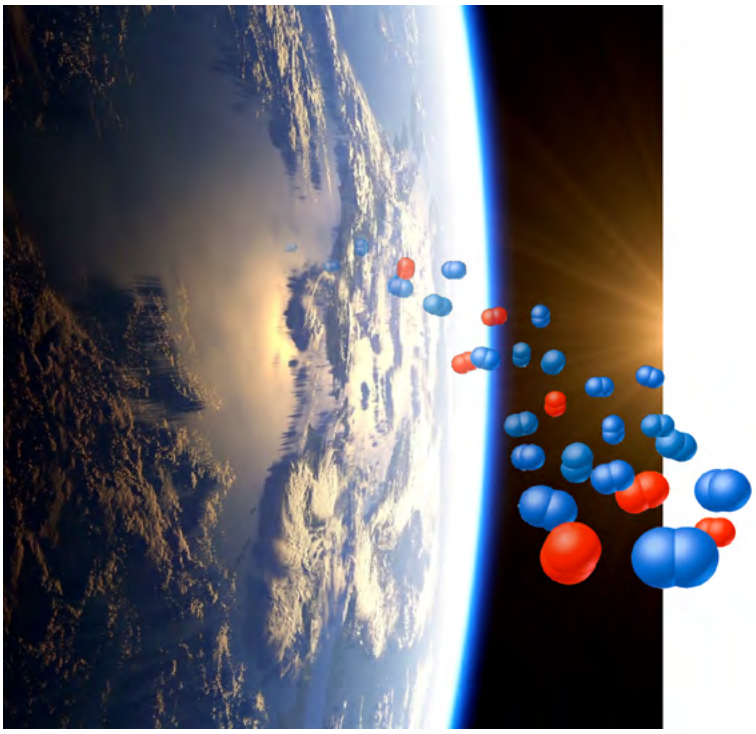


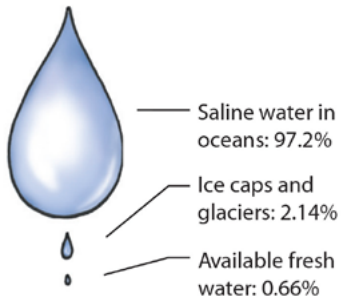
Chapter 16

Water and Air Resources

THE MAIN IDEA

The Earth is huge, but so is our ability to transform the environment.

Seen from space, Earth's atmosphere appears as a narrow blue sliver on the horizon.



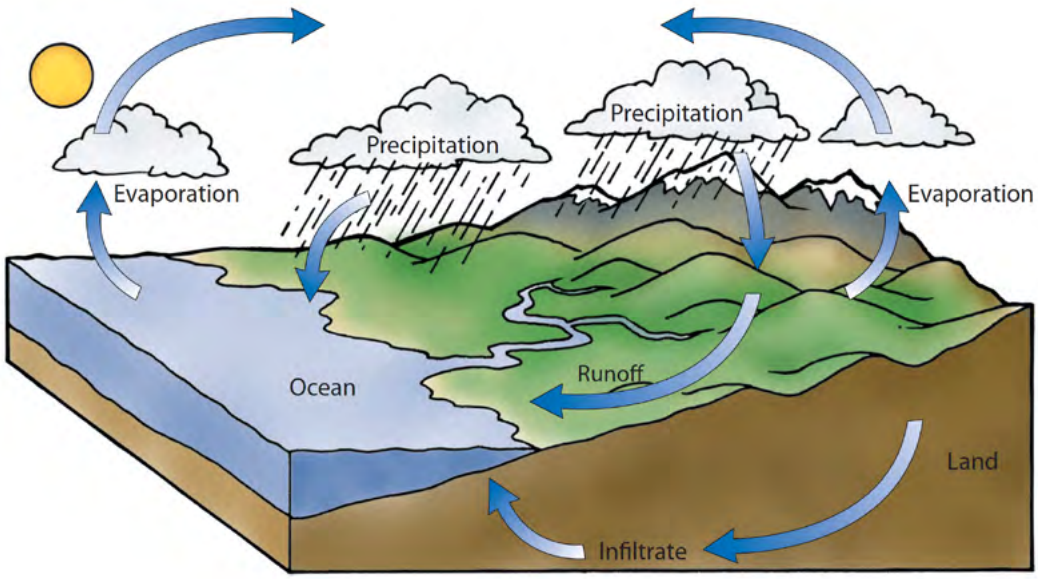
There is a lot of water on the Earth, but about 97.2 percent of this water is saline (salty) ocean water. Another 2.14 percent is fresh water frozen in polar ice caps and glaciers. All the remaining water, less than 1 percent of the Earth's total, comprises water vapor in the atmosphere, water in the ground, and water in rivers and lakes—the fresh water we rely on in our daily lives. The Earth is large, having a diameter of about 13,000 kilometers. The atmosphere that surrounds the Earth, however, is only about 30 kilometers thick.

