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Modules 26-28 Water ch. 9

Recall:

Energy->**Water**->Food->Culture
(Also Chapter 12 in Froggie book)

Water: key points

> **Section one: What is it, where is it:**
> Freshwater, saltwater, how it moves, aquifers and reservoirs, impact of climate change, water wars
> **Section two: Pollution**:
> Often human driven (anthropogenic): Nutrient, thermal, BOD, sediment
> Almost always human driven: Pathogens, inorganic chemicals, organic chemicals, radioactive chemicals
> **Section three: Water Quality index:**
> DO, BOD, pH, temp, turbidity, conductivity, nitrates (NO_3), phosphates (PO_4)

Section one: What is it, where is it?

Where is the water? Note: 97% salt water

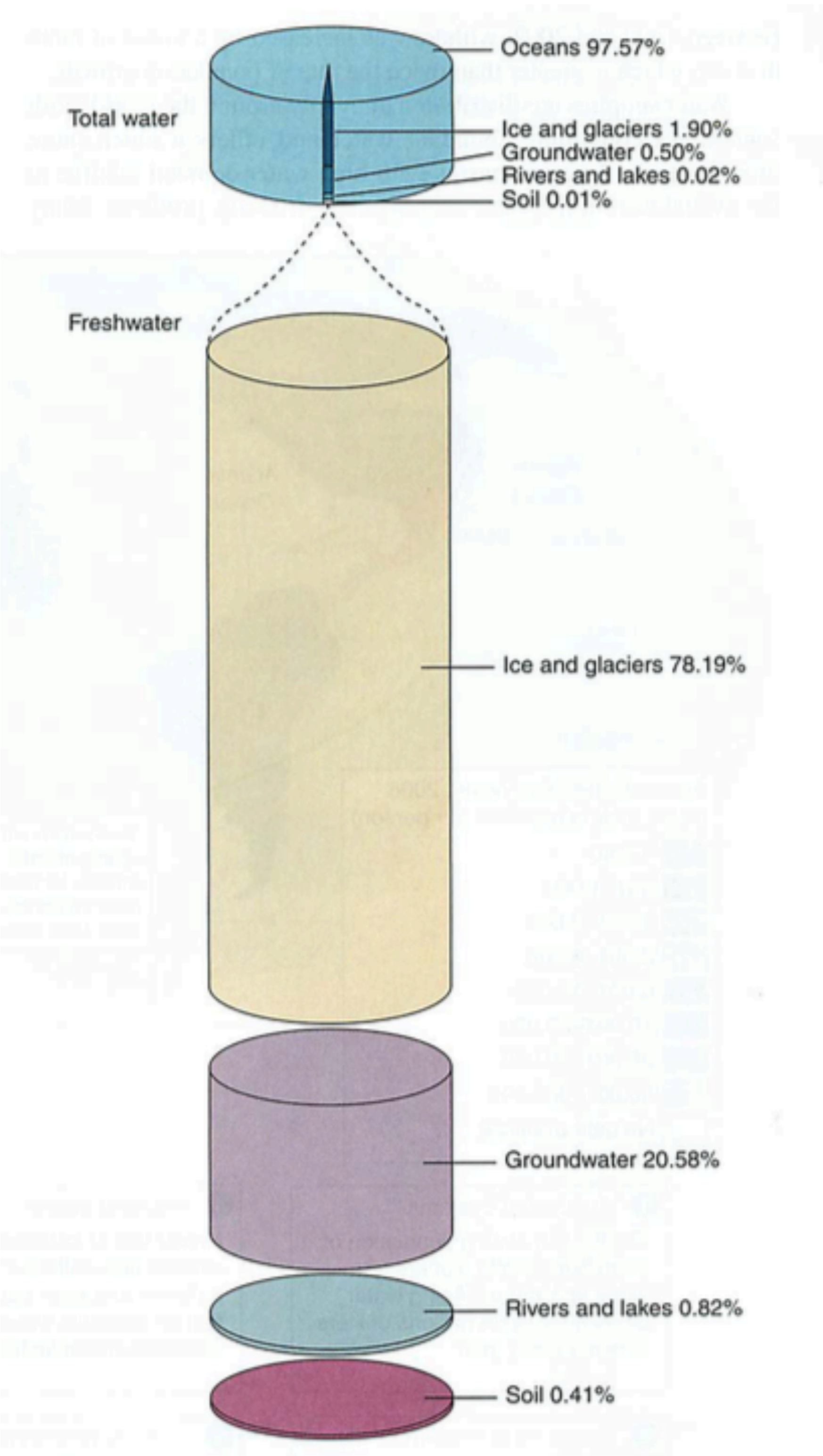

FIGURE 15.1 **Freshwater Resources** Although water covers about 70 percent of the Earth's surface, over 97 percent is saltwater. Of the less than 3 percent that is freshwater, only a tiny fraction is available for human use.

How does it get there?

