MILLER/SPOOLMAN

LIVING IN THE ENVIRONMENT

17TH

Chapter 13

Water Resources

Case Study: The Colorado River Basin— An Overtapped Resource (1)

- 2,300 km through 7 U.S. states
- 14 Dams and reservoirs
- Located in a desert area within the rain shadow of the Rocky Mountains
- Water supplied mostly from snowmelt of the Rocky Mountains

Case Study: The Colorado River Basin— An Overtapped Resource (2)

- Supplies water and electricity for about 30 million people
  - Las Vegas, Los Angeles, San Diego
- Irrigation of crops that help feed America
- Very little water reaches the Gulf of California
- Southwest experiencing recent droughts

The Colorado River Basin

Fig. 13-1, p. 317

Aerial View of Glen Canyon Dam Across the Colorado River and Lake Powell

Fig. 13-2, p. 317

13-1 Will We Have Enough Usable Water?

- ***Concept 13-1A*** *We are using available freshwater unsustainably by wasting it, polluting it, and charging too little for this irreplaceable natural resource.*

- ***Concept 13-1B*** *One of every six people does not have sufficient access to clean water, and this situation will almost certainly get worse.*

Freshwater Is an Irreplaceable Resource That We Are Managing Poorly (1)

- Why is water so important?
- Earth as a watery world: 71% of surface
- Poorly managed resource
- Water waste
- Water pollution

Freshwater Is an Irreplaceable Resource That We Are Managing Poorly (2)

- Access to water is
  - A global health issue
  - An economic issue
  - A women's and children's issue
  - A national and global security issue

Girl Carrying Well Water over Dried Out Earth during a Severe Drought in India

Fig. 13-3, p. 319

Most of the Earth's Freshwater Is Not Available to Us

- Freshwater availability: 0.024%
  - Groundwater, lakes, rivers, streams
- Hydrologic cycle
  - Movement of water in the seas, land, and air
  - Driven by solar energy and gravity
- People divided into
  - Water *haves*
  - Water *have-nots*

Hydrologic Cycle

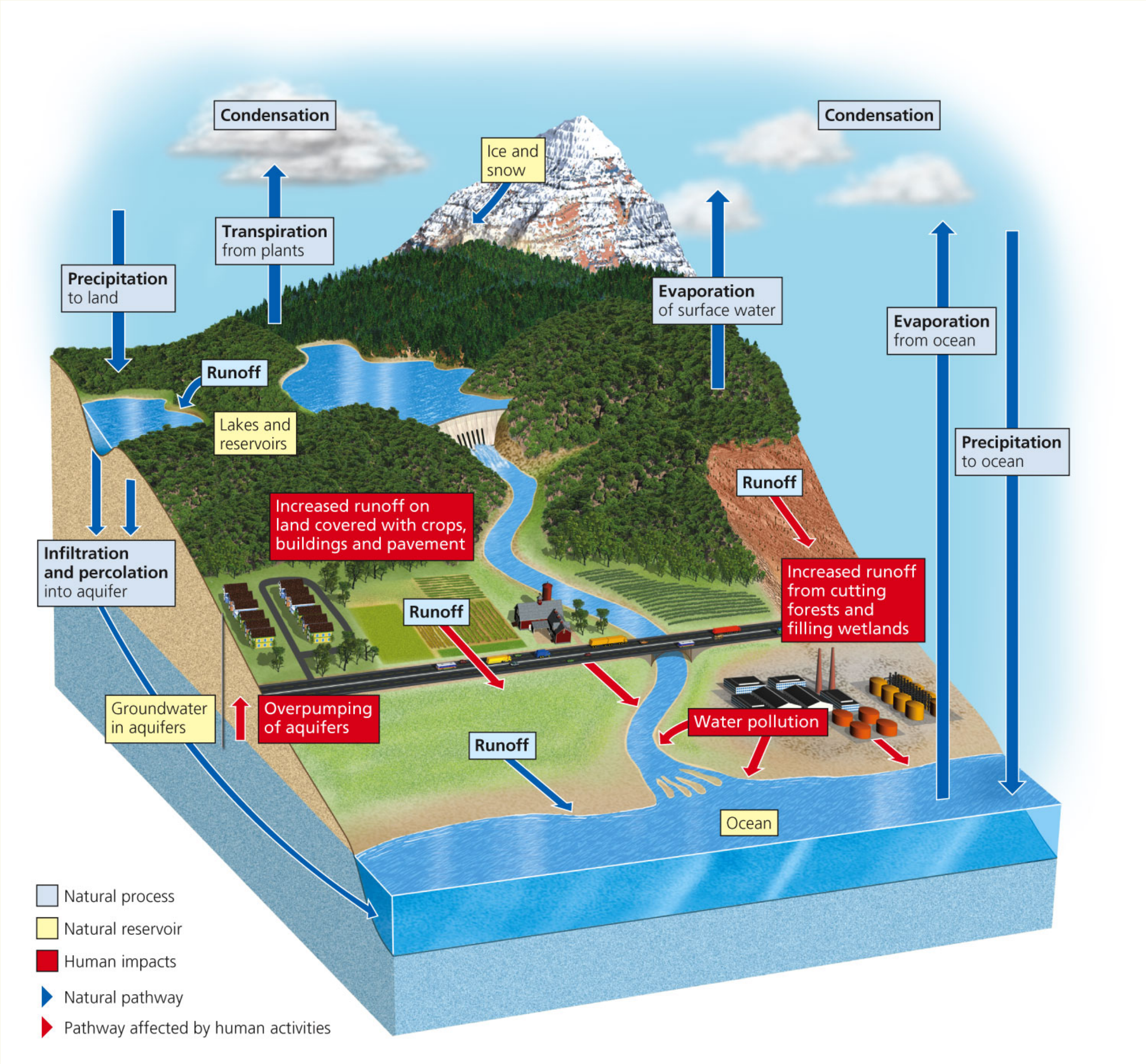


Fig. 3-16, p. 67

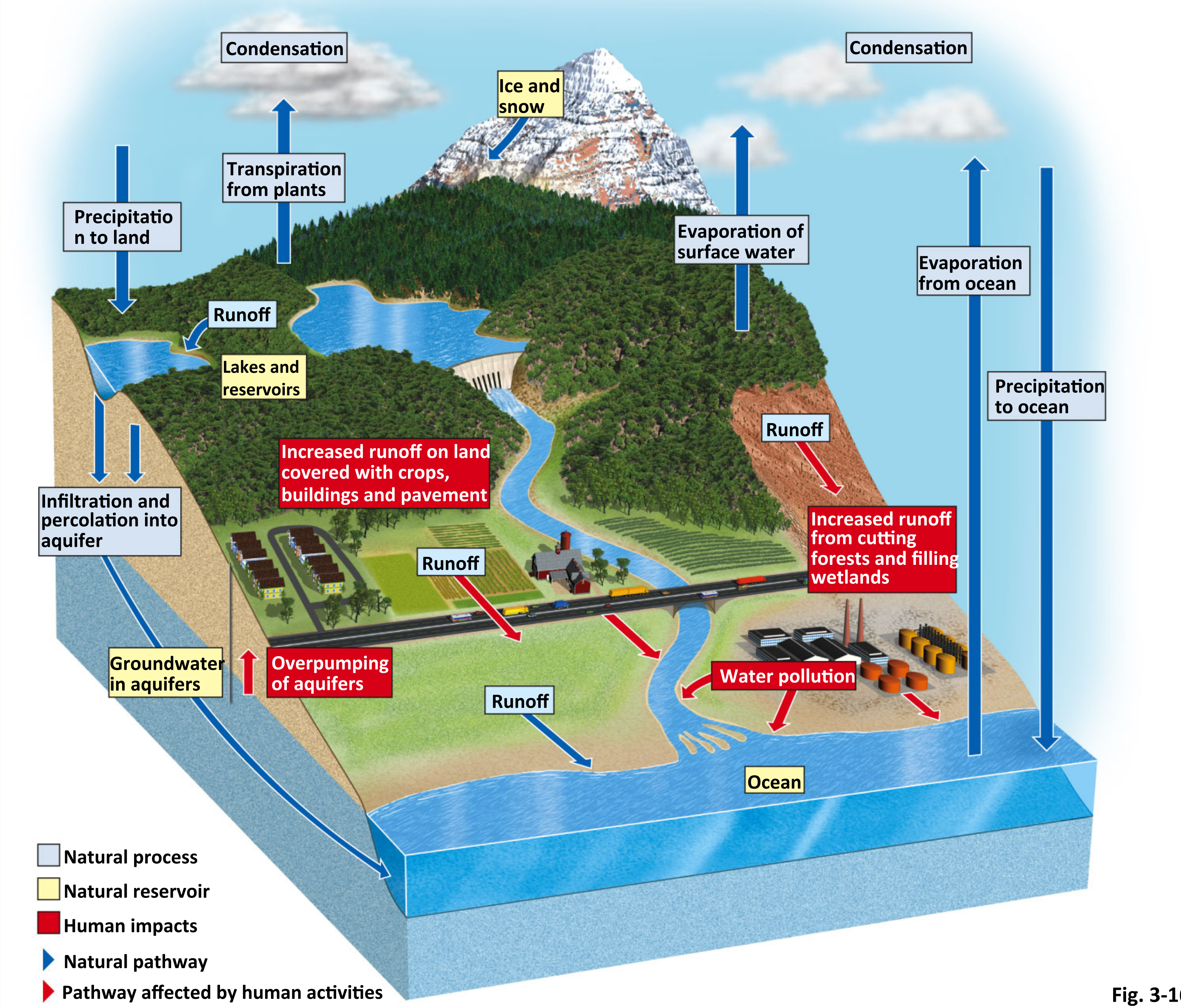

Condensation
Condensation
Ice and snow
Transpiration from plants
Precipitation to land
Evaporation of surface water
Evaporation from ocean
Runoff
Lakes and reservoirs
Precipitation to ocean
Runoff
Increased runoff on land covered with crops, buildings and pavement
Infiltration and percolation into aquifer
Increased runoff from cutting forests and filling wetlands
Runoff
Groundwater in aquifers
Overpumping of aquifers
Water pollution
Runoff
Ocean
Natural process
Natural reservoir
Human impacts
Natural pathway
Pathway affected by human activities

Fig. 3-16, p. 67

Groundwater and Surface Water Are Critical Resources (1)

- **Zone of saturation**
  - Spaces in soil are filled with water
- **Water table**
  - Top of zone of saturation
- **Aquifers**
  - Natural recharge
  - Lateral recharge

Groundwater and Surface Water Are Critical Resources (2)

- **Surface Water**
  - **Surface runoff**
  - **Watershed (drainage) basin**

We Use Much of the World's Reliable Runoff

- 2/3 of the surface runoff: lost by seasonal floods
- 1/3 is **reliable runoff** = usable
- World-wide averages
  - Domestic: 10%
  - Agriculture: 70%
  - Industrial use: 20%

Science Focus: Water Footprints and Virtual Water (1)

- **Water footprint**
  - Volume of water we directly and indirectly

- Average American uses 260 liters per day
  - Flushing toilets, 27%
  - Washing clothes, 22%
  - Taking showers, 17%
  - Running faucets, 16%
  - Wasted from leaks, 14%
  - World’s poorest use 19 liters per day

Science Focus: Water Footprints and Virtual Water (2)

- More water is used indirectly = **virtual water**
  - Hamburger, 2400 liters
- Virtual water often exported/imported
  - Grains and other foods

Virtual Water Use

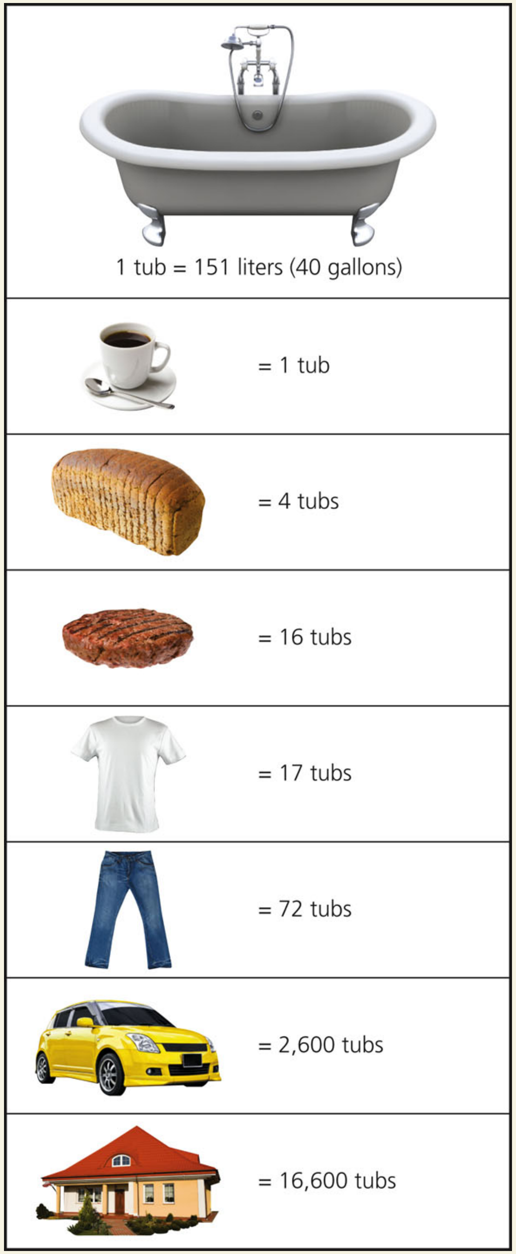


Fig. 13-A, p. 321

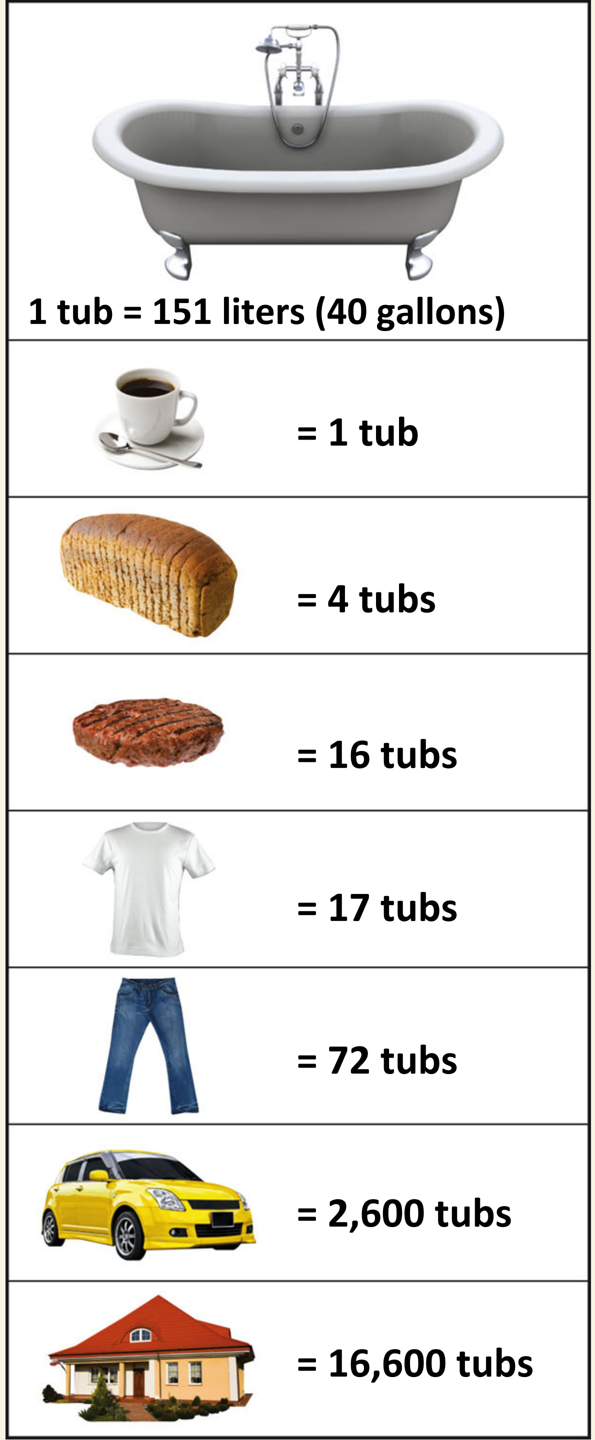

1 tub = 151 liters (40 gallons)
= 1 tub
= 4 tubs
= 16 tubs
= 17 tubs
= 72 tubs
= 2,600 tubs
= 16,600 tubs

Fig. 13-A, p. 321

Case Study: Freshwater Resources in the United States

- More than enough renewable freshwater, unevenly distributed and polluted

- Effect of
  - Floods
  - Pollution
  - **Drought**

- 2007: U.S. Geological Survey projection
  - Water hotspots

Average Annual Precipitation and Major Rivers, Water-Deficit Regions in U.S.

