Chapter 18: Water

"When the well's dry, we know the worth of water."
Benjamin Franklin

SOME WATER FACTS

Most living things are about 65% water. Chickens-75%, earthworms-80%, tomatoes-95%, YOU-65%.

Dissolves more substances than any other solvent.

The only substance on Earth naturally present in all 3 phases.

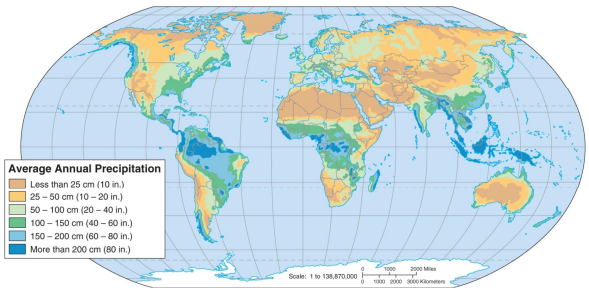
Outline

- Water Resources
- Water Availability and Use
- Freshwater Shortages
- Water Conservation

The Hydrologic Cycle Redistributes Water

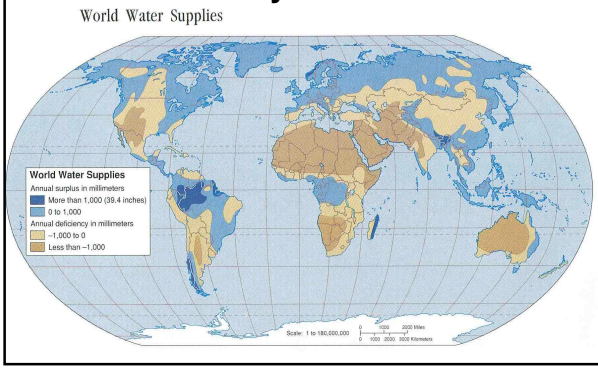
- Hydrologic Cycle —water evaporates from moist surfaces, falls as rain or snow, passes through living organisms and returns to the oceans.
- 500,000 km_3 of water evaporates each year from the world's oceans and enters the cycle.
- >90% of this water rains back into the oceans.
- Some is carried over land where it renews freshwater systems.
- Plants play a major role in the hydrologic cycle as they pump water from the soil and release it into the atmosphere.
- Solar energy drives the hydrologic cycle.

Average Annual Precipitation



The Big Picture – Fresh Water is unevenly distributed.

World Water Supplies



Water Supplies are Unevenly Distributed

- Rain falls unevenly across the earth's surface. Some areas receive practically no precipitation and other areas receive heavy rain on a daily basis.
- Three principal factors control global water deficits and surpluses:
  - Global atmospheric circulation
  - Proximity to water sources
  - Topography

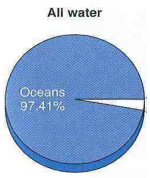
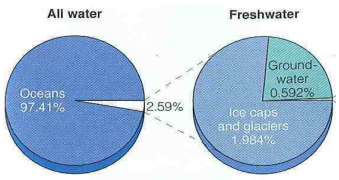


Figure 18-3



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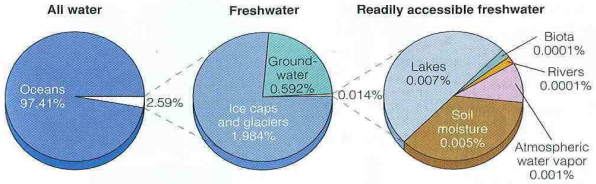

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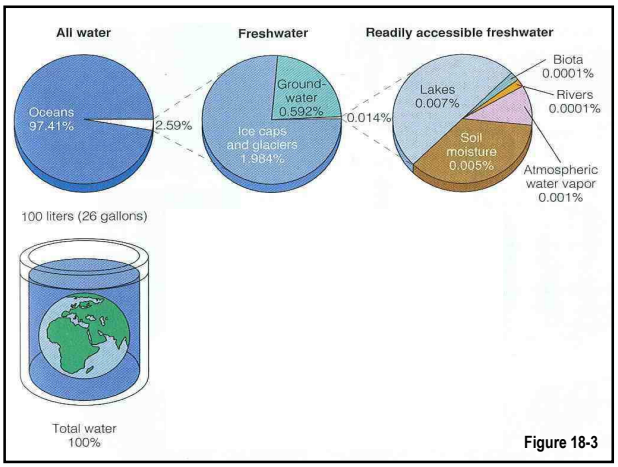

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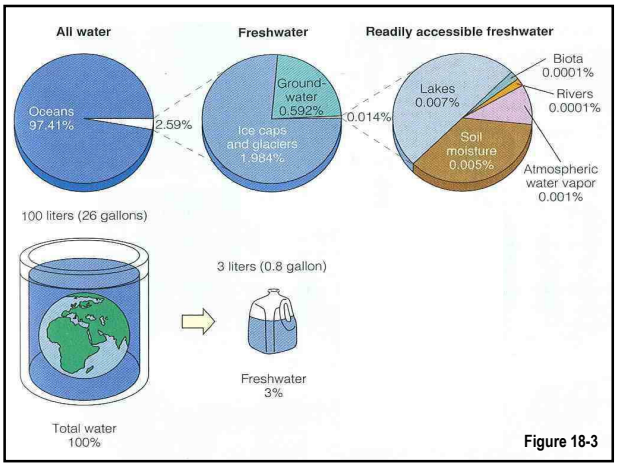

