Environmental Science *Systems and Solutions*

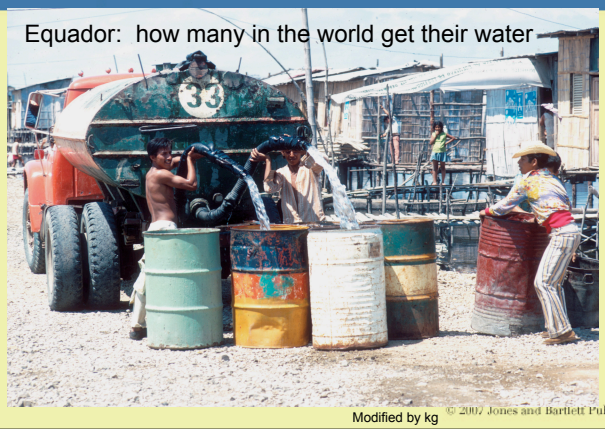
FOURTH EDITION

Michael I. McKinney
Robert M. Schoch
Logan Yonavjak

Chapter 9

WATER: Essential ingredient for life

Equador: how many in the world get their water



Modified by kg

Properties of Water

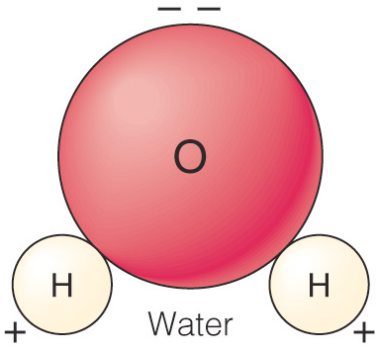
- **Water has unique properties when compared to most other liquids:**
  - **Water expands when it freezes (means fish can live under frozen lakes)**
  - **Water has a higher boiling point (very few materials are liquid)**
  - **Water has a very high specific heat (stores heat; keeps temperatures stable on planet Earth)**
  - **Water is a better solvent (means best for life; why our bodies are mostly made of it)**

NOTE: Since reading is now from the book, I am NOT using RED any more to mark what you are responsible for knowing!

Modified by kg

Properties of Water

- **These properties are caused by the bipolar distribution of electric charge on the neutral water molecule.**
- **Figure 9-1**



Modified by kg

World Water budget

- **Most of the Earth's water is not directly useful to people because it is salty or inaccessible.**

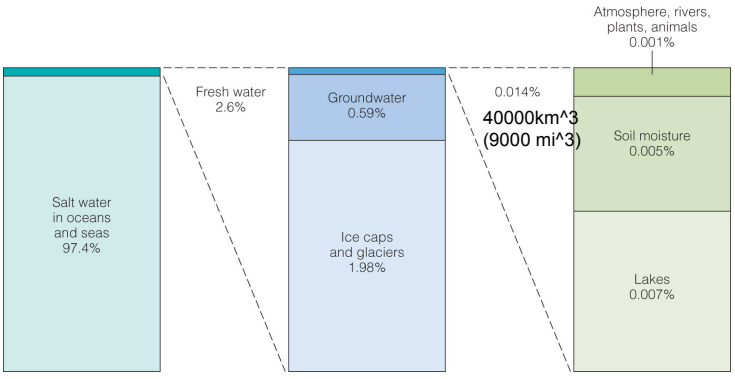


Figure 9.02 Percentages of fresh water on Earth.

Source: Data from D. Speidel and A. Agnew, "The World Water Budget" in D. Speidel et al., eds., Perspectives on Water Uses and Abuses [New York: Oxford University Press, 1988], p. 28.

Modified by kg

Hydrologic Cycle

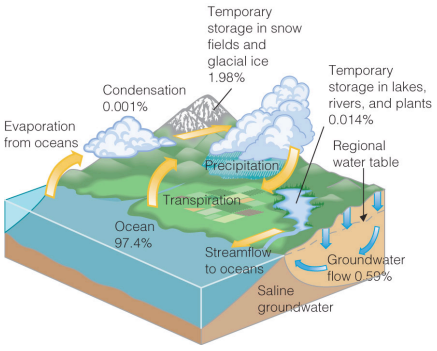
- **All of Earth's waters are connected, redistributed, and naturally purified through the hydrologic cycle.**
- **This solar-powered circulation involves two main processes (each year):**
  - **Evaporation (425,000 km^3 => 90% rains on oceans**
  - **Precipitation (40,000 km^3 on land (= 10,000 cubic miles)**
    - 9000 km^3 of this is accessible freshwater runnoff (rivers, etc.)
    - People already use 1/2 of this (4500 km^3), which is nearing the limit

