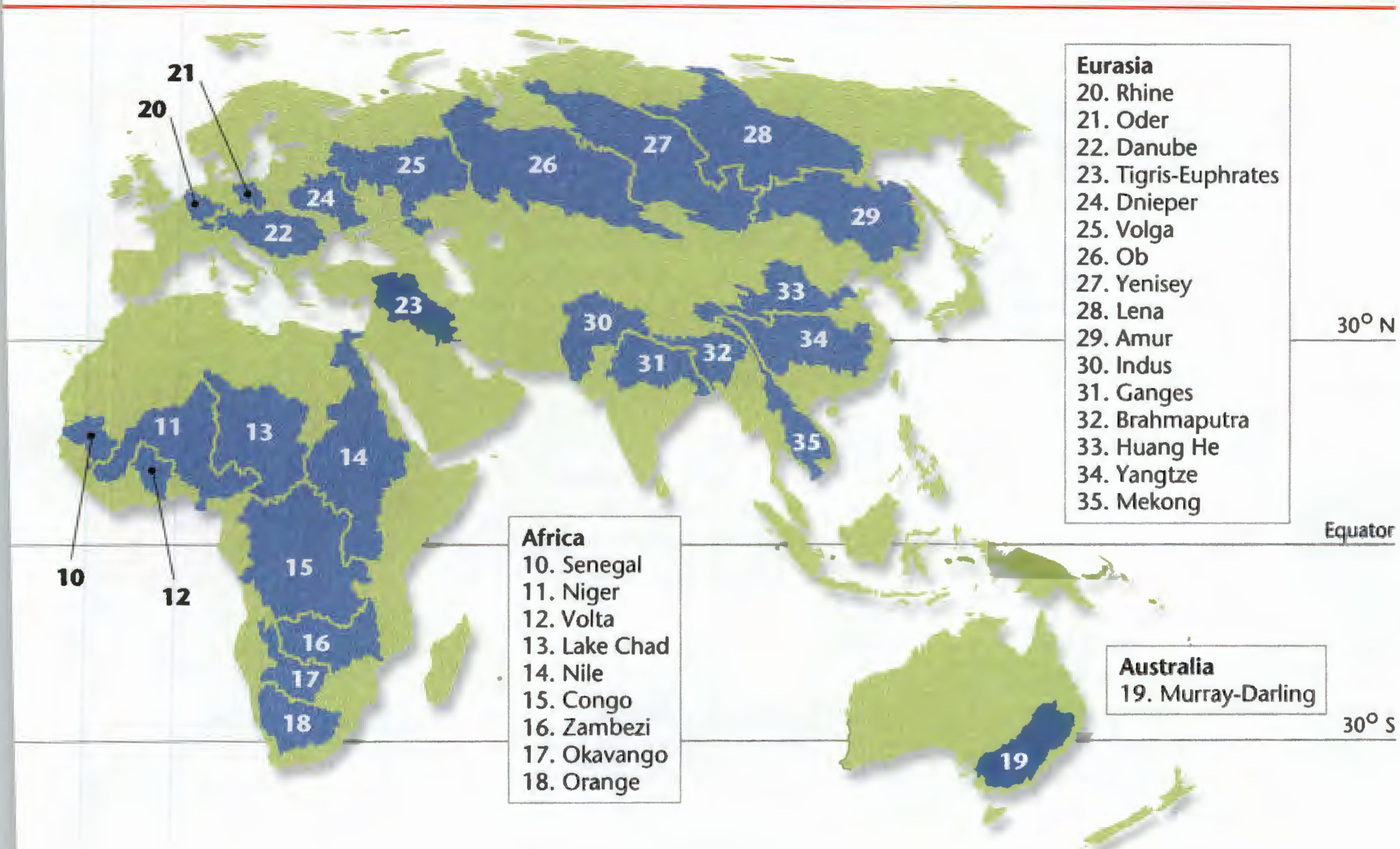
Connection to Biology

Amazon River Dolphins The Amazon River dolphin is one of the world's few freshwater dolphin species. The dolphins are almost completely blind, but they can easily navigate through the silty waters of the Amazon by using sonar.

internet connect

www.scilinks.org
Topic: Watersheds
SciLinks code: HE4124

SCILINKS. Maintained by the National Science Teachers Association



Geofact

How Much Groundwater Is There on Earth? There are about 50 million cubic kilometers of groundwater on Earth. That means there is about 20 times more water underground than in all of the rivers and lakes on Earth!

Groundwater

Most of the fresh water that is available for human use cannot be seen—it exists underground. When it rains, some of the water that falls onto the land flows into lakes and streams. But much of the water percolates through the soil and down into the rocks beneath. Water stored beneath the Earth's surface in sediment and rock formations is called **groundwater.**

As water travels beneath the Earth's surface, it eventually reaches a level where the rocks and soil are saturated with water. This level is known as the *water table*. In wet regions, the water table may be at the Earth's surface and a spring of fresh water may flow out onto the ground. But in deserts, the water table may be hundreds of meters beneath the Earth's surface. The water table is actually not as level as its name implies. The water table has peaks and valleys that match the shape of the land above it. Just as surface water flows downhill, groundwater tends to flow slowly from the peaks of the water table to the valleys.

Aquifers An underground formation that contains groundwater is called an **aquifer.** The water table forms the upper boundary of

CASE STUDY

The Ogallala Aquifer: An Underground Treasure

Anyone who has eaten food produced in the United States has probably enjoyed the benefits of the Ogallala Aquifer, one of the largest known aquifers in the world. This enormous underground water system formed from glaciers that melted at the end of the last Ice Age, 12,000 years ago. Today, the Ogallala Aquifer supplies about one-third of all the groundwater used in the United States.

People began to use the Ogallala Aquifer extensively for irrigation in the 1940s. With help from this ancient water source, farmers turned the Great Plains into one of the most productive farming regions in the world. For many years, farmers seemed to enjoy a limitless supply of fresh water. But in recent years, the Ogallala Aquifer has started to show its limits. Water is being withdrawn from the aquifer 10 to 40 times faster than it is being replaced. In some places, the water table has dropped more than 30 m (100 ft) since pumping began.

Humans are not the only living things that depend on the Ogallala Aquifer. In some areas, the aquifer flows onto the surface and creates wetlands, which are a vital habitat for many organisms, especially birds. These wetlands are often the first habitats to disappear when the water table falls.

Many people are working together to try to conserve the Ogallala Aquifer. For example, some farmers have begun to limit irrigation during bird migrations in order to allow surface-water levels

▶ **The Ogallala Aquifer** holds about 4 quadrillion liters of water—enough to cover the United States to a depth of 0.5 m (1.5 ft).

an aquifer. Most aquifers consist of materials such as rock, sand, and gravel that have a lot of spaces where water can accumulate. These aquifers hold water in much the same way that a sponge holds water. Groundwater can also dissolve rock formations, such as those made of limestone, and fill vast caves with water, which creates underground lakes. Aquifers are an important water source for many cities and for agriculture.

Porosity and Permeability How can a rock formation hold millions of gallons of water? Although most rocks appear solid, many kinds of rocks contain small holes, or pore spaces. **Porosity** is the amount of space between the particles that make up a rock. Water in an aquifer is stored in the pore spaces and flows from one pore space to another. The more porous a rock is, the more water it can hold. The ability of rock or soil to allow water to flow through it is called **permeability.** Materials such as gravel that allow the flow of water are *permeable*. Materials such as clay or granite that stop the flow of water are *impermeable*. The most productive aquifers usually form in permeable materials, such as sandstone, limestone, or layers of sand and gravel.

internet connect

www.scilinks.org
Topic: Groundwater
SciLinks code: HE4052
Topic: Aquifers
SciLinks code: HE4004

SCILINKS. Maintained by the National Science Teachers Association

▶ **Sandhill cranes** are among the many kinds of birds that rely on water from the Ogallala Aquifer.

to rise. Other farmers have adopted water-saving irrigation systems and are planting crops such as wheat or grain sorghum, which require less water than corn or cotton.

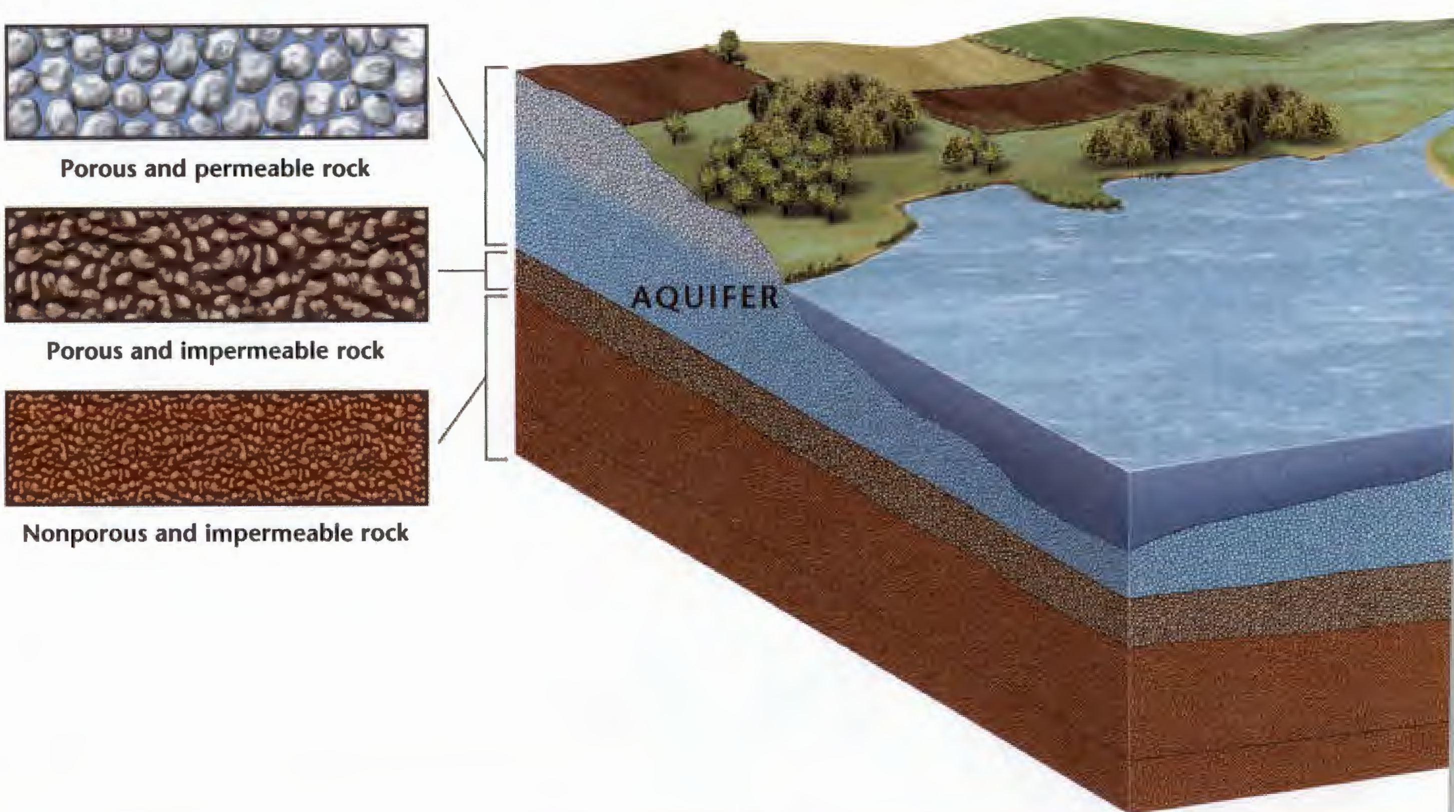
Many farmers and other residents of the Great Plains recognize the value of the Ogallala Aquifer and are fighting to preserve it. They are pressuring politicians to replace policies that encourage wasting water with policies that promote water conservation. These efforts may help save this underground treasure.

