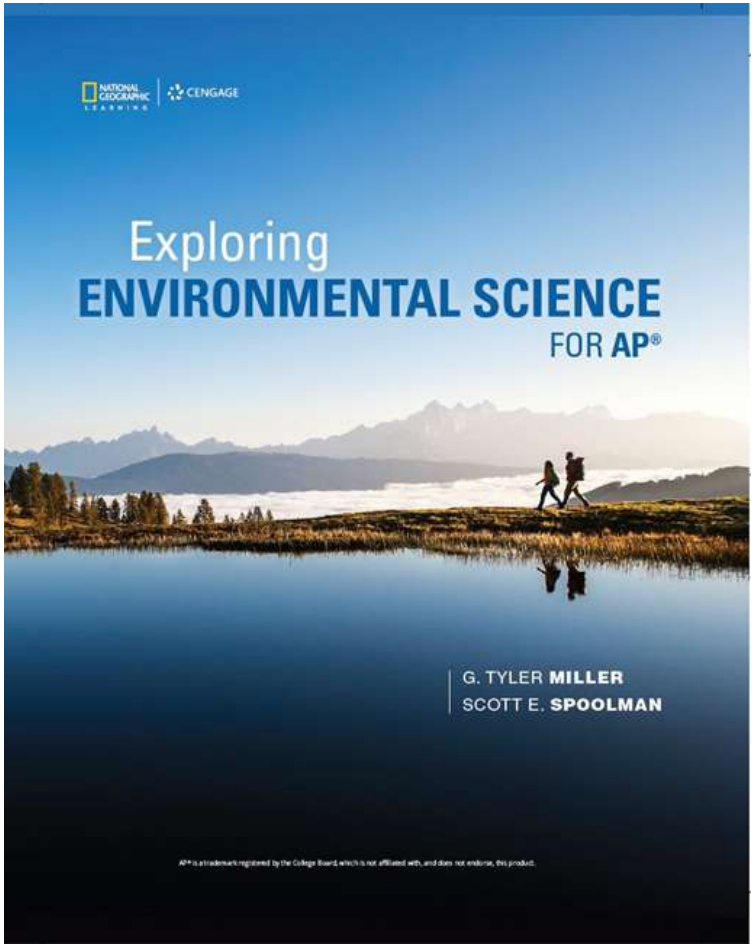
Exploring Environmental Science for AP®

1st Edition



Chapter 13
Water Resources

Case Study: The Colorado River Story (1 of 2)

- The Colorado River
  - Flows 2,300 km through seven U.S. states
  - Includes 14 dams and reservoirs
  - Water supplied mostly from snowmelt of the Rocky Mountains
  - Supplies water and electricity for about 40 million people
    - Las Vegas, Phoenix, Los Angeles, and San Diego
  - Irrigates crops that help feed America

Case Study: The Colorado River Story (2 of 2)

- Issues
  - Very little water is reaching the Gulf of California
  - System has experienced severe drought since 1999
  - Lake Mead fell to record low water level in 2015

The Colorado River Basin

13.1 Will We Have Enough Usable Water?

- Freshwater
  - One of the earth's most important forms of natural capital
  - Used inefficiently and polluted
  - Low cost encourages waste
  - Not accessible to many people

Freshwater Is an Irreplaceable Resource That We Are Managing Poorly

- Access to freshwater a global health issue
  - Over 4,000 people die each day from lack of access to safe drinking water
- Economic issue
  - Water vital for producing food and energy
- National and global security issue
- Environmental issue
  - Excessive withdrawal

Most of Earth's Freshwater Is Not Available to Us (1 of 2)

- Freshwater availability: 0.024% of water supply
  - Groundwater, lakes, rivers, and streams
- Hydrologic cycle
  - Movement of water in the seas, land, and air
  - Distributed unevenly
- Humans alter the hydrologic cycle
  - Withdrawing and polluting water, and causing climate change

Most of Earth's Freshwater Is Not Available to Us (2 of 2)

Shiv Ji Joshi/National Geographic Creative

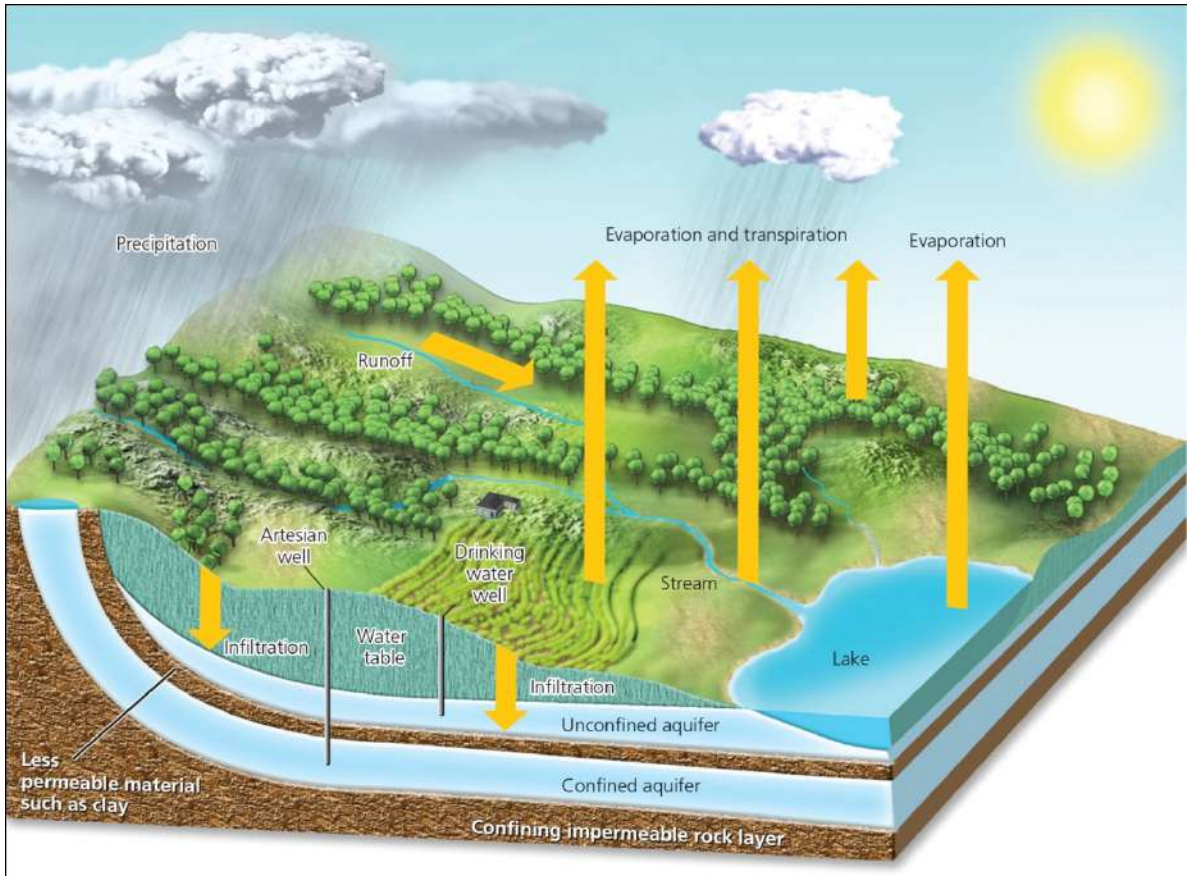
Groundwater and Surface Water Are Critical Resources (1 of 3)