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

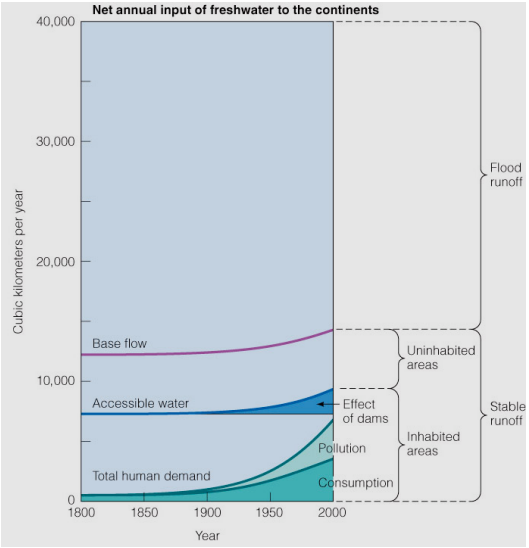
Hydrologic Cycle

- **Water moves through this cycle at various speeds:**
  - **40,000 years to recycle oceanic water**
  - **Two weeks to recycle river water**
  - **Nine to ten days to recycle atmospheric water**



Modified by kg

Figure 9-7 Estimated total human demand for fresh water and amount of accessible fresh water.



Source: Adapted from D. H. Meadows, D. L. Meadows, and J. Randers, Beyond the Limits [Post Mills, Vt.: Chelsea Green, 1992], p. 55.

Modified by kg

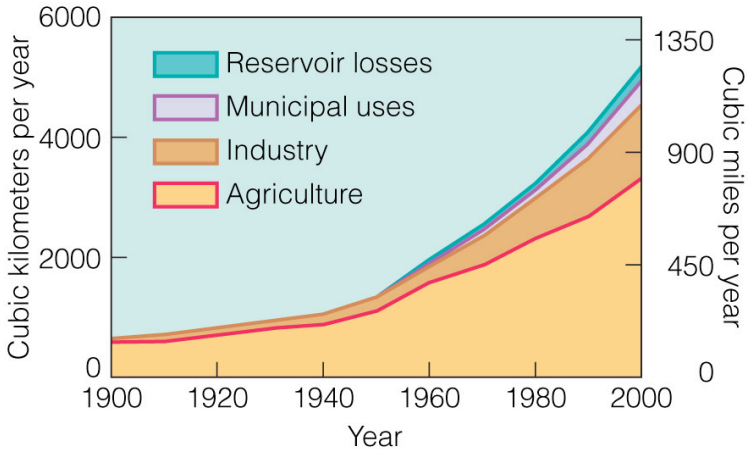
Environmental Science *Systems and Solutions* FOURTH EDITION

Important distinction in water use

- ***Withdrawn water*** **may be returned to its source (e.g. river) after use (but may be polluted and not usable).**
- ***Consumed water*** **is withdrawn water that is not returned to its original source (e.g. irrigation).**
- **Industry is the greatest withdrawer of water, but agriculture is the greatest consumer.**

Modified by kg

Figure 9-4 Estimated annual world water use, 1900 to 2000.



Source: Based on data from L. R. Brown, ed., State of the World 1993. Washington, D.C., Worldwatch Institute, 1993.

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

U.S. Water usage

- **U.S. uses about 1000 km^3/year (out of world ~5000 km^3)**
  - **About 1150 gallons/day per person**
  - **More than any other nation and twice the use in Europe**
  - **Humans only need about 1 gallon/day to survive**
- **Why?**
  - **41% for agriculture (~ 80% in California! 70% worldwide)**
    - California agriculture water is almost all (85%) inefficient irrigation where less than 40% of the water makes it into the crops! (rest if evaporated and lost) (drip irrigation would be better
  - **38% to cool electricity power plants! (note connection with energy)**
  - **11% for industrial manufacturing (though much more is withdrawn but not consumed; returned water is sometimes polluted)**
  - **10% for people, and much of this is for fire hydrants, etc. (8% worldwide)**
    - Americans personal use is about 60 gallons/day

Modified by kg

TABLE 9-2 Water Used to Make Various Agricultural and Industrial Products

Agricultural Products	Gallons	Liters	Industrial Products	Gallons	Liters
Egg, 1	40	151	Refine 1 gallon of crude oil	10	38
Milk, 1 glass	100	380	Sunday paper	280	1,060
Flour, 1 pound	75	285	Aluminum, 1 pound	1,000	3,800
Rice, 1 pound	560	2,120	Automobile, 1	100,000	380,000
Beef, 1 pound	800	3,030			

Source: Based on U.S. Geological Survey data, 1992.