CRITICAL THINKING

1. Applying Ideas Most of the water in the Ogallala Aquifer came from glaciers that melted thousands of years ago. What is the aquifer's primary water source today?

2. Expressing Viewpoints Do you think residents of the Great Plains are the only people who have an interest in conserving the Ogallala Aquifer? Write an editorial that expresses your viewpoint. WRITING SKILLS

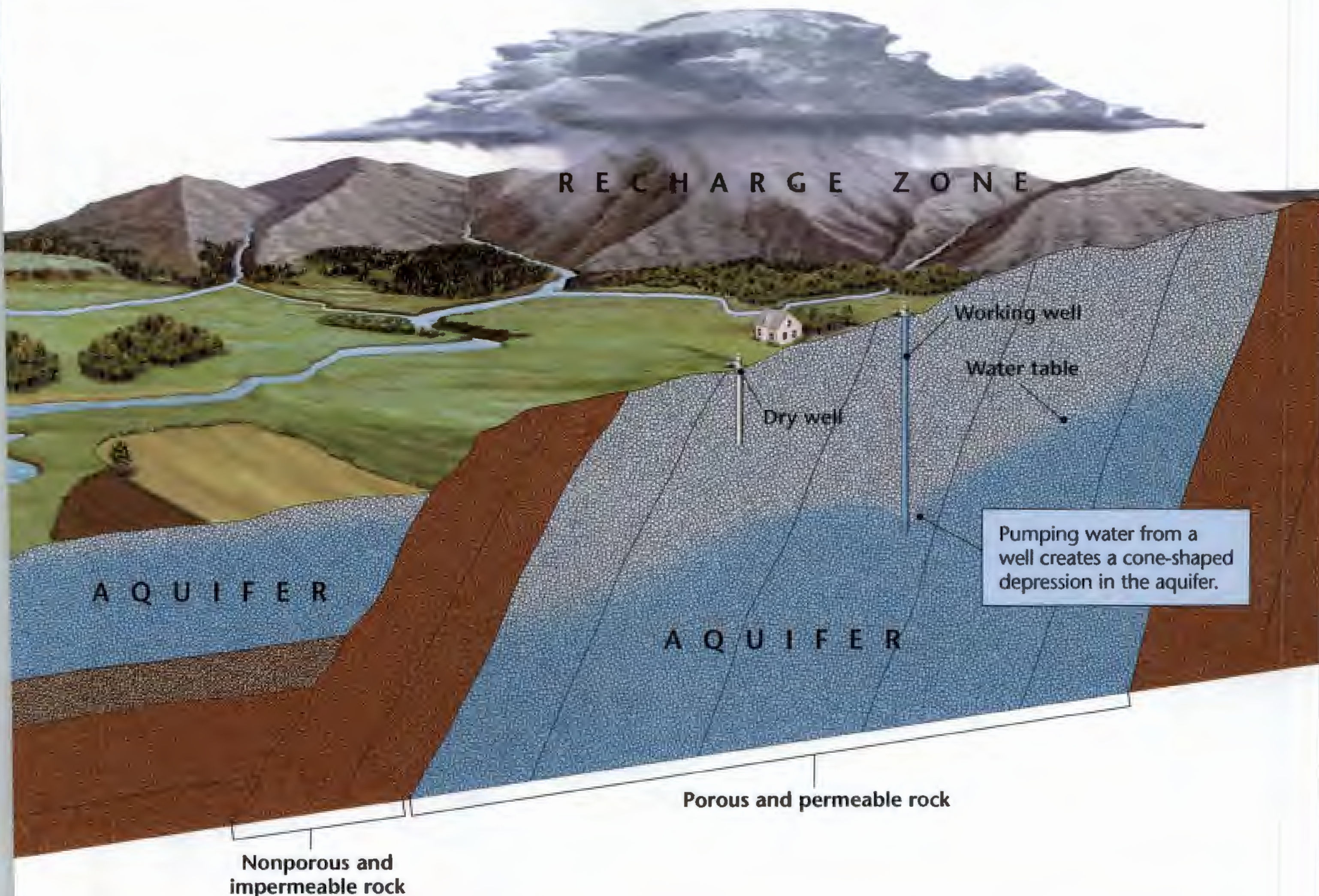
Figure 4 ▶ Groundwater and the Water Table Aquifers are underground formations that hold water. Impermeable rock can be porous or nonporous, but only permeable rock allows water to pass through it.



The Recharge Zone To reach an aquifer, surface water must travel down through permeable layers of soil and rock. Water cannot reach an aquifer from places where the aquifer is covered by impermeable materials. Notice the permeable layers above the aquifer in **Figure 4.** The area of the Earth's surface where water percolates down into the aquifer is called the **recharge zone.** Recharge zones are environmentally sensitive areas because any pollution in the recharge zone can also enter the aquifer.

The size of an aquifer's recharge zone is affected by the permeability of the surface above the aquifer. Structures such as buildings and parking lots can act as impermeable layers to reduce the amount of water entering an aquifer. Communities should carefully manage recharge zones, because surface water can take a very long time to refill an aquifer. In fact, aquifers can take tens of thousands of years to recharge.

Wells If you go nearly anywhere on Earth and dig a hole deep enough, you will eventually find water. A hole that is dug or drilled to reach groundwater is called a well. For thousands of years, humans have dug wells to reach groundwater. We dig wells because groundwater may be a more reliable source of water



than surface water and because water is filtered and purified as it travels underground. The height of the water table changes seasonally, so wells are drilled to extend below the water table. However, if the water table falls below the bottom of the well during a drought, the well will dry up. In addition, if groundwater is removed faster than it is recharged, the water table may fall below the bottom of a well. To continue supplying water, the well must be drilled deeper.

SECTION 1 Review

1. **Describe** the distribution of water on Earth. Where is most of the fresh water located?
2. **Explain** why fresh water is considered a limited resource.
3. **Explain** why pollution in a watershed poses a potential threat to the river system that flows through it.
4. **Describe** how water travels through rock.

CRITICAL THINKING

5. **Making Comparisons** Read the description of aquifers. How are aquifers like water-filled sponges? READING SKILLS
6. **Analyzing Relationships** Describe the relationship between groundwater and surface water in a watershed. What human activities in a recharge zone can affect the groundwater?

SECTION 2
Water Use and Management

Objectives

- Identify patterns of global water use.
- Explain how water is treated so that it can be used for drinking.
- Identify how water is used in homes, in industry, and in agriculture.
- Describe how dams and water diversion projects are used to manage freshwater resources.
- Identify five ways that water can be conserved.

Key Terms

potable
pathogen
irrigation
dam
reservoir
desalination

You may have heard the expression "We all live downstream." When a water supply is polluted or overused, everyone living downstream can be affected. The number of people who rely on the Earth's limited freshwater reserves is increasing every day. In fact, a shortage of clean, fresh water is one of the world's most pressing environmental problems. According to the World Health Organization, more than 1 billion people lack access to a clean, reliable source of fresh water.

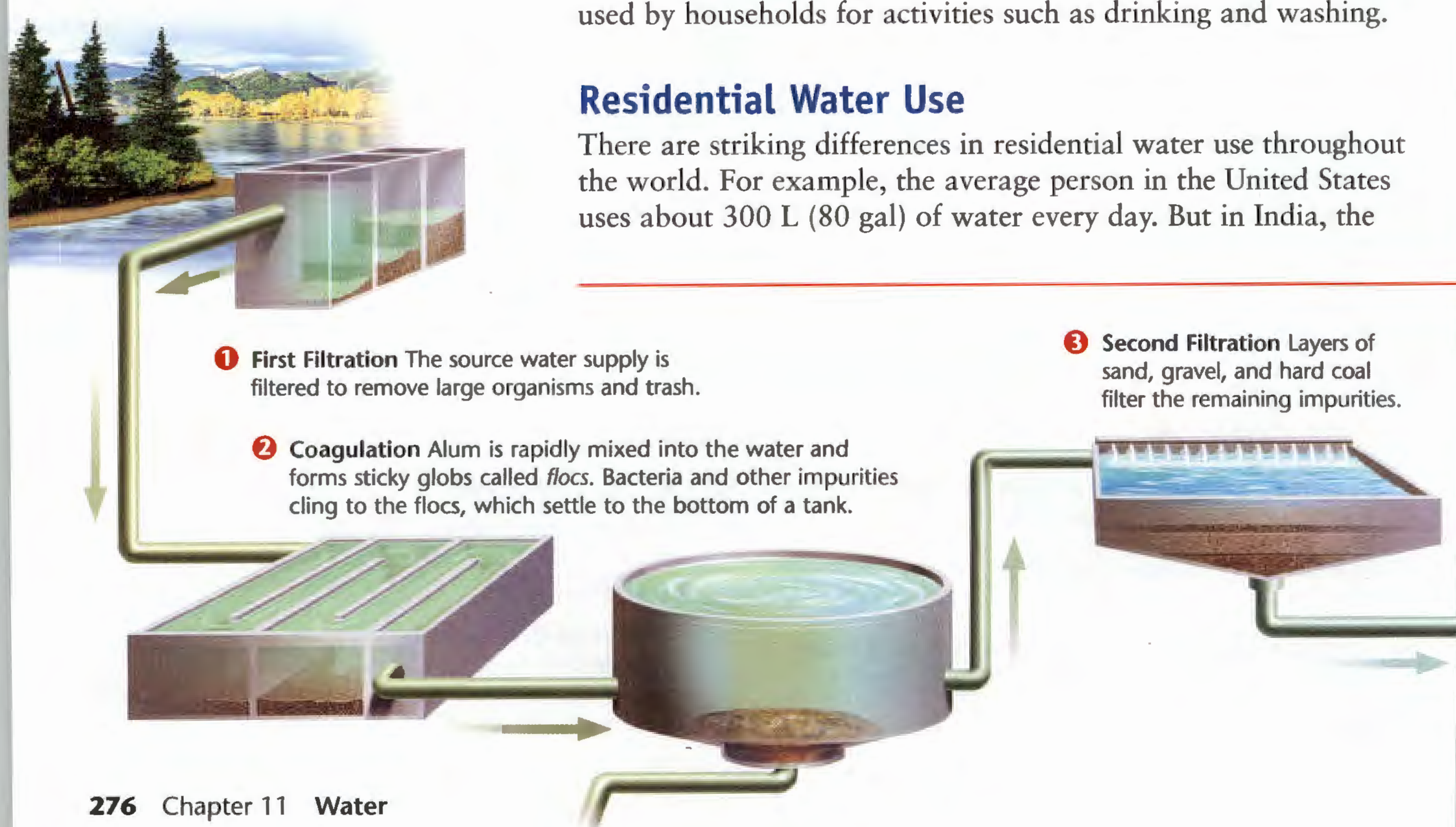
Global Water Use

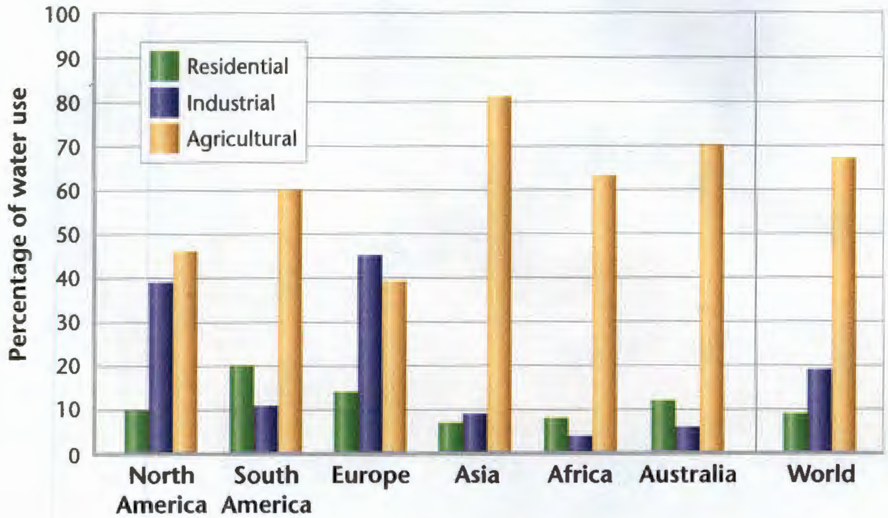
To understand the factors that affect the world's supply of fresh water, we must first explore how people use water. **Figure 5** shows the three major uses for water—residential use, agricultural use, and industrial use.

