18 April 2007
39th class meeting

Water

READINGS
Wednesday 18 April:
Water:
Postel 2001; EPA website; 3Gorges:
http://news.bbc.co.uk/2/hi/asia-pacific/5000092.stm
Friday 20 April: Earth Day or Video

Women in the Philippines vie for a place in Miss Earth - an international beauty pageant aiming to raise awareness of environmental issues.

Lab 18/20 April: meet at van s-side BSE
Thank Robichaux, Mangin, Delgado

Environmental Biology (ECOL 206)
University of Arizona, spring 2007

Kevin Bonine, Ph.D.
Anna Tyler, Graduate TA

http://eebweb.arizona.edu/courses/Ecol206/206_Page2007.html

1

Tuna
Dolphin-set nets
Trawling

Bycatch
Vaquita

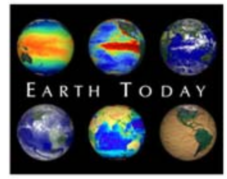
Shrimp/Fish Farms

Community Solutions

Shifting Baselines

Acidification
Mercury

Conservation of the marine environment
Dr. Katrina Mangin
Department of Ecology and Evolutionary Biology
mangin@email.arizona.edu



2

WATER

Elephants spray water on motorcyclists during a festival to mark Songkran, or Thai New Year, which falls on 13 April.

3

WATER (Ch9)

-Organisms made of water

-Hydrogen Bonds
Surface Tension

-Broad temp range as liquid

-High Specific Heat

-Energy of phase changes

-Universal Solvent

-Expands when freezes (less dense)

71% planet surface
(97.4% ocean)

2.6% fresh
-ice caps and glaciers (1.98%)
-0.014% accessible
lakes, soil, atmosphere
biota, rivers

100 liters vs. 2.5 teaspoons (14ml)

4

Reservoirs of Water on Earth

Reservoir	Volume (10^6 km^3)	Percent of Total	Residence T
Oceans	1350	97.3	10^3 -10^4 yr
Glaciers	29	2.1	10^1 -10^3 yr
Aquifers	8	0.6	2 wks-10^4 yr
Lakes	0.1	0.01	10 yr
Soil Moisture	0.1	0.01	52 days
Atmosphere	0.013	0.001	10 days
Rivers	0.002	0.0002	2 wks
Biosphere	0.001	0.0001	6 days

5

Aquatic and Marine Environments

A. Salinity

B. Layers:
1. Temperature
2. Sunlight
3. Dissolved O_2
4. Nutrients
- carbon
- nitrogen (nitrate)
- phosporus (phosphate)

6

Marine Environments

71% earth's surface is ocean

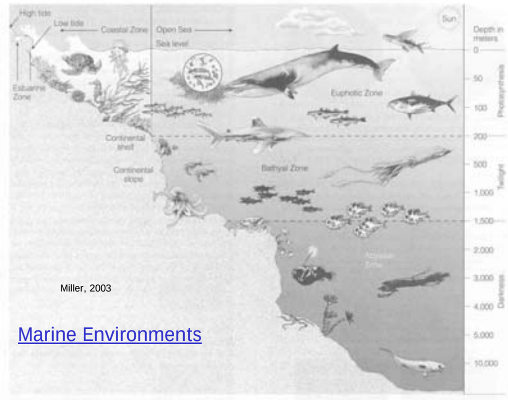
coastal vs. open sea

10% area, 90% species
high NPP
- nutrients
- sunlight

- Role of sunlight
- Not very productive per unit area
- Lots total NPP

1. Estuaries
2. Coastal Wetlands
   - mangroves
   - salt marshes
3. Coral Reefs

7



Miller, 2003

Marine Environments

Figure 3-14 Major life zones in an ocean. (Actual depths of zones may vary.)