TBL09_02: Water used to make various agricultural and industrial products

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

TABLE 9-3 Indoor Domestic Daily Water Use for an American Family of Four People

	Gallons	Liters
Toilet flushing	100	380
Showers and baths	80	303
Laundry	35	132
Dishwashing	15	57
Bathroom sink	8	30
Utility sink	5	19
Total	243	921

Source: U.S. Environmental Protection Agency, 1993. (Latest date for which accurate data are available, but it is believed that per capita domestic indoor water usage has not significantly changed in the last 2 decades.)

TBL09_03: Indoor daily water use for an American family of four.

Modified by kg © 2007 Jones and Bartlett Publishers

Types of Water Resources

- Inequalities exist in the distribution of Earth's water resources.
- Surplus areas are rich in water resources.
- Water resources are categorized as:
  - Surface waters (rivers, streams, ponds, and lakes)
  - Groundwater
- Deficit areas usually also have both types of water resources.
- These resources are replenished much more slowly in deficit areas.

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Regions of World Water Surplus (green) and Deficiency (brown)

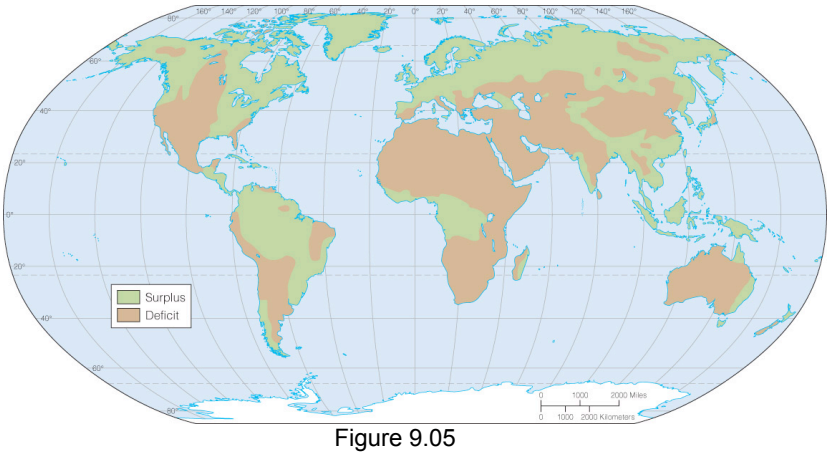


Figure 9.05

Source: Adapted from M. Fal-kenmark, "Water and Mankind," Ambio 6 [1977]: 5.

Modified by kg

Safe drinking water is a separate but related problem

- Cities in developing countries often do not have clean drinking water; water borne diseases are a major problem
- Not just lack of water, also corruption/politics. E.g. Onitsha, Nigeria: private vendors sell water to many city residences. Total money given the vendors in 1.5 years would pay for new municipal water system.
- Overall water shortages are getting worse throughout world. Currently 2.5 billion (out of 6 billion) people live in water scarce or water stressed regions. Number is rising.

Modified by kg

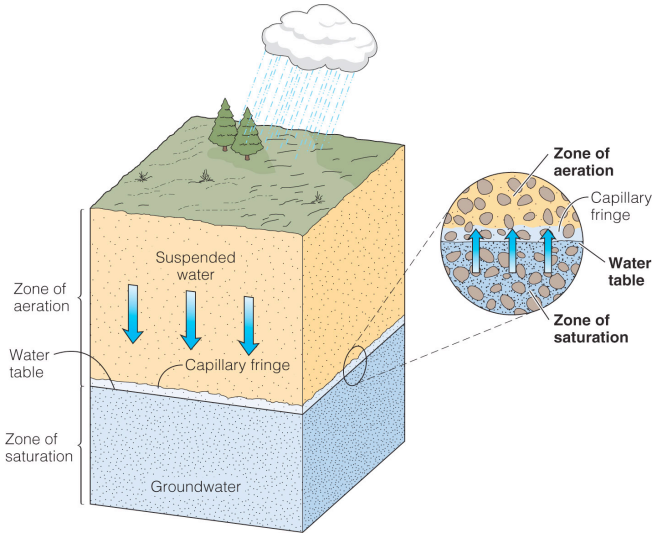
Environmental Science *Systems and Solutions* FOURTH EDITION

Surface water vs. Groundwater

- The majority of accessible fresh water is *groundwater*, water beneath Earth's surface.
- About 10% of precipitation will infiltrate through soil and rock to become groundwater, forming the water table.
- Permeable rock containing the *zone of saturation* is an *aquifer (sandstone, gravel, fractured limestone, etc)*.
- Bounded by aquicludes (clays, shale) that are impermeable
- As human population grows use of groundwater throughout the world is accelerating

Modified by kg

Figure 9-9- The zone of saturation.