Most of the fresh water used worldwide is used to irrigate crops. Patterns of water use are not the same everywhere, however. The availability of fresh water, population sizes, and economic conditions affect how people use water. In Asia, agriculture accounts for more than 80 percent of water use, whereas it accounts for only 38 percent of water use in Europe. Industry accounts for about 19 percent of the water used in the world. The highest percentage of industrial water use occurs in Europe and North America. Globally, about 8 percent of water is used by households for activities such as drinking and washing.

Residential Water Use

There are striking differences in residential water use throughout the world. For example, the average person in the United States uses about 300 L (80 gal) of water every day. But in India, the





Source: World Resources Institute.

Figure 5 ▶ Europe is the only continent that uses more water for industry than for agriculture.

average person uses only 41 L of water every day. In the United States, only about half of residential water use is for activities inside the home, such as drinking, cooking, washing, and toilet flushing. The remainder of the water used residentially is used outside the home for activities such as watering lawns and washing cars. **Table 1** shows how the average person in the United States uses water.

Table 1 ▼

Daily Water Use in the United States (per Person)	
Use	**Water (L)**
Lawn watering and pools	95
Toilet flushing	90
Bathing	70
Brushing teeth*	10
Cleaning (inside and outside)	20
Cooking and drinking	10
Other	5

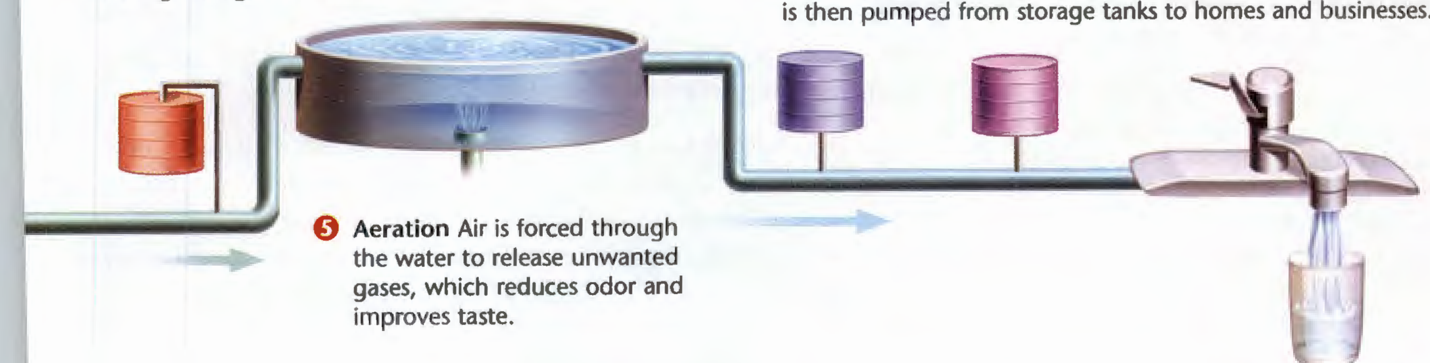
*with water running
Source: U.S. Environmental Protection Agency.

Water Treatment Most water must be treated to make it **potable,** or safe to drink. Water treatment removes elements such as mercury, arsenic, and lead, which are poisonous to humans even in low concentrations. These elements are found in polluted water, but they can also occur naturally in groundwater. Water treatment also removes **pathogens,** which are organisms that cause illness or disease. Bacteria, viruses, protozoa, and parasitic worms are common pathogens. Pathogens are found in water contaminated by sewage or animal feces. There are several methods of treating water to make it potable. **Figure 6** shows a common drinking water treatment method that includes both physical and chemical treatment.

Figure 6 ▶ Drinking-Water Treatment

4 Chlorination Chlorine is added to prevent bacteria from growing in the water.

6 Additional Treatment In some communities, fluoride may be added to prevent tooth decay. Sodium compounds or lime may also be added to soften hard water. Treated water is then pumped from storage tanks to homes and businesses.



5 Aeration Air is forced through the water to release unwanted gases, which reduces odor and improves taste.

Figure 7 ▶ Water is a very important industrial resource. These nuclear power plant cooling towers release the steam produced from water used to cool a nuclear reactor.

Industrial Water Use

Industry accounts for 19 percent of water used in the world. Water is used to manufacture goods, to dispose of waste, and to generate power. The amount of water needed to manufacture everyday items can be astounding. For instance, nearly 1,000 L of water are needed to produce 1 kg of aluminum, and almost 500,000 L of water are needed to manufacture a car. Vast amounts of water are required to produce computer chips and semiconductors.

Most of the water that is used in industry is used to cool power plants. **Figure** 7 shows water being released as steam from nuclear power plant cooling towers. Power-plant cooling systems usually pump water from a surface water source such as a river or lake, carry the water through pipes in a cooling tower, and then pump the water back into the source. The water that is returned is usually warmer than the source, but it is generally clean and can be used again.

Graphic Organizer **Comparison Table**

Create the **Graphic Organizer** entitled "Comparison Table" described in the Appendix. Label the columns with "Residential Water Use," "Industrial Water Use," and "Agricultural Water Use." Label the rows with "Characteristics" and "Water Conservation." Then, fill in the table with details about the characteristics and the ways water can be conserved in each type of water use.

Agricultural Water Use

Did you know that it can take nearly 300 L (80 gal) of water to produce one ear of corn? That's as much water as an average person in the United States uses in a day! Agriculture accounts for 67 percent of the water used in the world. Plants require a lot of water to grow, and as much as 80 percent of the water used in agriculture evaporates and never reaches plant roots.

Irrigation Fertile soil is sometimes found in areas of the world that do not have abundant rainfall. In regions where rainfall is inadequate, extra water can be supplied by irrigation. **Irrigation** is a method of providing plants with water from sources other than direct precipitation. The earliest form of irrigation probably involved flooding fields with water from a nearby river.

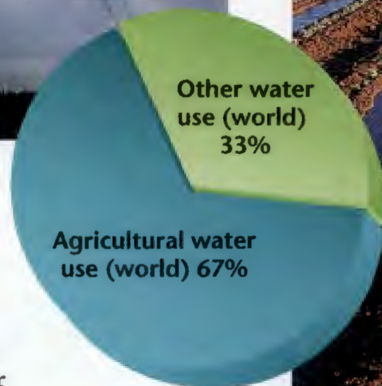


Figure 8 ▶ High-pressure overhead sprinklers (left) are inefficient because a lot of water is lost to evaporation. Water-filled ditches (above) irrigate cotton seedlings.

Many different irrigation techniques are used today. For example, some crops, such as cotton, are irrigated by shallow, water-filled ditches, as shown in **Figure 8.** In the United States, high-pressure overhead sprinklers are the most common form of irrigation. This method of irrigation is inefficient because nearly half the water evaporates and never reaches the plant roots. Irrigation systems that use water more efficiently are becoming more common.

Water Management Projects

For thousands of years, humans have altered streams and rivers to make them more useful. Nearly two thousand years ago, the Romans built aqueducts, huge canals that brought water from the mountains to the dry areas of France and Spain. One such aqueduct is shown in **Figure 9.** Some of these aqueducts are still used today. Engineering skills have improved since the time of the Romans, and water projects have become more complex.

People often prefer to live in areas where the natural distribution of surface water is inadequate. Water management projects, such as dams and water diversion canals, are designed to meet these needs. Water management projects can have various goals, such as bringing in water to make a dry area habitable, creating a reservoir for recreation or drinking water, or generating electric power. Water management projects have changed the American Southwest and have proved that if water can be piped in, people can live and grow crops in desert areas.

Figure 9 ▶ This Spanish aqueduct was built almost two thousand years ago by the Romans.

Water Diversion Projects To supply dry regions with water, all or part of a river can be diverted into canals that carry water across great distances. **Figure 10** shows a canal that diverts the Owens River in California to provide drinking water for Los Angeles. Another river, the Colorado River, is diverted to provide water for several states. The Colorado River begins as a glacial stream in the Rocky Mountains and quickly grows larger as other streams feed into it. As the river flows south, however, it is divided to meet the needs of seven western states. So much of the Colorado River's water is diverted for irrigation and drinking water in states such as Arizona, Utah, and California that the river often runs dry before it reaches Mexico and flows into the Gulf of California. In fact, the Colorado River reaches the Gulf only in the wettest years.

Dams and Reservoirs A **dam** is a structure built across a river to control the river's flow. When a river is dammed, an artificial lake, or **reservoir,** is formed behind the dam. Water from a reservoir can be used for flood control, drinking water, irrigation, recreation, and industry. Dams are also used to generate electrical energy. Hydroelectric dams use the power of flowing water to turn a turbine that generates electrical energy. About 20 percent of the world's electrical energy is generated by hydroelectric dams, such as the one shown in **Figure 11.**

Although dams provide many benefits, interrupting a river's flow can also have far-reaching consequences. When the land behind a dam is flooded, people are often displaced and entire ecosystems can be destroyed. It is estimated that 50 million people around the world have been displaced by dam projects. Dams also affect

Figure 10 ▶ This canal carries water more than 300 km across mountains and deserts to supply drinking water to Los Angeles, California.

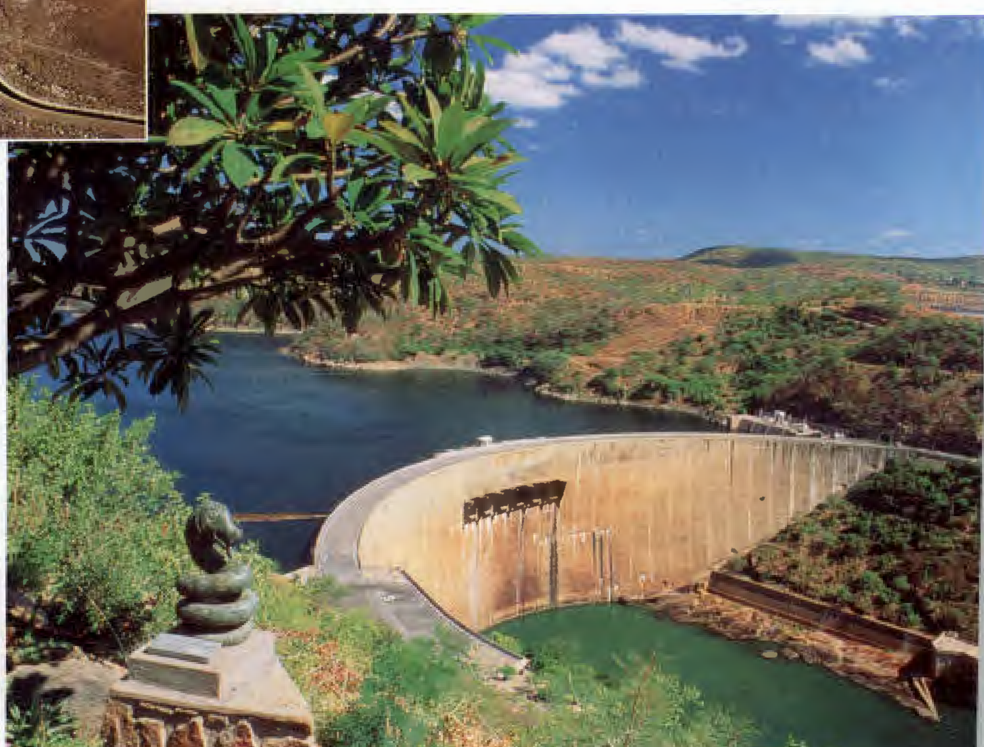


Figure 11 ▶ Dams, such as this one in Zimbabwe, are built to manage freshwater resources.

the land below them. As a river enters a reservoir, it slows down and deposits some of the sediment it carries. This fertile sediment builds up behind a dam instead of enriching the land farther down the river. As a result, the farmland below a dam may become less productive. Dam failure can be another problem—if a dam bursts, people living along the river below the dam can be killed. In the United States, the era of large dam construction is probably over. But in developing countries, such as Brazil, India, and China, the construction of large dams continues.