Coastal Pollution

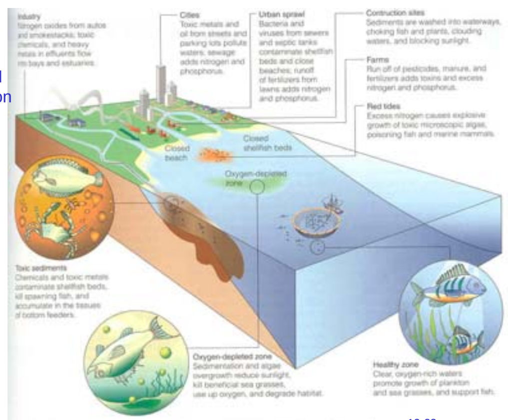


Figure 14-26 How residential areas, factories, and farms contribute to the pollution of coastal waters and bays =12-23; Miller, 2003 (other)

http://www.mindfully.org/Plastic/Ocean/Moore-Trashed-PacificNov03.htm

Bottle caps and other plastic objects are visible inside the decomposed carcass of this Laysan albatross on Kure Atoll, which lies in a remote and virtually uninhabited region of the North Pacific. The bird probably mistook the plastics for food and ingested them while foraging for prey.

10

The Algalita Marine Research Foundation's investigation of plastic in the **North Pacific Central Gyre of the Pacific Ocean** showed that **the mass of plastic pieces was six times greater than zooplankton floating on the water's surface.** This study is one of many that demonstrate that *our oceans have become the virtual garbage can for the developed and developing world.*(1)

(1) C.J. Moore, S.L. Moore, M.K. Leecaster, and S.B. Weisberg, *A Comparison of Plastic and Plankton in the North Pacific Central Gyre,* Marine Pollution Bulletin, 13 February 2004.

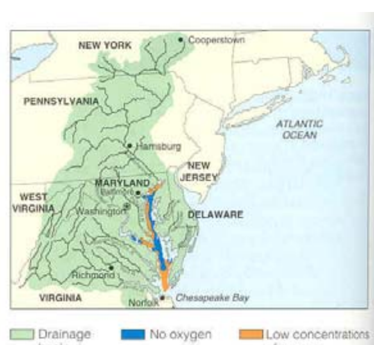
Manatee flipper and monofilament

Whiting and condom

The trash was found in a patch of ocean called the North Pacific Gyre where the currents can trap floating debris for years.

11

Chesapeake Bay



=12-24; Miller, 2003 (other)

Figure 14-29 Chesapeake Bay, the largest estuary in the United States, is severely degraded as a result of water pollution from point and nonpoint sources in six states and from deposition of air pollutants.

http://www.cbf.org/site/PageServer?pagename=cbf_homepage

Oxygen Depletion
Gulf of Mexico

'Dead Zone'

Figure 14-28 A large zone of oxygen-depleted water forms for half of the year in the Gulf of Mexico as a result of oxygen-depleting algal blooms. It is created by huge inputs of nitrate (NO_3^-) and phosphate (PO_4^{3-}) plant nutrients from the massive Mississippi River Basin. Miller, 2003 (other)

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Oxygen Depletion

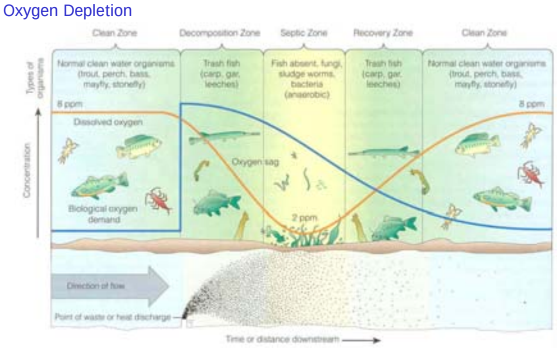
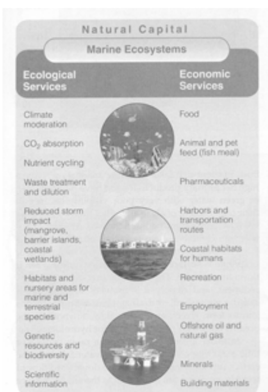


Figure 14-21 Dilution and decay of degradable, oxygen-demanding wastes and heat, showing the oxygen sag curve (orange) and the curve of oxygen demand (blue). Depending on flow rates and the amount of pollutants, streams recover from oxygen-demanding wastes and heat if they are given enough time and are not overloaded. =12-19; Miller, 2003 (other)

14

Marine
Ecosystem
Services



Miller 2005
Figure 3-15 Natural capital: major ecological and economic services provided by marine systems.