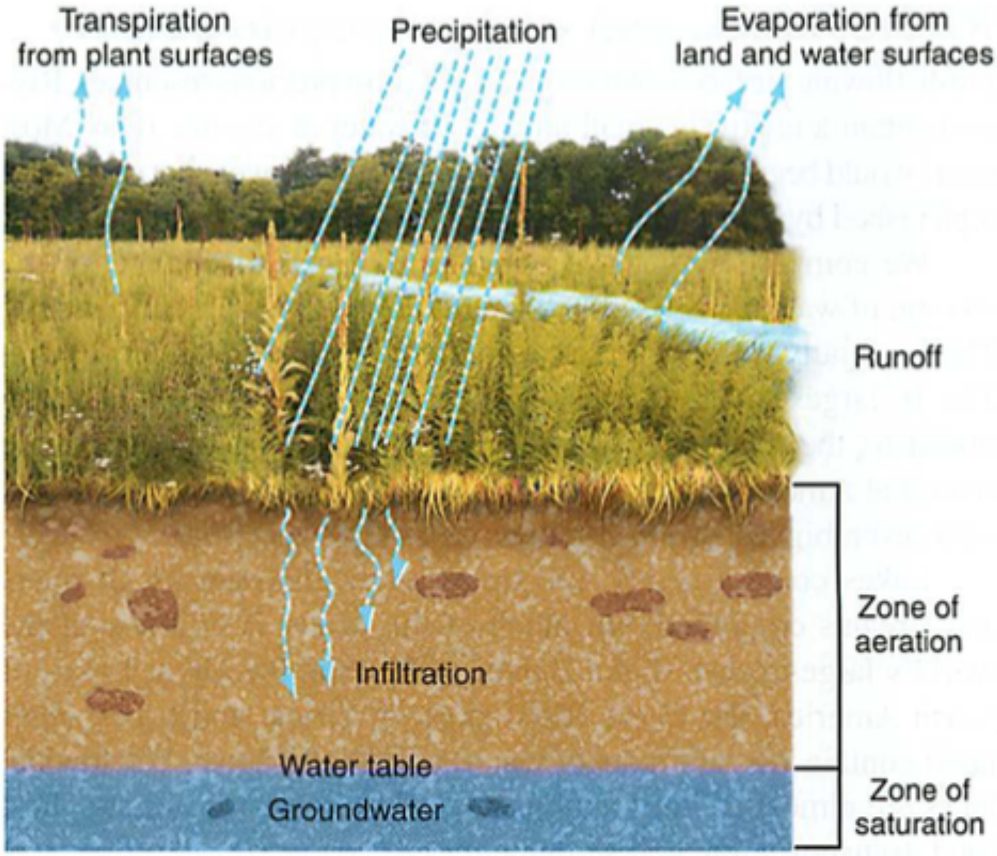

Figure 10.5 Precipitation that does not evaporate or run off over the surface percolates through the soil in a process called infiltration. The upper layers of soil hold droplets of moisture between air-filled spaces. Lower layers, where all spaces are filled with water, make up the zone of saturation, or groundwater.

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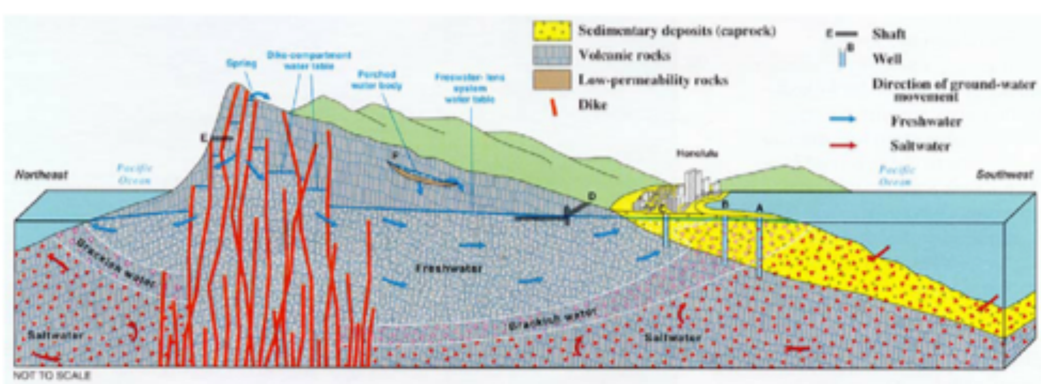
Our volcanic island is a bit different: A shield volcano



schematic cross section of the island of Oahu showing various hydrogeological features and different water development installations (Gingerich and Oki, 2000).

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Water "boxes" on our planet (your planet may vary):

Table 10.2 | Earth's Water Compartments

Compartment	Volume (1,000 km^3)	Percent of Total Water	Average Residence Time
Total	1,386,000	100	2,800 years
Oceans	1,338,000	96.5	3,000 to 30,000 years*
Ice and snow	24,364	1.76	1 to 100,000 years*
Saline groundwater	12,870	0.93	Days to thousands of years*
Fresh groundwater	10,530	0.76	Days to thousands of years*
Fresh lakes	91	0.007	1 to 500 years*
Saline lakes	85	0.006	1 to 1,000 years*
Soil moisture	16.5	0.001	2 weeks to 1 year*
Atmosphere	12.9	0.001	1 week
Marshes, wetlands	11.5	0.001	Months to years
Rivers, streams	2.12	0.0002	1 week to 1 month
Living organisms	1.12	0.0001	1 week

*Depends on depth and other factors.