MATHPRACTICE

Israeli Agriculture
From 1950 to 1980, Israel reduced the amount of water loss in agriculture from 83 percent to 5 percent, mainly by switching from overhead sprinklers to water-saving methods such as drip irrigation. If a small farm uses 10,000 L of water a day for overhead sprinkler irrigation, how much water would be saved in one year by using a drip irrigation system that consumes 75 percent less water?

Water Conservation

As water sources become depleted, water becomes more expensive. This is because wells must be dug deeper, water must be piped greater distances, and polluted water must be cleaned up before it can be used. Water conservation is one way that we can help ensure that everyone will have enough water at a reasonable price.

Water Conservation in Agriculture Most of the water loss in agriculture comes from evaporation, seepage, and runoff, so technologies that reduce these problems go a long way toward conserving water. *Drip irrigation systems* offer a promising step toward conservation. Shown in **Figure 12**, drip irrigation systems deliver small amounts of water directly to plant roots by using perforated tubing. Water is released to plants as needed and at a controlled rate. These systems are sometimes managed by computer programs that coordinate watering times by using satellite data. Using precise information, a well-designed drip irrigation system loses very little water to evaporation, seepage, or runoff.

Water Conservation in Industry As water resources have become more expensive, many industries have developed water conservation plans. In industry today, the most widely used water conservation practices involve the recycling of cooling water and wastewater. Instead of discharging used water into a nearby river, businesses often recycle water and use it again. Thus, the production of 1 kg of paper now consumes less than 30 percent of the water it required 50 years ago. Small businesses are also helping conserve water. Denver, Colorado, was one of the first cities to realize the value of conserving water in business. In an innovative program, the city pays small businesses to introduce water conservation measures. The program not only saves money for the city and for businesses but also makes more water available for agricultural and residential use.

Figure 12 ▶ Drip irrigation systems use perforated tubing to deliver water directly to plant roots.

Figure 13 ▶ This xeriscaped yard in Arizona features plants that are native to the state. What kinds of plants are native to your region?

Table 2 ▼

What You Can Do to Conserve Water
• Take shorter showers, and avoid taking baths unless you keep the water level low.
• Install a low-flow shower head in your shower.
• Install inexpensive, low-flow aerators in your water faucets at home.
• Purchase a modern, low-flow toilet, install a water-saving device in your toilet, or simply place a water-filled bottle inside your toilet tank to reduce the water used for each flush.
• Do not let the water run while you are brushing your teeth.
• Fill up the sink basin rather than letting the water run when you are shaving, washing your hands or face, or washing dishes.
• Wash only full loads in your dishwasher and washing machine.
• Water your lawn sparingly.

Water Conservation at Home Although households use much less water than agriculture or industry, a few changes to residential water use will make a significant contribution to water conservation. People can conserve water by changing a few everyday habits and by using only the water that they need. Some of these conservation methods are shown in **Table 2.**

Water-saving technology, such as low-flow toilets and shower heads, can also help reduce household water use. These devices are required in some new buildings. Many cities will also pay residents to install water-saving equipment in older buildings.

About one-third of the water used by the average household in the United States is used for landscaping. To conserve water, many people water their lawns at night to reduce the amount of water lost to evaporation. Another way people save water used outside their home is a technique called *xeriscaping* (ZIR i SKAY ping). Xeriscaping involves designing a landscape that requires minimal water use. **Figure 13** shows one example of xeriscaping in Arizona.

Can one person make a difference? When you multiply one by the millions of people who are trying to conserve water—in industry, on farms, and at home—you can make a big difference.

Solutions for the Future

In some places, conservation alone is not enough to prevent water shortages, and as populations grow, other sources of fresh water need to be developed. Two possible solutions are desalination and transporting fresh water.

Desalination Some coastal communities rely on the oceans to provide fresh water. Desalination (DEE SAL uh NAY shuhn) is the process of removing salt from salt water. Some countries in drier parts of the world, such as the Middle East, have built desalination plants to provide fresh water. Most desalination plants heat salt water and collect the fresh water that evaporates. **Figure 14** shows one such plant in Kuwait. Because desalination consumes a lot of energy, the process is too expensive for many nations to consider.

Transporting Water In some areas of the world where freshwater resources are not adequate, water can be transported from other regions. For example, the increasing number of tourists visiting some Greek islands in the Mediterranean Sea have taxed the islands' freshwater supply. As a result, ships travel regularly from the mainland towing enormous plastic bags full of fresh water. The ships anchor in port, and fresh water is then pumped onto the islands. This solution is also being considered in the United States, where almost half of the available fresh water is in Alaska. Scientists are exploring the possibility of filling huge bags with water from Alaskan rivers and then towing the bags down the coast to California, where fresh water is often in short supply.

Because 76 percent of the Earth's fresh water is frozen in icecaps, icebergs are another potential freshwater source. For years, people have considered towing icebergs to communities that lack fresh water. But an efficient way to tow icebergs is yet to be discovered.

internet connect
www.scilinks.org
Topic: Water Conservation
SciLinks code: HE4121
SCILINKS. Maintained by the National Science Teachers Association

Figure 14 ▶ Most desalination plants, such as this one in Kuwait, use evaporation to separate ocean water from the salt it contains.

SECTION 2 Review

1. **Describe** the patterns of global water use for each continent shown in the bar graph in Figure 5.
2. **Describe** the drinking water treatment process in your own words.
3. **Describe** the benefits and costs of dams and water diversion projects.
4. **List** some things you can do to help conserve the world's water supply. Give at least three examples.

CRITICAL THINKING

5. **Making Comparisons** Write a description of the evaporative method of desalination using terms from the water cycle. WRITING SKILLS
6. **Identifying Alternatives** Describe three ways that communities can increase their freshwater resources.

SECTION 3

Water Pollution

Objectives

- Compare point-source pollution and nonpoint-source pollution.
- Classify water pollutants by five types.
- Explain why groundwater pollution is difficult to clean.
- Describe the major sources of ocean pollution, and explain the effects of pollution on ecosystems.
- Describe six major laws designed to improve water quality in the United States.

Key Terms

water pollution
point-source pollution
nonpoint-source pollution
wastewater
artificial eutrophication
thermal pollution
biomagnification

You might think that you can tell if a body of water is polluted by the way that the water looks or smells, but sometimes you can't. There are many different forms of water pollution. **Water pollution** is the introduction of chemical, physical, or biological agents into water that degrade water quality and adversely affect the organisms that depend on the water. Almost all of the ways that we use water contribute to water pollution. However, the two underlying causes of water pollution are industrialization and rapid human population growth.

In the last 30 years, developed countries have made great strides in cleaning up many polluted water supplies. Despite this progress, some water is still dangerously polluted in the United States and in other countries. In developing parts of the world, water pollution is a big problem. Industry is usually not the major cause of water pollution in developing countries. Often, the only water available for drinking in these countries is polluted with sewage and agricultural runoff, which can spread waterborne diseases. To prevent water pollution, people must understand where pollutants come from. As you will learn, water pollution comes from two types of sources: point and nonpoint sources.

Figure 15 ▶ Point-source pollution comes from a single, easily identifiable source. In this photo, the waste from an iron mine is being stored in a pond.

Table 3 ▼

Sources of Point Pollution
• leaking septic-tank systems
• leaking storage lagoons for polluted waste
• unlined landfills
• leaking underground storage tanks that contain chemicals or fuels such as gasoline
• polluted water from abandoned and active mines
• water discharged by industries
• public and industrial wastewater treatment plants

Point-Source Pollution

When you think of water pollution, you probably think of a single source, such as a factory, a wastewater treatment plant, or a leaking oil tanker. These are all examples of **point-source pollution,** which is pollution discharged from a single source. **Table 3** lists some additional examples of point-source pollution. Point-source pollution can often be identified and traced to a source. But even when the source of pollution is known, enforcing cleanup is sometimes difficult.

Nonpoint-Source Pollution

Nonpoint-source pollution comes from many different sources that are often difficult to identify. For example, a river can be polluted by runoff from any of the land in its watershed. If a farm, a road, or any other land surface in a watershed is polluted, runoff from a rainstorm can carry the pollution into a nearby river, stream, or lake. **Figure 16** shows common sources of nonpoint pollutants. **Table 4** lists some additional causes of nonpoint pollution.

Because nonpoint pollutants can enter bodies of water in many different ways, they are extremely difficult to regulate and control. The accumulation of small amounts of water pollution from many sources is a major pollution problem—96 percent of the polluted bodies of water in the United States were contaminated by nonpoint sources. Controlling nonpoint-source pollution depends to a great extent on public awareness of the effects of activities such as spraying lawn chemicals and using storm drains to dispose of used motor oil.

Figure 16 ▶ Sources of Nonpoint Pollution Examples of nonpoint-source pollution include ❶ livestock polluting water holes that can flow into streams and reservoirs, ❷ oil on a street, which can wash into storm sewers and then drain into waterways, and ❸ thousands of watercraft, which can leak gasoline and oil.

FIELD ACTIVITY

Identifying Sources of Pollution Walk around your neighborhood, and record potential sources of nonpoint pollution. See Table 4 for examples. Count the number of potential sources of nonpoint pollution, and suggest ways to reduce each source of pollution in your ***EcoLog.***

Table 4 ▼

Nonpoint Sources of Pollution
• chemicals added to road surfaces (salt and other de-icing agents)
• water runoff from city and suburban streets that may contain oil, gasoline, animal feces, and litter
• pesticides, herbicides, and fertilizer from residential lawns, golf courses, and farmland
• feces and agricultural chemicals from livestock feedlots
• precipitation containing air pollutants
• soil runoff from farms and construction sites
• oil and gasoline from personal watercraft

Table 5 ▼

Pollutant Types and Sources		
Type of pollutant	**Agent**	**Major sources**
Pathogens	disease-causing organisms, such as bacteria, viruses, protozoa, and parasitic worms	mostly nonpoint sources; sewage or animal feces, livestock feedlots, and poultry farms; sewage from overburdened wastewater treatment plants
Organic matter	animal and plant matter remains, feces, food waste, and debris from food-processing plants	mostly nonpoint sources
Organic chemicals	pesticides, fertilizers, plastics, detergents, gasoline and oil, and other materials made from petroleum	mostly nonpoint sources; farms, lawns, golf courses, roads, wastewater, unlined landfills, and leaking underground storage tanks
Inorganic chemicals	acids, bases, salts, and industrial chemicals	point sources and nonpoint sources; industrial waste, road surfaces, wastewater, and polluted precipitation
Heavy metals	lead, mercury, cadmium, and arsenic	point sources and nonpoint sources; industrial discharge, unlined landfills, some household chemicals, and mining processes; heavy metals also occur naturally in some groundwater
Physical agents	heat and suspended solids	point sources and nonpoint sources; heat from industrial processes and suspended solids from soil erosion

Principal Water Pollutants

There are many different kinds of water pollutants. **Table 5** lists some common types of pollutants and some of the possible sources of each pollutant.

