Introduction to Environmental Geology, 5e

Chapter 13

Water Resources

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Chapter 13: Overview

- Understand the water cycle and supply
- Understand the main types of water use
- Know basic surface and groundwater processes
- Be able to discuss principles of water management
- Know why we are facing a global water shortage linked to food supply

Case History: Long Island

- GW pollution – serious problem on western end of the island since beginning of 20th century
- GW below Nassau County is extensive, yet intense pumping has caused ~15m decline in water level.
- Water needs for 3 million people.
- Salt water intrusion due to decline in water level
- Urbanization triggered more serious water pollution – urban runoff, sewage, fertilizers, road salt, industrial and other waste, landfills

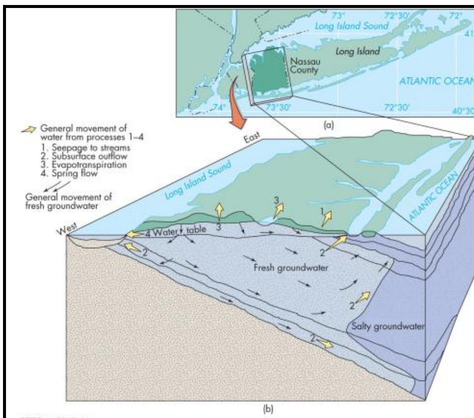


Figure 13.2

Water: A Global Perspective

- Cyclic, dynamic nature
  - Global movement of water between different water storage compartments
- Global distribution
  - Abundance is not necessarily the problem
  - Distribution in space and over time is an issue
  - Supply versus usage is an issue
  - Water quality is an issue
- Major processes: evaporation, precipitation, transpiration, surface runoff, groundwater flow

Global Water Cycle

- Water's vertical movement
  - Upflow: Evaporation, transpiration
  - Downflow: Precipitation and infiltration
- Water's horizontal movement
  - Surface runoff
  - Shallow subsurface through flow
  - Groundwater flow

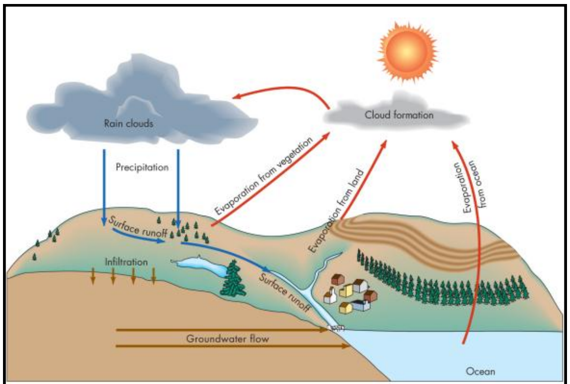
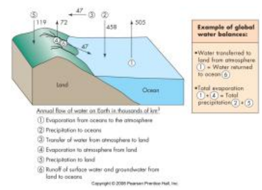


Figure 13.3

Global Water Supply



Water as a resource -

- Found in liquid, solid, or gaseous state on or near Earth surface
- Residence time varies depending upon location
- More than 99% of Earth's water unavailable or unsuitable for human use

Figure 13.4

Global Water Supply

TABLE 13.1 The World's Water Supply (Selected Examples)

Location	Surface Area (km^2)	Water Volume (km^3)	Percentage of Total Water	Estimated Average Residence Time
Oceans	361,000,000	1,230,000,000	97.2	Thousands of years
Atmosphere	510,000,000	12,700	0.001	9 days
Rivers and streams	—	1,200	0.0001	2 weeks
Groundwater; shallow to depth of 0.8 km	130,000,000	4,000,000	0.31	Hundreds to many thousands of years
Lakes (freshwater)	855,000	123,000	0.009	Tens of years
Ice caps and glaciers	28,200,000	28,600,000	2.15	Up to tens of thousands of years and longer

Data from U.S. Geological Survey.