- Zone of saturation
  - Spaces in soil below a certain depth are filled with water
- Water table
  - Top of zone of saturation
- Aquifers
  - Recharged naturally by precipitation or by nearby lakes, rivers, and streams

Groundwater and Surface Water Are Critical Resources (2 of 3)

- Surface water
  - Surface runoff
  - Watershed (drainage) basin

Groundwater and Surface Water Are Critical Resources (3 of 3)



We Are Using Increasing Amounts of the World's Reliable Runoff (1 of 2)

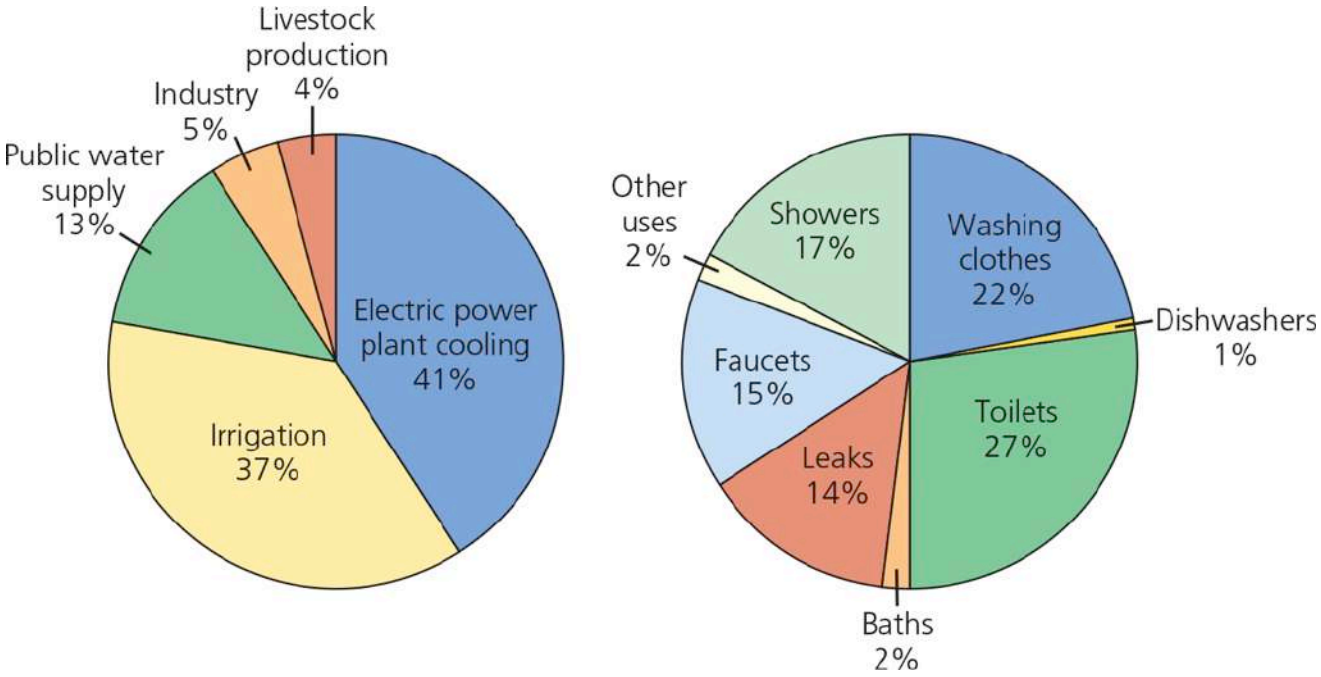
- Two-thirds of surface runoff lost to seasonal floods
- Reliable runoff
  - Remaining one-third reliable source of freshwater
- Worldwide averages
  - Irrigation for crops and livestock: 70%
  - Industrial use: 20%
  - Cities and residences: 10%

We Are Using Increasing Amounts of the World's Reliable Runoff (2 of 2)

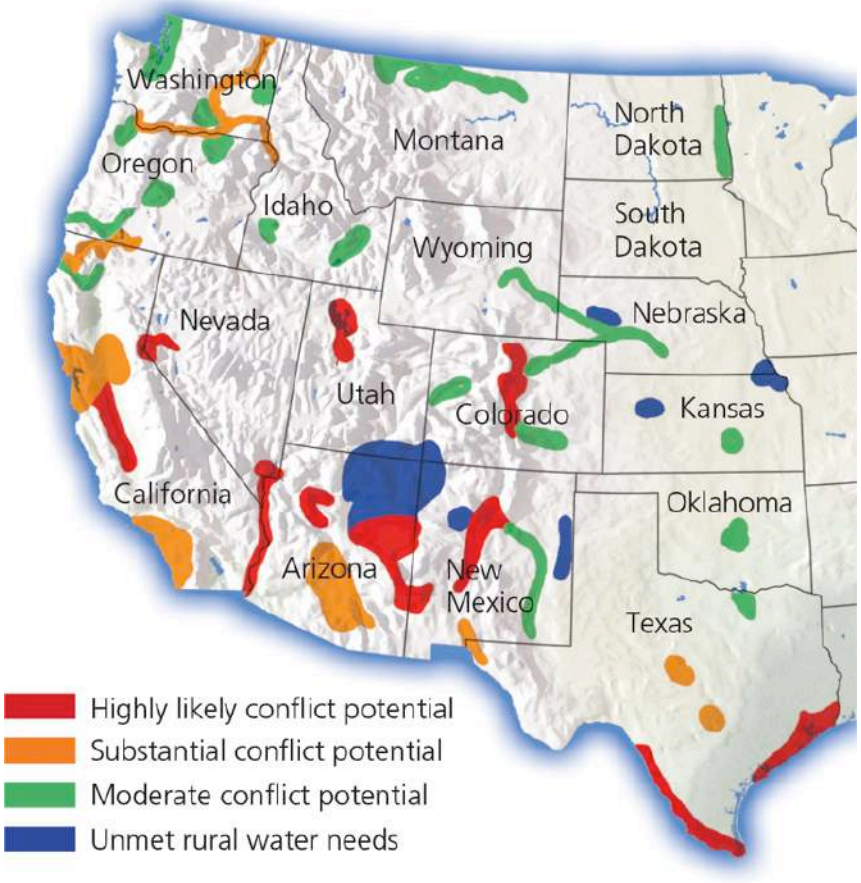
- Virtual water
  - Water used to produce food and other products

