15

Freshwater Systems and Resources

Chapter Objectives

This chapter will help you:

Explain water’s importance to people and ecosystems, and describe the distribution of fresh water on Earth

Describe major types of freshwater systems

Discuss how we use water and alter freshwater systems

Assess problems of water supply and propose solutions to address depletion of fresh water

Assess problems of water quality and propose solutions to address water pollution

Explain how we treat drinking water and wastewater

Lecture Outline

I. Central Case: Gambling With Water in the Colorado River Basin

A. Nevada’s largest city, Las Vegas, is desperate for water because it is outgrowing its allotment from the Colorado River, whose declining supply Nevada is legally obliged to share with neighboring states.

B. The Colorado River originates in the high peaks of the Rocky Mountains, charges through arid canyonlands, crosses into Mexico, and empties into the Gulf of California, draining 637,000 km^2 (246,000 mi^2) of southwestern North America.

C. Water is siphoned off for irrigation to make agriculture possible in this dry region. It is piped to cities in canals and aqueducts to quench the thirst of 30 million people. It keeps golf courses green in the desert, fills swimming pools in southern California backyards, and gushes through fountains in Las Vegas casinos.

D. Since 1922, the seven states along the Colorado have divided its water among themselves, guided by the Colorado River Compact they signed that year. In this treaty, Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming apportioned water according to the needs and negotiating power each state had at the time.

E. Las Vegas, in particular, faces disaster if drought conditions continue. Vegas is feeling the heat not only because it gets just 11 cm (4.5 in) of rain a year, but because in 1922 Nevada was barely populated, and so it won only 4% of the river's water in the Colorado River Compact.

F. In 2007, the seven states worked out a plan that allowed upper-basin states to withhold more water when needed and encouraged lower-basin states to develop supplies elsewhere. The plan backed Las Vegas' controversial proposal to mine groundwater from rural areas of eastern Nevada.

G. The first phase of Las Vegas' contentious plan won approval by Nevada's state engineer in 2008, but a district judge overturned this approval in 2009 and blocked the project. The Southern Nevada Water Authority board appealed the judge's ruling, and as of 2010 the stage appears set for a showdown in Nevada's Supreme Court.

II. Freshwater Systems

1. Of all the water on Earth, only 2.5% is considered **freshwater**, or water that is relatively pure, with few dissolved salts. Most of that is tied up in glaciers, ice caps, and aquifers.
2. Water is renewed and recycled as it moves through the *hydrologic cycle.*

A. Surface water converges within watersheds.

1. **Surface water**, water located atop Earth's surface, accounts for just 1% of fresh water, but it is vital for our survival and for the planet's ecological systems.
2. Once water falls from the sky as rain, emerges from springs, or melts from snow or a glacier, it may soak into the ground or it may flow downhill over land. Water that flows over land is called **runoff**.
3. The area of land drained by a *river system*—a river and all its tributaries—is that river's **watershed**.

B. Rivers and streams wind through landscapes.

1. Landscapes determine where rivers flow, but rivers shape the landscapes through which they run.
2. Areas nearest a river's course that are flooded periodically are said to be within the river's **floodplain**.
3. Rivers and streams host diverse ecological communities.

C. Lakes and ponds are ecologically diverse systems.

1. Lakes and ponds are bodies of standing surface water.
2. The region ringing the edge of a water body is the *littoral zone.*
3. The bottom of a lake or pond is the *benthic zone.*
4. The shallow waters away from shore are termed the *limnetic zone,* where light enters and supports phytoplankton, which in turn support zooplankton.
5. Deeper in open water, where the sunlight does not reach, is the *profundal zone,* which lacks plant life.
6. Ponds and lakes change over time as streams and runoff bring them sediment and nutrients.
7. The largest lakes are sometimes known as inland seas.

D. Wetlands include marshes, swamps, bogs, and seasonal pools.

1. **Wetlands** are systems in which the soil is saturated with water and that generally feature shallow standing water with ample vegetation.
2. Some wetlands are seasonal, being wet only at some times of year.
3. Wetlands are extremely valuable as habitat for wildlife, and they also provide important ecosystem services by slowing runoff, reducing flooding, recharging aquifers, and filtering pollutants.

E. Groundwater plays key roles in the hydrologic cycle.

1. Any precipitation reaching Earth's land surface that does not evaporate, flow into waterways, or get taken up by organisms infiltrates the surface. Most percolates downward through the soil to become **groundwater**, water beneath the surface held within pores in soil or rock
2. Groundwater is contained in **aquifers**—porous, spongelike formations of rock, sand, or gravel that hold water.
3. The water table is the boundary between the upper layer, or zone of aeration, and the lower layer, or zone of saturation, which is completely filled with water.
4. There are two broad categories of aquifers—**confined aquifers**, also known as **artesian aquifers**, which are under pressure, and **unconfined aquifers**.