All people compete for <1% of the worlds water supply.

Table 13.1

Surface Water

Surface runoff:

- Drainage basin or watershed
- Drainage divide
- Stream order
- Drainage density
- Runoff affects erosion and trans-port of material

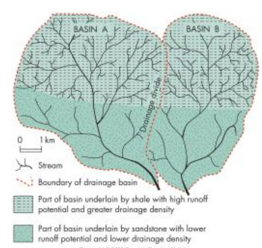


Figure 13.6

Surface Water

Factors affecting runoff and sediment yield:

- Geologic factors – type and structure of soils and local rocks.
  - *Drainage density* is high on shale and low on sandstone.
- Topographic factors – relief and slope gradient
- Climatic factors – type, intensity, duration, and distribution of precipitation
- Vegetation factors – type, size, and distribution
- Land-use factors
  - Agriculture, grazing, and urbanization

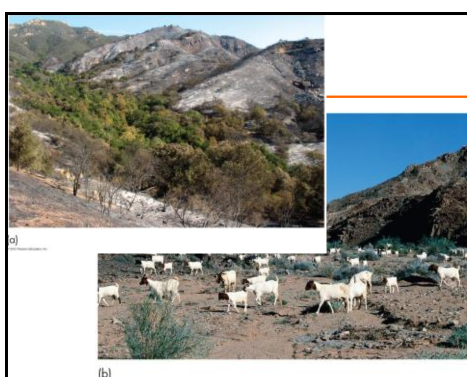


Figure 13.7 a/b

Groundwater

Water found beneath the surface of Earth within the zone of saturation.

- Vadose zone (unsaturated zone or zone of aeration): pores mostly filled with air
- Zone of saturation: pores mostly filled with H_2O
- Water table: the boundary between the zone of saturation and zone of aeration
- Perched water table: local water table above a regional water table

Groundwater

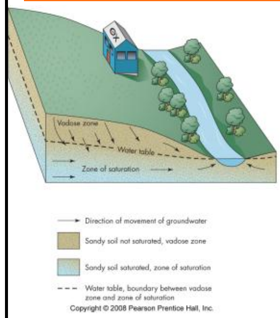


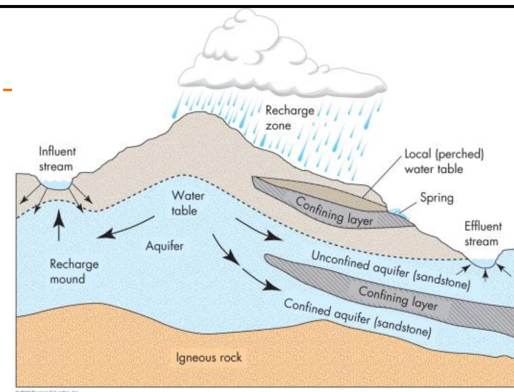
Figure 13.9

Factors influencing rate of **infiltration**:

- Topography
- Soil and rock type
- Amount and intensity of precipitation
- Vegetation
- Land use

Groundwater

- Aquifer: a unit capable of supplying water at an econimically useful rate
- Aquitard or aquiclude: a confining layer or unit restricting and retarding GW flow
- Unconfined aquifer: no overlying confining layer
- Confined aquifer: has an overlying aquitard layer
- Perched aquifer: local zone of saturation above a regional water table



Groundwater

Groundwater recharge and discharge –

- Recharge zone: area where water infiltrates downward from the surface to GW
- Discharge zone: area where GW is removed from and aquifer (spring, well, river)
- Influent stream: above the water table, recharge water to GW, may be intermittent
- Effluent stream: perennial stream with the addition of GW when precipitation is low

Groundwater

Groundwater pressure surface: generally declining from source along the flow from recharge area to discharge area

Artesian well: water self-rising above the land surface in a confined aquifer

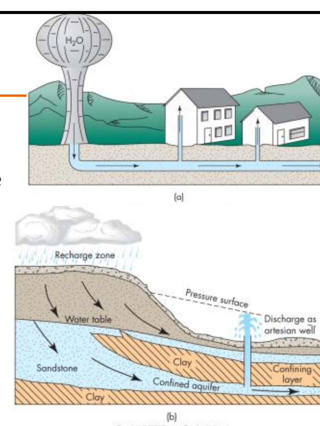


Figure 13.11 a/b

Groundwater

Cone of depression: drawdown cone of groundwater in a well.