Case Study: Freshwater Resources in the United States (1 of 2)

- More than enough renewable freshwater
  - Unevenly distributed and polluted



Case Study: Freshwater Resources in the United States (2 of 2)



Critical Concept: Your Water Footprint (1 of 2)

- Rough measure of all the water an individual uses
- Virtual water is water used indirectly to produce products and food, but is considered part of a person's water footprint depending on what they consume

Critical Concept: Your Water Footprint (2 of 2)

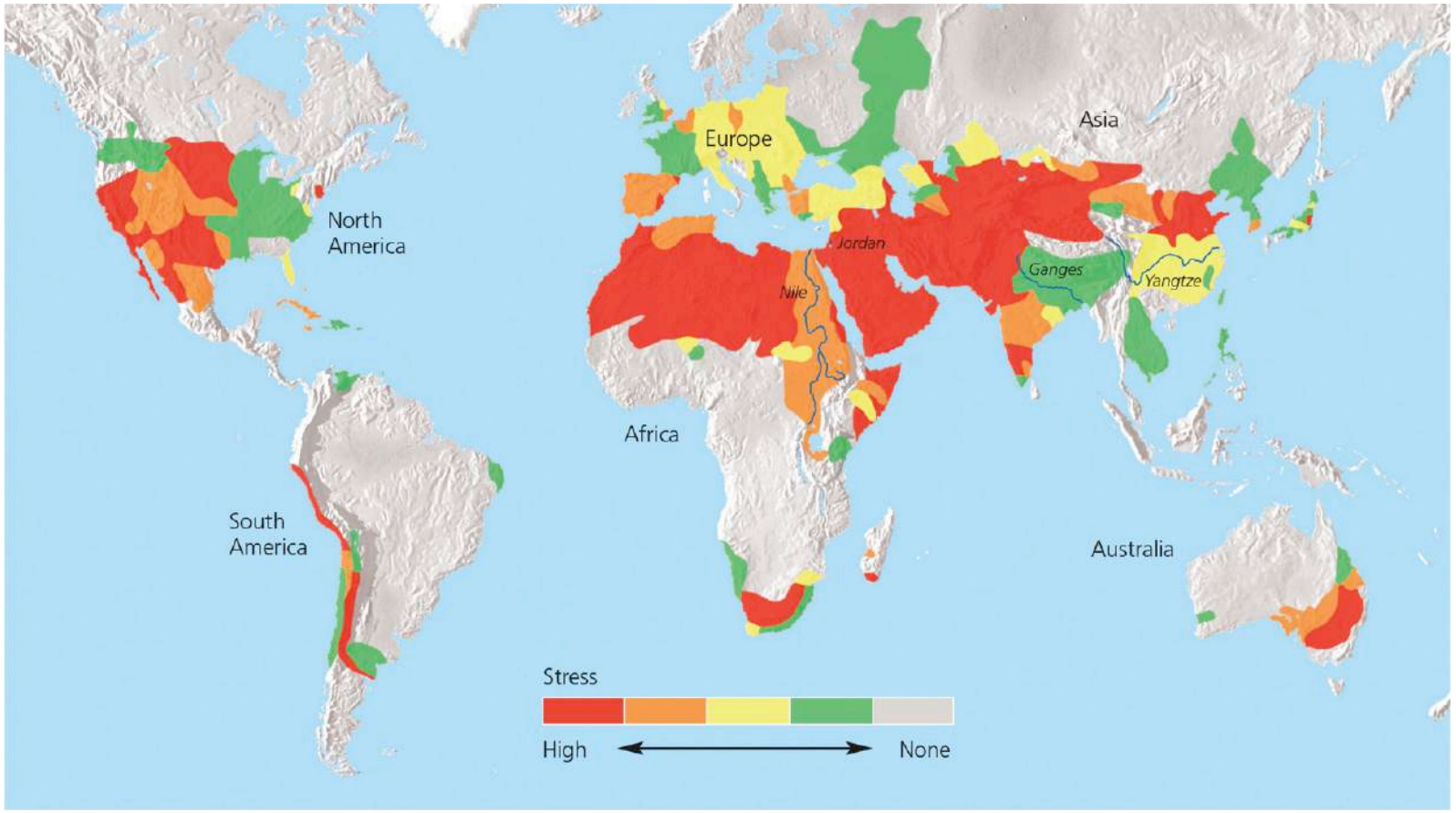
Producing and delivering a single one of each of the products listed here requires the equivalent of nearly one and usually many bathtubs full of freshwater, called *virtual water*. *Note:* 1 bathtub = 151 liters (40 gallons).

Bathtub: Baloncici/Shutterstock.com. Coffee: Aleksandra Nadeina/Shutterstock.com. Bread: Alexander Kalina/Shutterstock.com. Hamburger: Joe Belanger/Shutterstock.com. T-shirt: grmarc/Shutterstock.com. Jeans: Eyes wide/Shutterstock.com. Car: L Barnwell/Shutterstock.com. House: Rafal Olechowski/Shutterstock.com

Freshwater Shortages Will Grow (1 of 2)

- Many of the world's major river systems are highly stressed
  - Nile, Jordan, Yangtze, and Ganges
- More than 30 countries face freshwater scarcity
  - Estimate: 60 countries by 2050
- 30% of the earth's land area experiences severe drought
  - Research predicts this will worsen

Freshwater Shortages Will Grow (2 of 2)



13.2 Is Groundwater a Sustainable Resource?

- Groundwater used to supply cities and grow food is being pumped form many aquifers faster than it is being replenished by precipitation.