F. Water is unequally distributed across Earth.

G. Climate change may bring shortages.

III. How We Use Water

A. Water supplies households, industry, and especially agriculture.

1. Most uses of water are **consumptive use,** in which water is removed from a particular body of water and is not returned to it.

2. **Nonconsumptive use** of water does not remove, or only temporarily removes, water from an aquifer or surface water body.

B. We divert surface water to suit our needs.

C. We build dikes and levees to control floods.

1. **Flooding** is a normal, natural process that occurs when snowmelt or heavy rain swells the volume of water in a river so that water spills over the river's banks.

D. We have erected thousands of dams.

1. A **dam** is any obstruction placed in a river or stream to block its flow.
2. Dams create **reservoirs**, artificial lakes that store water for human use.

E. Some dams are being removed.

1. By removing dams and letting rivers flow free, we can restore riparian ecosystems, reestablish economically valuable fisheries, and reintroduce river recreation.
2. Many dams have aged and are in need of costly repairs or have outlived their economic usefulness.

F. We are depleting surface water.

G. The world is losing wetlands.

H. We are depleting groundwater.

1. When quickly depleting aquifers, salt water can flood the aquifer, making water undrinkable.
2. Or, we can accidentally create **sinkholes**, areas where the ground gives way with little warning, occasionally swallowing homes and businesses.

I. Can we quench our thirst for bottled water?

1. Our groundwater is being withdrawn for a new purpose: to be packaged in plastic bottles and sold on supermarket shelves.

J. Will we see a future of water wars?

1. Many predict that water's role in regional conflicts will increase as human population continues to grow and as climate change alters precipitation patterns.

IV. Solutions to Depletion of Fresh Water

A. Solutions can address supply or demand.

B. Desalination —makes‖ more water.

1. The best-known technological approach to generate freshwater is **desalination**, or desalinization—the removal of salt from seawater or other water of marginal quality.

2. One method of desalination mimics the hydrologic cycle by hastening evaporation from allotments of ocean water with heat and then condensing the vapor—essentially *distilling* freshwater.
3. Another method involves forcing water through membranes to filter out salts; the most common process is called *reverse osmosis*.
4. Desalination is expensive, requires large inputs of fossil fuel energy, kills aquatic life at water intakes, and generates concentrated salty waste.
5. As individuals, we can all help reduce agricultural water use by eating less meat, because producing meat requires far greater water inputs than producing grain or vegetables.

C. Agricultural demand can be reduced.

1. Farmers can use technology to improve efficiency in a number of ways, including lining irrigation canals to prevent leaks and leveling fields to minimize runoff.
2. Techniques to increase irrigation efficiency include low-pressure spray irrigation, which sprays water downward toward plants, and drip irrigation systems, which target individual plants and introduce water directly onto the soil.
3. Choosing crops that match the land and climate in which they are being farmed can save huge amounts of water.
4. Selective breeding and genetic modification produce crop varieties that require less water.

D. We can lower residential and industrial waste use.

1. We can reduce our household water use by installing low-flow faucets, showerheads, washing machines, and toilets.
2. Automatic dishwashers use less water than washing dishes by hand.
3. Catching rain runoff from your roof in a barrel—*rainwater harvesting*—will reduce the amount you need to use from the hose.
4. If your city allows it, you can use *gray water*—the wastewater from showers and sinks—to water your yard.
5. If you have a lawn, it is best to water it at night, when water loss from evaporation is minimal.
6. Replacing water-intensive lawns with native plants adapted to your region's natural precipitation patterns saves the most water.
7. *Xeriscaping*, landscaping using plants adapted to arid conditions, has become a popular approach in much of the U.S. Southwest.
8. Manufacturers have shifted to processes that use less water and, in doing so, have reduced their costs.

9. Recycling wastewater for suitable uses is another water conservation practice. Wastewater can be made suitable for irrigation and for some industrial uses.
10. In Arizona and in England efforts are being made to capture excess surface runoff during the rainy seasons and pump it into aquifers, thus making more efficient use of the available water supply.
11. Finding and patching leaks in pipes has saved some cities and companies large amounts of water—and money.