Water table drops.

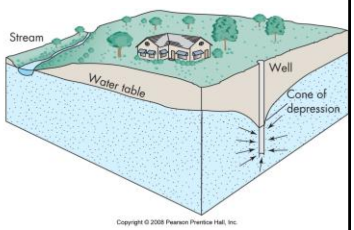


Figure 13.13

Groundwater Movement

- Hydraulic gradient: the gradient of water table, generally follows the topographic gradient
- Hydraulic conductivity: ability of rock or materials to transmit water ($m^3/day/m^2$)
- Porosity: percentage of void (empty) space in sediment or rock to store water
- Permeability: measuring the interconnected-ness of pores in a rock material or sediment
- Darcy's Law: rate of flow of GW

Groundwater Movement

TABLE 13.2 Porosity and Hydraulic Conductivity of Selected Earth Materials

	Material	Porosity (%)	Hydraulic Conductivity[1] (m/day)
Unconsolidated	Clay	50	0.041
	Sand	35	32.8
	Gravel	25	205.0
	Gravel and sand	20	82.0
Rock	Sandstone	15	28.7
	Dense limestone or shale	5	0.041
	Granite	1	0.0041

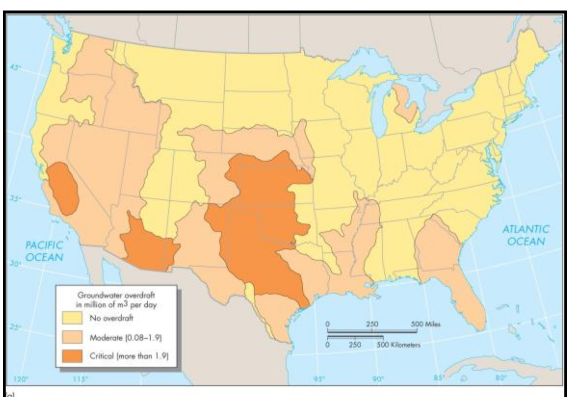
[1] In older works, may be called *coefficients of permeability*.

Modified after Linsley, Kohler, and Paulhus, 1958. *Hydrology for Engineers*. New York: McGraw-Hill. Copyright © 1958 by McGraw-Hill Book Company. Used by permission of McGraw-Hill Book Company.

Table 13.2

Groundwater Use and Supply

- Groundwater as primary drinking water source for ~50 percent of the U.S. population.
- Groundwater *overdraft** problems in many parts of the country.
  - *Extraction rate exceeding recharging rate
- Estimated 5 percent of groundwater depleted, but water level declined more than 15 m (50 ft) in some areas.
  - "Groundwater mining"
  - Ogallala Aquifer in the U.S.



Ogallala

Water-bearing sands and gravels.

Water use is 20 times natural recharge rate.

Cities facing shortage.

May need to return to dry farming.