Groundwater Withdrawals are Unsustainable in Some Areas (1 of 2)

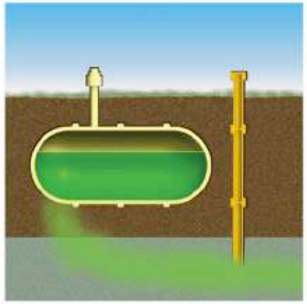
- Aquifers are renewable resources for fresh water unless they are contaminated
- Widespread drilling of wells by farmers
  - Accelerated aquifer overpumping
  - Water tables falling
- In 2008, Saudi Arabia announced it had depleted its major deep aquifer

Groundwater Withdrawals are Unsustainable in Some Areas (2 of 2)

Trade-Offs

Withdrawing Groundwater

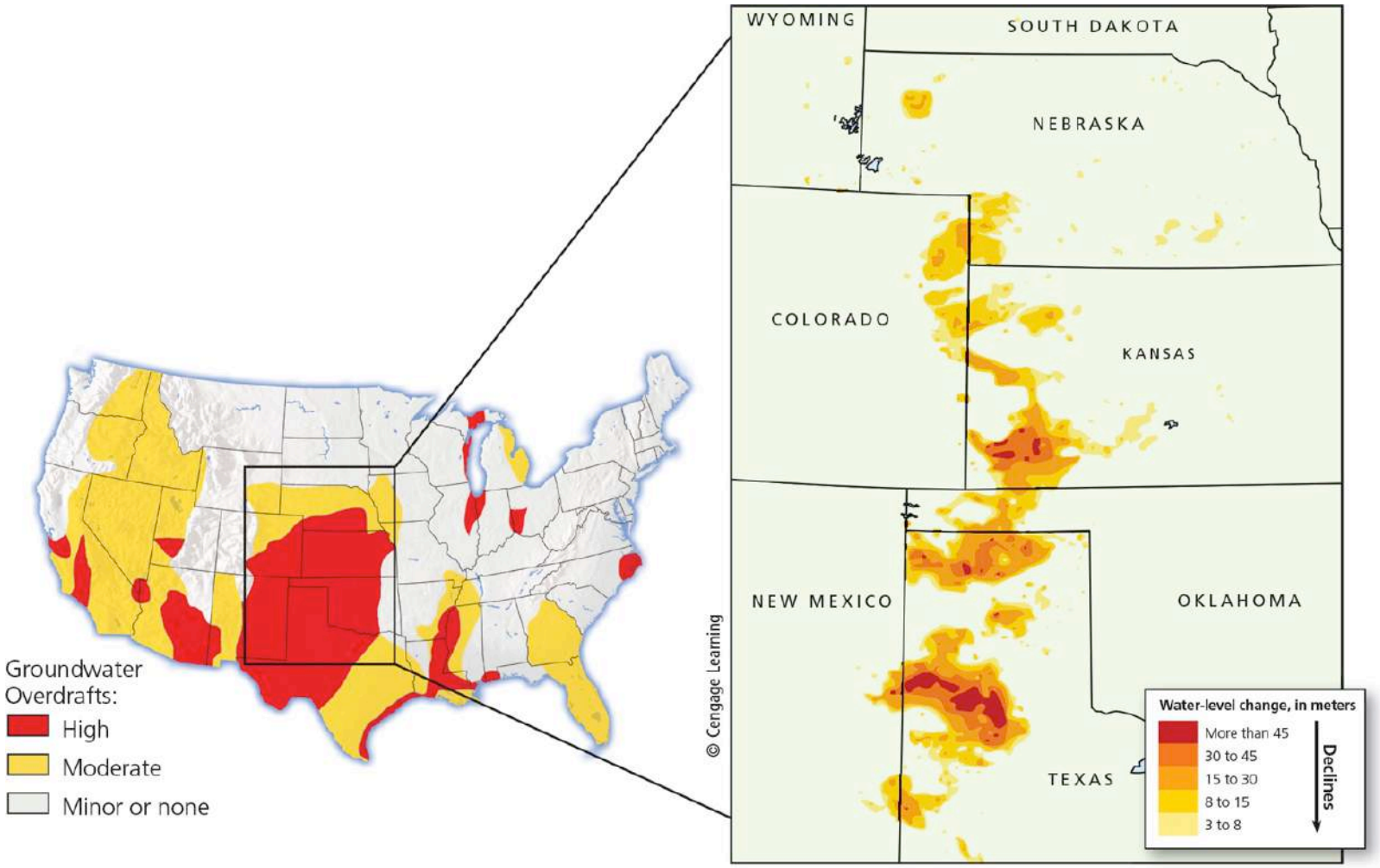
Advantages	Disadvantages
Useful for drinking and irrigation	Aquifer depletion from overpumping
Exists almost everywhere	Sinking of land (subsidence) from overpumping
Renewable if not overpumped or contaminated	Some deeper aquifers are nonrenewable
Cheaper to extract than most surface waters	Pollution of aquifers lasts decades or centuries



Case Study: Overpumping the Ogallala Aquifer (1 of 2)

- Ogallala Aquifer–largest known aquifer
  - Irrigates the Great Plains
  - Very slow recharge
  - Water table dropping
    - Water pumped 10–40 times faster than recharge rate
  - Government farm subsidies result in further depletion
  - Biodiversity threatened in some areas

Case Study: Overpumping the Ogallala Aquifer (2 of 2)



Overpumping Aquifers Can Have Harmful Effects (1 of 3)

- Limits food production and raises prices
- Widens gap between rich and poor
- Land subsidence
  - San Joaquin Valley in California
  - Mexico City
- Groundwater overdrafts near coastal regions
  - Contamination of groundwater with saltwater

Overpumping Aquifers Can Have Harmful Effects (2 of 3)

Overpumping Aquifers Can Have Harmful Effects (3 of 3)

Solutions

Groundwater Depletion

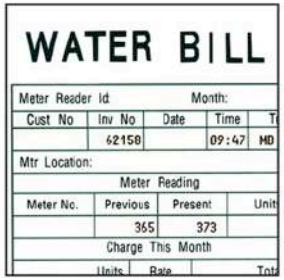
Prevention

Use water more efficiently

Subsidize water conservation

Limit number of wells

Stop growing water-intensive crops in dry areas



Control

Raise price of water to discourage waste

Tax water pumped from wells near surface water

Build rain gardens in urban areas

Use permeable paving material on streets, sidewalks, and driveways

13.3 How Can We Increase Freshwater Supplies?

- Large dam-and-reservoir systems
  - Greatly expanded water supplies in some areas
  - Disrupted ecosystems and displaced people

Large Dams Provide Benefits and Create Problems (1 of 6)

- Main goal of a dam and reservoir system
  - Capture and store runoff
  - Release runoff as needed for:
    - Flood control
    - Generating electricity
    - Supplying irrigation water
    - Recreation (reservoirs)

Large Dams Provide Benefits and Create Problems (2 of 6)

- Reservoirs
  - Increase the reliable runoff available for use
  - Displace people
  - Impair ecological services of rivers
  - Endanger plant and animal species
  - Fill up with sediment within 50 years

Large Dams Provide Benefits and Create Problems (3 of 6)

- Oroville dam in California was compromised by extremely heavy rainfall after a severe drought
- Main spillway was damaged which almost caused the weir to collapse
- 180,000 people were evacuated with only an hour's notice.