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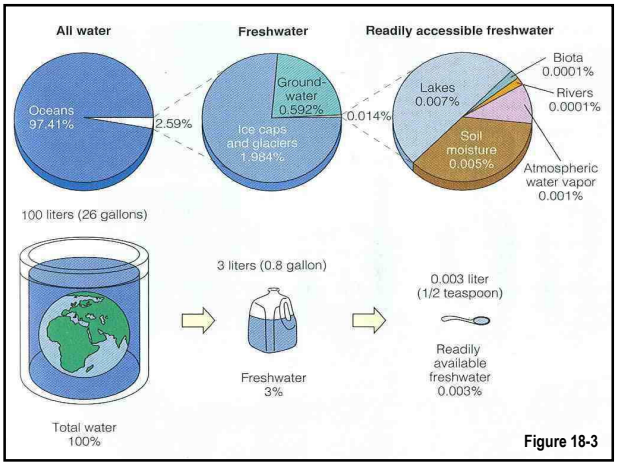
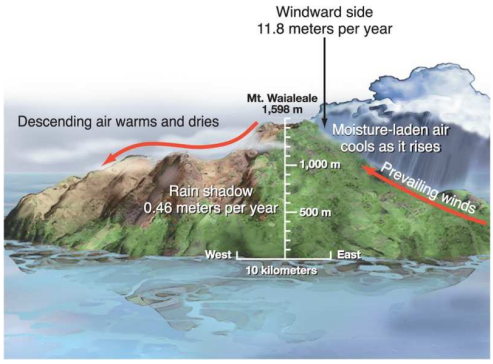


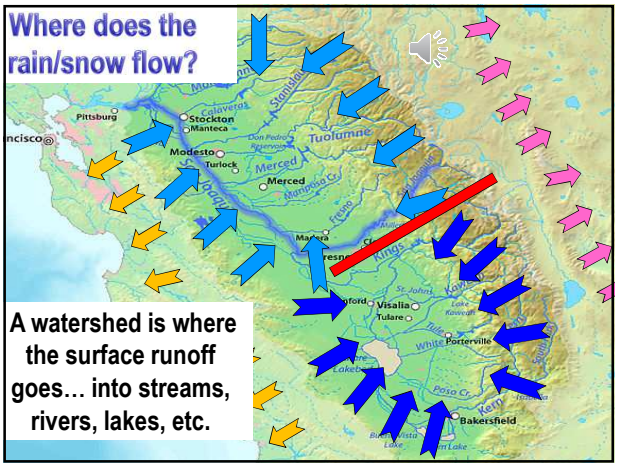
Figure 18-3

Mountains Act as Cloud Formers and Rain Catchers

- Air sweeps up the windward side of a mountain, pressure decreases, and the air cools.
  - ❖Eventually saturation point is reached, and moisture in the air condenses.
    - –Rain falls on the mountaintop.
    - –Rain Shadow - Cool, dry air descends from the mountaintop down the other side of the mountain (leeward side) creating dry areas with very little precipitation.
      - »For example, at Mount Waialeale in Hawaii, rain on the east side of mountain is >20 times that on the west side.

Rain Shadow Effect



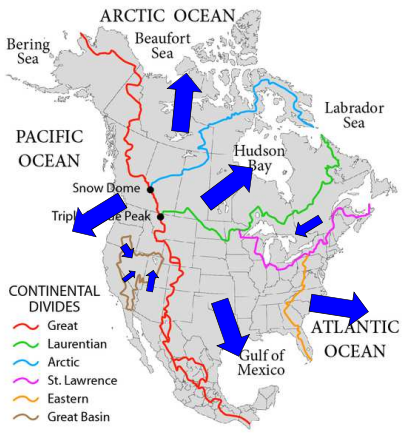


Major Water Compartments

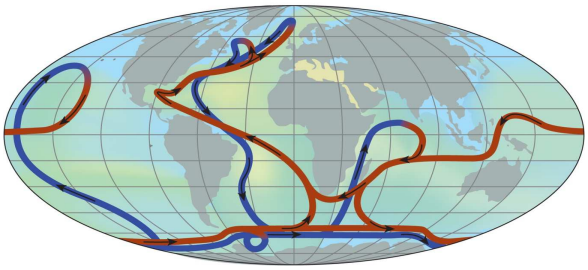
- The distribution of water across the earth is often described as interacting water compartments.
- Water may reside briefly in one compartment or stay there for eons.
- The length of time water typically spends in a compartment is called the Residence Time.
- For example, the average residence time of water in the ocean is about 3,000 years before the water evaporates and enters the hydrologic cycle.

The Oceans are a Major Water Compartment

- The oceans hold 97% of all liquid water on the earth.
- 90% of the earth's biomass is found in the oceans.
- The oceans play a major role in moderating earth's climate.
- Ocean currents moderate the climate by redistributing warm and cold water around the earth.



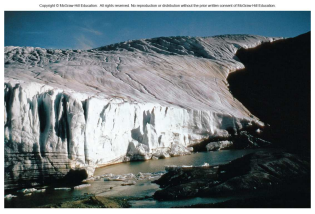
Global Ocean Currents



- Ocean currents act as a global conveyor system, redistributing warm and cold currents around the globe.