Source: Data from UNEP, 2002.

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Aquifers: open or closed ("captive")

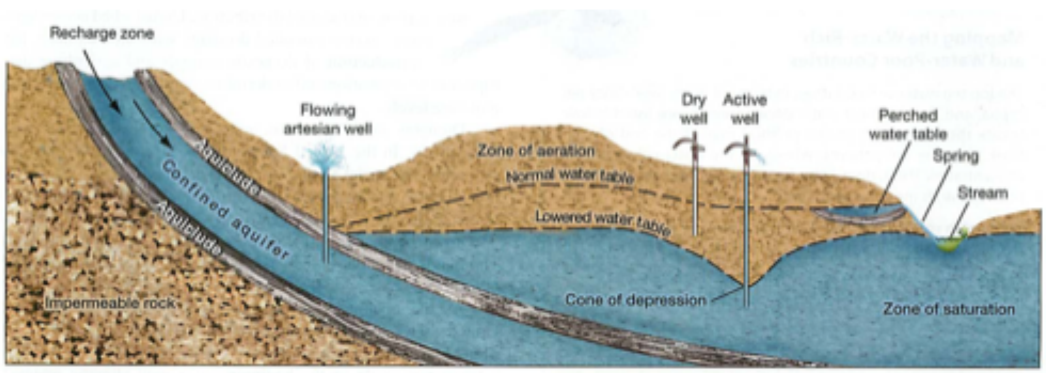

Figure 10.6 An aquifer is a porous or cracked layer of rock. Impervious rock layers (aquicludes) keep water within a confined aquifer. Pressure from uphill makes an artesian well flow freely. Pumping can create a cone of depression, which leaves shallower wells dry.

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Huge Ogallala aquifer-note recharge time is in centuries, pesticides in Nebraska, cancer rates there are very high...

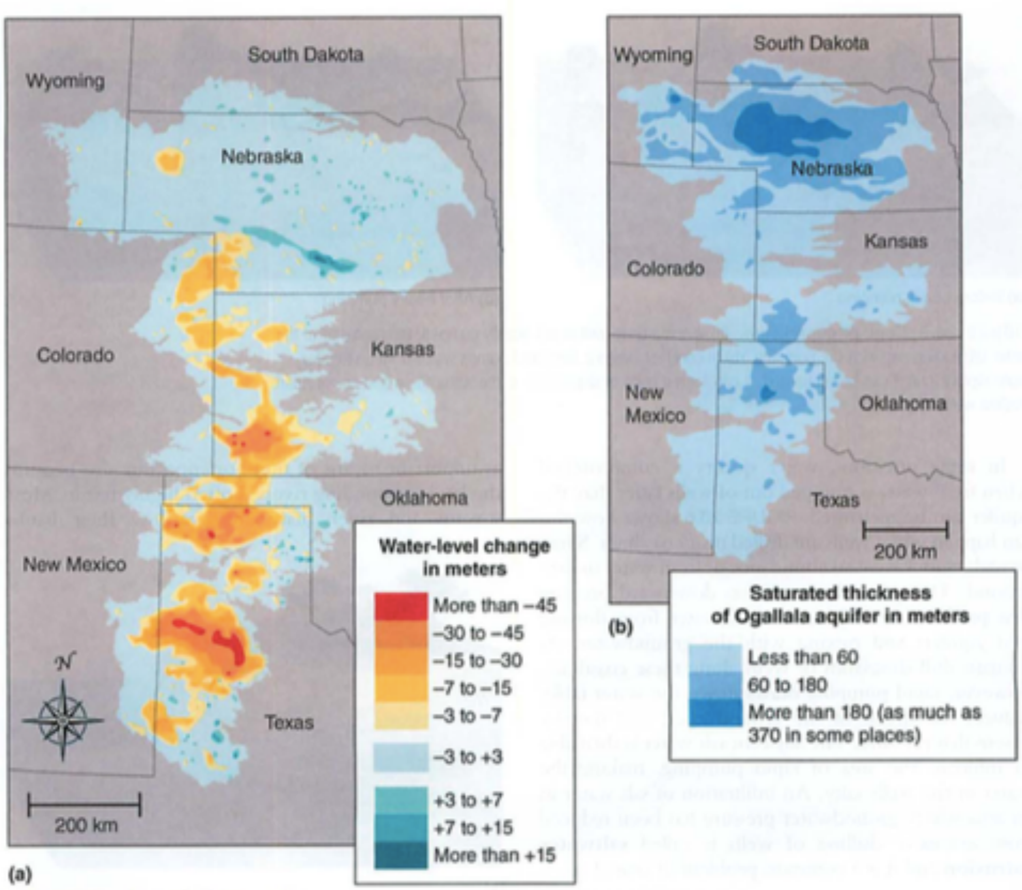

FIGURE 26.4 **The Ogallala aquifer.** The Ogallala aquifer, also called the High Plains aquifer, is the largest in the United States, with a surface area of about 450,000 km^2 (174,000 $miles^2$). (a) The change in water level from 1950 to 2005, mostly due to withdrawals for irrigation that have exceeded the aquifer's rate of recharge. (b) The current thickness of the aquifer. *(Data from http://pubs.usgs.gov/fs/2004/3097/ and http://ne.water.usgs.gov/ogw/hpwlms/)*