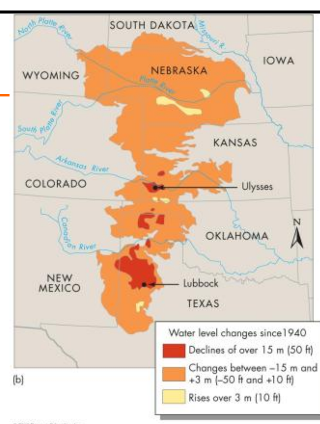
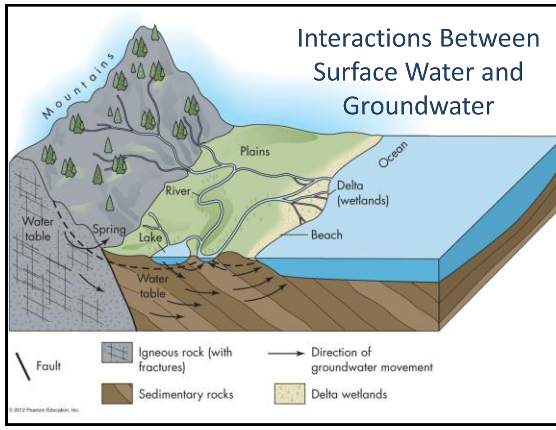


Figure 13.14b

SW and GW Interactions

- Overdraft of GW leads to lower water levels in streams, lakes, and reservoirs
- Overuse of SW yields lower discharge rates of GW (discharge…volume of water per unit time)
- Effluent stream (in GW discharge zone): tends to be perennial
- Influent stream (in GW recharge zone above water table): often intermittent
- “Special linkages” – karst terrains

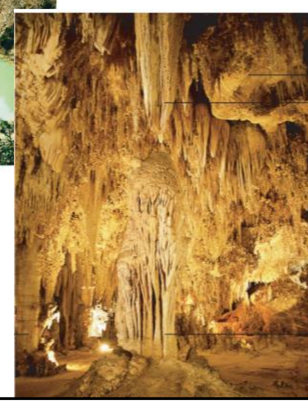
Interactions Between Surface Water and Groundwater



Karst Topography Problems

Water pollution occurs where sinkholes have been used for waste disposal.

- Cavern systems prone to collapse-
  - sinkholes may form in areas that damage buildings on the ground surface, roads, and other facilities
- Areas underlain by limestone.
- As a result of the mining, important karst springs where water emerges from caverns are being changed, causing a reduction in biodiversity



Sinkholes & Caverns

Figure 13.16 & 13.18

Water Use

- Desalination: reduction of salt content in water
  - High cost and high consumption of energy
- Offstream use: removal or diversion from SW or GW sources temporarily (irrigation, hydroelectric, and industrial use)
- Consumptive use: type of offstream use of water without intermediate return to SW or GW system (transpiration and human use)
- Instream use: navigation, fish and wildlife, and recreational uses

Water Use

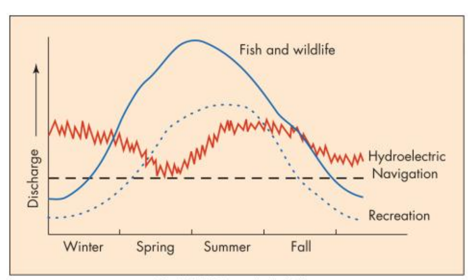


Figure 13.19

Water Use

Association with major urban areas:

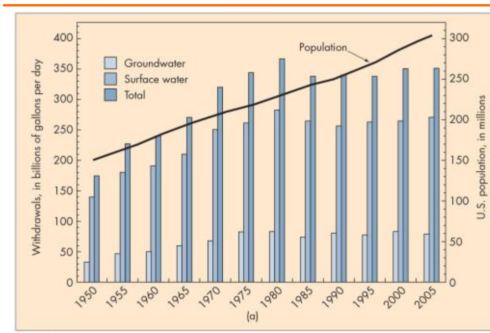
- Overwithdrawal of groundwater
- Overuse of local surface water
- Threats of local urban landfills to the water supply (Long Island, NY)
- Water import issues and problems:
  - What is the distance to transport?
  - How much water is available? From where?
  - Conflicts with other areas for water rights?
  - Long-range planning? Population growth? Quality?