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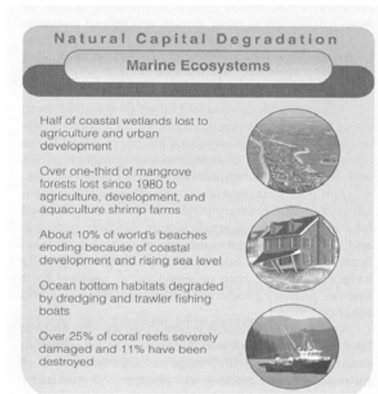
Marine
Ecosystem
Degradation



Miller 2005
Figure 3-17 Natural capital degradation: major human impacts on the world's marine systems.

16

Cyprinodon macularius

Desert Pupfish

Family Cyprinodontidae

Photograph Courtesy of John Rinne

-1-1/4 inches long
max. age of three years

-females are gray and drab
males are bluish, turning bright blue during spring breeding season.

-feed on insect larvae and other organic matter from pond bottom.

-prefer shallow pond depths, about 12 to 18 inches deep.

Quitobaquito pupfish (Endangered since 1986)

This tiny fish was once part of a widespread population, the range of which included the Colorado, Gila, San Pedro, Salt and Santa Cruz rivers and their tributaries in Arizona and California. The ancestors of the Quitobaquito and Sonoyta river pupfish are believed to have been cut off from their relatives in the Colorado River drainage about one million years ago.

The warm, slightly brackish water at Quitobaquito is ideal habitat for pupfish. Pupfish can tolerate salinity levels ranging from normal tap water to water three times saltier than the ocean. Therefore, they are well suited to desert environments where high evaporation rates create water with high salinity levels.

Although the water temperature at the spring is a constant 74°F, the water temperature in the pond fluctuates greatly during the year, from about 40°F or cooler in January to almost 100°F in August, especially in shallow areas... very tolerant of rapid temperature change and low oxygen content due to summer heat.

17

Cyprinodon macularius

Desert Pupfish

Photograph Courtesy of John Rinne

Desert pupfish declined due to the introduction and spread of exotic predatory and competitive fishes, water impoundment and diversion, water pollution, groundwater pumping, stream channelization, and habitat modification.

Healthy population of almost 10,000 fish inhabits this oasis. This last refuge of a unique fish is being actively managed.

Aquatic Environments

Only 1% earth's surface:

1. Lakes → nutrients, clarity, NPP
   - oligotrophic
   - eutrophic

2. Streams
3. Rivers

→ - Watershed
- Runoff
- Erosion

4. Inland Wetlands → Marshes, swamps, floodplains

Aquatic Environments

- oligotrophic

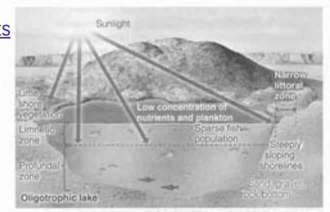
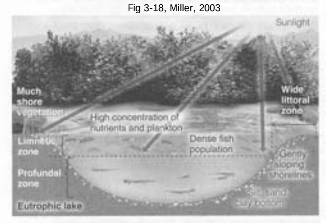
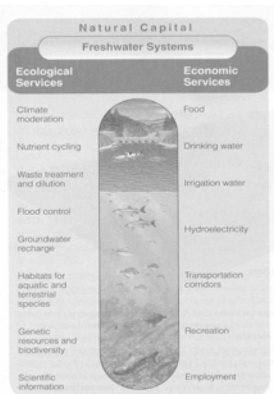


Fig 3-18, Miller, 2003

- eutrophic



Freshwater Ecosystem Services



Miller 2005

Figure 3-18 Natural capital: major ecological and economic services provided by freshwater systems.