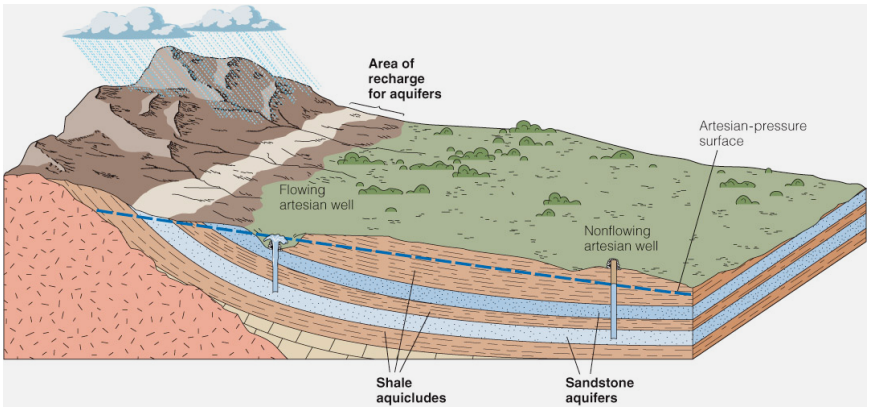


Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Aquifers

Figure 9-10 Water from a recharge area flows into sandstone aquifers enclosed by aquicludes.



Modified by kg

Groundwater Problems

- **Two kinds of problems reduce groundwater's utility:**
  - **Discharge problems**
    - Groundwater pollution (underground gasoline storage, landfill seepage, septic tanks)
    - pollution moves roughly 50 ft per year so problems take years to notice
  - **Worse are withdrawal problems**
    - Depletion
    - Land subsidence
    - Saltwater intrusion

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Groundwater Problems

- **Withdrawal problems occur because human pumping can remove water from aquifers much faster than they recharge. Thus much ground water is NOT really a renewable resource (e.g. if it takes 1000 years to recharge aquifer and we use up water in few decades)**
- **Example: Ogallala aquifer (see picture)**
  - **Covers most of Nebraska, plus parts of Kansas, Texas, Colorado**
  - **Filled up 10,000 at end of last ice age**
  - **Was originally around 65 feet thick; now less than 10**
  - **Water table is droping by 1/2 ft to 2 ft PER YEAR.**
  - **14 million acres of croplands are watered from this aquifer**
  - **Will be used up soon, then most of area may return to dust bowl like conditions**
  - **Currently little incentive to stop draining!**
    - Govt subsidies encourage growing water intensive crops like cotton
    - Tax breaks giving most tax relief to whoever pumps the most water
- **CA centeral valley similar! Land has subsided up to 30 feet from over pumping**

Modified by kg

U.S. Groundwater Overdraft

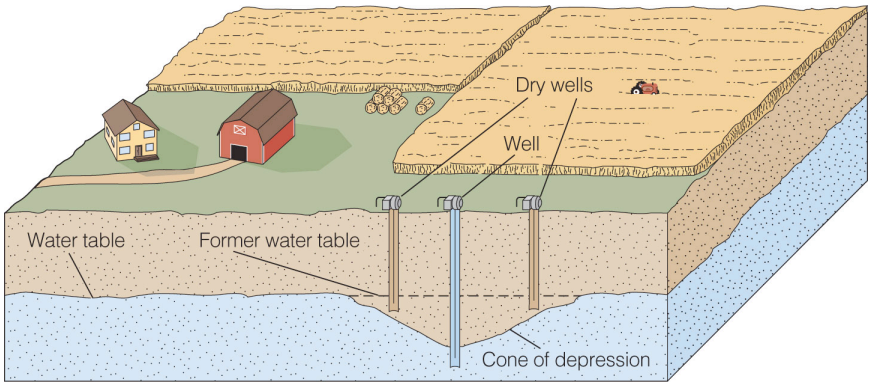
Figure 9-12

Source: U.S. Geological Survey.