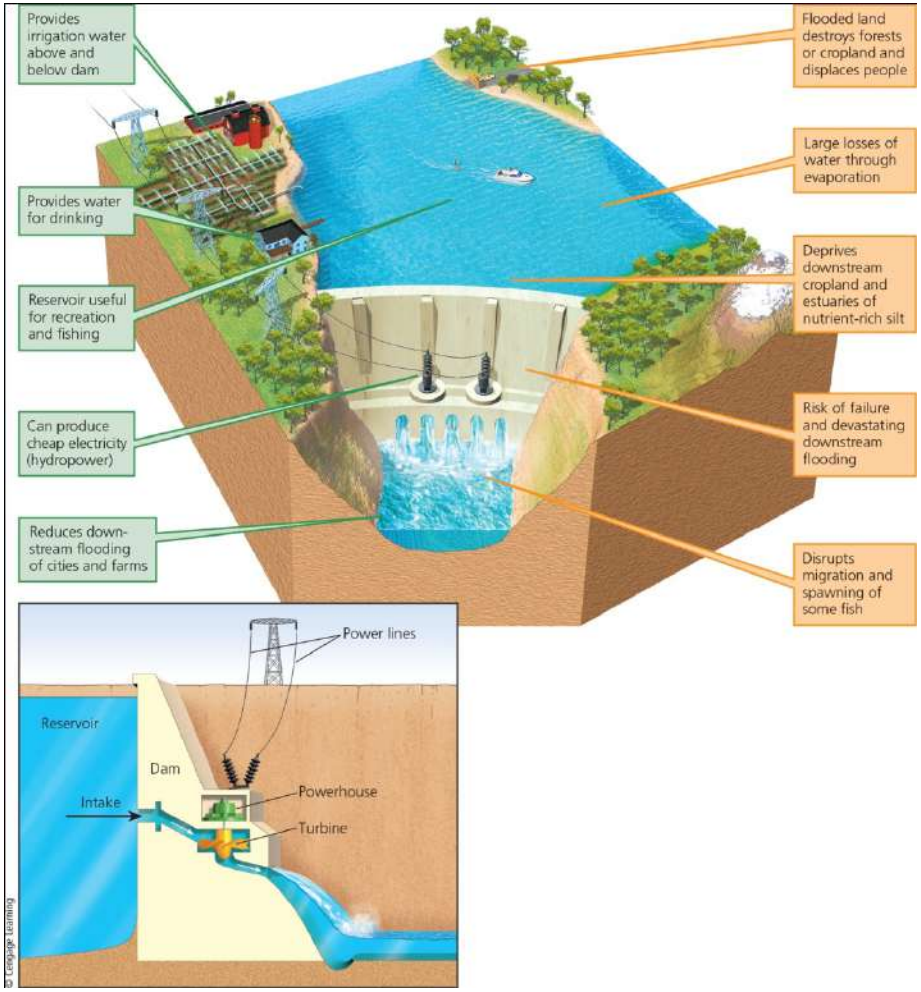
Large Dams Provide Benefits and Create Problems (4 of 6)

Courtesy of Paul Hames/California Department of Water Resources

Courtesy of Dale Kolke/California Department of Water Resources

Two images of Oroville Dam, before (left) and during (right) the spillway failure in February, 2017 when severe rain and snowmelt required use of the spillways to prevent the dam from overtopping.

Large Dams Provide Benefits and Create Problems (5 of 6)



Large Dams Provide Benefits and Create Problems (6 of 6)

- Climate change intensifies weather extremes
  - Mountain snowpack will be reduced, making less freshwater available downstream
  - When water levels drop, hydroelectric dams cannot function
  - Colorado River will most likely not be able to meet water needs in Arizona, New Mexico, and California

How Dams Can Kill an Estuary (1 of 3)

- Only a small amount of Colorado River water reaches Gulf of California
  - Threatens aquatic species in river and species that live in the estuary
- Current rate of river withdrawal is not sustainable
- Inefficient use of irrigation water for agriculture

How Dams Can Kill an Estuary (2 of 3)

- Proposed actions for states using Colorado river
  - Enact strict conservation measures
  - Phase out agricultural subsidies
  - Shift water-thirsty crops to less arid areas
  - Raise the price of freshwater

How Dams Can Kill an Estuary (3 of 3)

- 2014: Morelos dam near Yuma, AZ opened for two months to release water through the delta to the Gulf of California
  - Dramatic short-term results

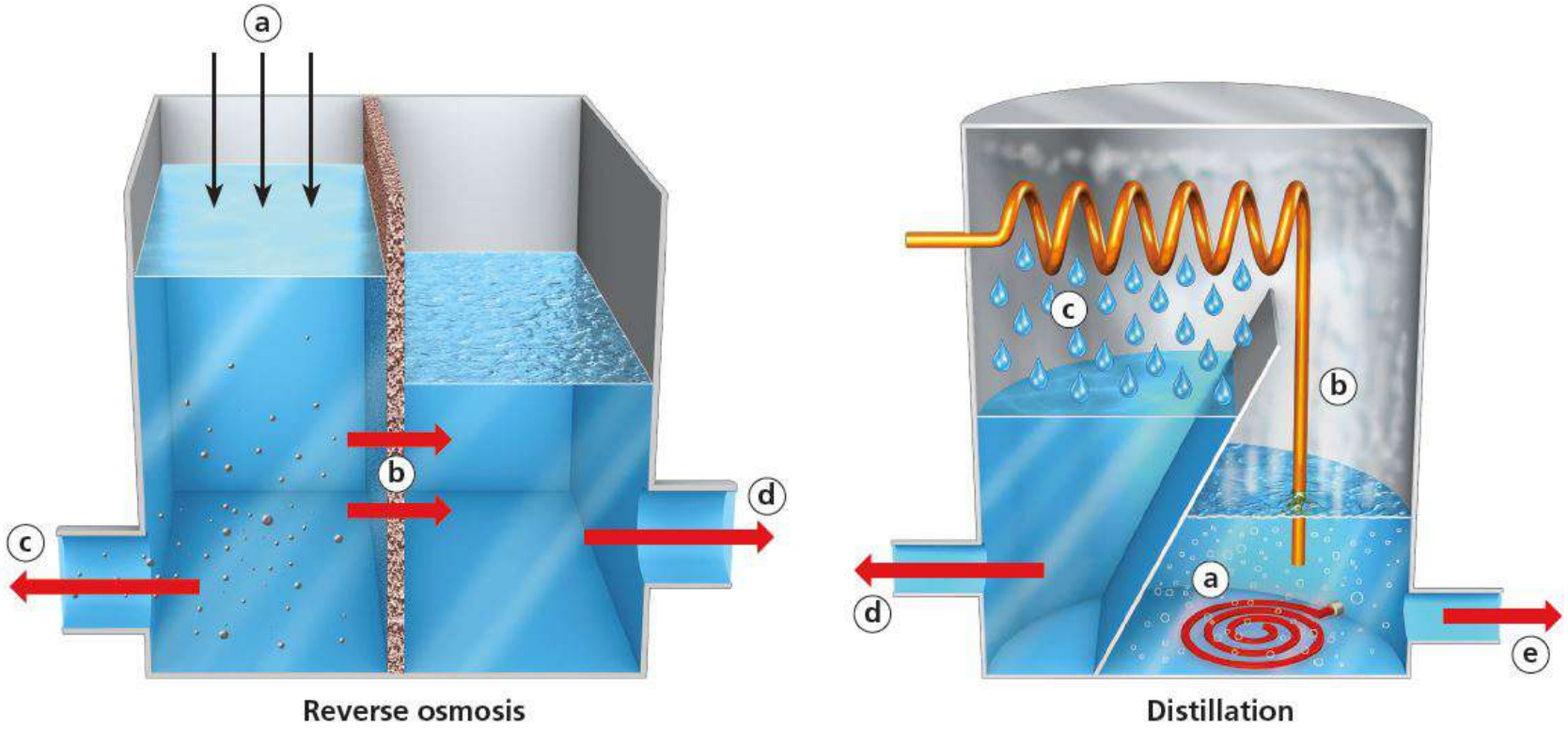
Critical Concept: NEPA and Environmental Impact Statements