Wastewater

Do you know where water goes after it flows down the drain in a sink? The water usually flows through a series of sewage pipes that carry it—and all the other wastewater in your community—to a wastewater treatment plant. **Wastewater** is water that contains waste from homes or industry. At a wastewater treatment plant, water is filtered and treated to make the water clean enough to return to a river or lake.

Treating Wastewater A typical residential wastewater treatment process is illustrated in **Figure 17.** Most of the wastewater from homes contains biodegradable material that can be broken down by living organisms. For example, wastewater from toilets and kitchen sinks contains animal and plant wastes, paper, and soap, all of which are biodegradable. But wastewater treatment plants may not remove all of the harmful substances in water. Some household and industrial wastewater and some storm-water runoff contains toxic substances that cannot be removed by the standard treatment.

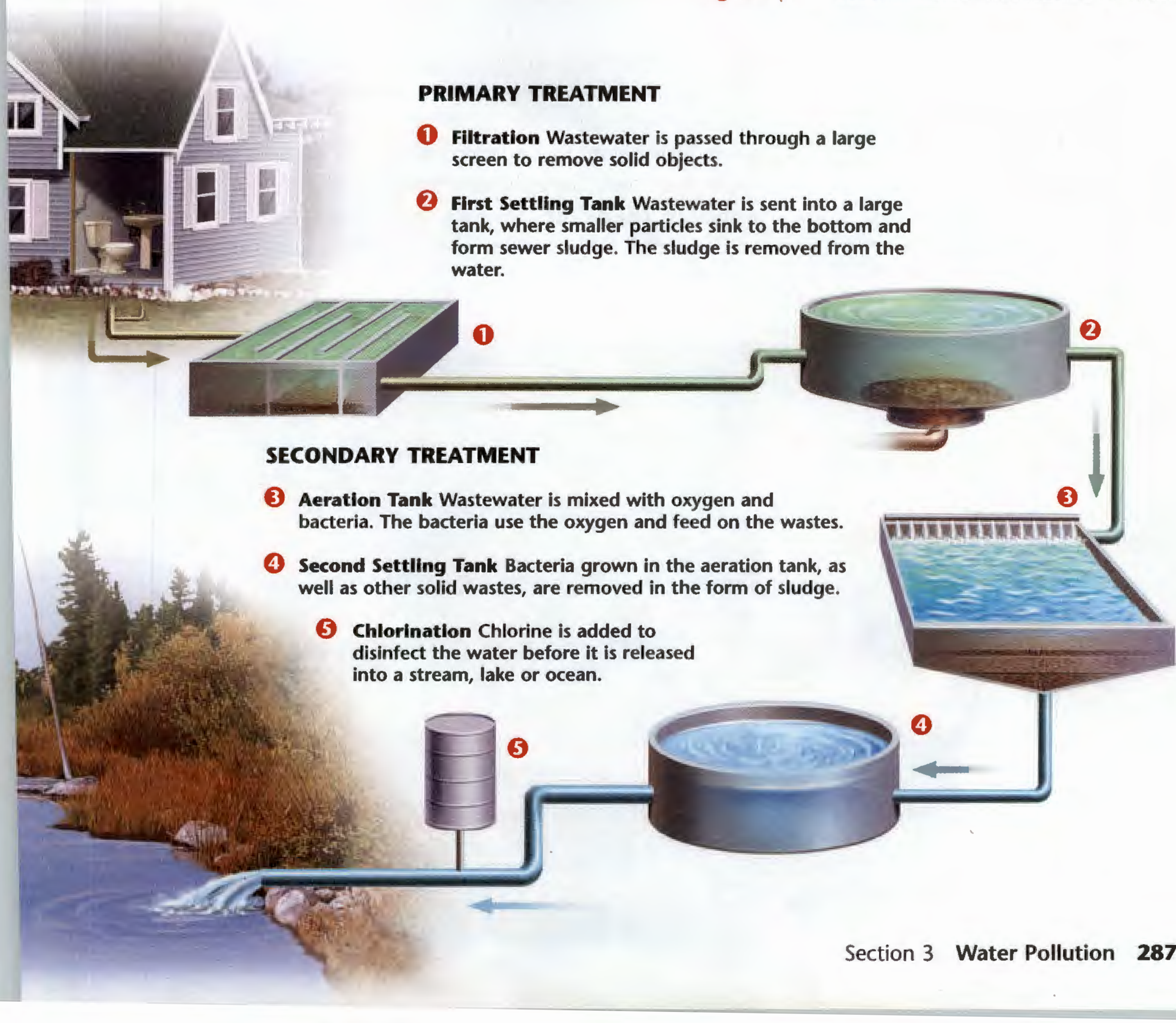
Sewage Sludge If you look again at **Figure 17,** you will see that one of the products of wastewater treatment is *sewage sludge,* the solid material that remains after treatment. When sludge contains dangerous concentrations of toxic chemicals, it must be disposed of as hazardous waste. The sludge is often incinerated, and then the ash is buried in a secure landfill. Sludge can be an expensive burden to towns and cities because the volume of sludge that has to be disposed of every year is enormous.

The problem of sludge disposal has prompted many communities to look for new uses for this waste. If the toxicity of sludge can be reduced to safe levels, sludge can be used as a fertilizer. In another process, sludge is combined with clay to make bricks that can be used in buildings. In the future, industries will probably find other creative ways to use sludge.

Connection to History

***Cryptosporidium* Outbreak** In 1993, a pathogen called *Cryptosporidium parvum* contaminated the municipal water supply of Milwaukee, Wisconsin. The waterborne parasite caused more than 100 deaths, and 400,000 people experienced a flulike illness. *Cryptosporidium* is found in animal feces, but the parasite usually occurs in low levels in water supplies. The outbreak in Milwaukee was probably caused by an unusual combination of heavy rainfall and agricultural runoff that overburdened the city's water treatment plants.

Figure 17 ▶ **Wastewater Treatment Process**



QuickLAB

Measuring Dissolved Oxygen

Procedure

1. Start with **three water samples,** each in a **plastic jar** that is ¾ full. Two water samples should be tap water from a faucet without an aerator. One sample should be water that has been boiled and allowed to cool.
2. Using a **dissolved-oxygen test kit,** test the boiled water and one other water sample.
3. Tighten the lid on the third sample, and then vigorously shake the sample for one minute. Unscrew the lid, and then recap the jar.
4. Repeat step 3 twice. Then, uncap the jar quickly, and test the sample.

Analysis

1. Which sample had the highest dissolved oxygen level? Which sample had the lowest level?
2. What effects do rapids and waterfalls have on the levels of dissolved oxygen in a stream? What effect does thermal pollution have?

Artificial Eutrophication

Most nutrients in water come from organic matter, such as leaves and animal waste, that is broken down into mineral nutrients by decomposers such as bacteria and fungi. Nutrients are an essential part of any aquatic ecosystem, but an overabundance of nutrients can disrupt an ecosystem. When lakes and slow-moving streams contain an abundance of nutrients, they are eutrophic (yoo TROH fik).

Eutrophication is a natural process. When organic matter builds up in a body of water, it will begin to decay and decompose. The process of decomposition uses up oxygen. As oxygen levels decrease, the types of organisms that live in the water change over time. For example, as a body of water becomes eutrophic, plants take root in the nutrient-rich sediment at the bottom. As more plants grow, the shallow waters begin to fill in. Eventually, the body of water becomes a swamp or marsh.

The natural process of eutrophication is accelerated when inorganic plant nutrients, such as phosphorus and nitrogen, enter the water from sewage and fertilizer runoff. Eutrophication caused by humans is called **artificial eutrophication.** Fertilizer from farms, lawns, and gardens is the largest source of nutrients that cause artificial eutrophication. Phosphates in some laundry and dishwashing detergents are another major cause of eutrophication. Phosphorus is a plant nutrient that can cause the excessive growth of algae. In bodies of water polluted by phosphorus, algae can form large floating mats, called *algal blooms,* as shown in **Figure 18.** As the algae die and decompose, most of the dissolved oxygen is used and fish and other organisms suffocate in the oxygen-depleted water.

Figure 18 ▶ In an effort to limit artificial eutrophication, some states have either banned phosphate detergents or limited the amount of phosphates in detergents.

Figure 19 ▶ Fish kills, such as this one in Brazil, can result from thermal pollution.

Thermal Pollution

If you look at **Figure 19**, you might assume that a toxic chemical caused the massive fish kill in the photo. But the fish were not killed by a chemical spill—they died because of thermal pollution. When the temperature of a body of water, such as a lake or stream, increases, **thermal pollution** can result. Thermal pollution can occur when power plants and other industries use water in their cooling systems and then discharge the warm water into a lake or river.

Thermal pollution can cause large fish kills if the discharged water is too warm for the fish to survive. But most thermal pollution is more subtle. If the temperature of a body of water rises even a few degrees, the amount of oxygen the water can hold decreases significantly. As oxygen levels drop, aquatic organisms may suffocate and die. If the flow of warm water into a lake or stream is constant, it may cause the total disruption of an aquatic ecosystem.

Groundwater Pollution

Pollutants usually enter groundwater when polluted surface water percolates down from the Earth's surface. Any pollution of the surface water in an area can affect the groundwater. Pesticides, herbicides, chemical fertilizers, and petroleum products are common groundwater pollutants. Leaking underground storage tanks are another major source of groundwater pollution. It is estimated that there are millions of underground storage tanks in the United States. Most of the tanks—located beneath gas stations, farms, and homes—hold petroleum products, such as gasoline and heating fuel. As underground storage tanks age, they may develop leaks, which allow pollutants to seep into the groundwater.

Connection to Chemistry

Dissolved Oxygen One of the most important measures of the health of a body of water is the amount of dissolved oxygen in the water. Gaseous oxygen enters water by diffusion from the surrounding air, as a byproduct of photosynthesis, and as a result of the rapid movement (aeration) of water. The amount of oxygen that water can hold is determined by the water's temperature, pressure, and salinity. Slow-moving waters tend to have low levels of dissolved oxygen, while rapidly flowing streams have higher levels. Artificial eutrophication and thermal pollution also reduce levels of dissolved oxygen. When dissolved oxygen levels remain below 1 to 2 mg/L for several hours, fish and other organisms suffocate, and massive fish kills can result.

MATHPRACTICE

Parts per Million Water contamination is often measured in parts per million (ppm). If the concentration of a pollutant is 5 ppm, there are 5 parts of the pollutant in 1 million parts of water. If the concentration of gasoline is 3 ppm in 650,000 L of water, how many liters of gasoline are in the water?

The location of aging underground storage tanks is not always known, so the tanks often cannot be repaired or replaced until after they have leaked enough pollutants to be located. Modern underground storage tanks are contained in concrete and have many features to prevent leaks. Other sources of groundwater pollution include septic tanks, unlined landfills, and industrial wastewater lagoons, as shown in **Figure 20.**

Cleaning Up Groundwater Pollution Groundwater pollution is one of the most challenging environmental problems that the world faces. Even if groundwater pollution could be stopped tomorrow, some groundwater would remain polluted for generations to come. As you have learned, groundwater recharges very slowly. The process for some aquifers to recycle water and purge contaminants can take hundreds or thousands of years. Groundwater is also difficult to decontaminate because the water is dispersed throughout large areas of rock and sand. Pollution can cling to the materials that make up an aquifer, so even if all of the water in an aquifer were pumped out and replaced with clean water, the groundwater could still become polluted.

Figure 20 ▶ This diagram shows some of the major sources of groundwater pollution. Runoff and percolation transport contaminants to the groundwater.