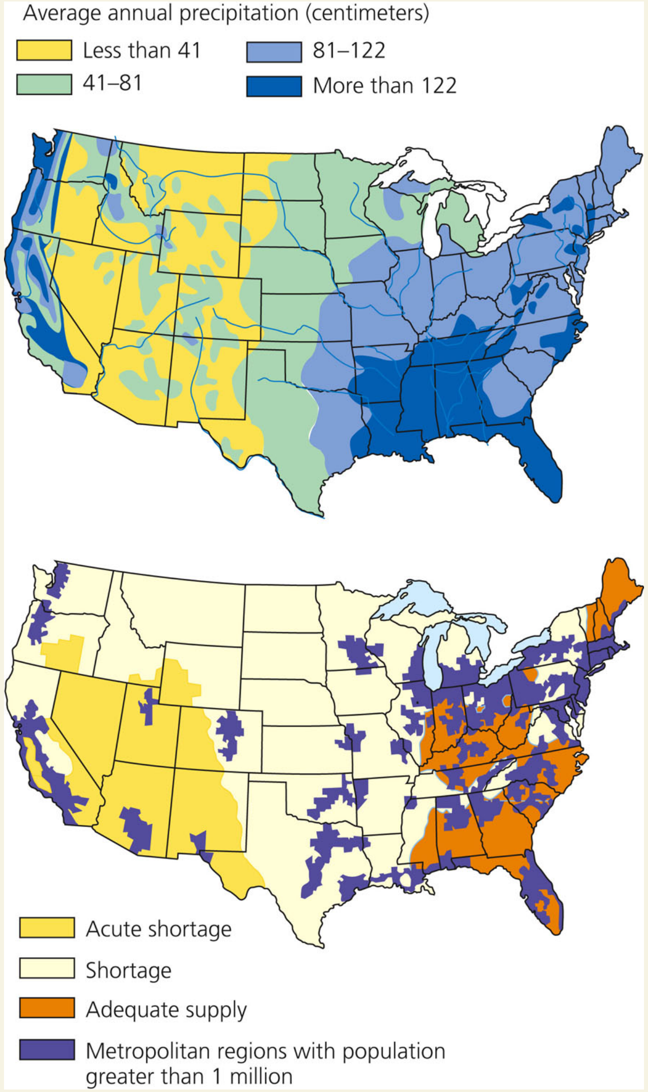


Fig. 13-4, p. 322

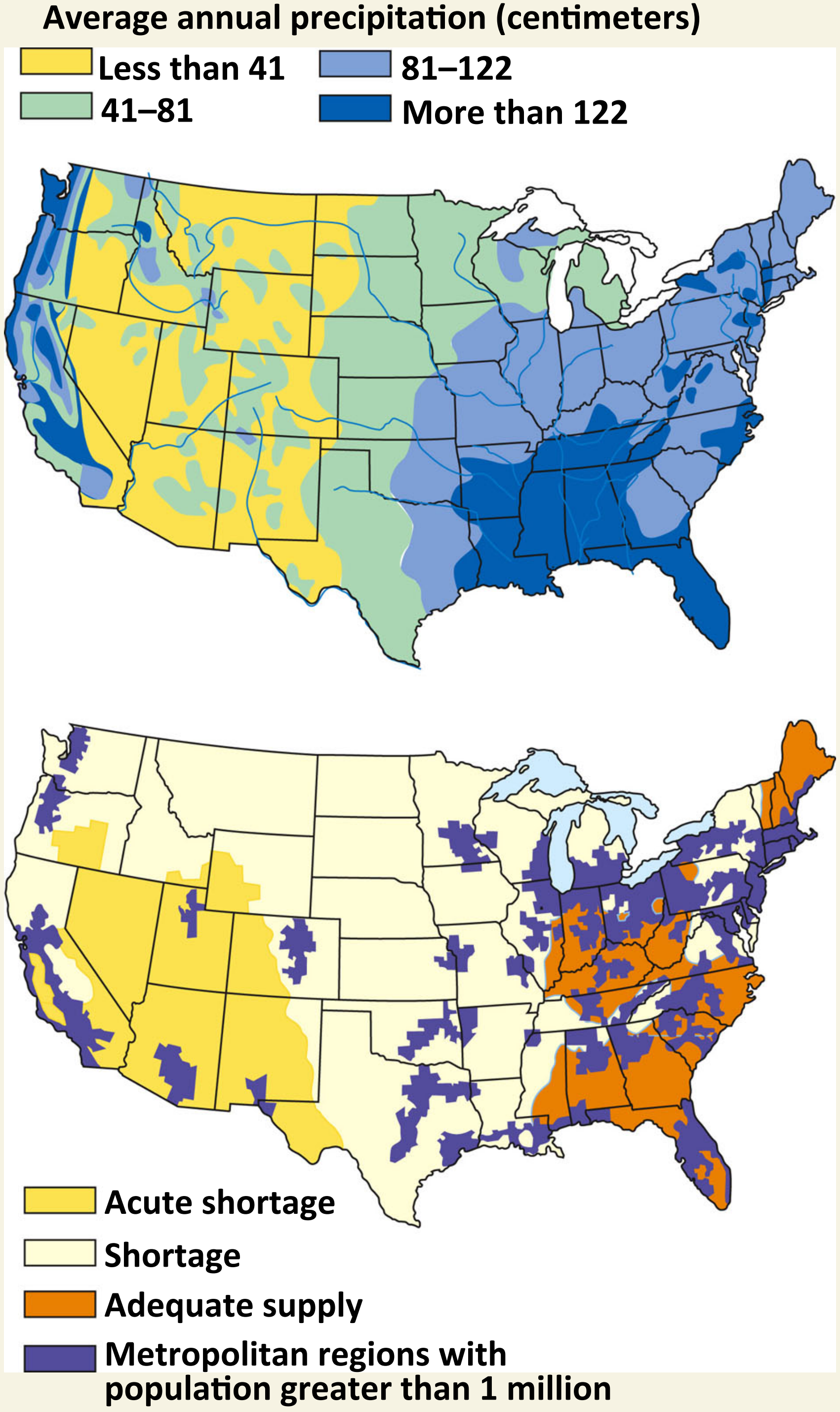
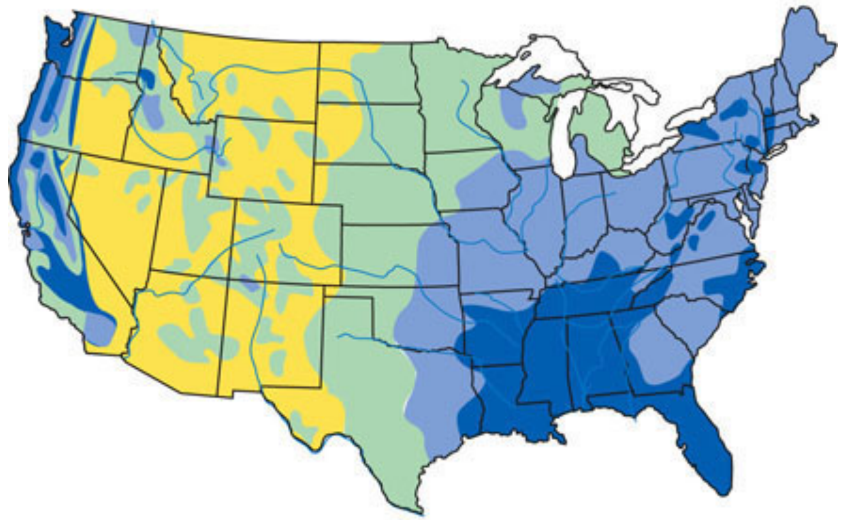
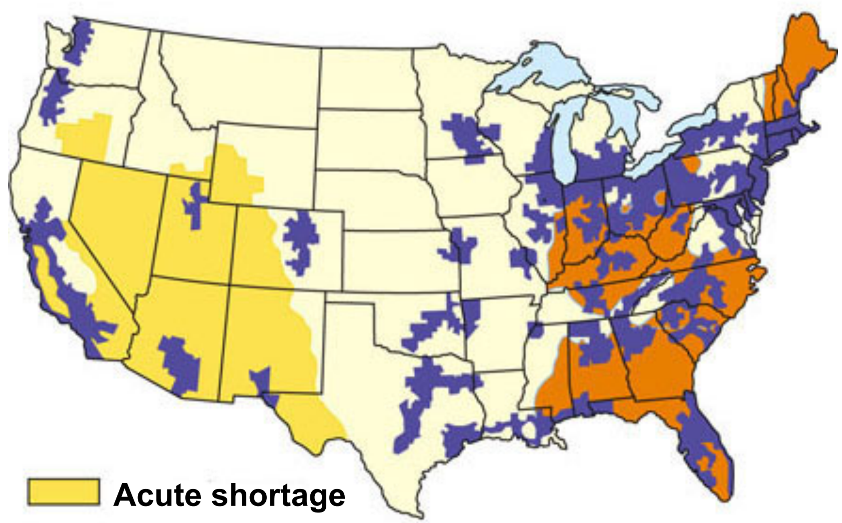

Average annual precipitation (centimeters)
Less than 41
41–81
81–122
More than 122
Acute shortage
Shortage
Adequate supply
Metropolitan regions with population greater than 1 million

Fig. 13-4, p. 322





Stepped Art

Fig. 13-4, p. 322

Water Hotspots in 17 Western U.S. States

Fig. 13-5, p. 322

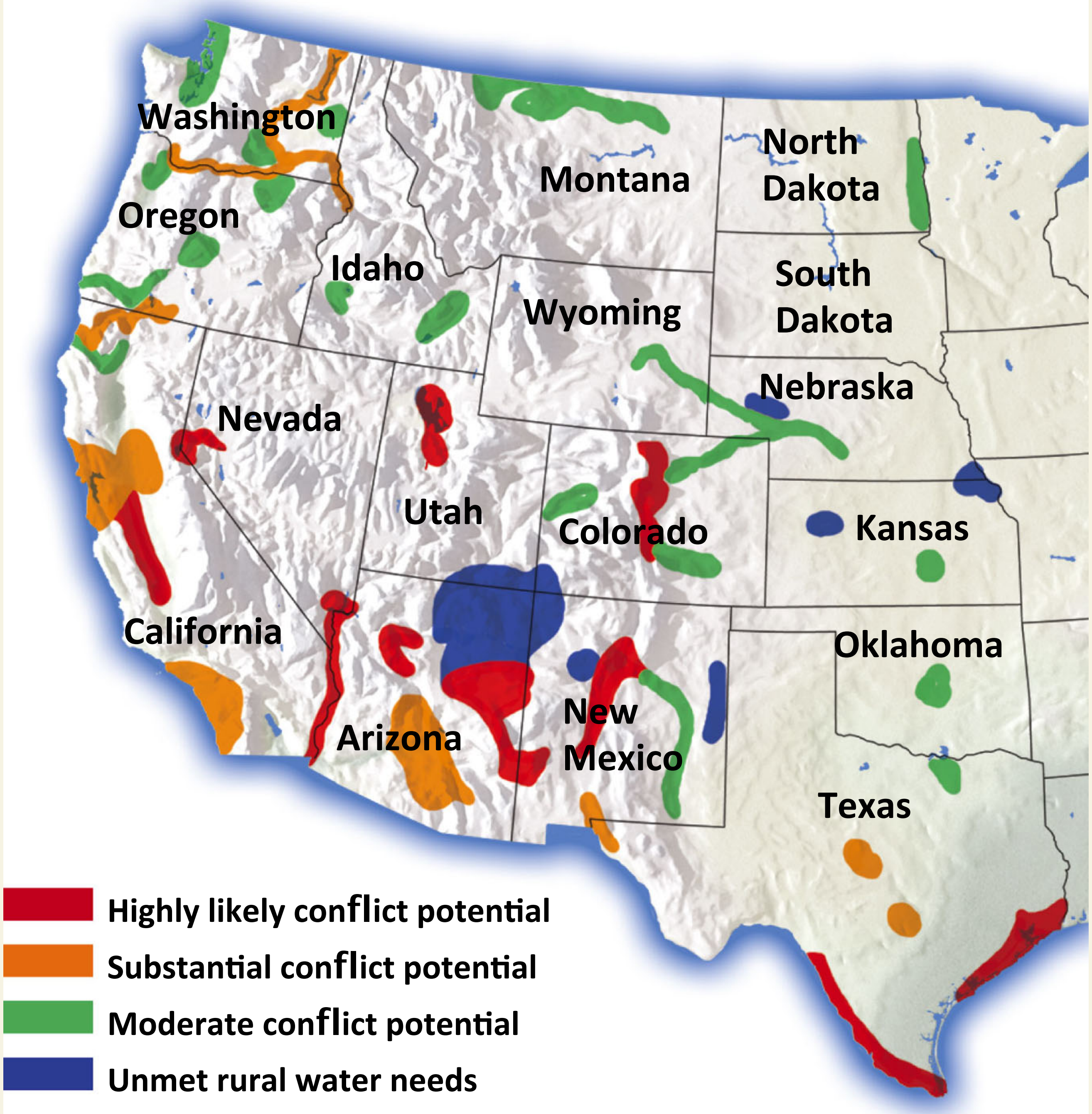

Washington
Montana
North Dakota
Oregon
Idaho
South Dakota
Wyoming
Nebraska
Nevada
Utah
Colorado
Kansas
California
Oklahoma
New Mexico
Arizona
Texas
Highly likely conflict potential
Substantial conflict potential
Moderate conflict potential
Unmet rural water needs