- National Environmental Policy Act requires that an *environmental impact statement* be developed for every federal project likely to have an effect of environmental quality
- Impact on water, soils, air quality, wildlife habitat, etc.

Removing Salt from Seawater to Provide Freshwater (1 of 2)

- Desalination methods
  - Distillation
  - Reverse osmosis
- More than 17,000 desalination plants currently operating in 150 countries
  - Most in arid nations of Middle East, North Africa, Caribbean, and Mediterranean
- Issues: high cost, high energy use, and large amounts of salty wastewater

Removing Salt from Seawater to Provide Freshwater (2 of 2)



Desalination: Reverse osmosis (left) involves applying high pressure **(a)** to force sea water from one chamber into another through a semipermeable membrane **(b)** that separates the salt **(c)**, producing freshwater **(d)**. Distillation (right) involves heating sea water **(a)** to produce steam **(b)**, which is then condensed **(c)** and collected as freshwater **(d)**, while brine is also collected **(e)** for processing.

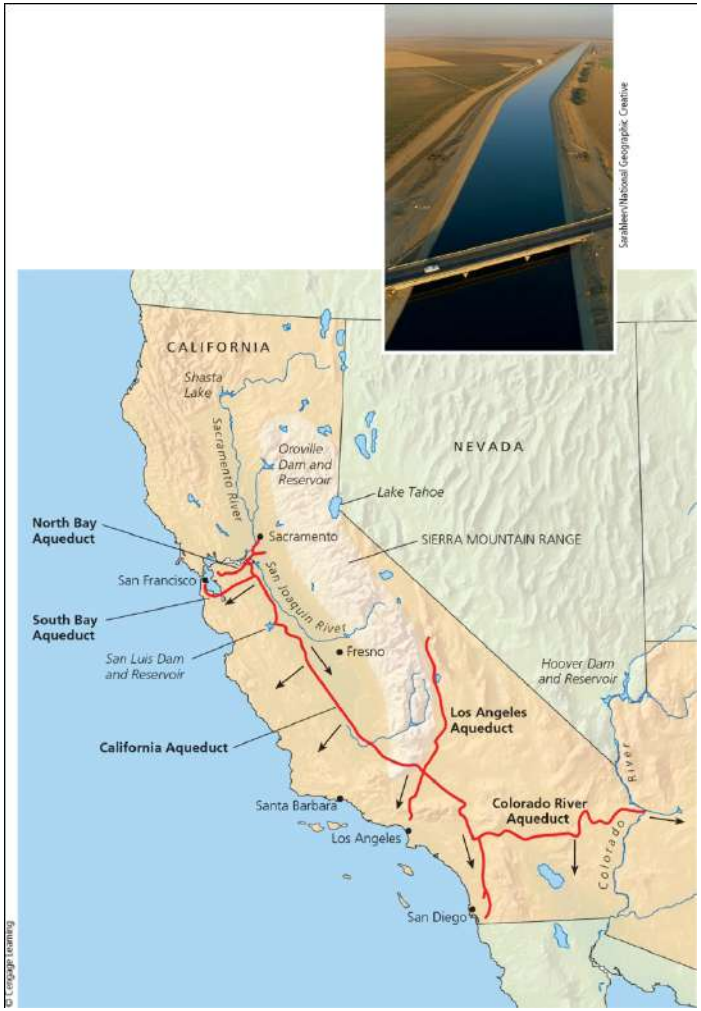
13.4 Can Water Transfers Expand Water Supplies?

- Transferring water from one place to another has greatly increased water supplies in some areas
  - Has also disrupted ecosystems

Water Transfers Have Benefits and Drawbacks (1 of 2)

- China
  - South-North Water Diversion Project
    - Diverts six trillion gallons of water per year
- California central valley
  - Aqueducts
- Water loss through evaporation and leaks
- Ecosystem degradation

Water Transfers Have Benefits and Drawbacks (2 of 2)



Case Study: The Aral Sea Disaster (1 of 3)

- Large-scale water transfers in dry central Asia have led to:
  - Wetland destruction
    - Desertification
  - Greatly increased salinity
  - Fish extinctions and decline of fishing
  - Blowing salt and dust destroying wildlife and crops
  - Increased glacial melting in the Himalayas

Case Study: The Aral Sea Disaster (2 of 3)

- Shrinkage of the Aral Sea has altered local climate
  - Hot, dry summers, colder winters, and a shortened growing season
- Restoration efforts
  - Cooperation of neighboring countries
  - More efficient irrigation
  - Dike construction raised level of Northern Sea

Case Study: The Aral Sea Disaster (3 of 3)

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13.5 How Can We Use Freshwater More Sustainably?