Frozen Water

- Glaciers, Ice, and Snow
  - 2.4% of world's water is classified as fresh.
  - 90% in glaciers, ice caps, and snowfields
  - Climate change is shrinking glaciers and snowfields



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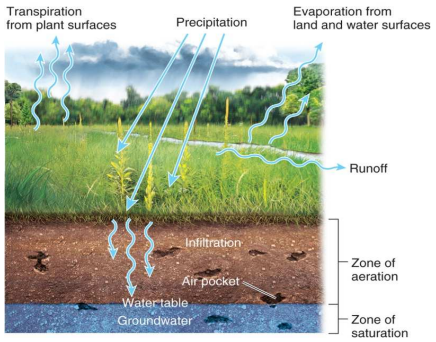
Groundwater

- Groundwater is the second largest reservoir of fresh water
  - ❖Infiltration - process of water percolating through the soil and into fractures and permeable rocks
    - –Zone of aeration - upper soil layers that hold both air and water
    - –Zone of saturation - lower soil layers where all spaces are filled with water
      - »Water table - top of zone of saturation

Infiltration



Groundwater in Aquifers comes from surface water that percolates down.

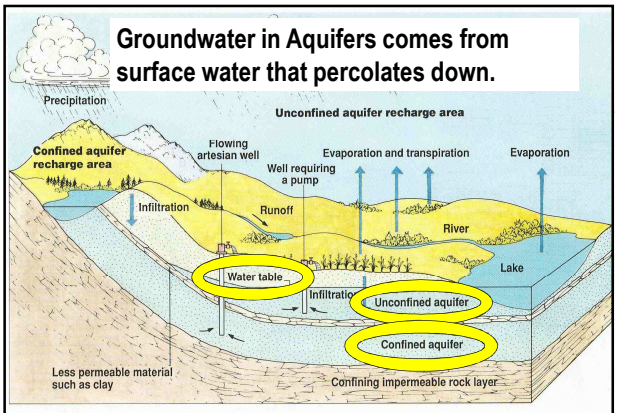
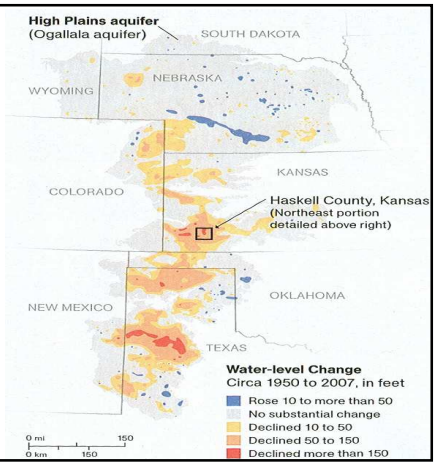


Figure 18-5: The groundwater system

Figure 18-17

Earth's largest known aquifer: Ogallala Aquifer in the Midwest

What is the trend you see over time?

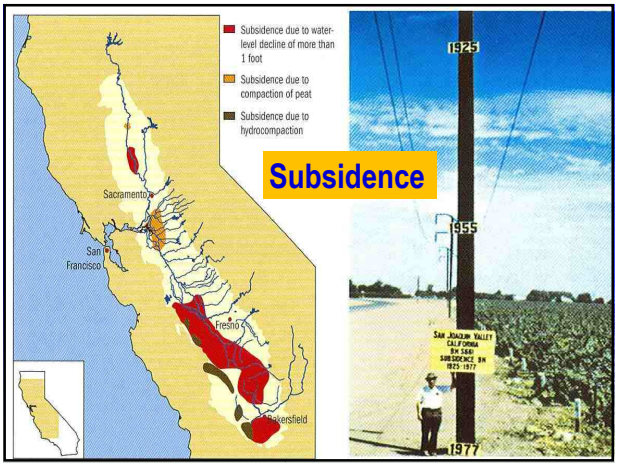


Groundwater Stores Large Water Resources

- Aquifers - porous layers of sand, gravel, or rock lying below the water table
  - Artesian - Pressurized aquifer intersects the surface (water flows without pumping).
- Recharge zones - area where water infiltrates into an aquifer
  - Recharge rate is often very slow.
    - Presently, groundwater is being removed faster than it can be replenished in many areas.

Groundwater is Being Depleted

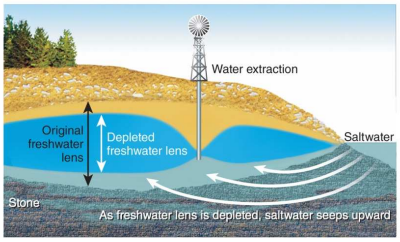
- Groundwater is the source of nearly 40% of fresh water in the U.S.
- 50% of Americans (95% in rural areas) depend on groundwater for drinking and domestic uses.
- In many places in the U.S., groundwater is being withdrawn faster than it is replenished.
- Heavy pumping can deplete entire aquifers.