Trends in Water Use

Based on the data from 1950–1995

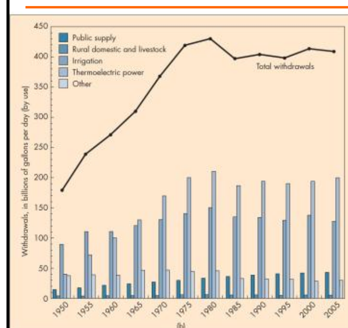
- Surface water use far greater than groundwater use
- The rate of water use decreased and leveled off since 1980
- Irrigation and thermoelectric are major fresh consumptive water use
- Less fresh water use since 1980 due to new tech and water recycling
- Water use in rural and urban areas is up

Trends in Water Use



Trends in Water Use

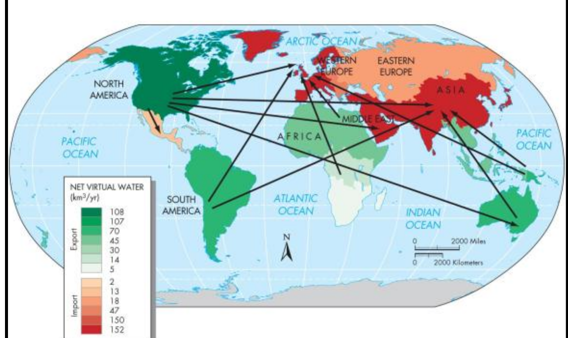
Figure 13.20 a/b



Water Conservation

- Engineering technology and structure (canals)
  - Regulating irrigation and reducing evaporation
- Engineering technology and structure (canals): Regulating irrigation and reducing evaporation
- Better technologies in power plants and other industries to reduce or reuse.
  - Less use of water due to improved efficiency
- Increased water reuse and recycling
- Domestic water use (10% of total national withdrawals) poses a threat to local supplies

Conservation of Water at the Global Scale



Water Management

Needs for water management

- Increasing demand for water use (population and economic development)
- Water supply problems in semiarid to arid regions
- Water supply problems in mega cities of humid regions. Water quality is also an issue.
- Water traded as a commodity: Capital, market, and regulations?

Water Management

Aspects to be considered: Leopold philosophy

- Natural environmental factors: Geologic, geographic, and climatic
- Human environmental factors: Economic, social, and political issues.
- Strategies:
  - More SW use in wet years, more GW use in dry years
  - Reuse and recycle water regular basis as well as emergencies

Management of the Colorado River

Managing the water

- Water appropriation to seven states in the United States and to Mexico
- Local needs versus regional needs (Colorado River compact of 1922)
- The United States versus Mexico (Treaty with Mexico in 1944)
- Human use versus needs of lands (1974 Salinity Control Act)

Management of the Colorado River

Managing the river:

- Dam construction
- Impact on flood frequency
- Impact on sediment distribution, particularly downstream
- Impact on wildlife habitats
- Controlled and planned floods

Water and Ecosystems

- Ecosystems: changes in response to climate, nutrient input, soils, and hydrology
- General tendency: increased human use of water, increased degradation of natural ecosystems
- Reconciliation between multiple water uses
  - Dams, reservoirs, canals – and associated impact on surface water environment
  - Reconcile uses of water – agriculture, industry, urbanization, and recreation
  - Protection of wetlands and water resources

Emerging Global Water Shortage

- Global patterns of water shortage
- Depleted water resources: over-drafted aquifers, dried lakes (Aral Sea), troubled streams (Colorado and Yellow River)
- Polluted, limited water resources due to development and increased wastes
- Demands for water resources tripled as population more than doubled in the last 50 yr
- Climate change…causing more problems

Critical Thinking Topics

- In your area, which type of water source (surface water or groundwater) is more important? Why? Why not?
- If we change the ways we use water, what would be the impact on the global water cycle?
- What sort of wetlands are found in your region? Any changes over the years?
- Which continent will the global warming have a greater impact on its water resources?