- Ways to use freshwater more sustainably
  - Cut water waste
  - Raise water prices
  - Slow population growth
  - Protect aquifers, forests, and other ecosystems that store and release freshwater

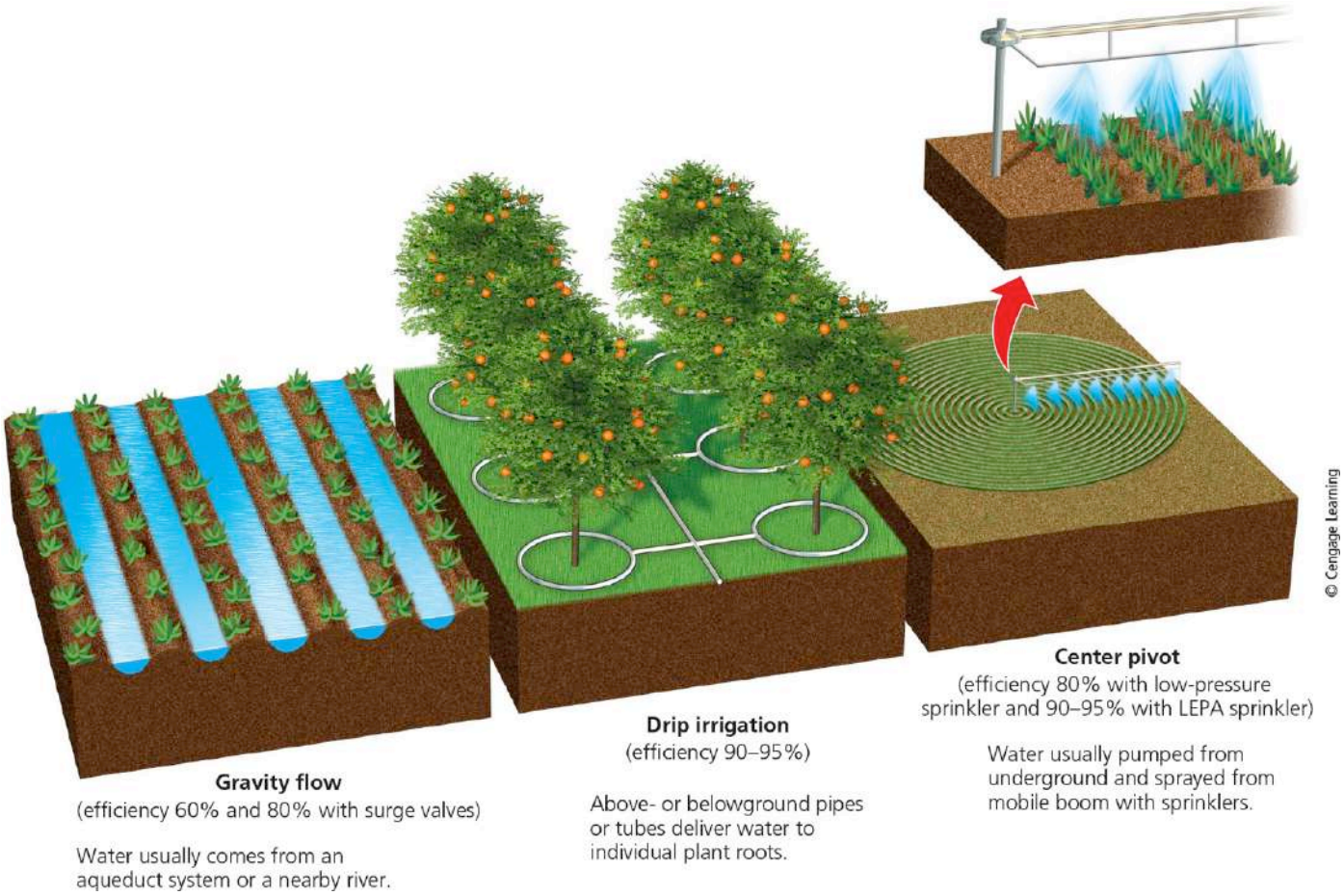
Cutting Water Waste Would Have Many Benefits

- One-half to two-thirds of water is wasted
  - Evaporation, leaks, and inefficient use
- The cost of water to users is low
  - Government subsidies mask the true cost of water
    - No subsidies for improved efficiency
- Raising prices could hurt lower-income farmers and city dwellers
  - Solution: establish lifeline rates

We Can Improve Efficiency in Irrigation (1 of 3)

- Flood irrigation
  - 45% of water lost
- More efficient techniques
  - Center pivot, low pressure sprinkler
  - Low-energy, precision application sprinklers
  - Drip or trickle irrigation, microirrigation
    - Costly
    - Less water waste

We Can Improve Efficiency in Irrigation (2 of 3)



Stepped Art

We Can Improve Efficiency in Irrigation (3 of 3)

Solutions

Reducing Irrigation Water Losses

- Avoid growing thirsty crops in dry areas
- Import water-intensive crops and meat
- Encourage organic farming and polyculture to retain soil moisture
- Monitor soil moisture to add water only when necessary
- Expand use of drip irrigation and other efficient methods
- Irrigate at night to reduce evaporation
- Line canals that bring water to irrigation ditches
- Irrigate with treated wastewater

Poor Farmers Conserve Water Using Low-Tech Methods (1 of 2)

- Human-powered treadle pumps bring water into irrigation ditches
- Harvest and store rainwater
- Capture water from fog
- Use polyculture to create canopy vegetation
  - Reduces evaporation

Poor Farmers Conserve Water Using Low-Tech Methods (2 of 2)

Courtesy of International Development Enterprises

Cutting Freshwater Losses in Industry and Homes (1 of 3)

- Recycle water used in industry
- Use low-flow toilets, showerheads, and front-loading washing machines
- Fix leaks in the plumbing systems
- Use native plants in landscaping
- Use gray water
- Water meters reduce water use

Cutting Freshwater Losses in Industry and Homes (2 of 3)

karolinapatryk/Thinkstock

Cutting Freshwater Losses in Industry and Homes (3 of 3)

Solutions

Reducing Water Losses

- Redesign manufacturing processes to use less water
- Recycle water in industry
- Fix water leaks
- Landscape yards with plants that require little water
- Use drip irrigation on gardens and lawns
- Use water-saving showerheads, faucets, appliances, and toilets (or waterless composting toilets)
- Collect and reuse gray water in and around houses, apartments, and office buildings
- Raise water prices and use meters, especially in dry urban areas

Using Less Water to Remove Wastes

- Large amounts of freshwater used to flush away wastes
- Reuse wastewater
  - Only about 7% of wastewater is currently recycled
- Use waterless composting toilets

Using Water More Sustainably (1 of 2)

- Protect water supplies
- Apply strategies at local, regional, national, and international levels
- Apply strategies at a personal level
  - Use less freshwater and use it more efficiently

Using Water More Sustainably (2 of 2)

What Can You Do?