Fig. 13-5, p. 322

Water Shortages Will Grow (1)

- Dry climates
- Drought
- Too many people using a normal supply of water
- Wasteful use of water

Water Shortages Will Grow (2)

- China and urbanization
- 30% earth's land area experiences severe drought
  - Will rise to 45% by 2059 from climate change
- Potential conflicts/wars over water
  - Refugees from arid lands
  - Increased mortality

Natural Capital Degradation: Stress on the World's Major River Basins

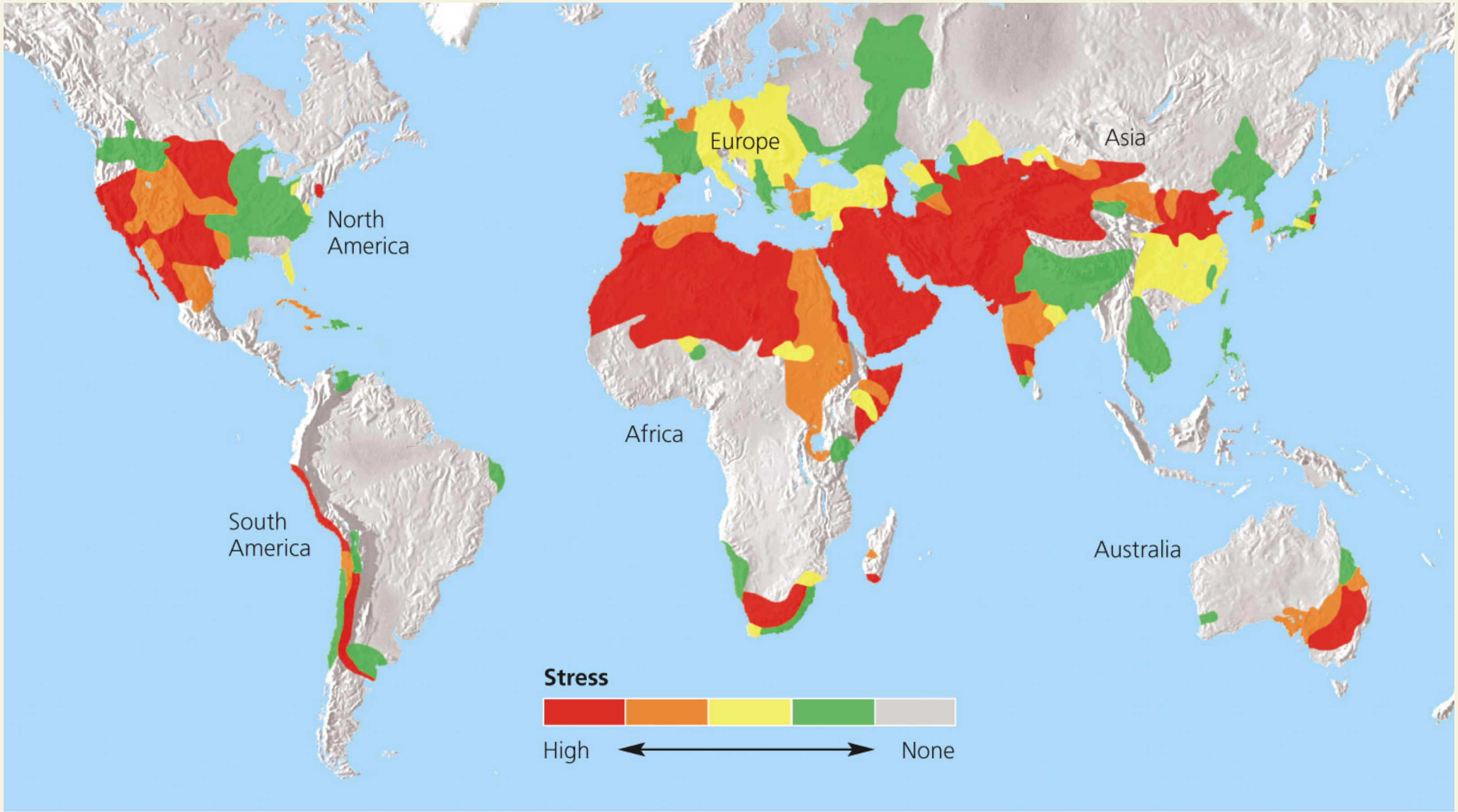
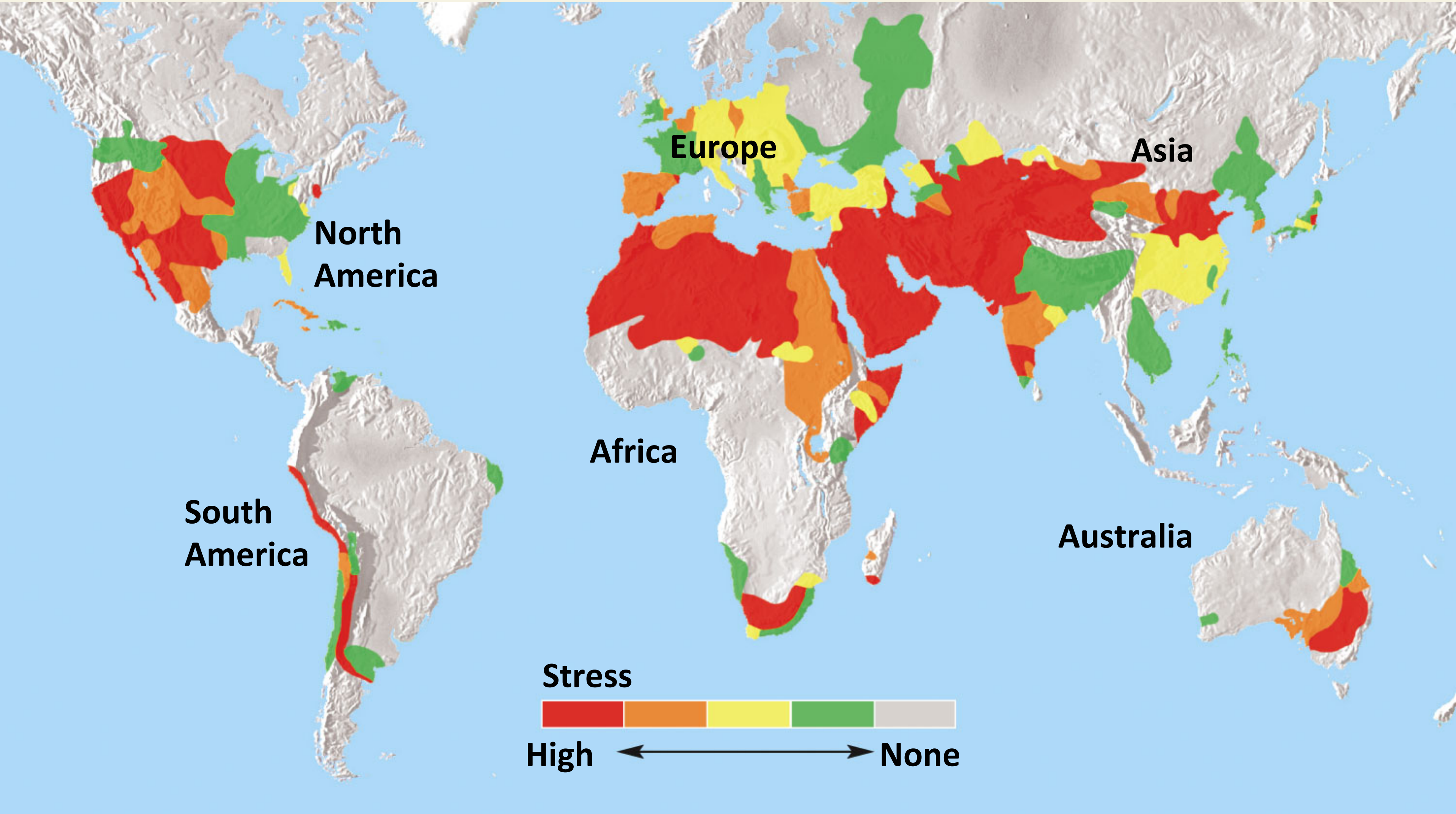


Fig. 13-6, p. 323



Europe
Asia
North
America
Africa
South
America
Australia
Stress
High
None

Fig. 13-6, p. 323

13-2 Is Extracting Groundwater the Answer?

- ***Concept 13-2*** *Groundwater used to supply cities and grow food is being pumped from aquifers in some areas faster than it is renewed by precipitation.*

Groundwater is Being Withdrawn Faster Than It Is Replenished (1)

- Most aquifers are renewable
- Aquifers provide drinking water for half the world
- Water tables are falling in many parts of the world, primarily from crop irrigation

Groundwater is Being Withdrawn Faster Than It Is Replenished (2)

- India, China, and the United States
  - Three largest grain producers
  - Overpumping aquifers for irrigation of crops
- India and China
  - Small farmers drilling tubewells
  - Effect on water table
- Saudi Arabia
  - Aquifer depletion and irrigation

Trade-Offs: Withdrawing Groundwater, Advantages and Disadvantages

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	Pollution of aquifers lasts decades or centuries
Cheaper to extract than most surface waters	Deeper wells are nonrenewable

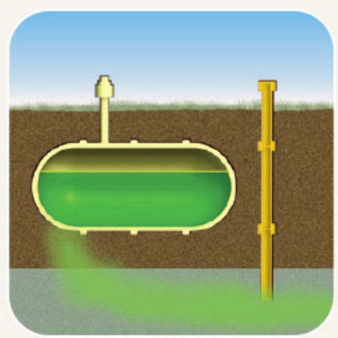


Fig. 13-7, p. 325

Trade-Offs

Withdrawing Groundwater

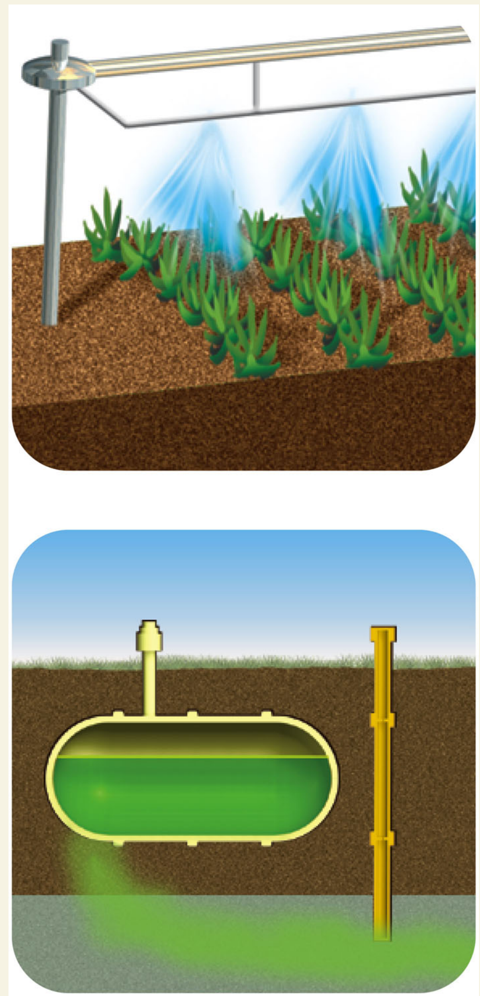
Advantages

Useful for drinking and irrigation

Exists almost everywhere

Renewable if not overpumped or contaminated

Cheaper to extract than most surface waters



Disadvantages

Aquifer depletion from overpumping

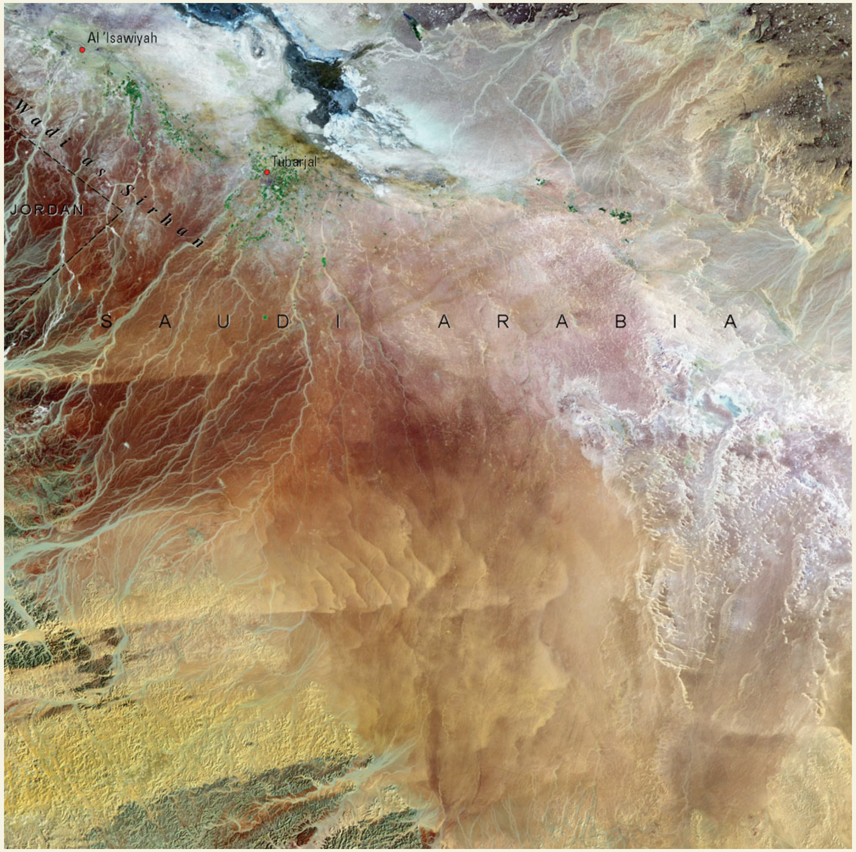
Sinking of land (subsidence) from overpumping

Pollution of aquifers lasts decades or centuries

Deeper wells are nonrenewable

Fig. 13-7, p. 325

Natural Capital Degradation: Irrigation in Saudi Arabia Using an Aquifer



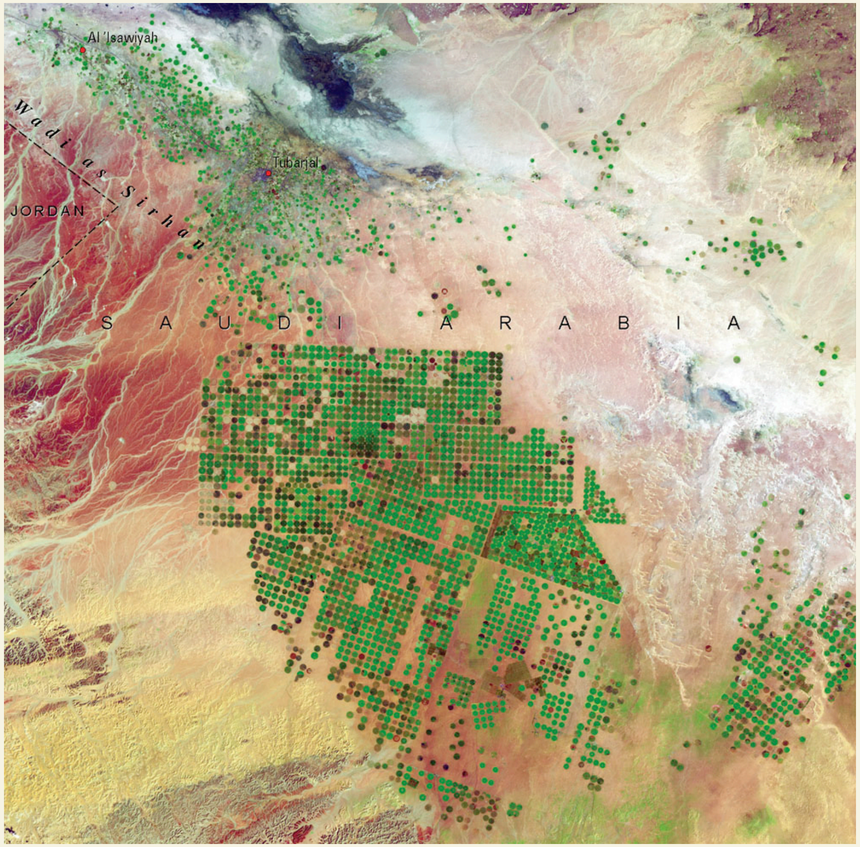


Fig. 13-8, p. 325

Case Study: Aquifer Depletion in the United States

- Ogallala aquifer: largest known aquifer
  - Irrigates the Great Plains
  - Very slow recharge
  - Water table dropping
  - Government subsidies to continue farming deplete the aquifer further
  - Biodiversity threatened in some areas

- California Central Valley: serious water depletion

Natural Capital Degradation: Areas of Greatest Aquifer Depletion in the U.S.