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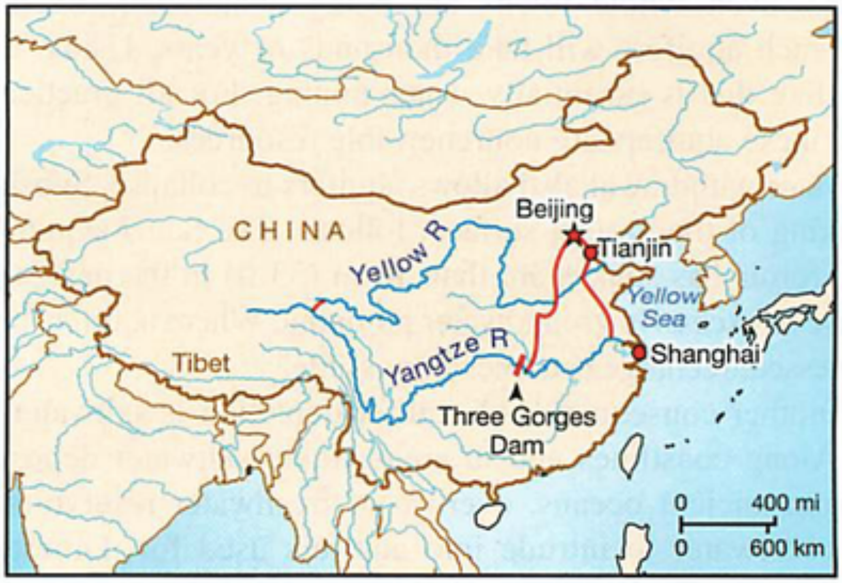
Water diversion schemes, usually rivers:

Look up Three Gorges Dam in China



With the Yellow River nearly depleted by overuse, northern China now plans canals (*red*) to deliver Yangtze water to Beijing.

Two emerging critical issues for China due to climate crisis:

- Pearl river delta and salt intrusion (sea level rise): gradual slope, so 1 meter of sea-level rise is many km of salt intrusion, so no more rice farming in that area
- Vanishing Himalayan Glaciers: no farming in western China, no annual flow through their two main rivers

Glaciers

Glaciers are the "water towers" for all of Asia...

Rivers impacted:

Ganges, Yangtze, Yellow, Mekong, Brahmaputra, Irrawaddy, Indu, Salween,

Another example: Aral Sea (asia minor)