Ecological Services (e.g., rivers)

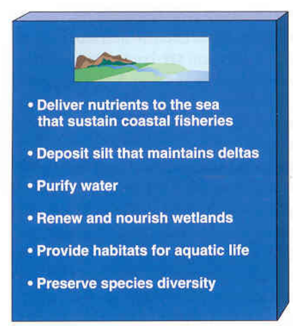


Figure 14-10 Some ecological services provided by rivers. Currently, the services are given little or no monetary value when the costs and benefits of dam and reservoir projects are assessed. According to environmental economists, attaching even crudely estimated monetary values to these ecosystem services would help sustain rivers. ←

=12-11; Miller, 2003 (other)

Lessons from New Orleans?

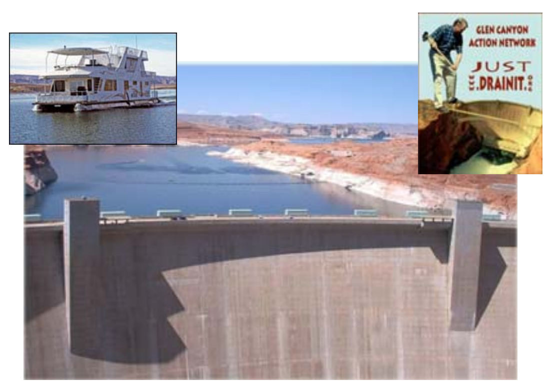
What did the fish say when it ran into a concrete wall?

Dam!

Hoover Dam, Colorado River (Lake Mead)

Why build dams?

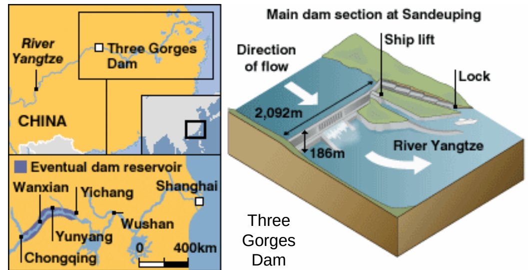
Why might dams be environmentally harmful?



Glen Canyon Dam, Colorado River, Lake Powell

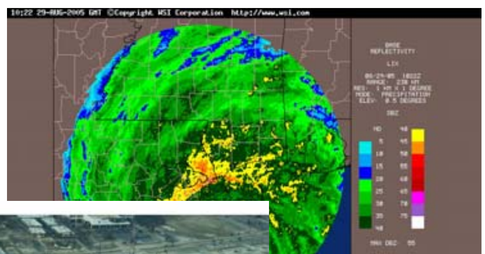
Three Gorges Dam

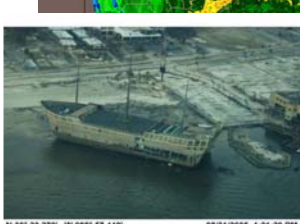
BBC News



Three Gorges Dam

When its 26 turbines become operational in 2009, the dam will have a capacity of more than 18,000 megawatts. Already the world's second-largest consumer of oil, China says it needs alternative energy sources to combat widespread power shortages and keep its booming economy powering along.





Channelization and Floods

Rillito at First Ave. 1983 (Pete Kresan)

Santa Cruz at St. Mary's 1983 (Pete Kresan)