Depleting Groundwater

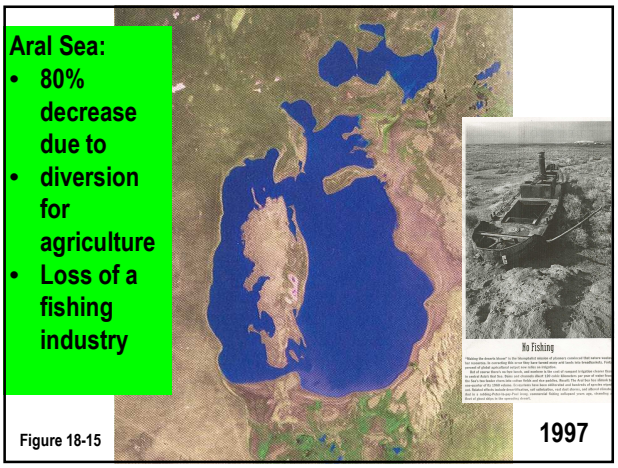
- Withdrawing large amounts of groundwater in a small area causes porous formations to collapse, resulting in subsidence (settling).
- Saltwater intrusion can occur along coastlines where overuse of freshwater reservoirs draws the water table low enough to allow saltwater to intrude.

Saltwater Intrusion



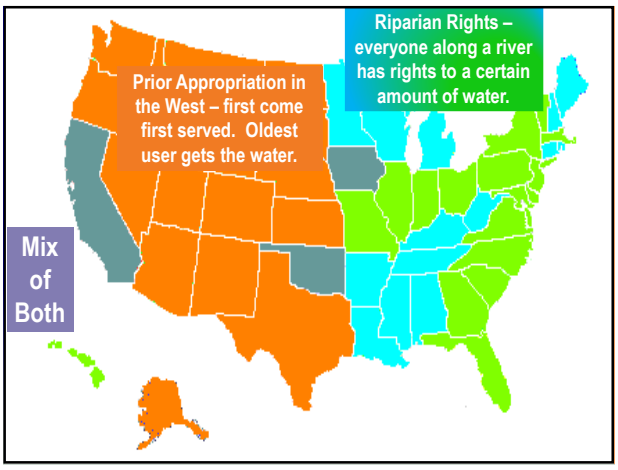
Diversions

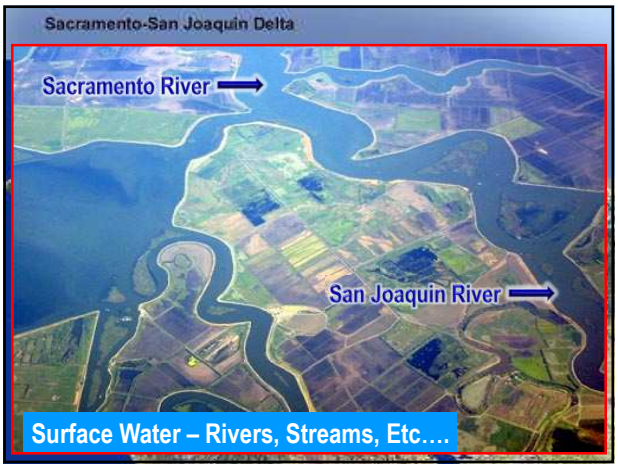
- Transfer and store water for redistribution
- China faces a massive water crisis
  - South-Water-North diversion was first proposed by Mao Zedong 50 years ago
  - Plan to build three canals to move water from the Yangtze River to northern China.
  - Preliminary cost estimate is 400 billion yuan (about US $62 billion)



River & Streams

- Precipitation that does not evaporate or infiltrate into the ground runs off the surface, back toward the sea.
  - Best measure of water volume carried by a river is discharge
    - –The amount of water that passes a fixed point in a given amount of time
      - »Usually expressed as cubic feet per second





Major Rivers of the World

Table 17.3 Major Rivers of the World

River	Countries in River Basin	Average Annual Discharge at (m^3/sec)
Amazon	Brazil, Peru	175,000
Orinoco	Venezuela, Colombia	45,300
Congo	Congo	39,200
Yangzi	Tibet, China	28,000
Bramaputra	Tibet, India, Bangladesh	19,000
Mississippi	United States	18,400
Mekong	China, Laos, Burma, Thailand, Cambodia, Vietnam	18,300
Parana	Paraguay, Argentina	18,000
Yenisey	Russia	17,200
Lena	Russia	16,000

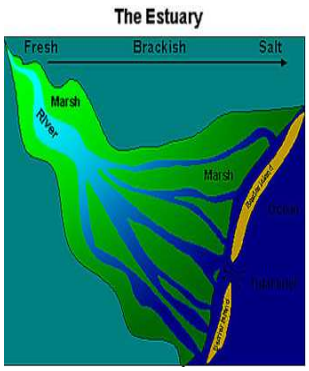
Lakes and Ponds

- Ponds are generally considered small bodies of water shallow enough for rooted plants to grow over most of the bottom.
- Lakes are inland depressions that hold standing fresh water year-round with depths ranging from a few meters to >1500 meters.
- Both ponds and lakes will eventually fill with sediment, or be emptied by an outlet stream.

Wetlands

- Play a vital role in hydrologic cycle
  - Lush plant growth stabilizes soil and retards surface runoff, allowing more aquifer infiltration.
- Disturbance reduces natural water-absorbing capacity, resulting in floods and erosion in wet periods, and less water flow the rest of the year.
  - Half of U.S. wetlands are gone primarily due to agricultural drainage.