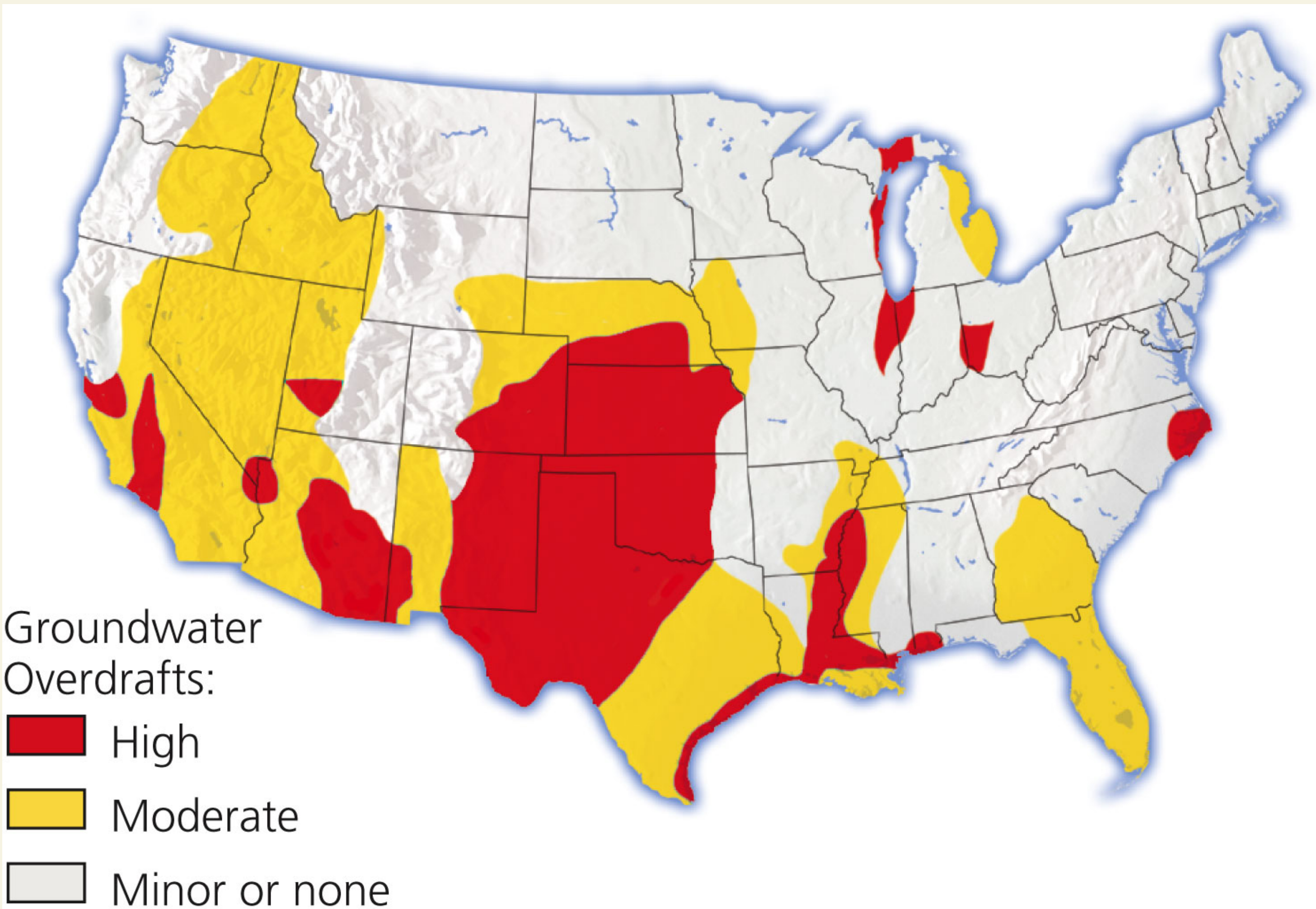


Fig. 13-9, p. 326

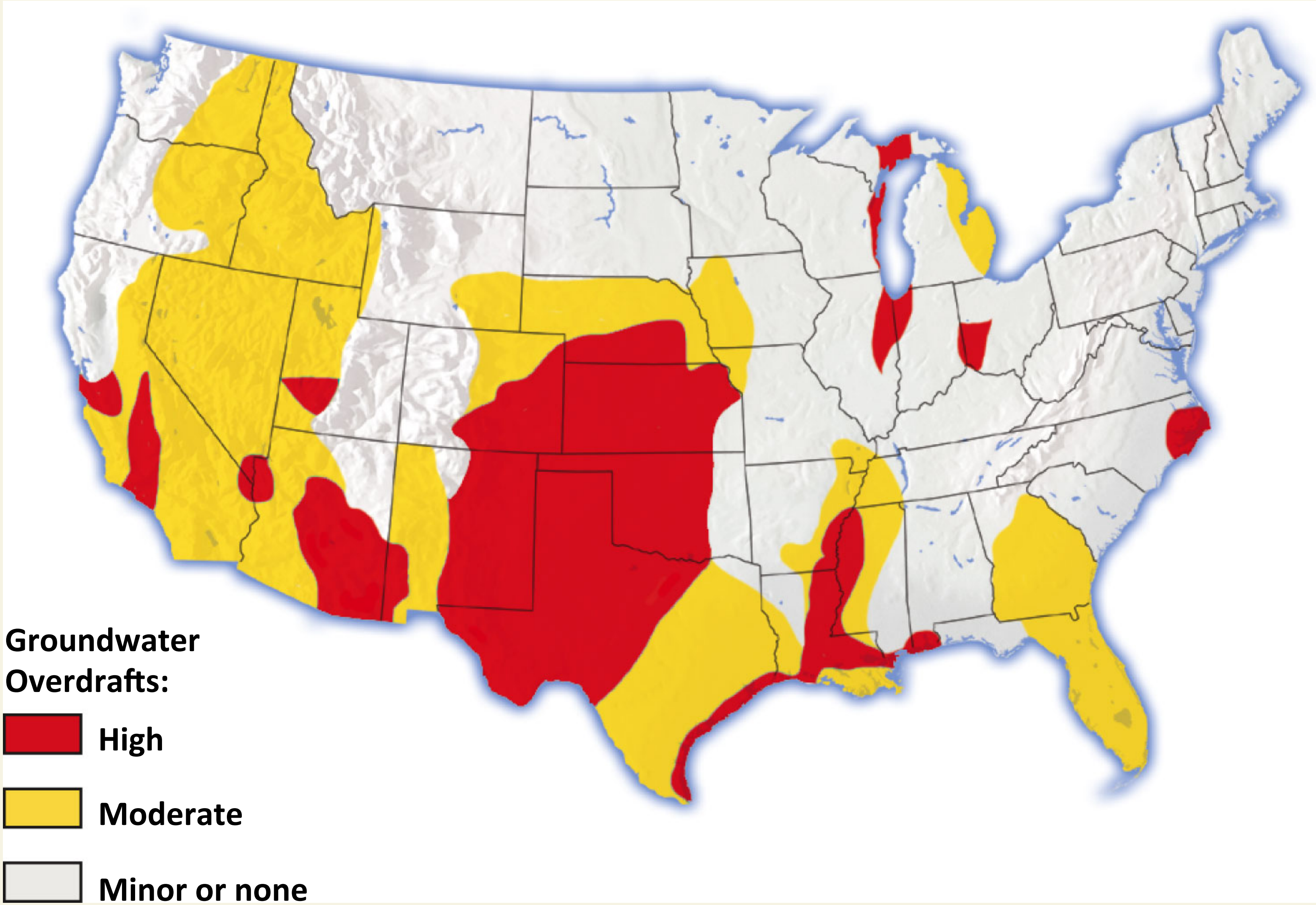


Fig. 13-9, p. 326

Kansas Crops Irrigated by the Ogallala Aquifer

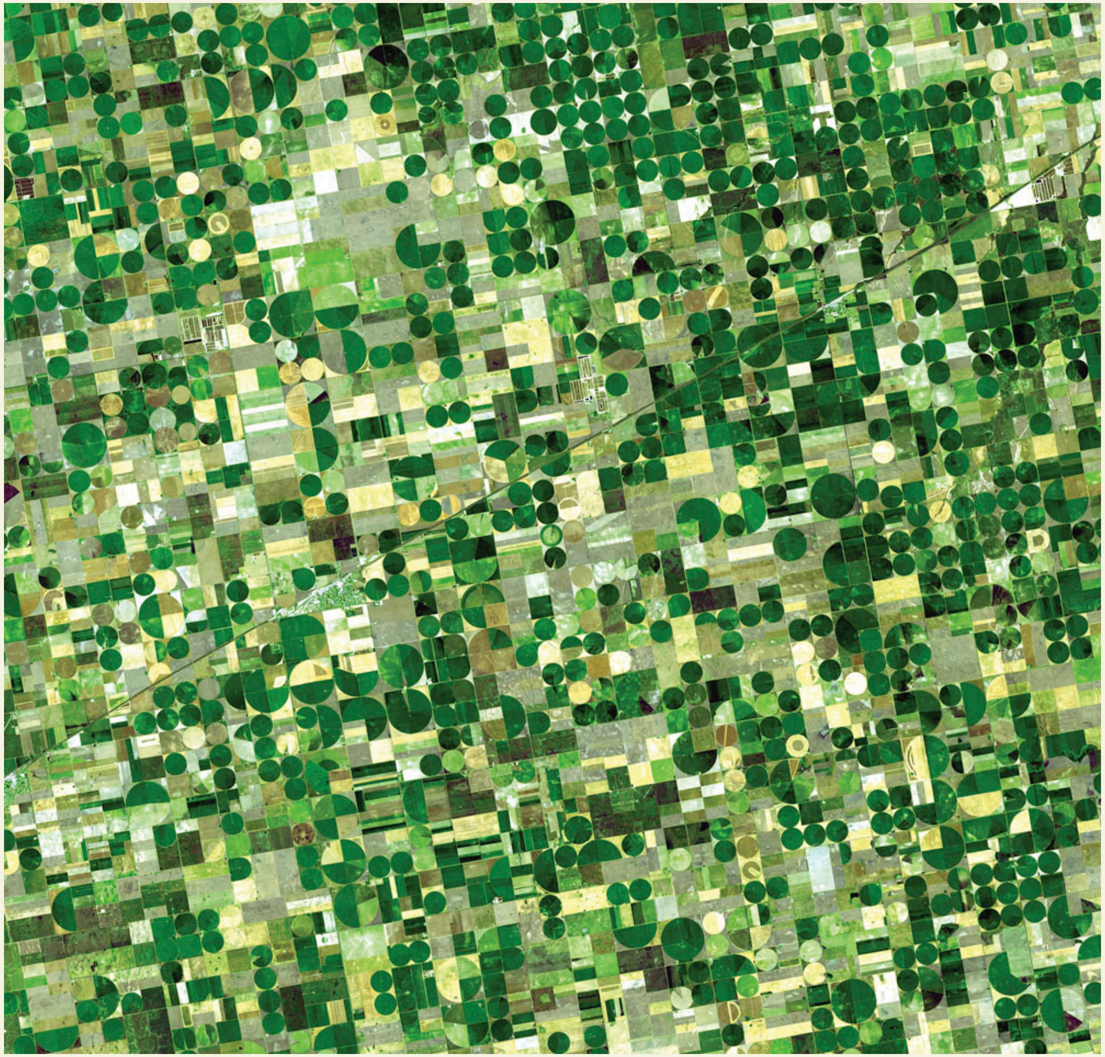


Fig. 13-10, p. 326

Overpumping Aquifers Has Several Harmful Effects

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

Subsidence in the San Joaquin Valley

Fig. 13-11, p. 327

Solutions: Groundwater Depletion, Prevention and Control

Solutions

Groundwater Depletion

Prevention

Waste less water

Subsidize water conservation

Limit number of wells

Do not grow water-intensive crops in dry areas

Control

Raise price of water to discourage waste

Tax water pumped from wells near surface waters

Set and enforce minimum stream flow levels

Divert surface water in wet years to recharge aquifers

Fig. 13-12, p. 327

Solutions

Groundwater Depletion

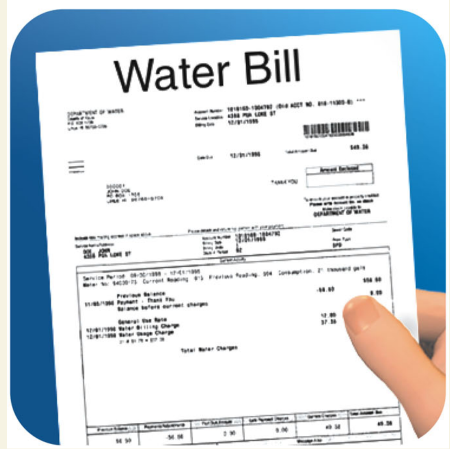
Prevention

Waste less water

Subsidize water conservation

Limit number of wells

Do not grow water-intensive crops in dry areas



Control

Raise price of water to discourage waste

Tax water pumped from wells near surface waters

Set and enforce minimum stream flow levels

Divert surface water in wet years to recharge aquifers

Fig. 13-12, p. 327

Deep Aquifers Might Be Tapped

- May contain enough water to provide for billions of people for centuries

- Major concerns
  1. Nonrenewable
  2. Little is known about the geological and ecological impacts of pumping deep aquifers
  3. Some flow beneath more than one country
  4. Costs of tapping are unknown and could be high

13-3 Is Building More Dams the Answer?