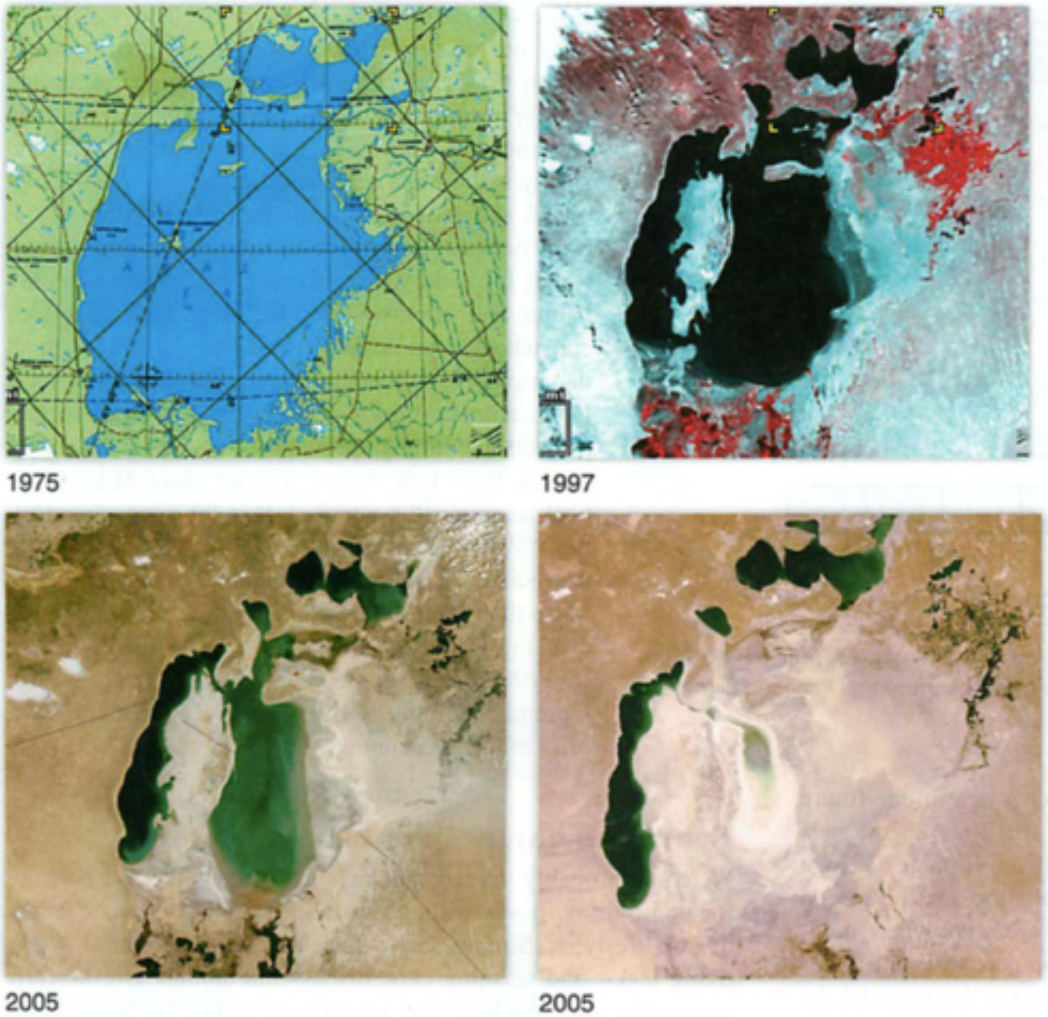


Figure 10.11 For 30 years, rivers feeding the Aral Sea have been diverted to irrigate cotton and rice fields. The main body of the sea has lost more than 90 percent of its volume. Dust storms from remaining salt flats now contaminate the region.

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Notable Water disputes: Energy wars, water wars, then food wars...

TABLE 15.2 International Water Disputes

River/Lakes	Countries Involved	Issues
	Asia	
Brahmaputra, Ganges, Farakka	Bangladesh, India, Nepal	Alluvial deposits, dams, floods, irrigation, international quotas
Mekong	Cambodia, Laos, Thailand, Vietnam	Floods, international quotas
Salween	Tibet, China (Yunan), Burma	Alluvial deposits, floods
	Middle East	
Euphrates, Tigris	Iraq, Syria, Turkey	International quotas, salinity levels
West Bank Aquifer, Jordan, Litani, Yarmuk	Israel, Jordan, Lebanon, Syria	Water diversion, international quotas
	Africa	
Nile	Mainly Egypt, Ethiopia, Sudan	Alluvial deposits, water diversion, floods, irrigation, international quotas
Lake Chad	Nigeria, Chad	Dam
Okavango	Namibia, Angola, Botswana	Water diversion
	Europe	
Danube	Hungary, Slovak Republic	Industrial pollution
Elbe	Germany, Czech Republic	Industrial pollution, salinity levels
Meuse, Escaut	Belgium, Netherlands	Industrial pollution
Szamos (Somes)	Hungary, Romania	Water allocation
Tagus	Spain, Portugal	Water allocation
	Americas	
Colorado, Rio Grande	United States, Mexico	Chemical pollution, international quotas, salinity levels
Great Lakes	Canada, United States	Pollution
Lauca	Bolivia, Chile	Dams, salinity
Paran	Argentina, Brazil	Dams, flooding of land
Cenepa	Ecuador, Peru	Water allocation

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Section two: Water Pollution
Big ideas:

1. Rivers are continuous, so easier to find sources along the route (continuity analysis: all sources add to total)
2. Groundwater is harder to determine point sources, as flow is over larger area (not confined by river banks) and there is no continuity analysis possible (we don't know sources and sinks)
3. Oceans are the hardest to trace, and impact everyone eventually, just like the atmosphere, only without the rain, and it is wetter. And full of fish.

Major Water Pollution categories:

Table 10.3 | Major Categories of Water Pollutants

Category	Examples	Sources
Cause of Ecosystem Disruption		
1. Oxygen-demanding wastes	Animal manure, plant residues	Sewage, agricultural runoff, paper mills, food processing
2. Plant nutrients	Nitrates, phosphates, ammonium	Agricultural and urban fertilizers, sewage, manure
3. Sediment	Soil, silt	Land erosion
4. Thermal changes	Heat	Power plants, industrial cooling
Cause of Health Problems		
1. Pathogens	Bacteria, viruses, parasites	Human and animal excreta
2. Inorganic chemicals	Salts, acids, caustics, metals	Industrial effluents, household cleansers, surface runoff
3. Organic chemicals	Pesticides, plastics, detergents, oil, gasoline	Industrial, household, and farm use
4. Radioactive materials	Uranium, thorium, cesium, iodine, radon	Mining and processing of ores, power plants, weapons production, natural sources

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Water Pollutant list: Common culprits