Water Use and Waste

- Use water-saving toilets, showerheads, and faucets
- Take short showers instead of baths
- Turn off sink faucets while brushing teeth, shaving, or washing
- Wash only full loads of clothes or use the lowest possible water-level setting for smaller loads
- Repair water leaks
- Wash your car from a bucket of soapy water, use gray water, and use the hose for rinsing only
- If you use a commercial car wash, try to find one that recycles its water
- Replace your lawn with native plants that need little if any watering
- Water lawns and gardens only in the early morning or evening and use gray water
- Use drip irrigation and mulch for gardens and flowerbeds

13.6 How Can We Reduce the Threat of Flooding?

- We can lessen the threat of flooding by:
  - Protecting more wetlands and natural vegetation in watersheds
  - Not building in areas subject to frequent flooding

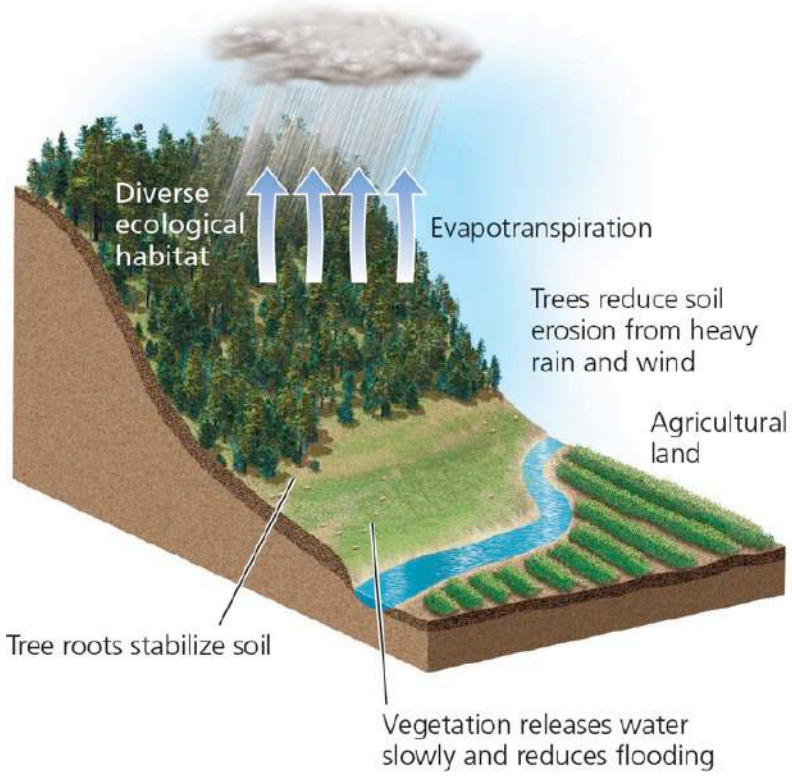
Some Areas Get Too Much Water from Flooding (1 of 3)

- Floodplain
  - Area flooded when a stream overflows its channel
  - Fertile soils for farming
  - Recharge groundwater and refill wetlands
- Human activities that damage floodplains
  - Vegetation removal
  - Draining of wetlands

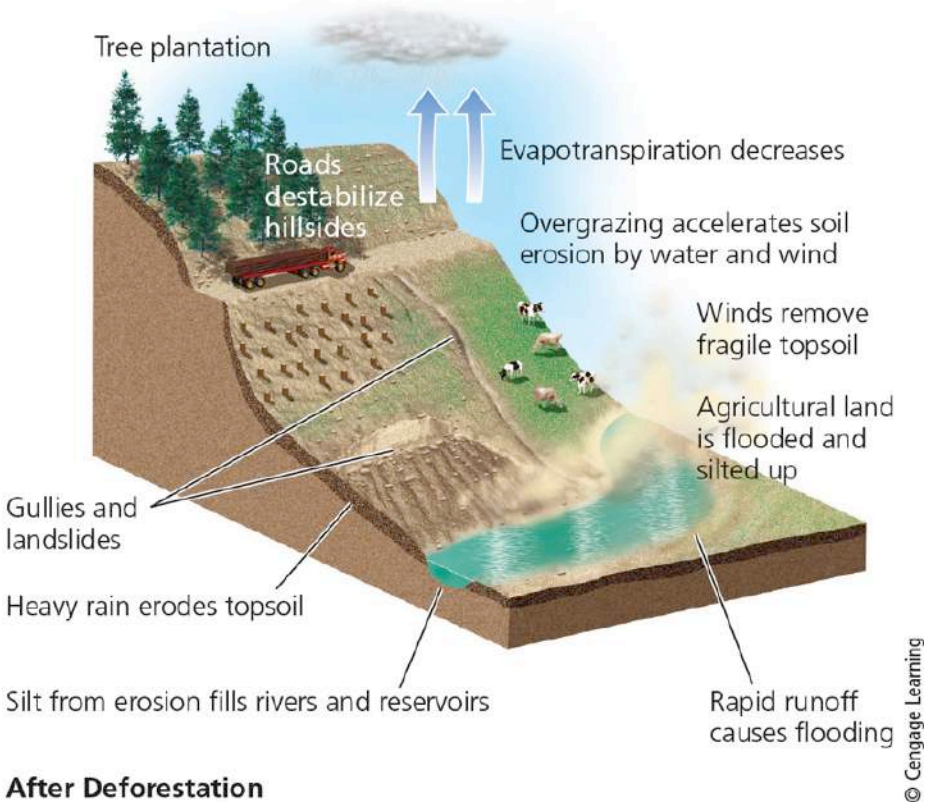
Some Areas Get Too Much Water from Flooding (2 of 3)

- Human activities that damage floodplains (cont'd.)
  - Rising sea levels from global warming means more coastal flooding

Some Areas Get Too Much Water from Flooding (3 of 3)



Forested Hillside



After Deforestation

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Case Study: Living Dangerously on Floodplains in Bangladesh

- Dense population on coastal floodplain
- Moderate floods maintain fertile soil
- Recent increased frequency of severe floods
- Destruction of coastal wetlands
  - Mangrove forests cleared
  - Increased storm damage
- Adapting: using more flood-tolerant crops

Reducing Flood Risks (1 of 2)

- Rely more on nature's systems
  - Wetlands
  - Natural vegetation in watersheds
- Rely less on engineering devices
  - Dams
  - Levees
  - Channelized streams

We Can Reduce Flood Risks (2 of 2)

Solutions

Reducing Flood Damage

Prevention

Preserve forests in watersheds

Preserve and restore wetlands on floodplains

Tax development on floodplains

Increase use of flood-plains for sustainable agriculture and forestry

Control

Strengthen and deepen streams (channelization)

Build levees or floodwalls along streams

Build dams