- ***Concept 13-3*** *Building dam-and-reservoir systems has greatly increased water supplies in some areas, but it has disrupted ecosystems and displaced people.*

Large Dams and Reservoirs Have Advantages and Disadvantages (1)

- Main goal of a **dam** and **reservoir** system
  - Capture and store runoff
  - Release runoff as needed to control:
    - Floods
    - Generate electricity
    - Supply irrigation water
    - Recreation (reservoirs)

Large Dams and Reservoirs Have Advantages and Disadvantages (2)

- Advantages
  - Increase the reliable runoff available
  - Reduce flooding
  - Grow crops in arid regions

Large Dams and Reservoirs Have Advantages and Disadvantages (3)

- Disadvantages
  - Displaces people
  - Flooded regions
  - Impaired ecological services of rivers
  - Loss of plant and animal species
  - Fill up with sediment
  - Can cause other streams and lakes to dry up

Advantages and Disadvantages of Large Dams and Reservoirs

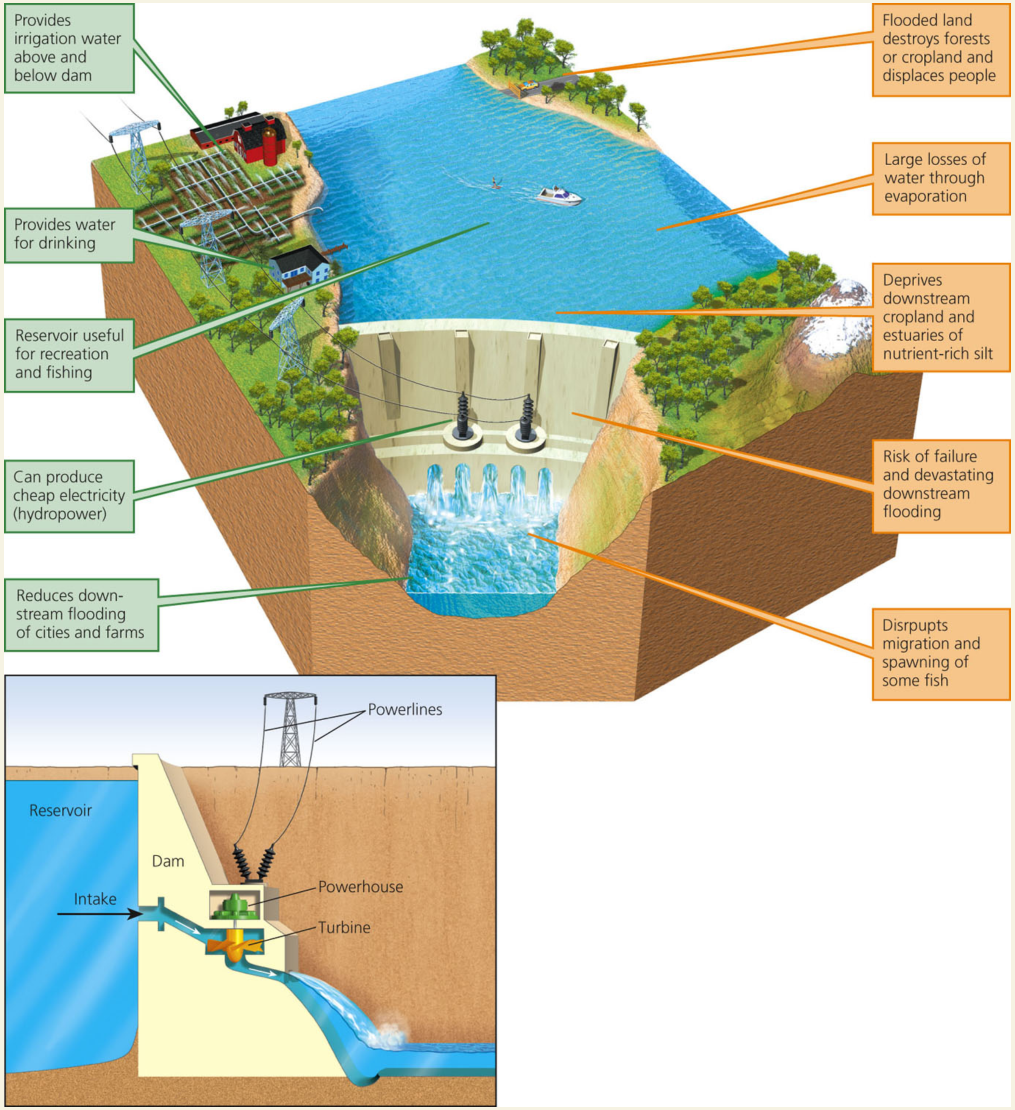


Fig. 13-13, p. 328

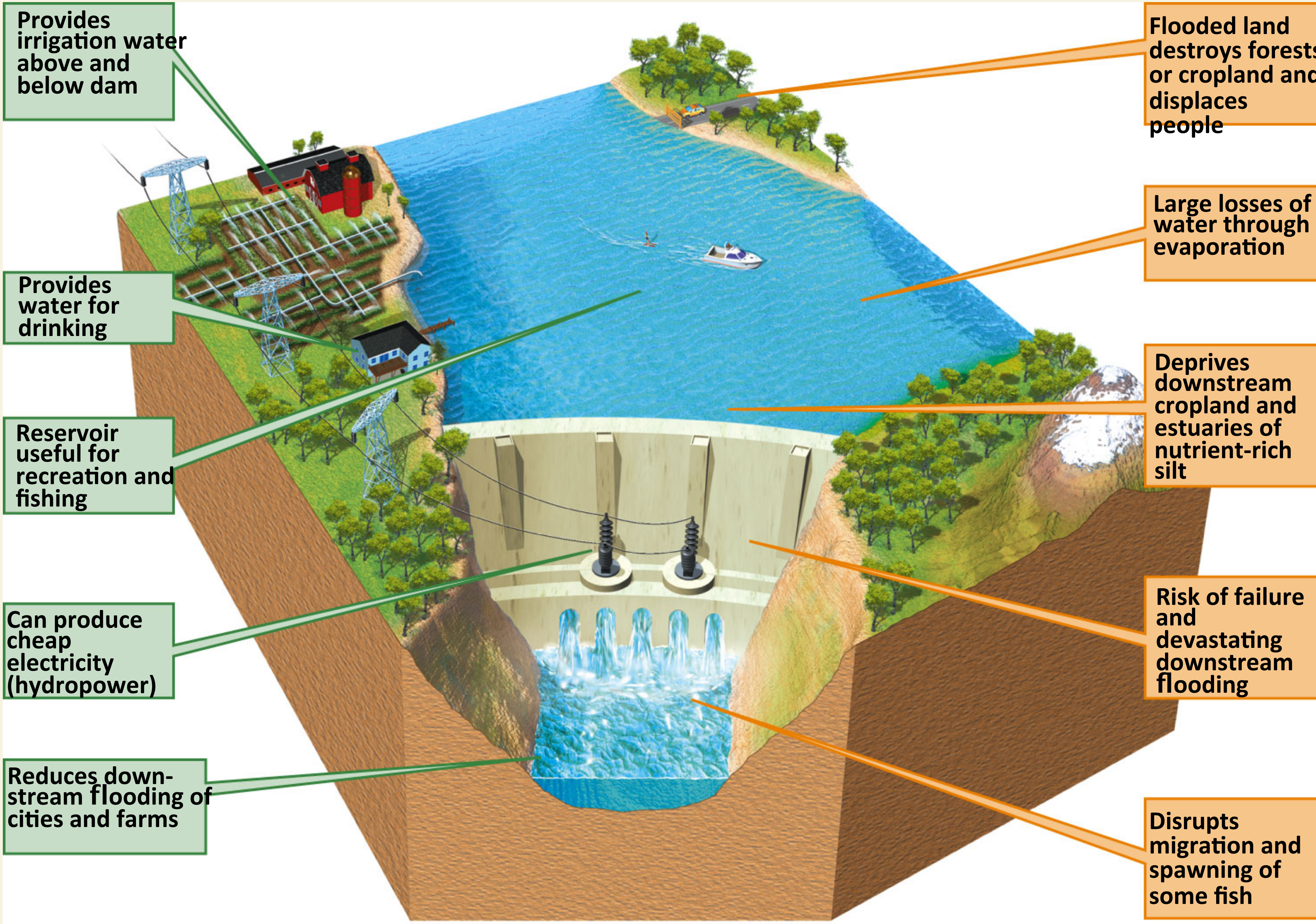


Fig. 13-13a, p. 328

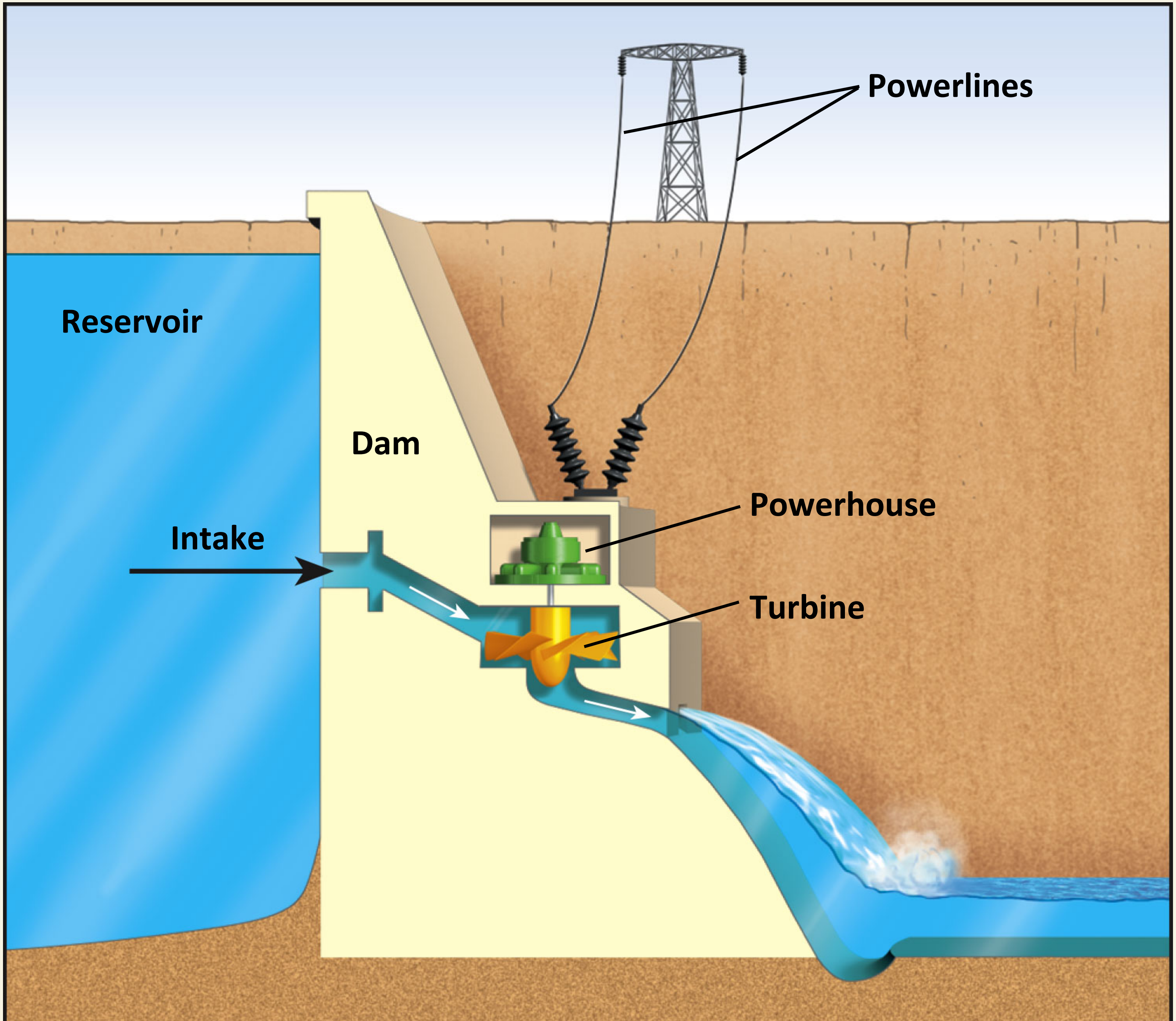


Fig. 13-13b, p. 328

A Closer Look at the Overtapped Colorado River Basin (1)

- Only 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
- Much water used for agriculture that is inefficient with water use: cotton, alfalfa, rice
  - Water use subsidized by government

A Closer Look at the Overtapped Colorado River Basin (2)

- Reservoirs
  - Leak water into ground below
  - Lose much water through evaporation
  - Fill up with silt load of river, depriving delta
  - Could eventually lose ability to store water and create electricity