TABLE 15.1 Sources and Impacts of Selected Pollutants

Pollutant	Source	Effects on Humans	Effects on Aquatic Ecosystem
Acids	Atmospheric deposition; mine drainage; decomposing organic matter	Reduced availability of fish and shellfish; increased heavy metals in fish	Death of sensitive aquatic organisms; increased release of trace metals from soils, rock, and metal surfaces, such as water pipes
Chlorides	Runoff from roads treated for removal of ice or snow; irrigation runoff; brine produced in oil extraction; mining	Reduced availability of drinking water supplies; reduced availability of shellfish	At high levels, toxic to freshwater organisms
Disease-causing organisms	Dumping of raw and partially treated sewage; runoff of animal wastes from feedlots	Increased costs of water treatment; death and disease; reduced availability and contamination of fish, shellfish, and associated species	Reduced survival and reproduction of aquatic organisms due to disease
Elevated temperatures	Heat trapped by cities that is transferred to water; unshaded streams; solar heating of reservoirs; warm-water discharges from power plants and industrial facilities	Reduced availability of fish	Elimination of cold-water species of fish and shellfish; less oxygen; heat-stressed animals susceptible to disease; inappropriate spawning behavior
Heavy metals	Atmospheric deposition; road runoff; discharges from sewage treatment plants and industrial sources; creation of reservoirs; acidic mine effluents	Increased costs of water treatment; disease and death; reduced availability and healthfulness of fish and shellfish; biomagnification	Lower fish population due to failed reproduction; death of invertebrates leading to reduced prey for fish; biomagnification
Nutrient enrichment	Runoff from agricultural fields, pastures, and livestock feedlots; landscaped urban areas; dumping of raw and treated sewage and industrial discharges; phosphate detergents	Increased water treatment costs; reduced availability of fish, shellfish, and associated species; color and odor associated with algal growth; impairment of recreational uses	Algal blooms occur. Death of algae results in low oxygen levels and reduced diversity and growth of large plants. Reduced diversity of animals; fish kills
Organic molecules	Runoff from agricultural fields and pastures; landscaped urban areas; logged areas; discharges from chemical manufacturing and other industrial processes; combined sewers	Increased costs of water treatment; reduced availability of fish, shellfish, and associated species; odors	Reduced oxygen; fish kills; reduced numbers and diversity of aquatic life
Sediment	Runoff from agricultural land and livestock feedlots; logged hillsides; degraded stream banks; road construction; and other improper land use	Increased water treatment costs; reduced availability of fish, shellfish, and associated species; filling of lakes, streams, and artificial reservoirs and harbors, requiring dredging	Covering of spawning sites for fish; reduced numbers of insect species; reduced plant growth and diversity; reduced prey for predators; clogging of gills and filters
Toxic chemicals	Urban and agricultural runoff; municipal and industrial discharges; leachate from landfills and mines; atmospheric deposits	Increased costs of water treatment; increased risk of certain cancers; reduced availability and healthfulness of fish and shellfish	Reduced growth and survivability of fish eggs and young; fish diseases; death of carnivores due to biomagnification in the food chain

Source: Data, in part, from World Resources Institute.

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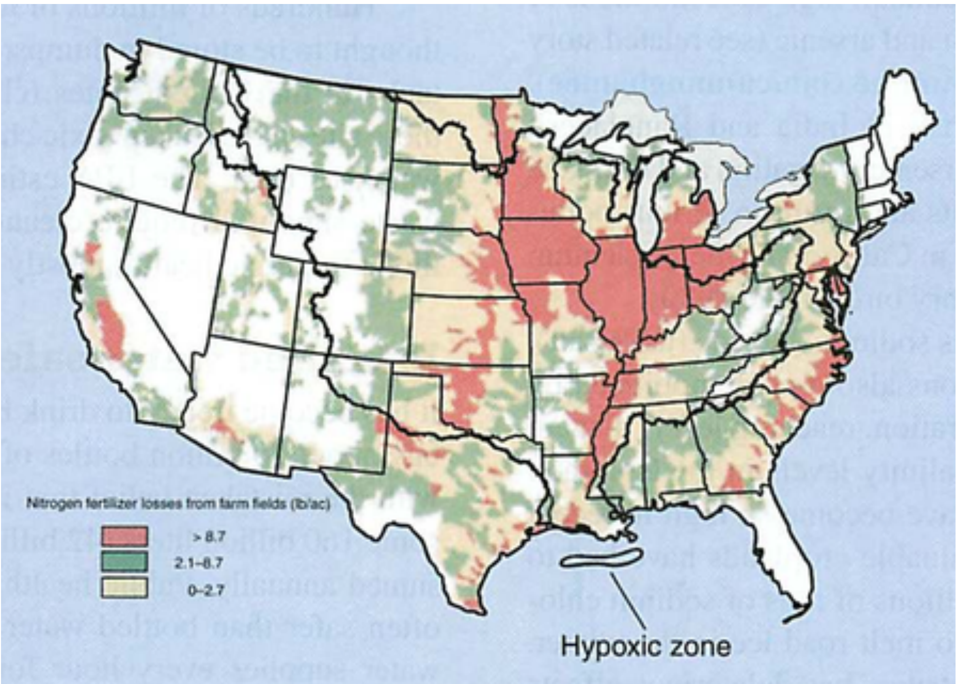
Industrial farming: note nitrate levels:



Why is there a hypoxic zone there?