Modified by kg

Overpumping of Groundwater

Figure 9-13 Overpumping can cause a cone of depression; then have to dill deeper (until water is gone).



Modified by kg

Subsidence

- In general "subsidence" happens. Mexico city, Venice, Florida, etc.
- Land subsidence is more localized than aquifer depletion.
- Subsidence sometimes occurs where groundwater depletion causes the water table to drop.
- If the water-filed voids in the aquifer were large or supported by water pressure of the groundwater, the emptied aquifer rock strata are likely to compress.
- The overlaying land tends to sink, which destabilizes roads, buildings, and other structures. In some cases get "sinkholes"

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Saltwater Intrusion

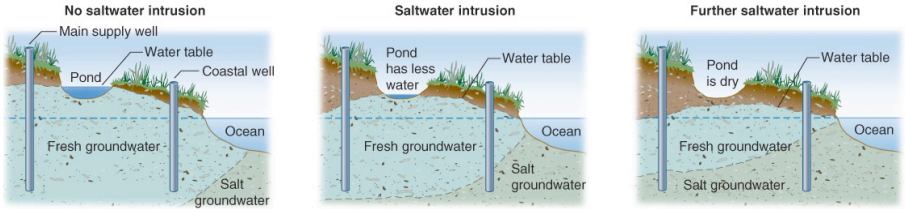


Figure 9-15

Modified by kg

Increasing Our Water Resources

- **There are several ways to address the water shortages facing much of the United States and other parts of the world:**
  - **Increasing efficiency of use**
  - **Recycling by reusing wastewater**
  - **Substitution by using salt water**
  - **(Almost never mentioned: reduce human population)**
    - This is method most often used in past! (e.g. Anazasi) and may happen again in future if strong actions above not taken

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Redirecting Water Resources

- **Other approaches extend local water supplies by shifting water from one region to another:**
  - **Dams and reservoirs**
  - **Canals and pipelines**

Modified by kg

TABLE 9-4 Ways to Conserve Water

Normal water consumption		Water-Saving Methods	
Bathing in a full tub	36 gallons	Regular shower Wet down, soap-up, rinse off	25 gallons 4 gallons
Washing hands with the water running	2 gallons	Fill the basin	1 gallon
Brushing teeth with the water running	10 gallons	Wet brush & quick rinse	½ gallon
Each toilet flush	5-7 gallons	Minimize flushing	
Leaking faucet	25 gallons a day	Fix as soon as possible	

But compare to 800 gallons for pound of beef, 100 gallons for a glass of milk 40 gals for an egg, 5 gallons for a flour tortilla or 30 gallons for an aluminum can

TBL09_04: Ways to conserve water.

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

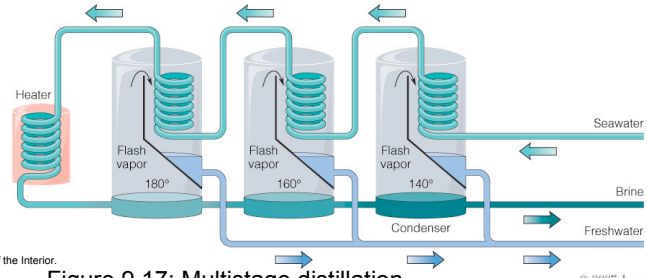
Water Efficiency

- **Water resources provide many opportunities for conservation:**
  - **Microirrigation for agriculture**
  - **Individual lifestyle conservation**
    - Shorter showers
    - Don't let the water run
    - Low-flush toilets
    - Xeriscaping
    - Consume less!
  - **Wastewater reclamation includes:**
    - Closed loop reclamation
    - Graywater use

Modified by kg

Desalination

- Energy costs are high-ish
  - Regular water get about 1000-2000gal/$ (you personally only get 250gal/$)
  - Desalination get about 500gal/$ and use 10 about kWh of electricity
  - If all San Diego water came from desalination it would increase electricity use in San Diego by around 25%.
- 200 lbs of salt per 1000 gallons of water must be disposed
- Membrane and distillation methods are the most cost-efficient.
- Big new plant planned for Carlsbad (Poseidon Resources)(50 million gal/day)



Source: U.S. Department of the Interior.

Figure 9.17: Multistage distillation.