Estuary – Where the river meets the sea



An estuary in a low coastal plain of Georgia

The Atmosphere:
A Small Water Compartment

- Among the smallest water reservoirs
  - Contains < 0.001% of total water supply
  - Has most rapid turnover rate
  - Provides mechanism for distributing fresh water over landmasses and replenishing terrestrial reservoirs

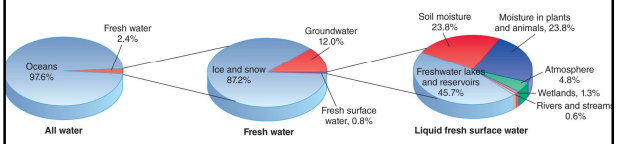
Water Availability and Use

- Renewable Water Supplies
  - Made up of surface runoff plus infiltration into accessible freshwater aquifers
    - About two-thirds of water carried in rivers and streams annually occurs in seasonal floods too large or violent to be stored effectively for human use.
      - Readily accessible, renewable supplies are only about 400,000 gal /person/year.

Many Countries Suffer Water Scarcity

- The United Nations considers 264,172 gallons per person per year to be the minimum necessary to meet human needs.
- Water Stress occurs when human and ecosystem needs exceed the renewable water supplies, resulting in competition.
- Periodic droughts create severe regional water shortages in semiarid zones where moisture availability is the critical factor in plant and animal distributions.
- The effects on water supplies may be the most serious consequence of global climate change.

Easily Available Fresh Water is Scarce



Quantities of Water Used

- Human water use has been increasing about twice as fast as population growth over the past century, but impact varies with location.
  - Canada withdraws less than 1% of its renewable supply per year.
  - In Israel, Libya and Yemen groundwater and surface water withdrawals equal more than 100% of the renewable supply. This "mining" is not sustainable.
  - U.S. uses 20% of renewable water/yr.

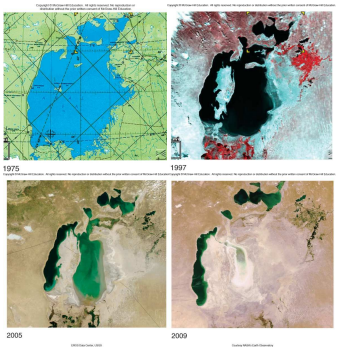
Water Withdrawal & Consumption

- Withdrawal
  - total amount of water removed from a water body.
- Consumption
  - loss of water due to evaporation, absorption, or contamination.

Agriculture Is the Greatest Water Consumer

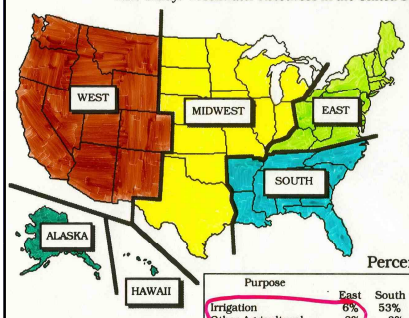
- Worldwide, agriculture claims about 70% of total water withdrawal and 85% of consumption.
- The Aral Sea is a tragic example of this.
  - once the fourth largest inland body of water in world, it has now lost 90% of its volume since 1975, as water was diverted for irrigation of rice and cotton crops
  - commercial fisheries have also been lost

Aral Sea reduction over time



WATER USE IN THE U.S.

Case Study: Freshwater Resources in the United States



Percent of Water Used

Purpose	Area					
	East	South	Midwest	West	Alaska	Hawaii
Irrigation	6%	53%	75%	90%	1%	79%
Other Agricultural	2%	3%	4%	1%	----	----
Homes/Offices	32%	14%	6%	5%	13%	11%
Manufacturing	40%	17%	8%	2%	19%	10%
Power Generating	13%	10%	4%	1%	1%	----
Mining	7%	3%	3%	1%	66%	----

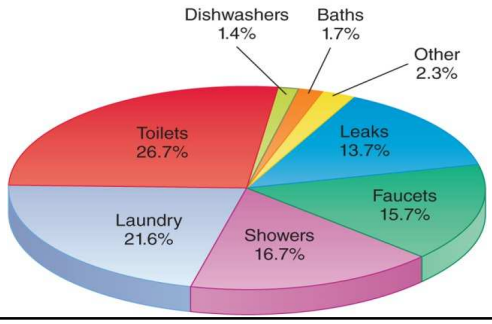
Water Use in Agriculture

- Irrigation accounts for 70% of water withdrawal.
  - It can be inefficient.
- Flood or furrow irrigation
  - Half of water can be lost through evaporation.
  - Flood irrigation used to remove salts from field, but salt contaminates streams
- Sprinklers have high evaporation.
- Drip irrigation releases water near roots, conserving water. It is used in only 1% of the world's cropland.

Domestic and Industrial Water Use

- Worldwide, domestic water use accounts for about 6% of water withdrawals.
  - Only about 10% of consumption
    - But where sewage treatment is unavailable, water is degraded
- Industry accounts for 20% of global freshwater withdrawals.
  - Range from 5% to 70% in various locations based upon the amount of industry
    - Small proportion is consumed, but degradation is a problem

Typical Household Water Use in U.S.