Biochemical Oxygen Demand (BOD):

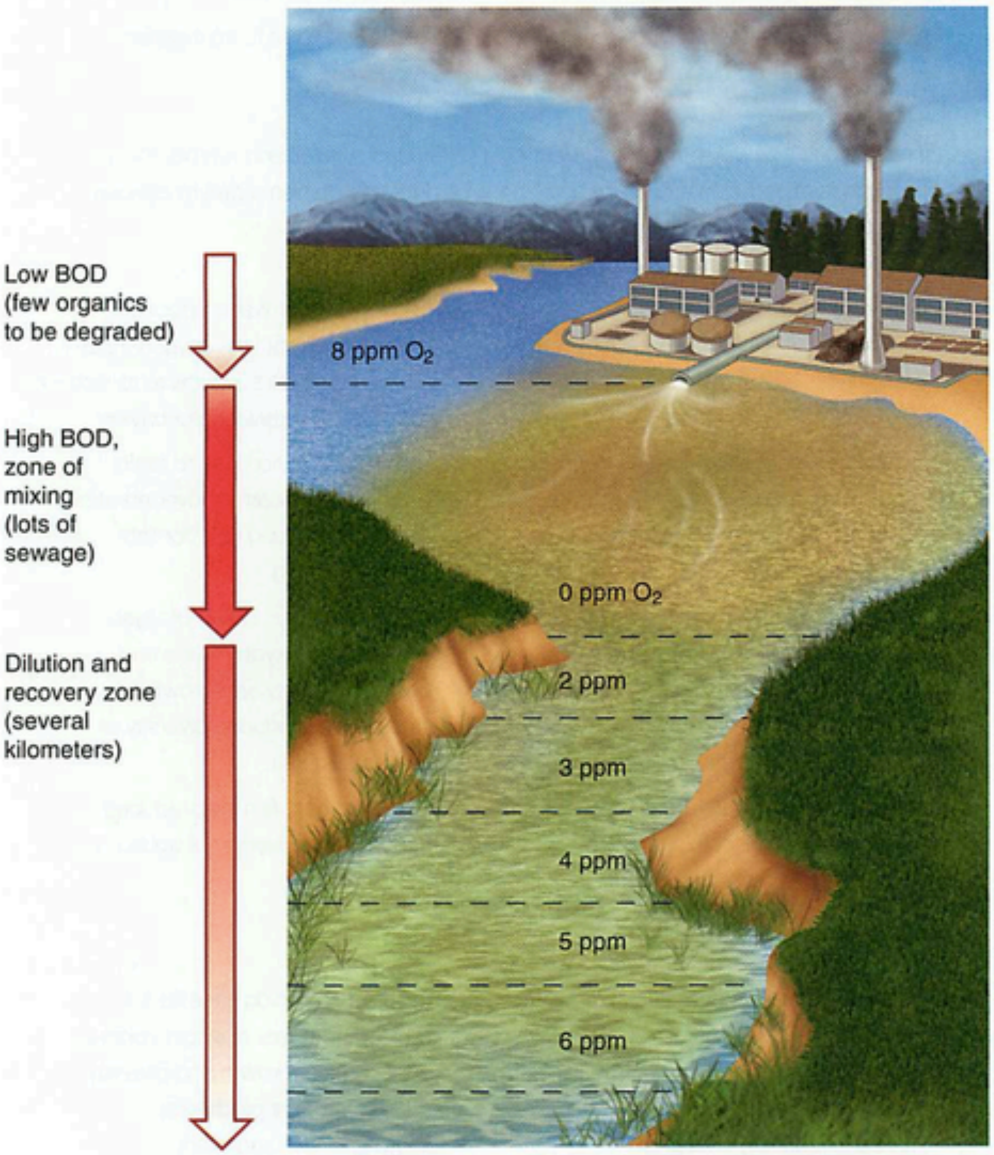


FIGURE 15.12 Effect of Organic Wastes on Dissolved Oxygen
Sewage contains a high concentration of organic materials. When these are degraded by organisms, oxygen is removed from the water. This is called the biochemical oxygen demand (BOD). An inverse relationship exists between the amount of organic matter and oxygen in the water. The greater the BOD, the more difficult it is for aquatic animals to survive and the less desirable the water is for human use. The more the organic pollution, the greater the BOD.