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Channelization and Floods

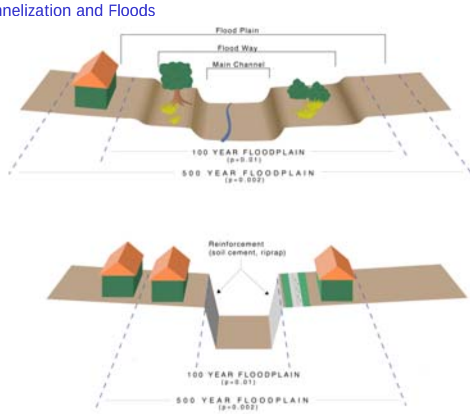

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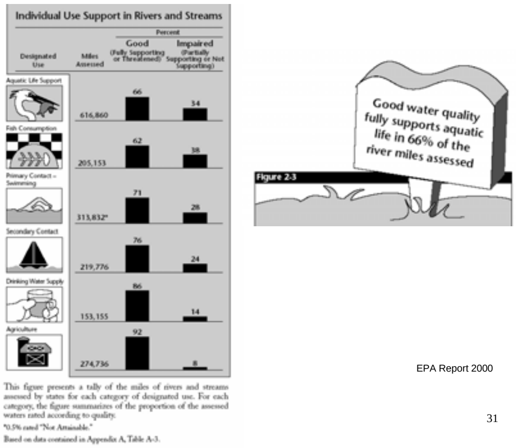
Figure 2-6

The Effects of Siltation in Rivers and Streams

EPA Report 2000

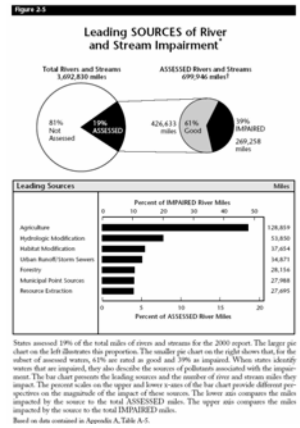
Siltation is one of the leading pollution problems in the nation's rivers and streams. Over the long term, unchecked siltation can alter habitat with profound adverse effects on aquatic life. In the short term, silt can kill fish directly, destroy spawning beds, and increase water turbidity resulting in depressed photosynthetic rates.

30



EPA Report 2000

31



+ 8% threatened

EPA Report 2000

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Water Requirements

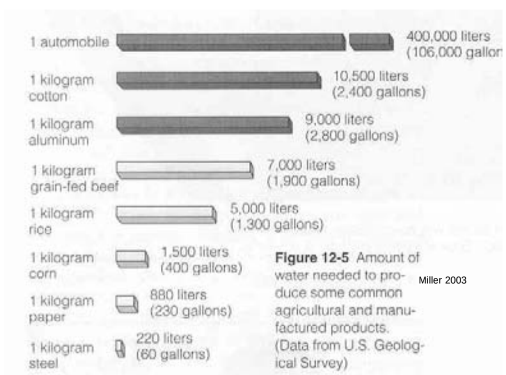
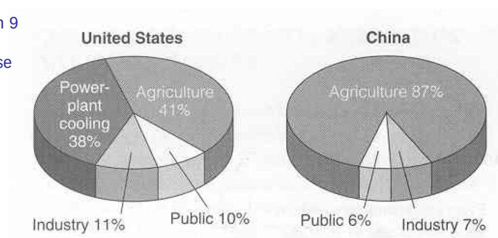


Figure 12-5 Amount of water needed to produce some common agricultural and manufactured products. (Data from U.S. Geological Survey)

Miller 2003

Water Ch 9

Water Use



We're #1!

Figure 12-4 Water use in the United States and China. The United States has the world's highest per capita use of water, amounting to an average of 4,800 liters (1,280 gallons) per person per day in 1999. Between 1980 and 1999, total water use in the United States decreased by 10% despite a 17% increase in population, mostly because of more efficient irrigation. (Data from Worldwatch Institute and World Resources Institute) Miller 2003