E. Market-based approaches to water conservation are being debated.

1. Many economists have suggested market-based strategies for achieving sustainability in water use.
    a. Ending government subsidies of inefficient practices.
    b. Letting water become a commodity whose price reflects the true costs of its extraction.
2. Others worry that making water a fully priced commodity would make it less available to the world's poor and increase the gap between rich and poor.
3. Because industrial use of water can be 70 times more profitable than agricultural use, market forces alone could favor uses that would benefit wealthy and industrialized people, companies, and nations at the expense of the poor and less industrialized.
4. The privatization of water supplies has been tried in hope of increasing efficiency, but many people worry that firms have little incentive to allow equitable access to water for rich and poor alike.
5. Decentralization of control over water, from the national level to the local level, may help conserve water.

V. Freshwater Pollution and Its Control

A. Water pollution comes from point sources and from diffuse nonpoint sources.

1. The term **pollution** describes any matter or energy released into the environment that causes undesirable impacts on the health and well-being of humans or other organisms.
2. Regardless of its source, **water pollution** exists in many forms and can cause diverse impacts on aquatic ecosystems and human health.
3. Some water pollution is emitted from **point sources**—discrete locations, such as a factory or sewer pipe.
4. In contrast, **non-point-source** pollution is cumulative, arising from multiple inputs over larger areas, such as farms, city streets, and residential neighborhoods.

B. Water pollution takes many forms.

   1. Nutrient pollution
   2. Pathogens and waterborne diseases
   3. Toxic chemicals
   4. Sediment
   5. Thermal pollution

C. Scientists use several indicators of water quality.

   1. Physical, chemical, and biological properties of water are all measured to characterize its quality.
   2. The important chemical properties include nutrient concentrations, pH, taste, odor, and hardness.
   3. Scientists also classify water according to three physical characteristics: turbidity, color, and temperature.

D. Groundwater pollution is a difficult problem.

E. There are many sources of groundwater pollution.

   1. A variety of chemicals that are toxic at high concentrations, including aluminum, fluoride, nitrates, and sulfates, occur naturally in groundwater.
   2. Industrial, agricultural, and urban wastes—from heavy metals to petroleum products to industrial solvents to pesticides—can leach through soil and seep into aquifers.
   3. Pathogens and other pollutants can also enter groundwater through improperly designed wells and from the pumping of liquid hazardous waste below ground.
   4. Leakage from underground tanks of oil is another major contributor to groundwater pollution.
   5. Agriculture also contributes to groundwater pollution:
      a. Pesticides
      b. Nitrate from fertilizers
      c. Pathogens
   6. Manufacturing industries and military sites have been heavy polluters through the years.

F. It is better to prevent pollution than to deal with it later.

G. Legislative and regulatory efforts have already helped reduce pollution.

H. We treat our drinking water.

I. We treat our wastewater.

   1. **Wastewater** refers to water that people have used in some way.

2. In rural areas, **septic systems** are the most popular method of wastewater disposal. In a septic system, wastewater runs from the house to an underground septic tank, inside which solids and oils separate from water. The clarified water proceeds downhill to a drain field of perforated pipes laid horizontally in gravel-filled trenches underground. Microbes decompose pollutants in the wastewater that these pipes emit. Periodically, solid waste from the septic tank is pumped out and taken to a landfill.

3. In more densely populated areas, municipal sewer systems carry wastewater from homes and businesses to centralized treatment locations. There, pollutants are removed by physical, chemical, and biological means.

   a. At a treatment facility, **primary treatment**, the physical removal of contaminants in settling tanks or clarifiers, removes about 60% of suspended solids.

   b. Wastewater then proceeds to **secondary treatment**, in which water is stirred and aerated so that aerobic bacteria degrade organic pollutants. Roughly 90% of suspended solids may be removed after secondary treatment.

   c. Finally, the clarified water is treated with chlorine, and sometimes ultraviolet light, to kill bacteria.

J. Artificial wetlands can aid the treatment.

VI. Conclusion

A. Citizen action, government legislation and regulation, new technologies, economic incentives, and public education are all helping us to confront a rising challenge of the new century: ensuring adequate quantity and quality of fresh water for ourselves and for the planet's ecosystems.

B. Accessible fresh water comprises a minuscule percentage of the hydrosphere, but we generally take it for granted.

C. There is hope that we may attain sustainability in our water usage, as potential solutions are numerous, and the issue is too important to ignore.

Key Terms for Chapter 15

aquifers

artesian aquifer

confined aquifer

consumptive use

dam

desalination

flooding

floodplain

fresh water

groundwater

irrigation

nonconsumptive use

nonpoint source

point source pollution

primary treatment

reservoir

runoff

secondary treatment

septic systems

sinkholes

surface water

unconfined aquifer wastewater

water pollution

watershed

water table