- States must conserve water, control population, and slow urban development

The Flow of the Colorado River Measured at Its Mouth Has Dropped Sharply

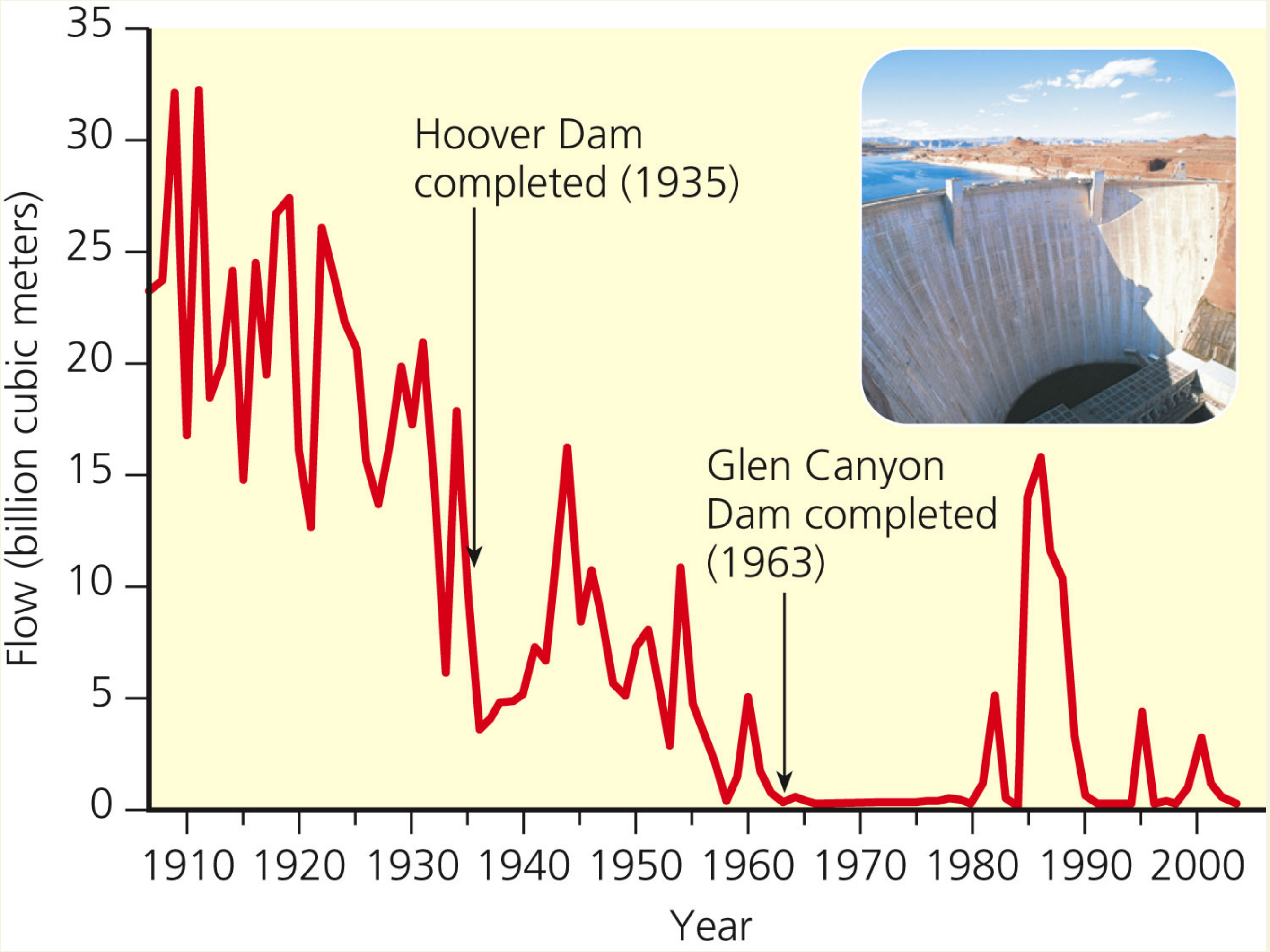


Fig. 13-14, p. 329

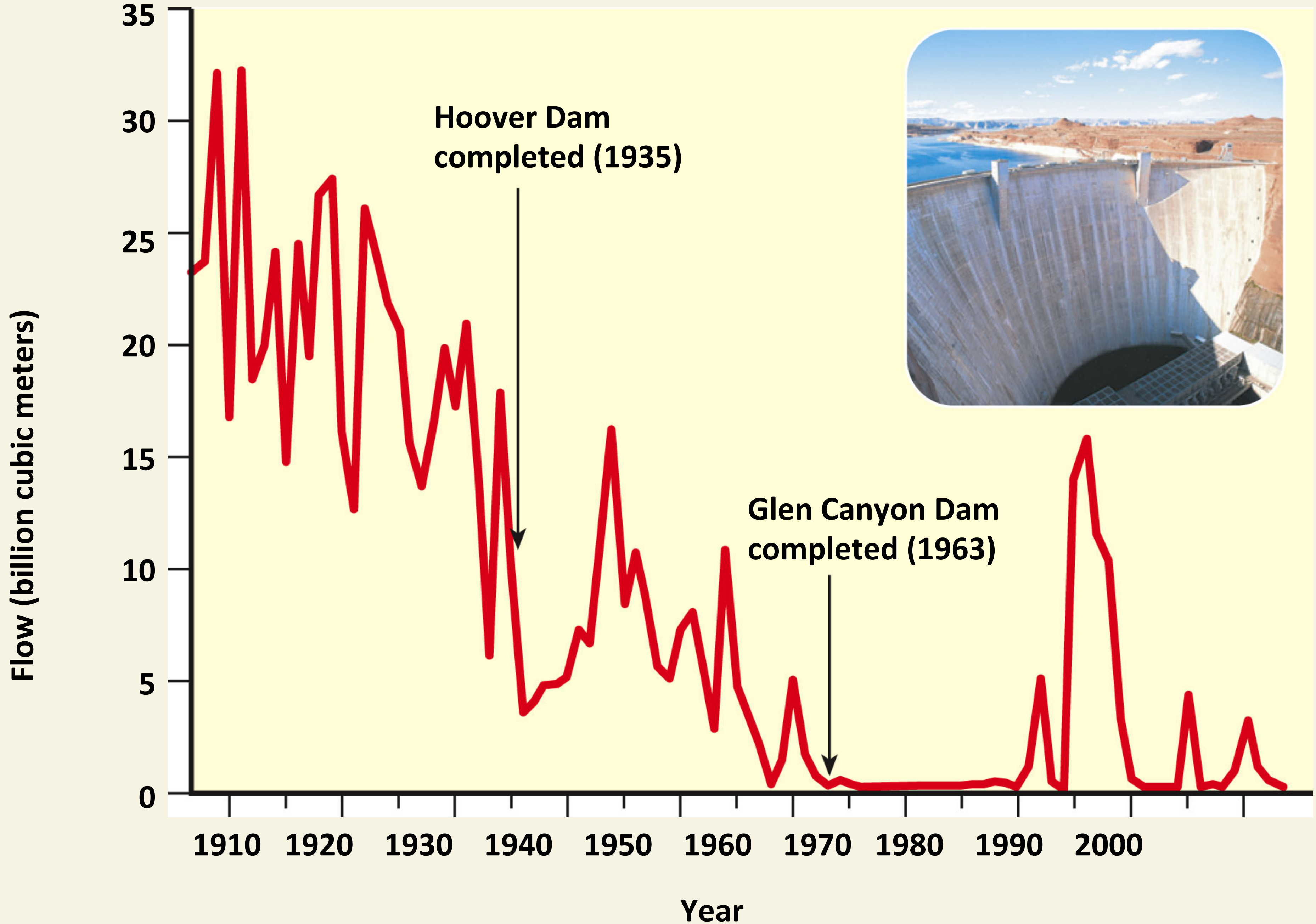


Fig. 13-14, p. 329

13-4 Is Transferring Water from One Place to Another the Answer?

- ***Concept 13-4*** *Transferring water from one place to another has greatly increased water supplies in some areas, but it has also disrupted ecosystems.*

California Transfers Water from Water-Rich Areas to Water-Poor Areas

- Water transferred from north to south by
  - Tunnels
  - Aqueducts
  - Underground pipes

- California Water Project
  - Inefficient water use
  - Environmental damage to Sacramento River and San Francisco Bay

Southern California Lettuce Grown with Northern California Water

Fig. 13-15, p. 331

The California Water Project and the Central Arizona Project

Fig. 13-16, p. 331

Fig. 13-16, p. 331

Case Study: The Aral Sea Disaster (1)

- Large-scale water transfers in dry central Asia
- Salinity
- Wetland destruction and wildlife
- Fish extinctions and fishing declines

Case Study: The Aral Sea Disaster (2)

- Wind-blown salt
- Water pollution
- Restoration efforts
  - Cooperation of neighboring countries
  - More efficient irrigation
  - Dike built to raise lake level

Natural Capital Degradation: The Aral Sea, Shrinking Freshwater Lake

Fig. 13-17, p. 332

13-5 Is Converting Salty Seawater to Freshwater the Answer?

- ***Concept 13-5*** *We can convert salty ocean water to freshwater, but the cost is high, and the resulting salty brine must be disposed of without harming aquatic or terrestrial ecosystems.*

Removing Salt from Seawater Is Costly, Kills Organisms, Creates Briny Wastewater (1)

- **Desalination**
  - Removing dissolved salts
  - Distillation: evaporate water, leaving salts behind
  - Reverse osmosis, microfiltration: use high pressure to remove salts

- 14,450 plants in 125 countries
  - Saudi Arabia: highest number

Removing Salt from Seawater Is Costly, Kills Organisms, Creates Briny Wastewater (2)

- Problems
  1. High cost and energy footprint
  2. Keeps down algal growth and kills many marine organisms
  3. Large quantity of brine wastes

Science Focus: The Search for Improved Desalination Technology

- Desalination on offshore ships
  - Solar or wind energy

- Use ocean waves for power

- Build desalination plants near electric power plants

13-6 How Can We Use Water More Sustainably?

- ***Concept 13-6*** *We can use water more sustainably by cutting water waste, raising water prices, slowing population growth, and protecting aquifers, forests, and other ecosystems that store and release water.*

Reducing Water Waste Has Many Benefits

- One-half to two-thirds of water is wasted
- Subsidies mask the true cost of water
- Water conservation
    - Improves irrigation efficiency
    - Improves collection efficiency
    - Uses less in homes and businesses

We Can Cut Water Waste in Irrigation

- Flood irrigation
  - Wasteful

- Center pivot, low pressure sprinkler

- Low-energy, precision application sprinklers

- Drip or trickle irrigation, microirrigation
  - Costly; less water waste

Major Irrigation Systems

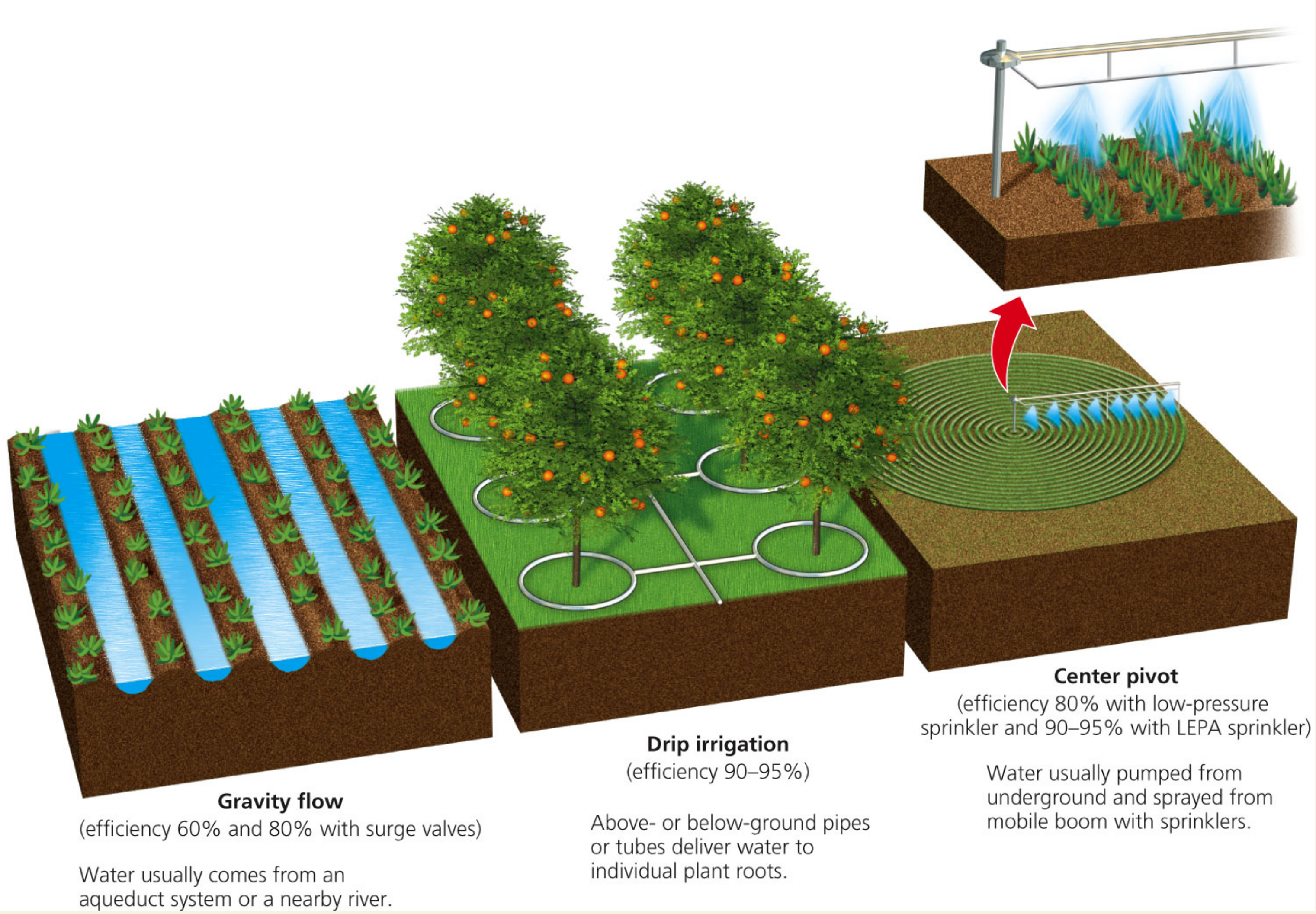
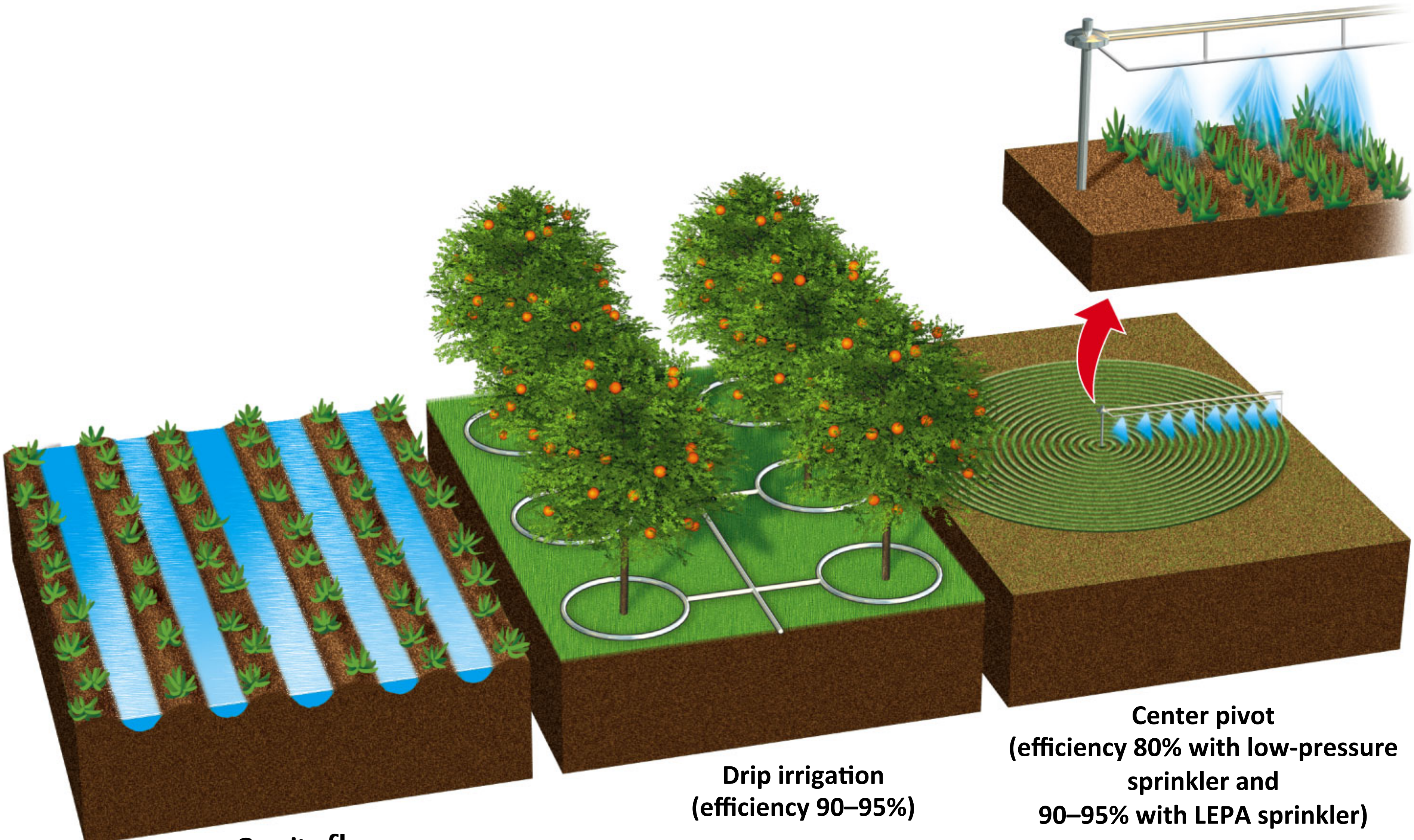


Fig. 13-18, p. 335



Gravity flow
(efficiency 60% and 80% with surge valves)

Water usually comes from an aqueduct system or a nearby river.