Freshwater Shortages

- U.N. estimates that a billion people lack access to safe drinking water.
  - 2.6 billion lack acceptable sanitation resulting in millions of water-related illnesses and deaths.
- In many countries it is not access to water that is a problem; it is access to **clean** water that is the problem.
- By 2025, the U.N. estimates that 2/3 of the

Many Lack Access to Clean Water

- More the 2/3 of the world's population lack indoor plumbing and must fetch water from outside the home.
- Where water is available in the home, it may be expensive. In Lima, Peru, a typical poor family uses 1/6 as much water as a typical middle class family in the US, pays 3 times as much for the water, and they must boil the water before it is safe to drink.

How do we Store and Move Water?

Increasing Water Supplies

- Seeding Clouds
  - Condensation nuclei
- Desalination - removing salt from ocean water or brackish water to get fresh water
  - Three to four times more expensive than most other sources
  - Oil-rich Middle East states produce 60% of desalinated water

Domestic Conservation

- Estimates suggest we could save as much as half of domestic water usage without change in lifestyle
  - Largest domestic use is toilet flushing
    - Can use low volume toilets or waterless composting
    - Anaerobic digesters use bacteria to produce methane gas from waste in waterless systems
  - Significant amounts of water can be reclaimed and recycled.
    - Purified sewage effluent
      - » San Diego pumps water from sewage plant directly into drinking reservoir

The Three Gorges Dam on the Yangtze (China) – largest hydroelectric powerplant in the world! 15 nuclear power plants! 37,000,000,000 dollars to build

Dams

- Dams -
  - Provide inexpensive hydroelectric power
  - Provide jobs
  - Reduce flooding
  - Allow farming on lands that would otherwise be too dry

Dams

- On the downside, dams
  - Submerge farmlands and towns displacing people
  - Cause earthquakes
  - Block fish migration (e.g., salmon)
  - Change aquatic habitats for native species
  - Reduce spring floods that drop sediment to enrich soils downstream

Sedimentation Limits Reservoir Life

- Sediment carried by rivers eventually fills up dams
- More than 10 million metric tons of sediment per year collect behind the Glen Canyon and Boulder Dams on the Colorado River.
- Within a century these reservoirs will be filled with sediment and useless for water storage or hydroelectric generation.
- In addition, downriver habitats lose nutrients and the beaches disappear as sediment is no longer available.

Climate Change Threatens Water Supplies

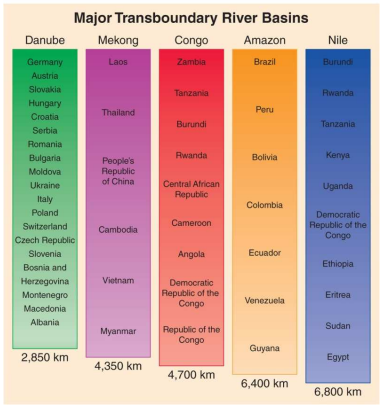
- The IPCC warns that climate change, together with the developing problems of urban sprawl, population growth, and pollution, will result in significant water shortages around the world.
- The IPCC predicts that reduced precipitation and increased evaporation from higher temps will result in 10-30% reduction in run-off in arid regions over the next 50 years.

Global Water Shortages

- In many parts of the world, severe droughts are already resulting in depleted rivers, empty reservoirs, and water shortages for millions of people.
- South Australia is suffering from droughts, water shortages, and wildfires.
- China is facing a massive water crisis.
- Prolonged drought in Syria and Yemen is threatening food supply

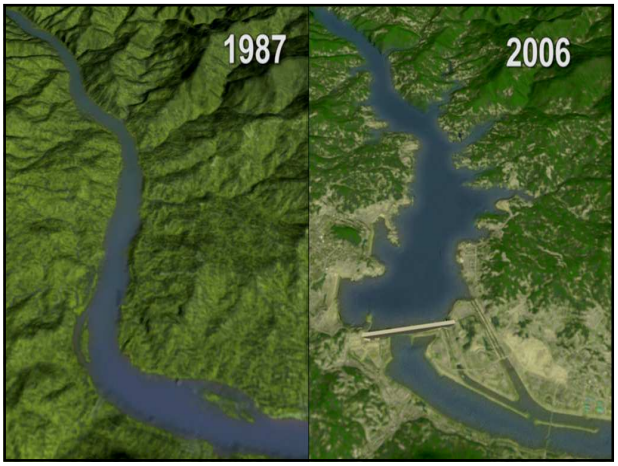
Would You Fight for Water?

- Many environmental scientists warn that declining water supplies could lead to wars between countries in the future.
- Nearly 40% of the world's population live in river or lake basins that are shared by 2 or more countries.
- There have already been water skirmishes:
  - Israel and its neighbors over the Jordan River.
  - Turkey and Iraq over the Tigris and Euphrates Rivers.
  - Nomadic tribes in Kenya over dwindling water resources.