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Wastewater Reclamation

- Wastewater can be safe to drink if treated properly.
- Gray water can be used for water needs other than drinking.
- It is cheaper to treat wastewater than to desalinate salt water.

Modified by kg

Where do we get our water?

- **Substantial portion from Colorado river**
- **Many Dams control water and make electricity**
- **25 million people use water from Hoover Dam alone (lake Mead)**
- **Glen Canyon Dam (lake Powell) Some environmentalists would like to remove it.**
- **Wetlands mostly gone (only 5% left); river runs out of water before reaching Gulf of Mexico**

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Figure 9.CS2_02: Dams on the Colorado River.

Modified by kg

Dams and Reservoirs

- **Dams and reservoirs and canals redistribute water from water surplus areas of low population to water-deficit areas with high populations.**

Figure 9-CS2_01 The Colorado River behind the Glen Canyon Dam.

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Dams and Reservoirs

- **Dams are built for one or several reasons:**
  - **Minimize flood damage through flow control**
  - **Create a storage reservoir**
  - **Provide hydroelectric power**

- **Even well-designed dams have several environmental impacts:**
  - **Sediment accumulation (lake Powell will fill in 100-300 years)**
  - **Downstream scouring**
  - **Water loss from evaporation**
  - **Salination from evaporation (colorado river is 20 times saltier and more polluted by the time it reaches Mexico)**
  - **Dam break catastrophes**
  - **Destruction of wetlands (wildlife dies, groundwater not recharged)**
    - Wetlands are like kidneys; hold fresh water for long times, purifying it and allowing it to infiltrate into aquifers below; a main source of groundwater

Modified by kg

Canals

- Also known as aqueducts, canals are artificial channels built to transfer water over long distances

Environmental Science *Systems and Solutions* FOURTH EDITION

Social Solutions to Water Scarcity

- The low cost of water offers little incentive to conserve the resource.
- Stopping subsidized water for agriculture will let market forces assist in conservation.
- Effluent charges can promote industrial and household water efficiency.

Conserving Water

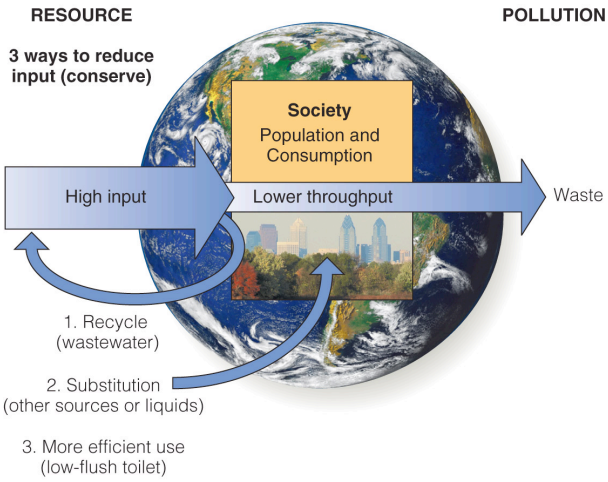


Figure 9-20 Three ways to conserve water.

Inserts © Photodisc

Modified by kg

Environmental Science *Systems and Solutions* FOURTH EDITION

Legal Solutions

- **Legal restrictions can also shape water use:**
  - **Surface water**
    - Riparian water law
    - Appropriation water law

Modified by kg

© 2007 Jones and Bartlett Publishers

Economic or Legal Solutions?

- Market conditions provide the optimal allocation of resources because it tends to distribute costs more equitably and often is the only practical way of controlling water use
- Legal solutions are usually used when
  - there are fewer parties involved
  - it is easier to monitor
  - a resource is in very short supply
  - regulation must be strict

Modified by kg

Introduction

- Water is one of the most remarkable materials on Earth.
- If the Earth's water were evenly distributed, it would cover the planet to a depth of two miles (3.2 km).
- Only a small portion of the Earth's water supply is fresh and fresh water is not evenly distributed.

Introduction

- Naturally occurring water shortages are aggravated by:
  - Lack of water conservation
  - Water pollution
- Flooding is also a major source of damage and people can exacerbate this problem.

Environmental Science *Systems and Solutions* FOURTH EDITION

Surface Water

- ***Surface waters*** **include flowing waters (rivers and streams) and basinal waters (ponds and lakes).**
- **About 20% of the precipitation that falls in a drainage basin flows as surface waters through tributaries into major rivers, creating a tree-like pattern.**
- ***Discharge*****, the volume of water carried in a stream channel, increases with the size of the channel.**

Modified by kg