Drip irrigation
(efficiency 90–95%)

Above- or below-ground pipes or tubes deliver water to individual plant roots.

Center pivot
(efficiency 80% with low-pressure sprinkler and 90–95% with LEPA sprinkler)

Water usually pumped from underground and sprayed from mobile boom with sprinklers.

Fig. 13-18, p. 335

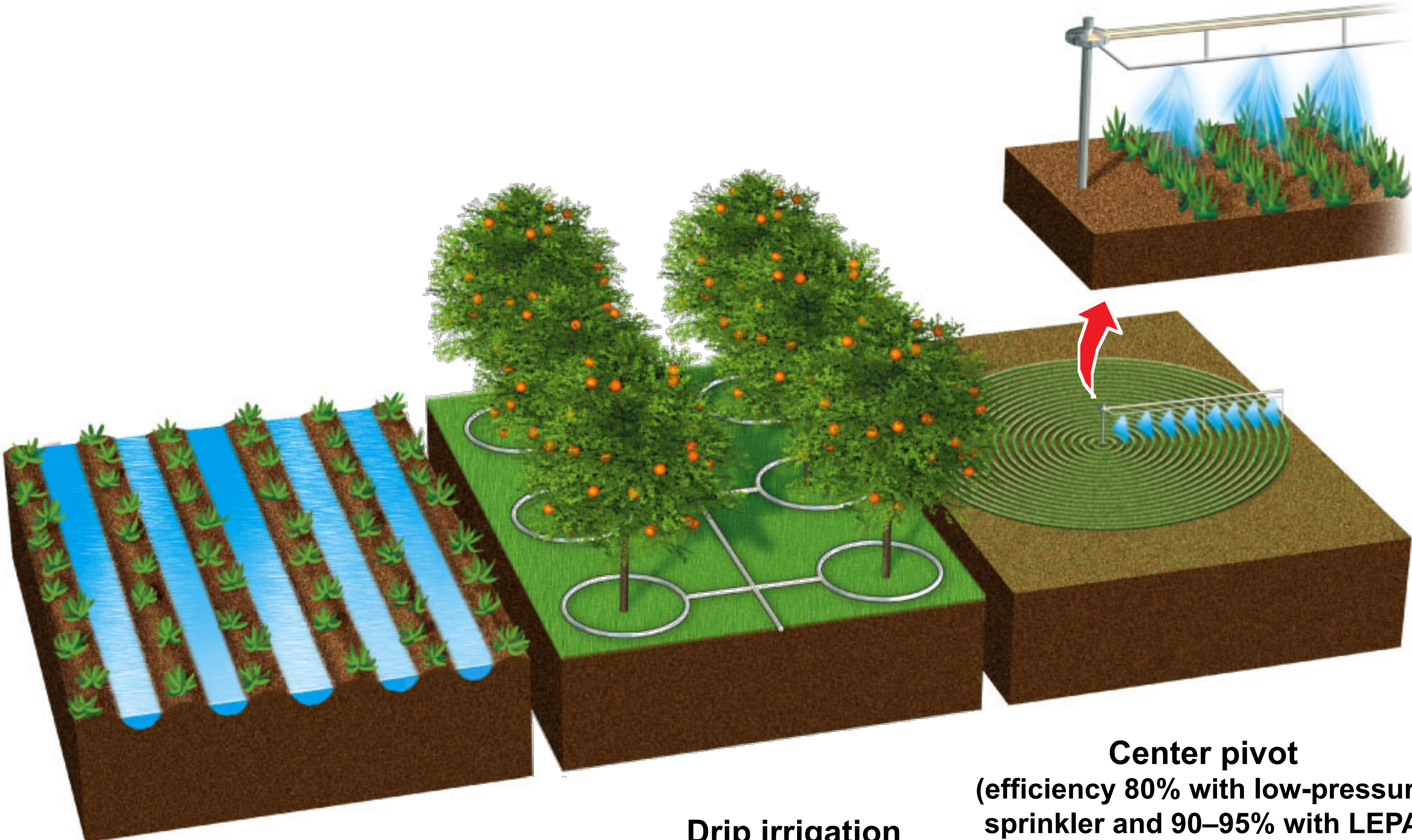


Fig. 13-18, p. 335

Solutions: Reducing Irrigation Water Waste

Solutions

Reducing Irrigation Water Waste

- Line canals bringing water to irrigation ditches
- Irrigate at night to reduce evaporation
- Monitor soil moisture to add water only when necessary
- Grow several crops on each plot of land (polyculture)
- Encourage organic farming
- Avoid growing water-thirsty crops in dry areas
- Irrigate with treated waste water
- Import water-intensive crops and meat

Fig. 13-19, p. 336

Less-Developed Countries Use Low-Tech Methods for Irrigation

- Human-powered treadle pumps
- Harvest and store rainwater
- Create a polyculture canopy over crops: reduces evaporation

Treadle Pump in Bangladesh

Fig. 13-20, p. 337

We Can Cut Water Waste in Industry and Homes

- Recycle water in industry
- Fix leaks in the plumbing systems
- Use water-thrifty landscaping: xeriscaping
- Use gray water
- Pay-as-you-go water use

Solutions: Reducing Water Waste

Solutions

Reducing Water Waste

- Redesign manufacturing processes to use less water
- Recycle water in industry
- Landscape yards with plants that require little water
- Use drip irrigation
- Fix water leaks
- Use water meters
- Raise water prices
- Use waterless composting toilets
- Require water conservation in water-short cities
- Use water-saving toilets, showerheads, and front-loading clothes washers
- Collect and reuse household water to irrigate lawns and nonedible plants
- Purify and reuse water for houses, apartments, and office buildings

Fig. 13-21, p. 337

Xeriscaping in Southern California

Fig. 13-22, p. 338

We Can Use Less Water to Remove Wastes

- Can we mimic how nature deals with waste?
- Use human sewage to create nutrient-rich sludge to apply to croplands
- Waterless composting toilets

Solutions: Sustainable Water Use

Solutions

Sustainable Water Use

- Waste less water and subsidize water conservation
- Do not deplete aquifers
- Preserve water quality
- Protect forests, wetlands, mountain glaciers, watersheds, and other natural systems that store and release water
- Get agreements among regions and countries sharing surface water resources
- Raise water prices
- Slow population growth

Fig. 13-23, p. 339

Solutions

Sustainable Water Use

- Waste less water and subsidize water conservation

- Do not deplete aquifers

- Preserve water quality

- Protect forests, wetlands, mountain glaciers, watersheds, and other natural systems that
- store and release water

- Get agreements among regions and countries sharing surface water resources

- Raise water prices

- Slow population growth

Fig. 13-23, p. 339

What Can You Do? Water Use and Waste

What Can You Do?

Water Use and Waste

- Use water-saving toilets, showerheads, and faucet aerators
- Shower instead of taking baths, and take short showers
- Repair water leaks
- 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
- Use recycled (gray) water for watering lawns and house-plants and for washing cars
- Wash a car from a bucket of soapy 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 yards only in the early morning or evening
- Use drip irrigation and mulch for gardens and flowerbeds

Fig. 13-24, p. 339

13-7 How Can We Reduce the Threat of Flooding?

- ***Concept 13-7*** *We can lessen the threat of flooding by protecting more wetlands and natural vegetation in watersheds, and by not building in areas subject to frequent flooding.*

Some Areas Get Too Much Water from Flooding (1)

- **Flood plains**
  - Highly productive wetlands
  - Provide natural flood and erosion control
  - Maintain high water quality
  - Recharge groundwater

- Benefits of floodplains
  - Fertile soils
  - Nearby rivers for use and recreation
  - Flatlands for urbanization and farming

Some Areas Get Too Much Water from Flooding (2)

- Human activities make floods worse
  - Levees can break or be overtopped
  - Paving and development increase runoff
  - Removal of water-absorbing vegetation
  - Draining wetlands and building on them
  - Rising sea levels from global warming means more coastal flooding

Natural Capital Degradation: Hillside Before and After Deforestation

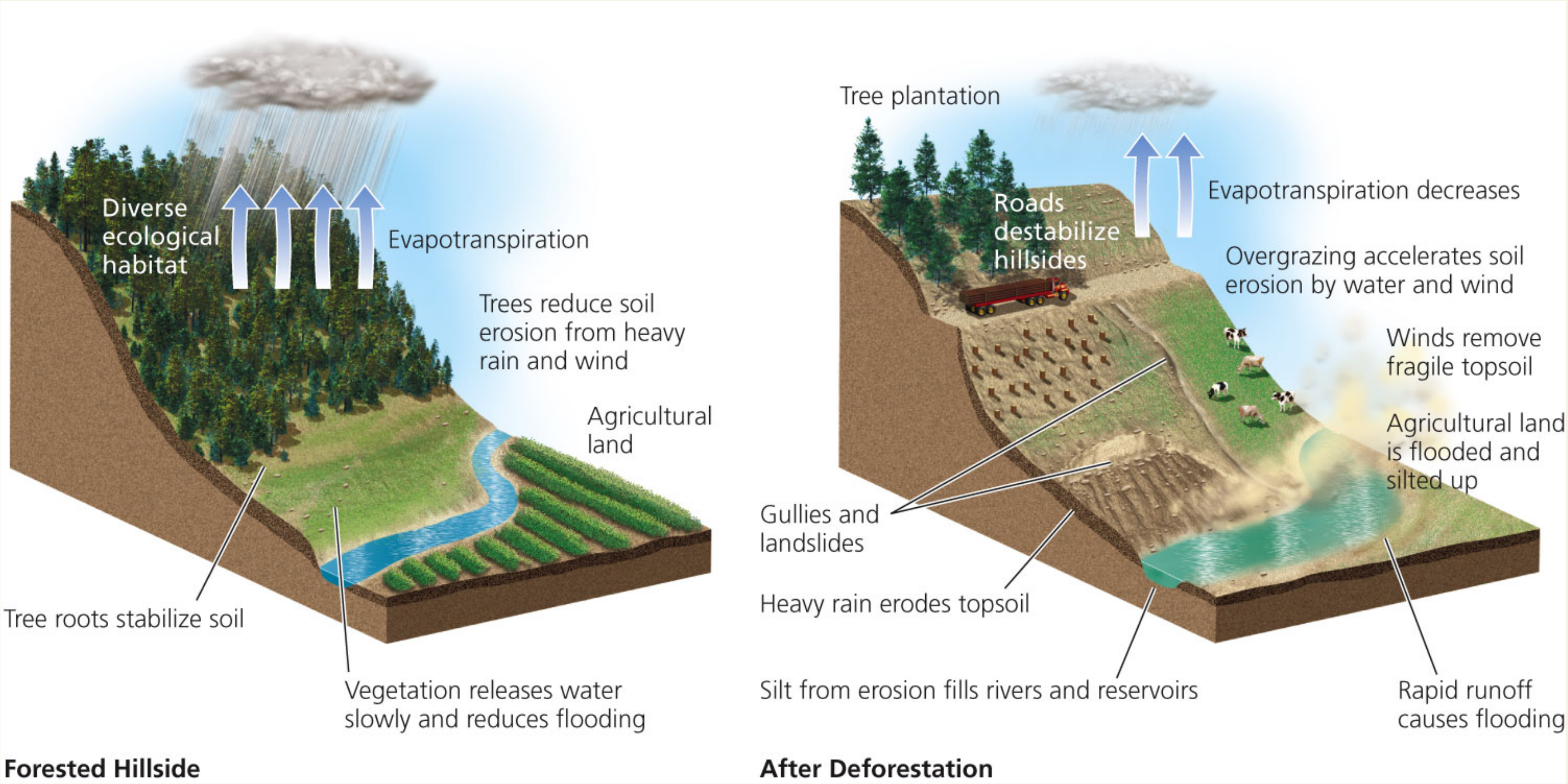
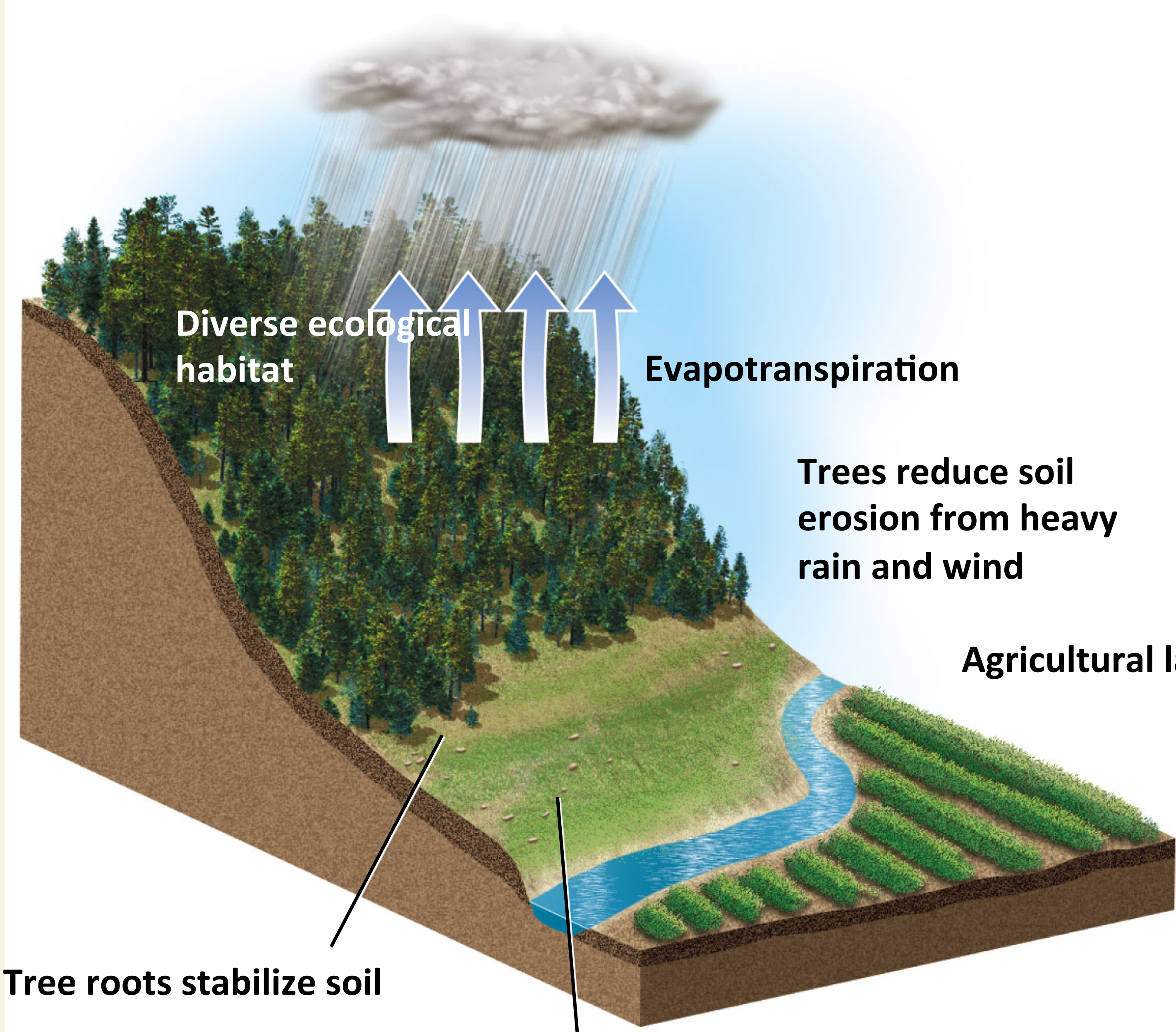
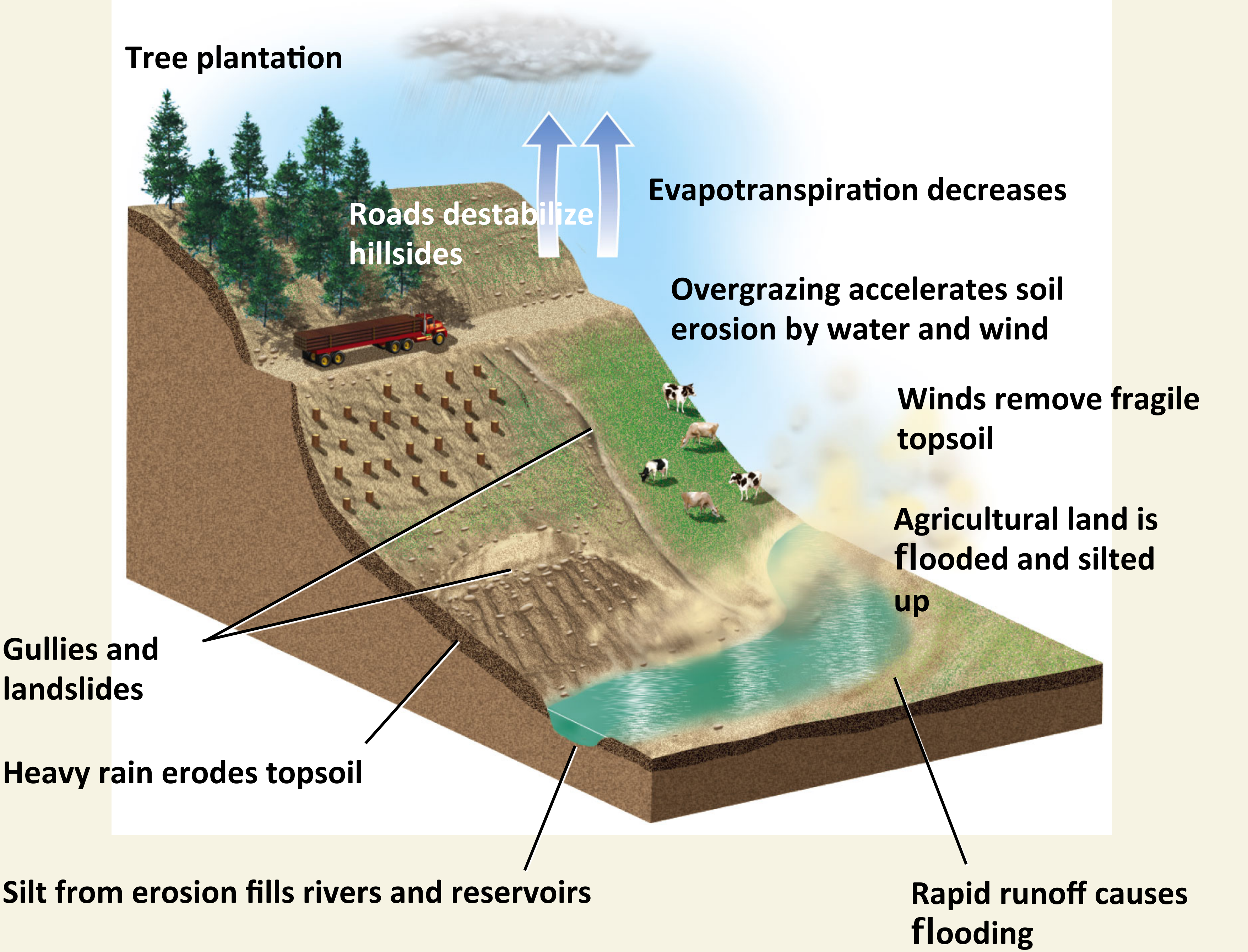