Getting By With Less Water

- In the Klamath River in California, farmers recently signed a water use agreement where they agreed to reduce water usage and install water conservation measures.
- Land Banking - Some farmers may decide to let some of their land lay fallow in dry years.
- Walking Wetlands - Others farmers may flood fields on a rotational basis to create temporary wetlands.
  - These strategies allow for farmers to plan ahead and wetlands birds to have habitat.
  - Money designated for endangered species protection will fund these new farming practices



Snow Geese Over the Klamath

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Water Recycling

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Price Mechanisms and Water Policy

- Through most of U.S. history, water policies have generally worked against conservation.
  - In well-watered eastern states, water policy was based on riparian use rights.
  - In drier western regions where water is often a limiting resource, water law is based primarily on prior appropriation rights.
    - Fosters “Use it or Lose it” policies, where if you conserve, you lose your rights to the water in the future

Price Mechanisms and Water Policy

- In most federal reclamation projects, customers were only charged for immediate costs of water delivery.
  - Dam and distribution system costs were subsidized.
  - Underpriced water in some areas amounted to a subsidy of $500,000 per farm per year.
- Growing recognition that water is a precious and finite resource has changed policies and encouraged conservation across the U.S.

Price Mechanisms and Water Policy

- Charging a higher proportion of real costs to users of public water projects has helped encourage conservation.
- Conservation has been successful. U.S. today uses 10% less water than in 1980, despite 37 million more people.

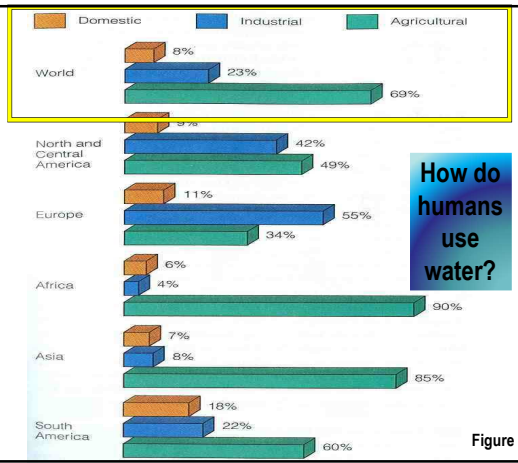
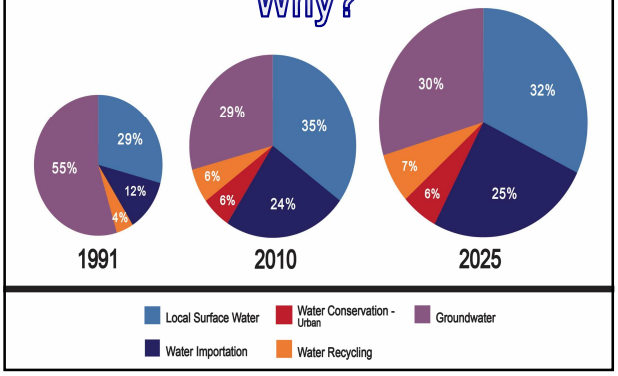
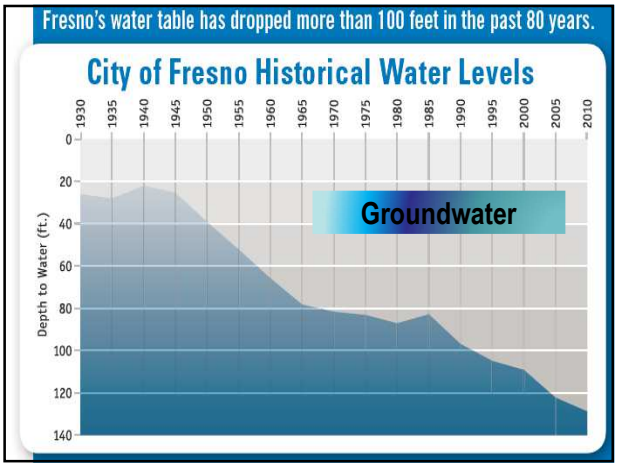


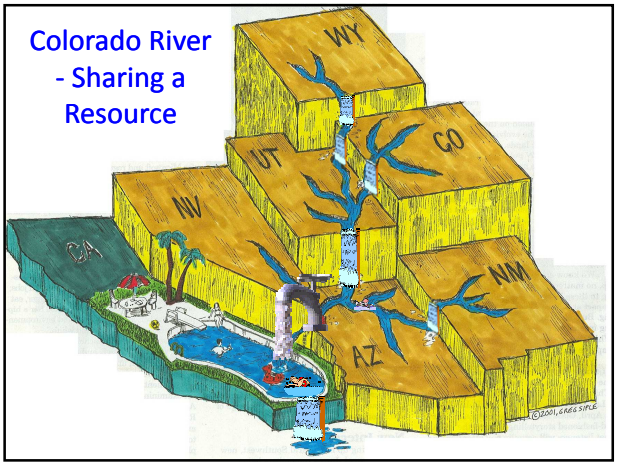
Figure 18-6

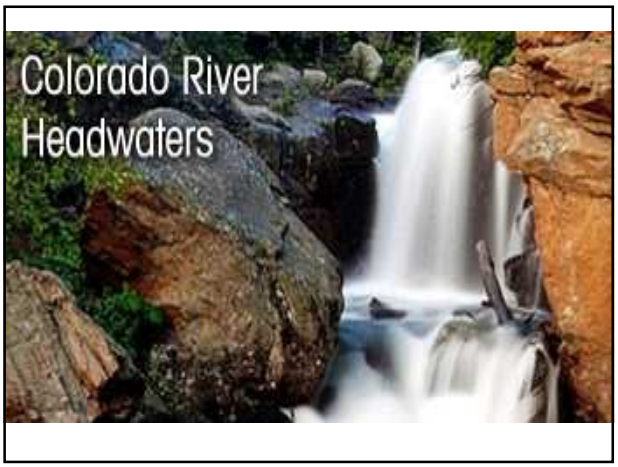
What trends can you identify? Why?