Better diagram:

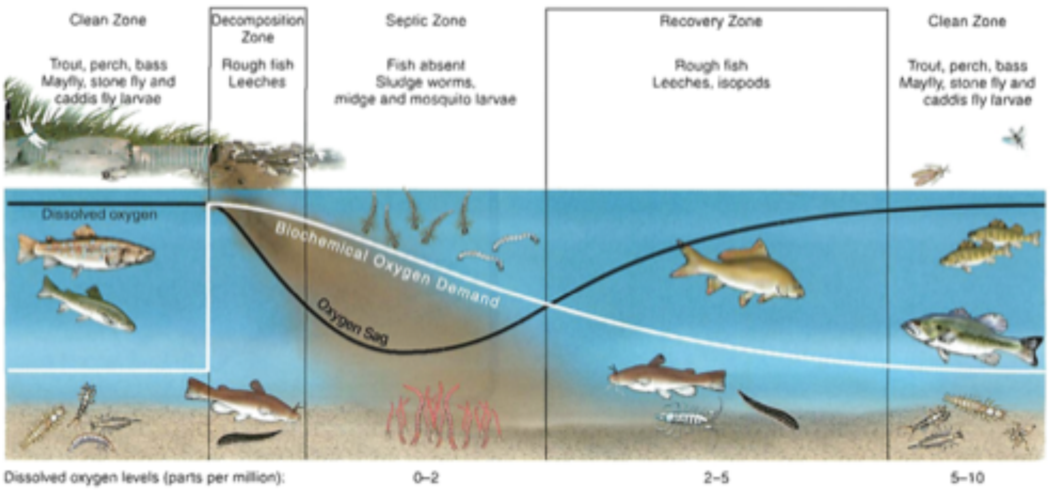


Figure 10.15 Oxygen sag downstream of an organic source. A great deal of time and distance may be required for the stream and its inhabitants to recover.

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Note that temperature changes DO (dissolved oxygen) content, so does physical agitation (aeration).

Section three: Water Quality Index:

http://www.water-research.net/index.php/water-treatment/water-monitoring/monitoring-the-quality-of-surfacewaters

http://www.water-research.net/watrqualindex/index.htm

http://www.pathfinderscience.net/stream/cproto4.cfm

Calculation worksheet:
http://www.pathfinderscience.net/stream/forms/WQI_worksheet.pdf

Main case studies-each related to a form of human pollution:

Case 1: High turbidity

Causes: erosion of topsoils, till farming, no cover crops, e.g. dustbowl in the US

Impact: poor light transmission, so low photosynthesis, low DO

Case 2: Low Dissolved Oxygen (DO)

Causes: Thermal pollution, e.g. power plants on rivers

Case 3: Eutrophication (high N and/or P)

Causes: Fertilizers, animal waste, e.g. Mississippi dead zone, Chesapeake bay

Chesapeake bay is the perfect storm of these three:
1. Warm water: shallow, so no cool lower zone away from sunlight, dissolved solids turn visible light into heat
2. High Turbidity: watershed runoff from rivers to the Appalachian range and north to NY state
3. Eutrophication: chicken and pig farms, runoff from farms along watershed

See also point source and non-point source pollution (from Poisoned Waters video, remember the Deer?)

Important: cooler water holds dissolved oxygen better (fishermen know this, so do the fish).

Water Quality Lab:

Tests: Probe sets

- Turbidity sensor: passes light through a small vial, measures light that passes, low light=high turbidity
- Conductivity: passes electric current through sample, proportional to salt content
- Temperature: warmer water has lower DO
- Dissolved Oxygen: amount of oxygen dissolved in the sample
- pH: acid/base tendency

Tests: dip strips:

- Alkalinity
- pH
- Hardness (calcium/mineral content)
- Iron
- Copper
- Lead
- Nitrate
- Nitrite
- Chlorine

Lab samples

1. Post waterfall
2. Post power plant
3. Everglades close to ocean
4. Post sewage plant
5. Best fishing spot
6. Mine tailings runoff
7. Snow melt river
8. Mississippi river
9. Chesapeake river
10. Flood after monsoon rains
11. Golf course runoff
12. Eutrophied lake

Metrics:

- DO
- BOD
- pH
- temperature
- turbidity
- conductivity
- nitrates
- phosphates

Simulated locations:

Samples:

Sample A

- DO:1.5
- BOD:low
- pH:7
- temperature:30°C
- turbidity:high
- conductivity:low
- nitrates:high

- phosphates:high

Sample B

- DO:6
- BOD:low
- pH:7
- temperature:10°C
- turbidity-low
- conductivity-low
- nitrates-low
- phosphates-low

Sample C

- DO: 4
- BOD:low
- pH:8
- temperature:25°C
- turbidity: high
- conductivity: high
- nitrates: high
- phosphates: high

Sample D-

- DO: 2
- BOD: high
- pH:5
- temperature: 28°C
- turbidity:high
- conductivity: low
- nitrates: low
- phosphates: high

Sample E

- DO: 2
- BOD:low
- pH:2
- temperature:20°C
- turbidity:high
- conductivity: high
- nitrates: low
- phosphates: low

Sample F

- DO: 1
- BOD: high
- pH: 4
- temperature: 30°C
- turbidity: high
- conductivity: high
- nitrates: high
- phosphates: high