From space, the atmosphere appears only as a narrow band along the horizon. Consider that if the Earth were the size of an apple, its atmosphere would be about as thick as the skin of the apple. Our planet is a gigantic terrarium, and collectively, we are its caretakers. With this job comes the responsibility to learn how the Earth's water and air resources can be properly managed for the benefit of all its inhabitants. In this chapter, we explore some of the fundamental dynamics of the Earth's water and atmosphere and the impact of human activities.

16.1 Water on the Move

The Earth's water is constantly circulating, powered by the heat of the Sun and the force of gravity. The Sun's heat causes water from the Earth's oceans, lakes, rivers, and glaciers to evaporate into the atmosphere. As the atmosphere becomes saturated with moisture, the water precipitates in the form of either rain or snow. This constant water movement and phase changing is called the **hydrologic cycle**. As **Figure 16.1** shows, the route of water through the cycle can be from ocean directly back to ocean or can take a more circuitous route over the ground and even underground.

In the direct route, water molecules in the ocean evaporate into the atmosphere, condense to form clouds, and then precipitate into the ocean as either rain or snow, to begin the cycle anew.



Λ Figure 16.1

The hydrologic cycle. Water evaporated at the Earth's surface enters the atmosphere as water vapor, condenses into clouds, precipitates as rain or snow, and falls back to the surface, only to go through the cycle yet another time.

The cycle is more complex when precipitation falls on land. As with the direct route, the cycle "begins" with ocean water evaporating into the atmosphere. Instead of forming clouds over the water, however, the moist air is blown by winds until it is over land. Now there are four possibilities for what happens to the water once it precipitates. It may (1) evaporate from the land back into the atmosphere, (2) infiltrate into the ground, (3) become part of a snowpack or glacier, or (4) drain to a river and then flow back to the ocean.

Water that seeps below the Earth's surface fills the spaces between soil particles until the soil reaches *saturation*, at which point every space is filled with water. The upper boundary of the saturated zone is called the **water table**. The depth of the water table varies with precipitation and with climate. It ranges from zero depth in marshes and swamps (meaning the water table is at ground level at these locations) to hundreds of meters deep in some desert regions.

READING CHECK

Is it possible for the water table to lie above ground?

The water table also tends to follow the contours of the land and lowers during times of drought, as shown in **Figure 16.2**. Many lakes and streams are simply regions where the water table lies above the land surface.

All water below the Earth's surface is called *groundwater*. (Liquid water that is on the surface—in streams, rivers, and lakes—is called, naturally enough, *surface water*.) Any water-bearing soil layer is called an **aquifer**, which can be thought of as an underground water reservoir. Aquifers underlie the land in many places and collectively contain an enormous amount of fresh water— approximately 35 times the total volume of water in fresh water lakes, rivers, and streams combined. More than half the land area of the United States is underlain by aquifers, such as the Ogallala Aquifer, stretching from South Dakota to Texas and from Colorado to Arkansas.

CHEMICAL CONNECTIONS

How are the tears of a crying baby in the United States connected to the Yangtze River in China?