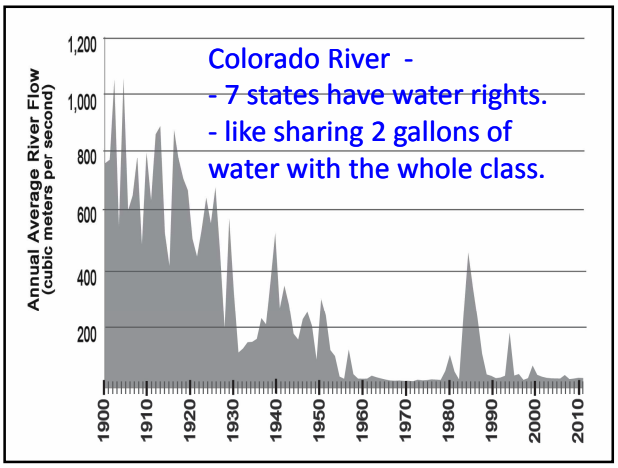




Colorado River - Sharing a Resource




Colorado River
Headwaters



Colorado River -
- ~~7 states have water rights.~~
- like sharing 2 gallons of water with the whole class.

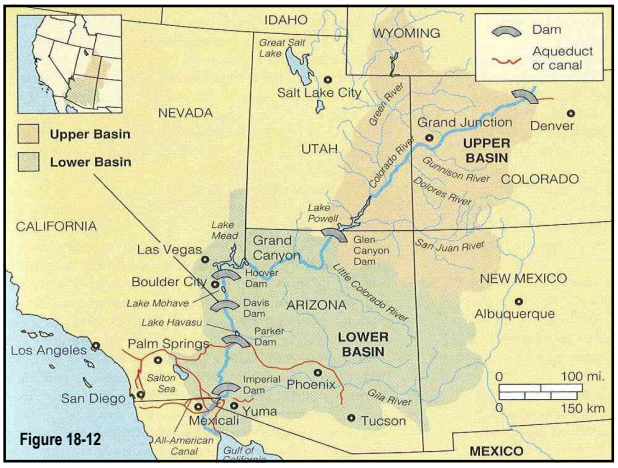


Figure 18-12

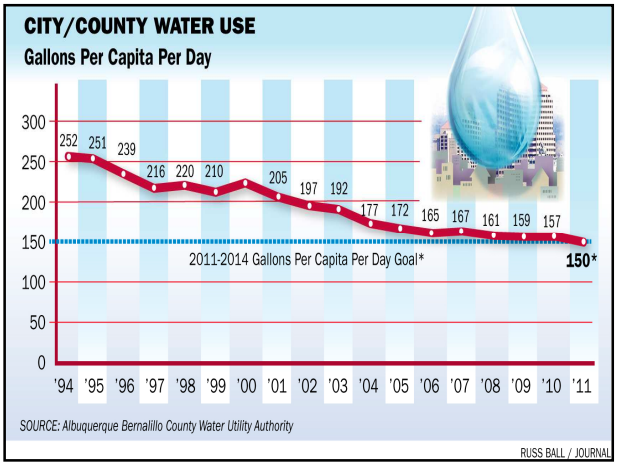
The Result – A river that doesn't make it to the sea.

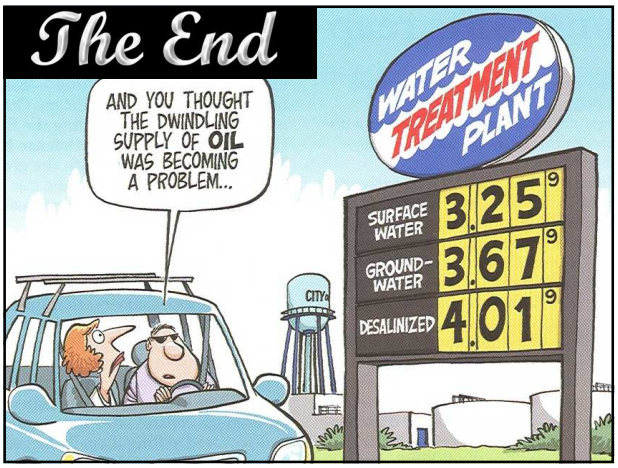
Increasing Efficiency and Water Saving

Increase Efficiency - Las Vegas has drastically decreased water use by increasing costs the more you use.

Las Vegas Rate Structure

Fifth 5,000 gallons and above	$4.58 per 1,000 gallons
Fourth 5,000 gallons	$3.09 per 1,000 gallons
Third 5,000 gallons	
Second 5,000 gallons	$2.08 per 1,000 gallons
First 5,000 gallons	$1.16 per 1,000 gallons
Fixed Fee	$8.06, per month for a 5/8 inch meter




The End
AND YOU THOUGHT THE DWINDLING SUPPLY OF OIL WAS BECOMING A PROBLEM...
WATER TREATMENT PLANT
SURFACE WATER 3.25
GROUND-WATER 3.67
DESALINIZED 4.01
CITY