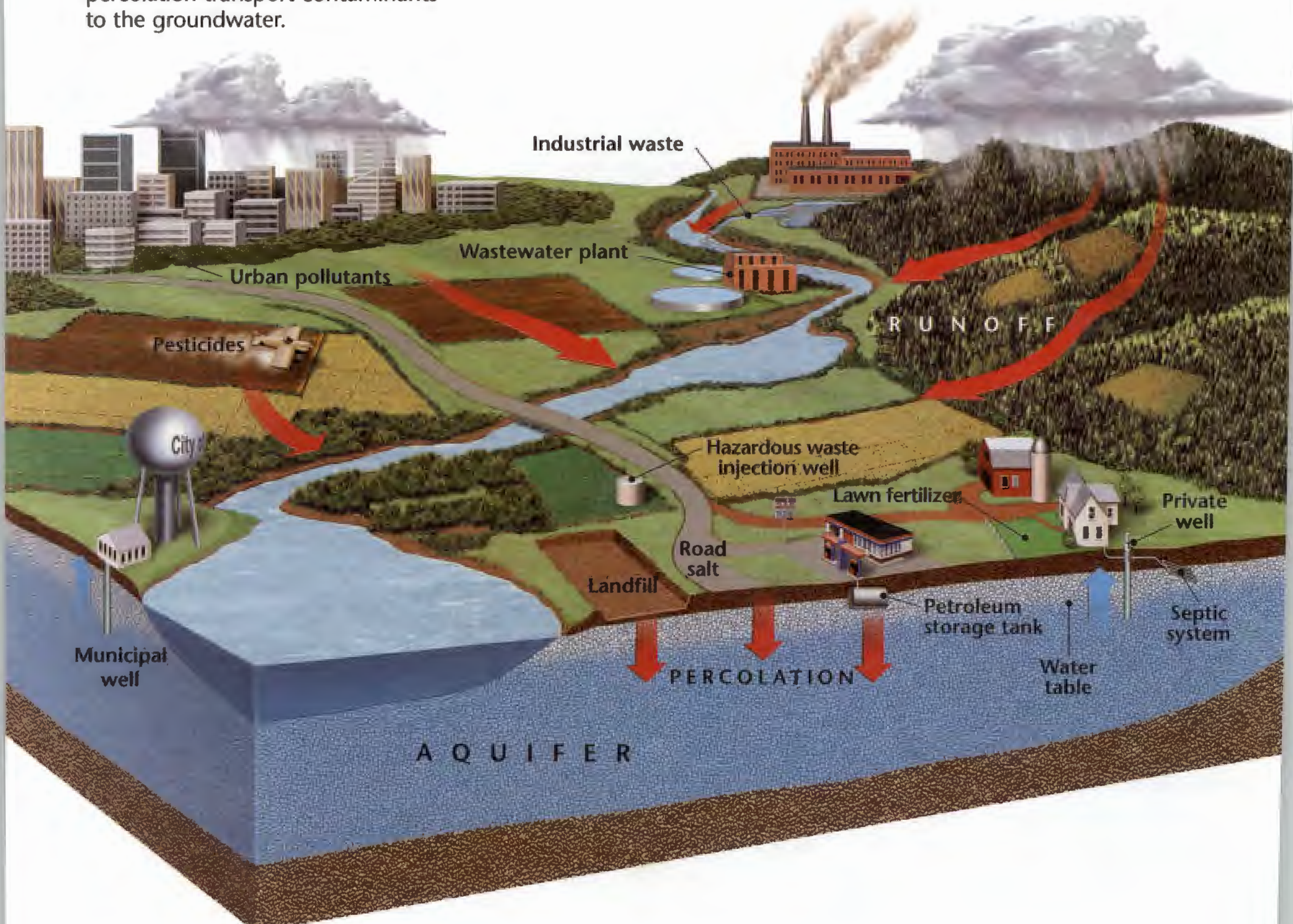
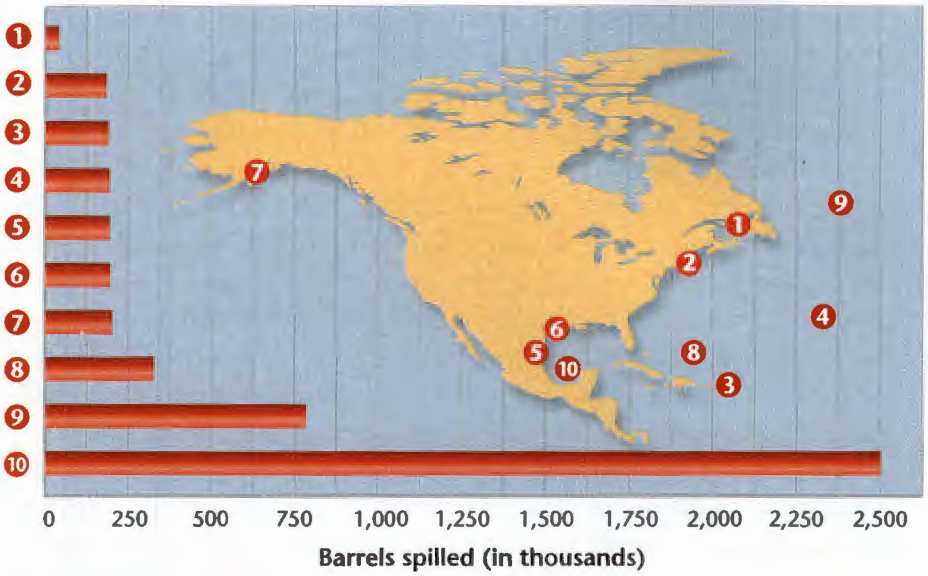


Figure 21 ▶ Major North American Oil Spills



1. *Kurdistan* Gulf of St. Lawrence, Canada, 1979
2. *Argo Merchant* Nantucket, MA, 1976
3. Storage Tank Benuelan, Puerto Rico, 1978
4. *Athenian Venture* Atlantic Ocean, 1988
5. *Unnamed Tanker* Tuxpan, Mexico, 1996
6. *Burmah Agate* Galveston Bay, TX, 1979
7. *Exxon Valdez* Prince William Sound, AK, 1989
8. *Epic Colocotronis* Caribbean Sea, 1975
9. *Odyssey* North Atlantic Ocean, 1988
10. Exploratory Well Bay of Campeche, 1979

Ocean Pollution

Although oceans are the largest bodies of water on Earth, they are still vulnerable to pollution. Pollutants are often dumped directly into the oceans. For example, ships can legally dump wastewater and garbage overboard in some parts of the ocean. But at least 85 percent of ocean pollution—including pollutants such as oil, toxic wastes, and medical wastes—comes from activities on land. If polluted runoff enters rivers, for example, the rivers may carry the polluted water to the ocean. Most activities that pollute oceans occur near the coasts, where much of the world's human population lives. As you might imagine, sensitive coastal ecosystems, such as coral reefs, estuaries, and coastal marshes, are the most affected by pollution.

Oil Spills Ocean water is also polluted by accidental oil spills. Disasters such as the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska, make front-page news around the world. In 2001, a fuel-oil spill off the coast of the Galápagos Islands captured public attention. Each year, approximately 37 million gallons of oil from tanker accidents are spilled into the oceans. **Figure 21** shows some of the major oil spills that occurred off the coast of North America in the last 30 years.

Such oil spills have dramatic effects, but they are responsible for only about 5 percent of oil pollution in the oceans. Most of the oil that pollutes the oceans comes from cities and towns. Every year, as many as 200 million to 300 million gallons of oil enter the ocean from nonpoint sources on land. That's almost 10 times the amount of oil spilled by tankers. In fact, in one year, the road runoff from a coastal city of 5 million people could contain as much oil as a tanker spill does. Limiting these nonpoint sources of oil pollution would go a long way toward keeping the oceans clean.

Ecofact

Cruise Ship Discharges In one year, ships dump almost 7 billion kilograms of trash into the ocean. About 75 percent of all ship waste comes from cruise ships. According to most international law, cruise ships are allowed to dump nonplastic waste—including untreated sewage—into the ocean. Increasing public pressure has begun to cause the cruise-ship industry to change this practice, however.

internet connect

www.scilinks.org
Topic: Water Pollution
SciLinks code: HE4122

SCILINKS. Maintained by the National Science Teachers Association

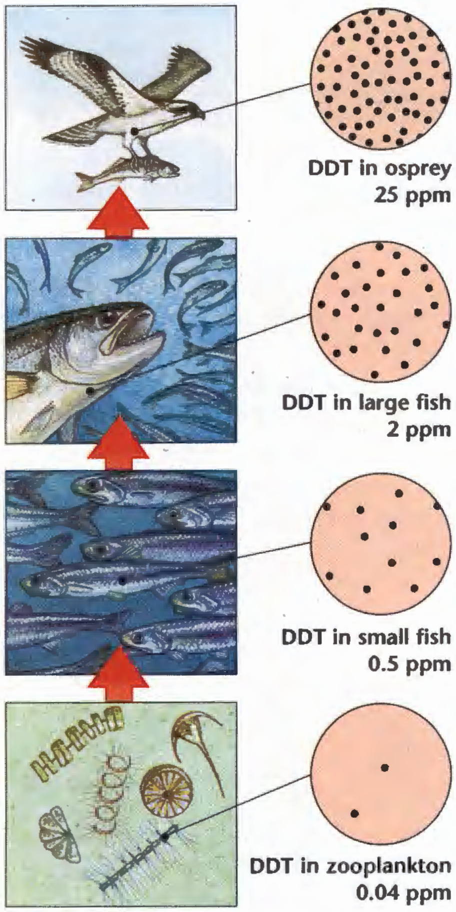


Figure 22 ▶ The accumulation of pollutants at successive levels of the food chain is called biomagnification.

Water Pollution and Ecosystems

Water pollution can cause immediate damage to an ecosystem. For example, toxic chemicals spilled directly into a river can kill nearly all living things for miles downstream. But the effects of water pollution can be even more far reaching. Many pollutants accumulate in the environment because they do not decompose quickly. As the pollutant levels increase, they can threaten an entire ecosystem.

Consider a river ecosystem. Soil tainted with pesticides washes into the river and settles to the river bottom. Some of the pesticides enter the bodies of tiny, bottom-dwelling organisms, such as insect larvae and crustaceans. A hundred of these organisms are eaten by one small fish. A hundred of these small fish are eaten by one big fish. A predatory bird, such as an eagle, eats 10 big fish. Each organism stores the pesticide in its tissues, so at each step along the food chain, the amount of the pesticide passed on to the next organism increases. This accumulation of pollutants at successive levels of the food chain is called **biomagnification.** Biomagnification, which is illustrated in **Figure 22,** has alarming consequences for organisms at the top of the food chain. Biomagnification is one reason why many U.S. states limit the amount of fish that people can eat from certain bodies of water.

Cleaning Up Water Pollution

In 1969, the Cuyahoga River in Cleveland, Ohio, was so polluted that the river caught on fire and burned for several days, as shown in **Figure 23.** This shocking event was a major factor in the passage of the Clean Water Act of 1972. The stated purpose of the act was to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." The goal of the act was to make all surface water clean enough for fishing and swimming by 1983. This goal was not achieved; however, much progress has been made since the act was passed. The percentage of lakes and rivers that are fit for swimming and fishing has increased by about 30 percent, and many states have passed stricter water-quality standards of their own. Many toxic metals are now removed from wastewater before the water is discharged.

The Clean Water Act opened the door for other water-quality legislation, some of which is described in **Table 6.** For example, the Marine Protection, Research, and Sanctuaries Act of 1972 strengthened the laws against ocean dumping.

The Oil Pollution Act of 1990 requires all oil tankers traveling in U.S. waters to

Figure 23 ▶ The Cuyahoga River was so polluted with petroleum and petroleum byproducts that it caught on fire and burned in 1969.