34

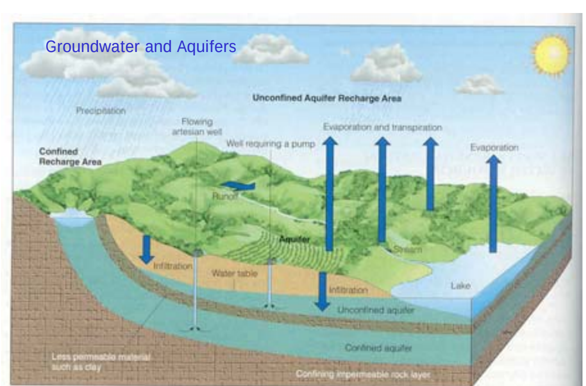
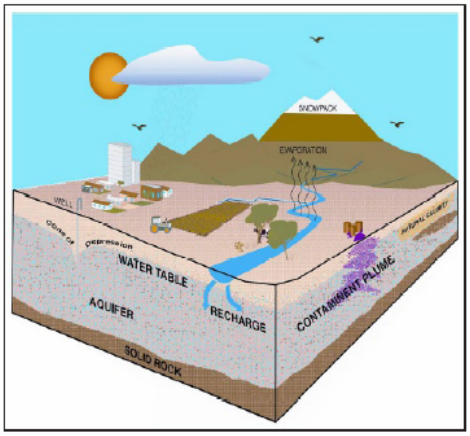


Figure 14-3 The groundwater system. An unconfined aquifer is an aquifer with a water table. A confined aquifer is bounded above and below by less permeable beds of rock. Groundwater in this type of aquifer is confined under pressure.

36

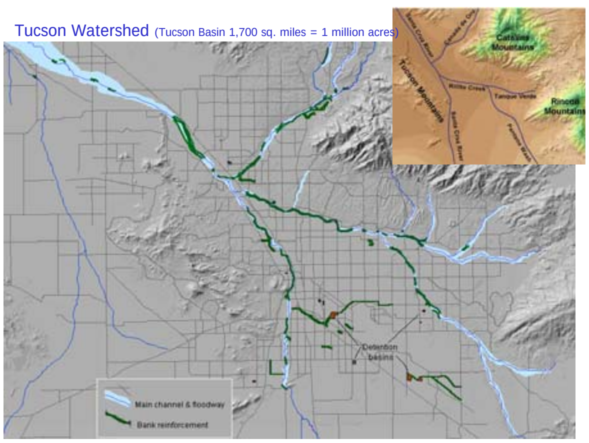


Watersheds

-Pacific
-Great Basin
-Gulf of Mexico
-Atlantic
-HudsonBay
-Arctic

National Geographic 1993

Tucson Watershed (Tucson Basin 1,700 sq. miles = 1 million acres)



Watershed Management

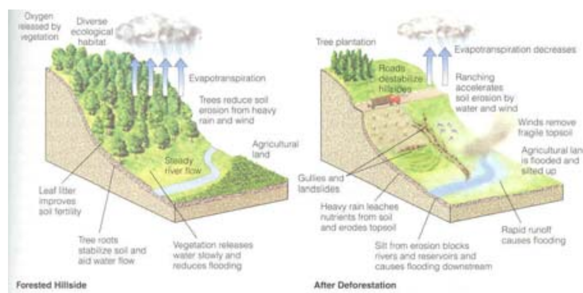
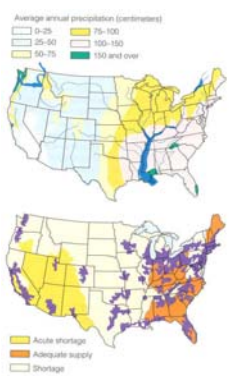


Figure 14-19 A hillside before and after deforestation. Once a hillside has been deforested for timber and fuelwood, livestock grazing, or unsustainable farming, water from precipitation **(1)** rushes down the denuded slopes, **(2)** erodes precious topsoil, and **(3)** floods downstream areas. A 3,000-year-old Chinese proverb says, "To protect your rivers, protect your mountains."

=12-10; Miller, 2003 (other)

Who has water?