As the human population grows, the demand for fresh water grows. Precipitation is the Earth's only natural source of groundwater recharge. Although the reservoir of groundwater is great, when the pumping rate exceeds the recharge rate, there can be a problem. In wet climates, such as in the Pacific Northwest, extraction is often balanced by recharge. In dry climates, however, extraction can easily exceed recharge. To support large

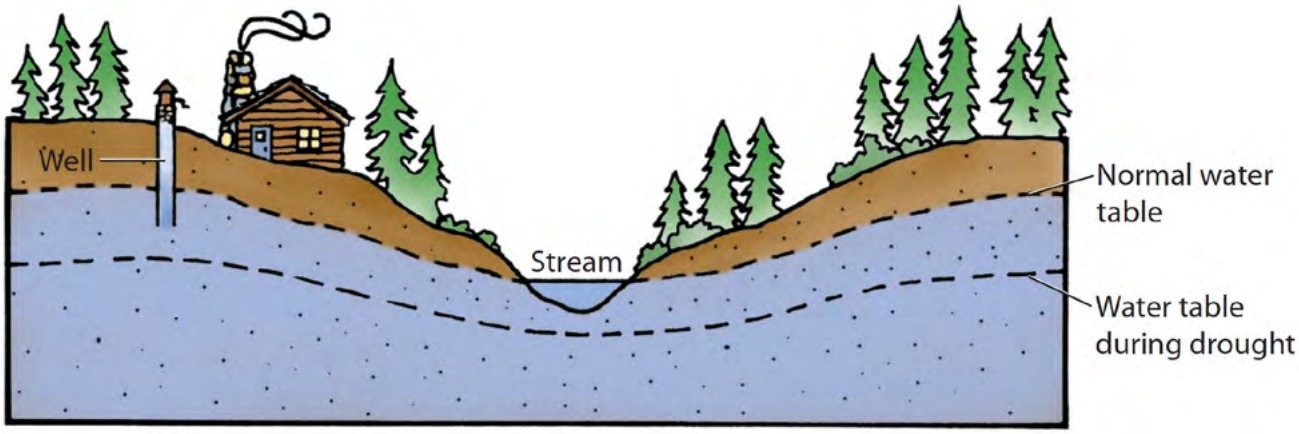


Figure 16.2

The water table in any location roughly parallels surface contouring. In times of drought, the water table falls, reducing stream flow and drying up wells. It also falls when the amount of water pumped out of a well exceeds the amount replaced as precipitated water infiltrates the ground and recharges the supply.

populations, these areas must import their water from distant sources, typically through aqueducts. In southern California, for example, most of the fresh water comes from the Colorado River through aqueducts that stretch hundreds of miles.

The Ogallala Aquifer, which is below the dry High Plains, has supplied water to this thirsty agricultural region for more than 100 years. Most of the aquifer is water from the last ice age, some 11,000 years ago, that has been locked underground with few sources of replenishment. If pumping were to cease, it would take many thousands of years for the water table to return to its original level. In this respect, the Ogallala, unlike most other aquifers, is a limited and nonrenewable resource.

As water is removed from the spaces between soil particles, the sediments compact and the ground surface is lowered—it subsides. In areas where groundwater withdrawal has been extreme, the ground surface has subsided significantly. In the United States, extensive groundwater withdrawal for irrigation of the San Joaquin Valley of California has caused the water table to drop 75 meters in 20 years, and the resulting land subsidence has been significant.

Probably the most well-known example of land subsidence is the Leaning Tower of Pisa in Italy, shown in **Figure 16.3**. Over the years, as groundwater has been withdrawn to supply the growing city, the tilt of the tower has increased.

Figure 16.3

The Leaning Tower of Pisa, built centuries ago, slowly acquired a deviation from the vertical of about 4.6 meters as a result of groundwater withdrawal. The tower's foundation has been stabilized by groundwater withdrawal management, and the tower should remain stable for years to come.

CONCEPT **CHECK**

An aquifer is a body of underground fresh water. Where does this water come from?

CHECK YOUR ANSWER

The source of all natural underground (and above ground) fresh water is the atmosphere, which gets most of its moisture from the evaporation of ocean water.