Fig. 13-25, p. 340



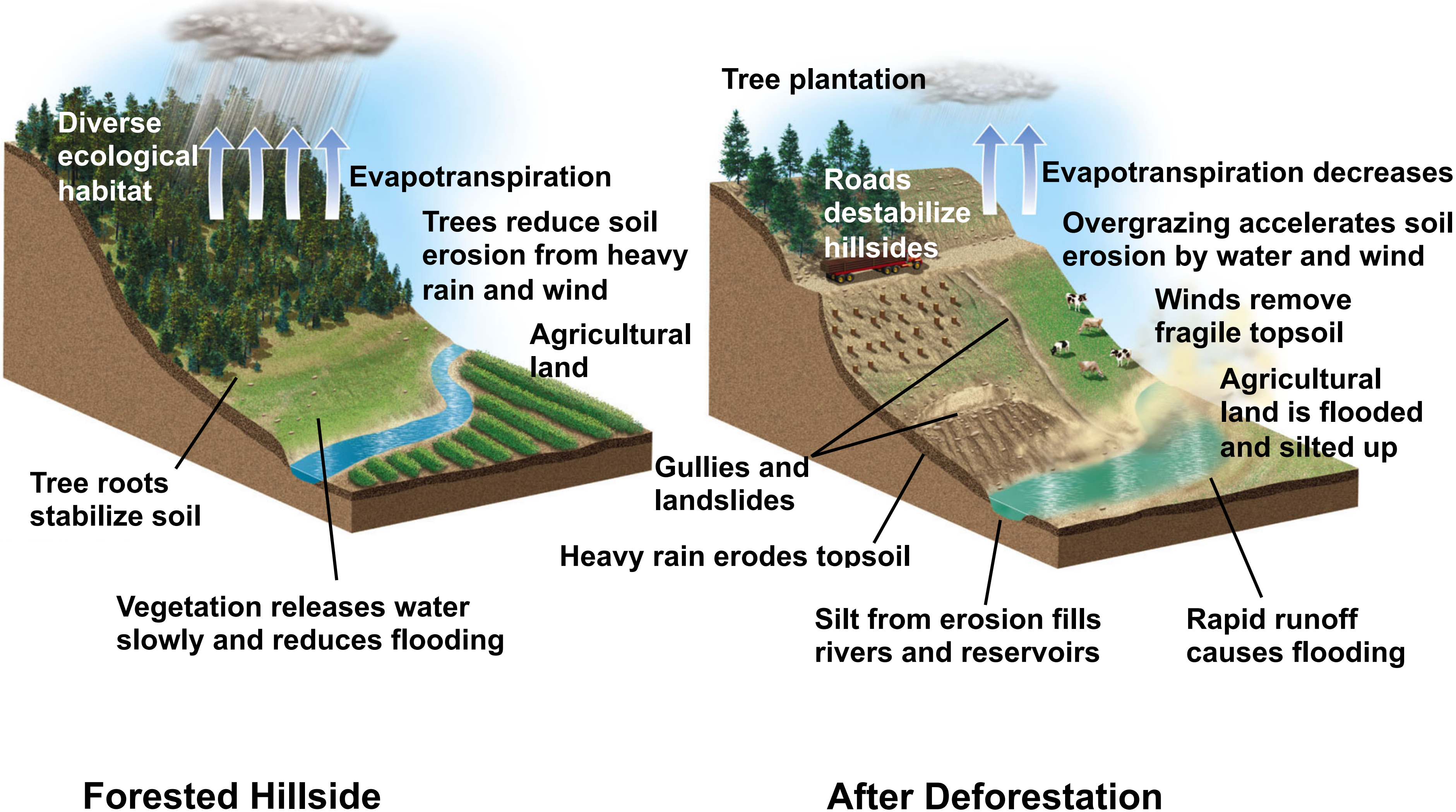
Forested Hillside

Fig. 13-25a, p. 340



After Deforestation

Fig. 13-25b, p. 340



Stepped Art

Fig. 13-25, p. 340

Deforestation Above China's Yangtze River Contribute to Erosion and Floods

Fig. 13-26, p. 341

Case Study: Living Dangerously on Floodplains in Bangladesh

- Dense population on coastal floodplain
- Moderate floods maintain fertile soil
- Increased frequency of large floods
- Effects of development in the Himalayan foothills
- Destruction of coastal wetlands: mangrove forests

We Can Reduce Flood Risks

- Rely more on nature's systems
  - Wetlands
  - Natural vegetation in watersheds

- Rely less on engineering devices
  - Dams
  - Levees
  - Channelized streams

Solutions: Reducing Flood Damage

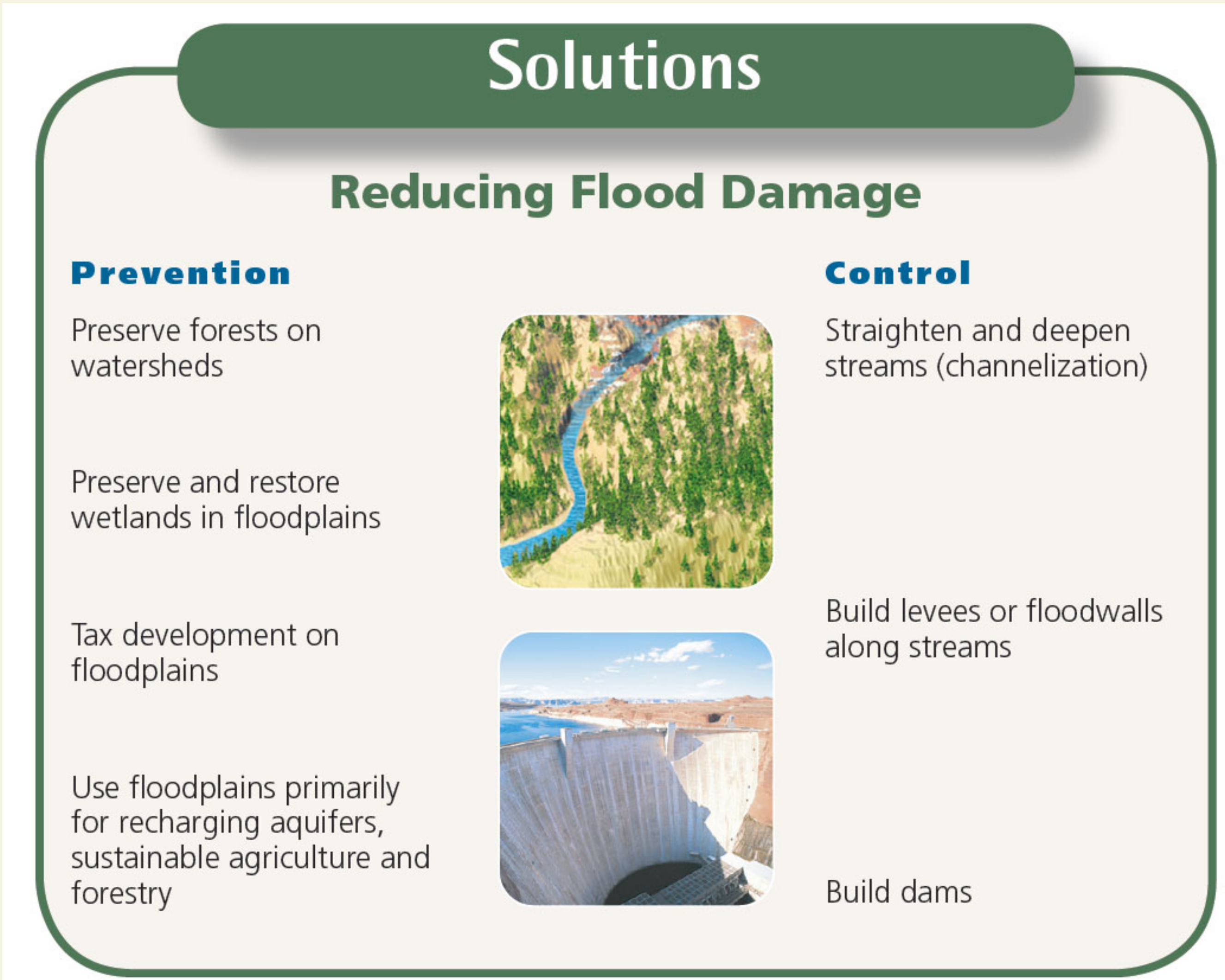


Fig. 13-27, p. 342

Solutions

Reducing Flood Damage

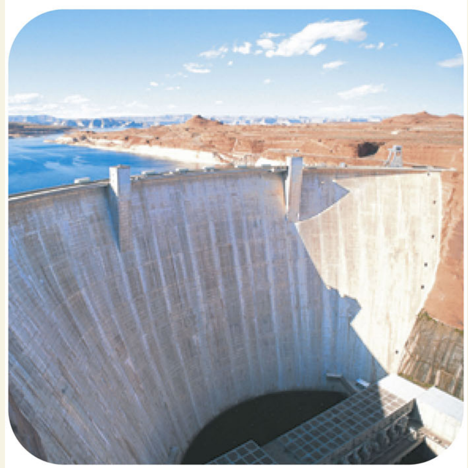
Prevention

Preserve forests on watersheds

Preserve and restore wetlands in floodplains

Tax development on floodplains

Use floodplains primarily for recharging aquifers, sustainable agriculture and forestry



Control

Straighten and deepen streams (channelization)

Build levees or floodwalls along streams

Build dams

Fig. 13-27, p. 342

Three Big Ideas

1. One of the world's major environmental problems is the growing shortage of freshwater in many parts of the world.

2. We can increase water supplies in water-short areas in a number of ways, but the most important way is to reduce overall water use and waste by using water more sustainably.

Three Big Ideas

3. We can use water more sustainably by cutting water waste, raising water prices, slowing population growth, and protecting aquifers, forests, and other ecosystems that store and release water.