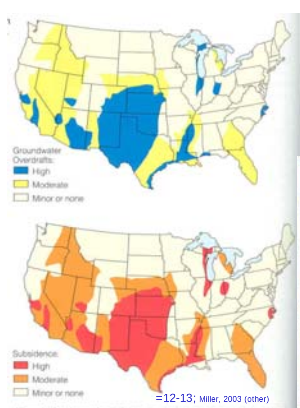


=12-6; Miller, 2003 (other)

Figure 14-7 Average annual precipitation and major rivers (top) and water deficit regions in the continental United States and their proximity to metropolitan areas with populations greater than 1 million (bottom). (Data from U.S. Water Resources Council and U.S. Geological Survey)

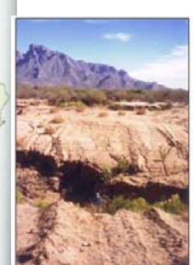
Water Use

Subsidence



=12-13; Miller, 2003 (other)

Figure 14-13 Areas of greatest aquifer depletion and groundwater contamination (top) and ground subsidence (bottom) in the continental United States. Aquifer depletion is also high in Hawaii and Puerto Rico (not shown on map). (Data from U.S. Water Resources Council and U.S. Geological Survey)



Stress on water basins

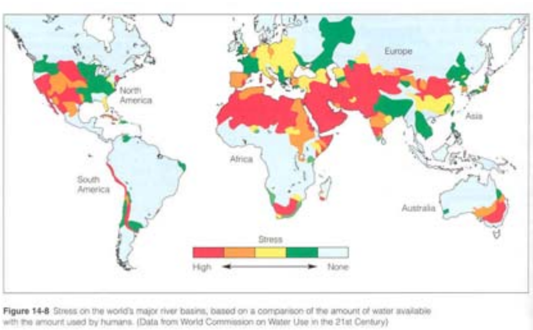


Figure 14-8 Stress on the world's major river basins, based on a comparison of the amount of water available with the amount used by humans. (Data from World Commission on Water Use in the 21st Century)

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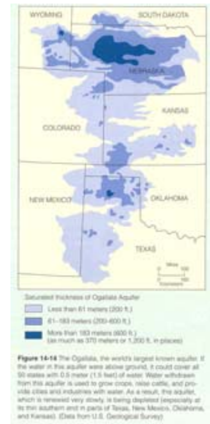
Ogallala Aquifer
(being depleted)



Irrigation
Cattle Industry

~Nonrenewable

=p.280; Miller, 2003 (other)

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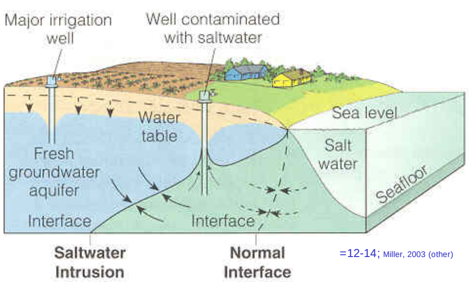
Saltwater Intrusion



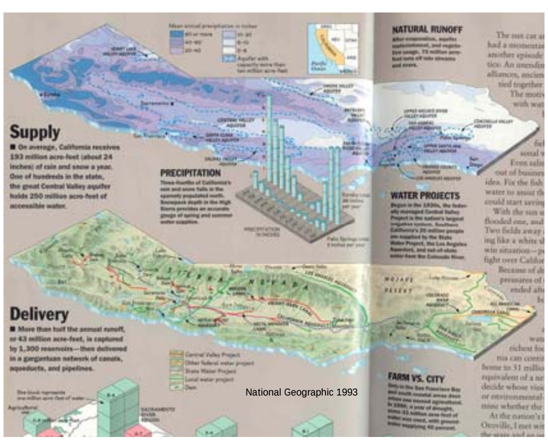
=12-14; Miller, 2003 (other)

Figure 14-15 Saltwater intrusion along a coastal region. When the water table is lowered, the normal interface (dotted line) between fresh and saline groundwater moves inland (solid line), making coastal groundwater drinking supplies unusable.

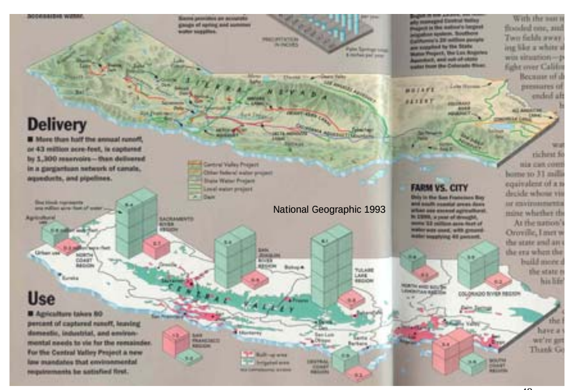
Moving Water

=12-12; Miller, 2003 (other)

Figure 14-11 The California Water Project and the Central Arizona Project involve large-scale water transfers from one watershed to another. Arrows show the general direction of water flow.