Table 6 ▼

Federal Laws Designed to Improve Water Quality in the United States
1972 Clean Water Act (CWA) The CWA set a national goal of making all natural surface water fit for fishing and swimming by 1983 and banned pollutant discharge into surface water after 1985. The act also required that metals be removed from wastewater.
1972 Marine Protection, Research, and Sanctuaries Act, amended 1988 This act empowered the EPA to control the dumping of sewage wastes and toxic chemicals in U.S. waters.
1975 Safe Drinking Water Act (SDWA), amended 1996 This act introduced programs to protect groundwater and surface water from pollution. The act emphasized sound science and risk-based standards for water quality. The act also empowered communities in the protection of source water, strengthened public right-to-know laws, and provided water system infrastructure assistance.
1980 Comprehensive Environmental Response Compensation and Liability Act (CERCLA) This act is also known as the Superfund Act. The act makes owners, operators, and customers of hazardous waste sites responsible for the cleanup of the sites. The act has reduced the pollution of groundwater by toxic substances leached from hazardous waste dumps.
1987 Water Quality Act This act was written to support state and local efforts to clean polluted runoff. It also established loan funds to pay for new wastewater treatment plants and created programs to protect major estuaries.
1990 Oil Pollution Act This act attempts to protect U.S. waterways from oil pollution by requiring that oil tankers in U.S. waters be double-hulled by 2015.

have double hulls by 2015 as an added protection against oil spills. Legislation has improved water quality in the United States, but the cooperation of individuals, businesses, and the government will be essential to maintaining a clean water supply in the future.

FIELD ACTIVITY

Coastal Cleanups You can be a part of a coastal cleanup. Every September, people from all over the world set aside one day to help clean up debris from beaches. You can join this international effort by writing to The Center for Marine Conservation.

If you do participate in a coastal cleanup, keep a record of the types of trash you find in your ***EcoLog***.

SECTION 3 Review

1. **Explain** why point-source pollution is easier to control than nonpoint-source pollution.
2. **List** the major types of water pollutants. Suggest ways to reduce the levels of each type of pollutant in a water supply.
3. **Describe** the unique problems of cleaning up groundwater pollution.
4. **Describe** the source of most ocean pollution. Is it point-source pollution or nonpoint-source pollution?

CRITICAL THINKING

5. **Interpreting Graphics** Read the description of biomagnification. Draw a diagram that shows the biomagnification of a pollutant in an ecosystem. READING SKILLS
6. **Applying Ideas** What can individuals do to decrease ocean pollution? Write and illustrate a guide that gives at least three examples. WRITING SKILLS

CHAPTER 11 Highlights

1 Water Resources

Key Terms

surface water, 270
river system, 271
watershed, 271
groundwater, 272
aquifer, 272
porosity, 273
permeability, 273
recharge zone, 274

Main Ideas

- Only a small fraction of Earth's water supply is fresh water. The two main sources of fresh water are surface water and groundwater.
- River systems drain the land that makes up a watershed. The amount of water in a river system can vary in different seasons and from year to year.
- Groundwater accumulates in underground formations called *aquifers*. Surface water enters an aquifer through the aquifer's recharge zone.
- If the water in an aquifer is pumped out faster than it is replenished, the water table drops, which can affect humans and animals that depend on the groundwater.

2 Water Use and Management

Key Terms

potable, 277
pathogen, 277
irrigation, 278
dam, 280
reservoir, 280
desalination, 283

Main Ideas

- There are three main types of water use: residential, industrial, and agricultural. Worldwide, most water use is agricultural.
- Dams and water diversion projects are built to manage surface-water resources. Damming and diverting rivers can have environmental and social consequences.
- Water conservation is necessary to maintain an adequate supply of fresh water. Desalination and transporting water are options to supplement local water supplies.

3 Water Pollution

Key Terms

water pollution, 284
point-source pollution, 285
nonpoint-source pollution, 285
wastewater, 286
artificial eutrophication, 288
thermal pollution, 289
biomagnification, 292

Main Ideas

- Water can become polluted by chemical, physical, or biological agents. Most water pollution in the United States is caused by nonpoint-source pollutants.
- Groundwater pollution is difficult to clean up because aquifers recharge slowly and because pollutants cling to the materials that make up an aquifer.
- Ocean pollution is mainly caused by coastal, nonpoint-source pollutants.
- Government legislation, such as the Clean Water Act of 1972, has succeeded in reducing surface-water pollution. Future challenges include reducing nonpoint-source pollution and groundwater pollution.

CHAPTER 11 Review

Using Key Terms

Use each of the following terms in a separate sentence.

1. *aquifer*
2. *recharge zone*
3. *irrigation*
4. *wastewater*
5. *biomagnification*

For each pair of terms, explain how the meanings of the terms differ.

6. *surface water* and *groundwater*
7. *porosity* and *permeability*
8. *watershed* and *river system*
9. *point-source pollution* and *nonpoint-source pollution*

STUDY TIP

Root Words To practice vocabulary, write the key terms and definitions on a piece of paper and fold the paper lengthwise so that the definitions are covered. First, see how many definitions you already know. Then, write the definitions you do not know on another piece of paper, and practice until you know all of the terms.

Understanding Key Ideas

10. Which of the following processes is *not* a part of the water cycle?
    a. evaporation
    b. condensation
    c. biomagnification
    d. precipitation
11. Most of the fresh water on Earth is
    a. located underground in aquifers.
    b. frozen in the polar icecaps.
    c. located in rivers, lakes, streams, and wetlands.
    d. found in Earth's atmosphere.
12. Which of the following processes is *not* used in a conventional method of water treatment?
    a. filtration
    b. coagulation
    c. aeration
    d. percolation
13. Which of the following is *not* an example of point-source pollution?
    a. oil that is escaping from a damaged tanker
    b. heavy metals that are leaching out of an underground mine
    c. water runoff from residential lawns
    d. untreated sewage that is accidentally released from a wastewater treatment plant
14. Which of the following pollutants causes artificial eutrophication?
    a. heavy metals from unlined landfills
    b. inorganic plant nutrients from wastewater and fertilizer runoff
    c. toxic chemicals from factories
    d. radioactive waste from nuclear power plants
15. Pumping large amounts of water from an aquifer may cause the
    a. water table to rise.
    b. recharge zone to shrink.
    c. wells in an area to run dry.
    d. percolation of groundwater to stop.
16. Oil pollution in the ocean is mostly caused by
    a. major oil spills, such as the 1989 *Exxon Valdez* oil spill.
    b. the cumulative effect of small oil spills and leaks on land.
    c. decomposed plastic materials.
    d. intentional dumping of excess oil.
17. Thermal pollution has a harmful effect on aquatic environments because
    a. water has been circulated around power-plant generators.
    b. it increases the number of disease-causing organisms in aquatic environments.
    c. it reduces the amount of dissolved oxygen in aquatic environments.
    d. it decreases the nutrient levels in aquatic environments.

CHAPTER 11 Review

Short Answer

18. What effect can buildings and parking lots have on an aquifer's recharge zone?

19. Why is the use of overhead sprinklers for irrigation inefficient? What is a more efficient method of irrigation?

20. List three advantages and three disadvantages of dams.

21. What is the process of eutrophication, and how do human activities accelerate it?

22. Describe the steps that are involved in the primary and secondary treatment of wastewater.

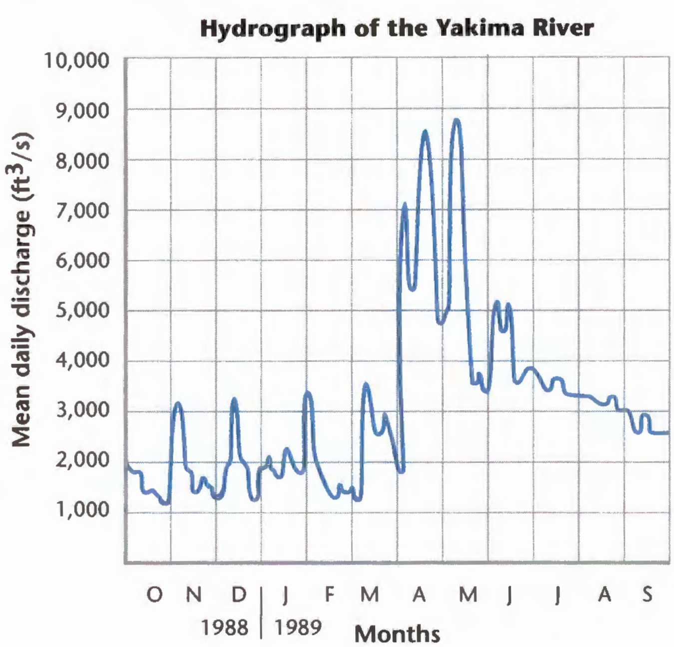
Interpreting Graphics

The graph below shows the annual flow, or discharge, of the Yakima River in Washington. Use the graph to answer questions 23–25.

23. In which months is the river's discharge highest? What might explain these discharge rates?

24. What might cause the peaks in river discharge between November and March?

25. How might the data be different if the hydrograph readings were taken below a large dam on the Yakima River?



Concept Mapping

26. Use the following terms to create a concept map: *Earth's surface, rivers, underground, fresh water, water table, 3 percent,* and *icecaps.*

Critical Thinking

27. Making Comparisons Read the description of artificial eutrophication in this chapter. Do you think artificial eutrophication is more disturbing to the stability of a water ecosystem than natural eutrophication is? READING SKILLS

28. Analyzing Relationships Water resources are often shared by several countries. A river, for example, might flow through five countries before it reaches an ocean. When water resources are shared, how should countries determine water rights and environmental responsibility?

29. Making Inferences Explain why it takes 36 gallons of water to produce a single serving of rice, but it takes more than 2,000 gallons of water to produce a single serving of steak. What do you think the water is used for in each case?

30. Making Inferences Why is there so little fresh water in the world? Do you think that there would have been more fresh water at a different time in Earth's history?

Cross-Disciplinary Connection

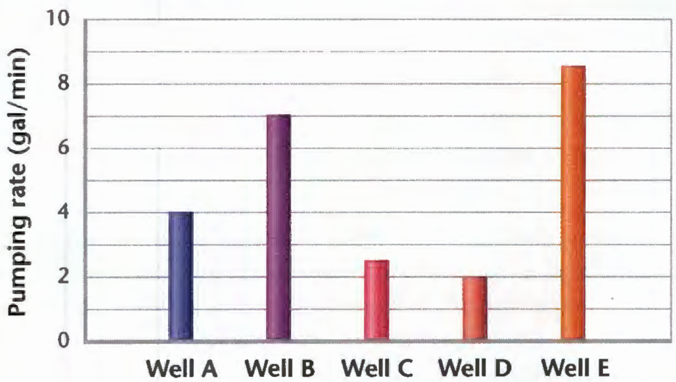
31. Social Studies Find out how freshwater resources affected the development of one culture in history. Use at least five key terms from this chapter to write a two-paragraph description of how the availability of fresh water affected the culture you chose. WRITING SKILLS

Portfolio Project

32. Investigation Find out about the source of the tap water in your home. Where does the tap water come from, and where does your wastewater go? Does the water complete a cycle? Make a poster to illustrate your findings. You may want to work with several classmates and visit the sites you discover.

MATH SKILLS

The graph below illustrates the pumping rates for a set of wells that provide water to a small community. Use the graph to answer question 33.



33. **Analyzing Data** How many gallons does Well B pump per day? What is the average pump rate for all of the wells? In one hour, how many more gallons of water will Well A pump than Well C?

34. **Making Calculations** If placing a container of water in your toilet tank reduces the amount of water per flush by 2 L, how much water would be saved each day if this were done in 80 million toilets? (Assume that each toilet is flushed five times per day.) Convert your answer into gallons (1 L = .26 Gal).

WRITING SKILLS

35. **Communicating Main Ideas** Why is water pollution a serious problem?

36. **Writing Persuasively** Write a letter to a senator in which you voice your support or criticism of a hypothetical water diversion project.

STANDARDIZED TEST PREP

For extra practice with questions formatted to represent the standardized test you may be asked to take at the end of your school year, turn to the sample test for this chapter in the Appendix.

READING SKILLS

Read the passage below, and then answer the questions that follow.

Water use is measured in two ways: by withdrawal and by consumption. Withdrawal is the removal and transfer of water from its source to a point of use, such as a home, business, or industry. Most of the water that is withdrawn is eventually returned to its source. For example, much of the water used in industries and in homes is treated and returned to the river or lake it came from. When water is withdrawn and is not returned to its source, the water is consumed. For example, when a potted plant is watered, almost all of the water eventually enters the atmosphere by *evapotranspiration* through the leaves of the plant. The evaporated water was consumed because it was not directly returned to its source.

1. According to the passage, which of the following statements is true?
   - **a.** Water that is consumed was never withdrawn.
   - **b.** Water that is withdrawn cannot be consumed.
   - **c.** A fraction of the water withdrawn is usually consumed.
   - **d.** All of the water withdrawn is consumed.

2. Which phrase best describes the meaning of the term *evapotranspiration*?
   - **a.** the absorption of water by plant leaves
   - **b.** the process by which potted plants transpire their leaves by evaporation
   - **c.** the process by which the atmosphere maintains water levels in plant leaves
   - **d.** the process by which water evaporates from plant leaves

3. Which of the following statements is an example of consumption?
   - **a.** A river is diverted to irrigate crops.
   - **b.** A power plant takes in cool water from a lake and returns the water to the lake.
   - **c.** A dam forms a reservoir on a river.
   - **d.** An aquifer is recharged by surface water.

CHAPTER 11

Exploration Lab: MODELING

Objectives

- **Construct** a model of the Earth's natural groundwater filtering system.
- USING SCIENTIFIC METHODS **Test** the ability of your groundwater filters to filter contaminants out of different solutions.

Materials

beakers, 750 mL (5)
glucose solution
glucose test paper
graduated cylinder
gravel
metric ruler
soda bottles, 2 to 3L (4)
red food coloring
sand
soil
stirring rod
wax pencil

optional contaminants:
cooking oil, detergent, fertilizer, vinegar, soda

optional filter materials:
alum, charcoal

Groundwater Filters

As surface water travels downward through rock and soil, the water is filtered and purified. As a result, the water in aquifers is generally cleaner than surface water. In this investigation, you will work in small teams to explore how layers of the Earth act as a filter for groundwater. You will make models of the Earth's natural filtration system and test them to see how well they filter various substances.

Procedure

1. Label four beakers as follows: "Contaminant: glucose," "Contaminant: soil," "Contaminant: food coloring," and "Water (control)."
2. Fill these beakers two-thirds full with clean tap water. Then add to each beaker the contaminant listed on its label. (The table on the next page shows how much of each contaminant you should use.) Stir each mixture thoroughly.
3. Copy the data table into your notebook. Carefully observe each beaker, and record your observations. Use some of the glucose test paper to test the glucose level in the glucose beaker.
4. Make four separate filtration systems similar to the one shown below. Your teacher will provide you with bottle caps that have holes poked through them. Fasten each cap to a bottle. Cut the bottom off of each soda bottle, and fill each bottle with layers of gravel, sand, and soil. Consider using the optional filter materials, such as alum or charcoal, but be sure to make each model identical to the next.

▶ **Filter Apparatus** Your ground filtration models should be layered as shown here.

Observations of Substances in Surface Water		
Contaminant	**Before filtration**	**After filtration**
Glucose (15 mL)	DO NOT	WRITE
Soil (15 mL)		
Food coloring (15 drops)	IN THIS	BOOK
Water (control)		

5. You are now going to pour each mixture through a filtration system. But first predict how well the filters will clean each water sample. Write your predictions in your notebook.
6. Stir a contaminant mixture in its beaker, and immediately pour the mixture through a filtration system into a clean beaker. Observe the resulting "groundwater," and record your observations in the table you created. CAUTION: Do not taste any of the substances you are testing.
7. Repeat this procedure for each mixture. Clean and relabel the contaminant beakers as you go along.

▶ **Step 6** Pour each sample of contaminated surface water through a filter.

Analysis

1. **Analyzing Results** Test the glucose-water mixture for the presence of glucose. Can you see the glucose?
2. **Analyzing Results** Was the soil removed from the water by filtering? Was the food coloring removed? How do you know?

Conclusions

3. **Drawing Conclusions** How accurate were your initial predictions?
4. **Drawing Conclusions** What conclusions can you draw about the filtration model and the materials you used?

Extension

1. **Making Predictions** Choose a substance from the materials list that has not been tested. Predict what will happen if you mix this substance in the water supply.
2. **Evaluating Results** Now test your prediction. Use the filter that was the control in the earlier experiment. How did your results compare with your prediction?
3. **Analyzing Results** Compare your results with the results of other teams. What precautions do you recommend for keeping groundwater clean?

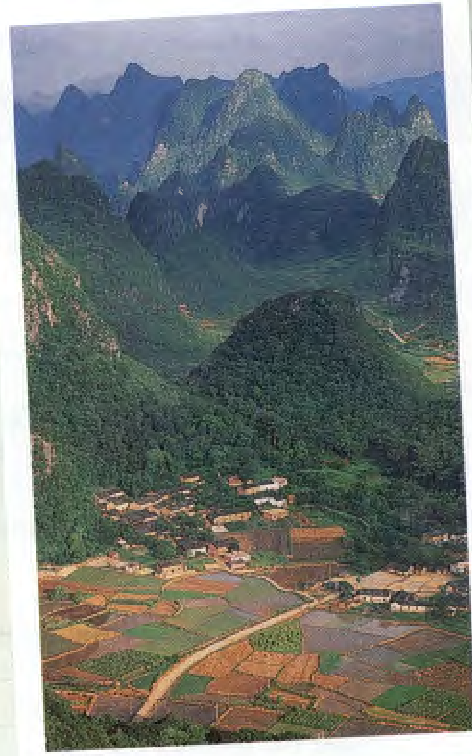
POINTS of view

THE THREE GORGES DAM

China's Yangtze River is the third-longest river in the world after the Nile and the Amazon. The Yangtze River flows through the Three Gorges region of central China, which is famous for its natural beauty and historical sites. For thousands of years, the area's sheer cliffs have inspired paintings and poems. This idyllic region seems like the sort of place that would be protected as a park or reserve. But in fact, it is the construction site for the Three Gorges Dam—the largest hydroelectric dam project in the world. When the Yangtze River is dammed, it will rise to form a reservoir that is 595 km (370 mi) long—as long as Lake Superior. In other words, the reservoir will be about as long as the distance between Los Angeles and San Francisco!

Benefits of the Dam

The dam has several purposes. It will control the water level of the Yangtze River to prevent flooding. About 1 million people died in the last century from flooding along the river. The damage caused by a severe flood in 1998 is estimated to cost as much as the entire dam project. The dam will also provide millions of people with hydroelectric power. China now burns air-polluting coal to meet 75 percent of the country's energy needs. Engineers project that when the dam is completed, its turbines will provide enough electrical energy to power a city that is 10 times the size of Los Angeles, California. When the Yangtze's flow is controlled, the river will be deep enough for large ships to navigate on it, so the dam will also increase trade in a relatively poor region of China.



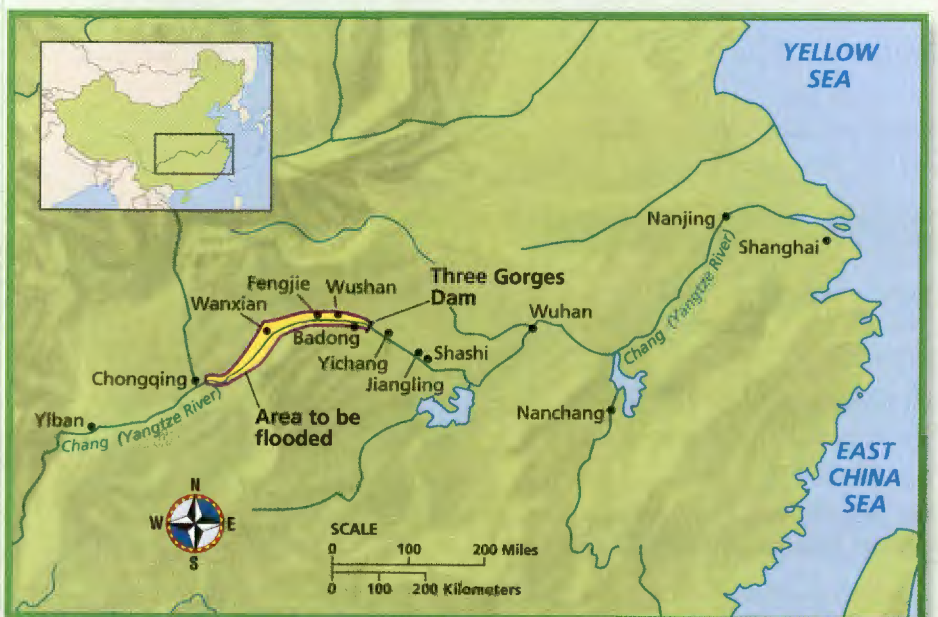
▶ **The Three Gorges Dam** is named for the beautiful canyons it will flood. When completed, the dam may meet 20 percent of China's energy needs with hydroelectric power.

Some Disadvantages

The project has many drawbacks, however. The reservoir behind the dam will flood an enormous area. Almost 2 million people living in the affected areas must be relocated—there are 13 cities and hundreds of villages in the area of the proposed reservoir. As the reservoir's waters rise, they will also destroy fragile ecosystems and valuable archeological sites.

Opponents of the project claim that the dam will increase pollution levels in the Yangtze River. Most of the cities and factories along the river dump untreated wastes directly into the water. Some people think the reservoir will become the world's largest sewer when 1 billion tons of sewage flow into the reservoir every year.

▶ The reservoir that will form behind the Three Gorges Dam is shown in yellow.



Long-Term Concerns

People have also raised long-term concerns about the project. The dam is being built over a fault line. Scientists question whether the dam would be able to withstand earthquakes that may occur along the fault. If the dam burst, towns and cities downstream would be flooded. Another concern is that the dam may quickly fill with sediment. The Yangtze picks up enormous amounts of yellowish soil and sediment as it flows across China. When the river is slowed by the dam, much of the silt will be deposited in the new reservoir. As sediment builds up behind the dam, the deposited sediment will reduce the size of the reservoir—limiting the flood-prevention capacity of the dam. In addition, productive farming regions below the dam will be deprived of the fertile sediment that is deposited every year when the river floods.

The enormous reservoir may also cause disease among the local population. The potential heath risks include an increase in encephalitis and malaria. The most deadly disease spread by the Three Gorges Dam could be a parasitic disease called schistosomiasis.

Hidden Costs?

Supporters of the dam claim that the project will cost $25 billion, while opponents claim that the costs will be closer to $75 billion. The true cost of the dam may never be known because corruption and inefficiency have plagued the project from the start. Controversy over the dam has prompted the U.S. government and the World Bank to withhold money for the project. Public opposition to the project has been silenced since the Tiananmen Square crackdown. But with help from private investment companies from the United States, the Chinese government is continuing with the project, and the dam is slowly being built. The world's third-longest river will soon swell in the middle, and China will change along with it.

▶ When the dam waters rise, these ancient temples will be flooded.

▶ Engineers discuss plans at the dam construction site. More than 20,000 people are working at the construction site.

What Do You Think?

Hundreds of dams in the western United States provide electrical energy, drinking water, and water for crops, but the dams also flooded scenic canyons and destroyed ecosystems. Now that the environmental consequences of large dams are known, do you think that China should reconsider the Three Gorges Dam project?