National Geographic 1993



National Geographic 1993

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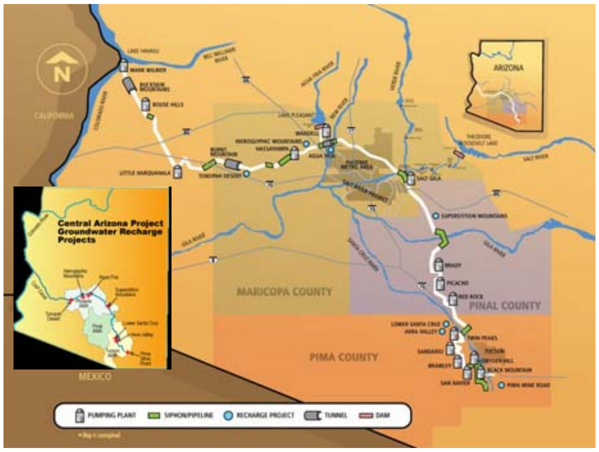


Figure 11- CAP canal east of Phoenix

Central Arizona Project

Water Use Example

=p279; Miller, 2003 (other)

Figure 14-12 Once the world's fourth-largest freshwater lake, the Aral Sea has been shrinking and getting saltier since 1960 because most of the water from the rivers that replenish it has been diverted to grow cotton and food crops. As the lake shrinks, it leaves behind a salty desert, economic ruin, increasing health problems, and severe ecological disruption.

Aral Sea

Water Wars?
(Religion, Ethnicity, Oil)

Egypt and Sudan
Syria and Palestine/Israel
Turkey

=12-8; Miller, 2003 (other)

Figure 14-1 The Middle East, whose countries have some of the highest population growth rates in the world. Because of the dry climate, food production depends heavily on irrigation. Existing conflicts between countries in this region over access to water may soon overshadow both long-standing religious and ethnic clashes and attempts to take over valuable oil supplies.

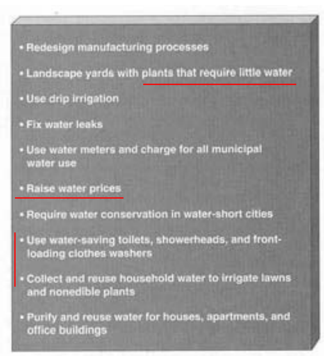
Water Sustainability

- Not depleting aquifers
- Preserving ecological health of aquatic systems
- Preserving water quality
- Integrated watershed management
- Agreements among regions and countries sharing surface water resources
- Outside party mediation of water disputes between nations
- Marketing of water rights
- Wasting less water
- Decreasing government subsidies for supplying water
- Increasing government subsidies for reducing water waste
- Slowing population growth

Figure 14-33 Methods for achieving more sustainable use of the earth's water resources. =12-29; Miller, 2003 (other)

Water Efficiency

Velocipede Recycling Shower



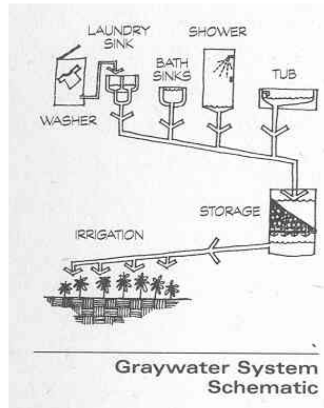
- Redesign manufacturing processes
- Landscape yards with plants that require little water
- Use drip irrigation
- Fix water leaks
- Use water meters and charge for all municipal water use
- Raise water prices
- Require water conservation in water-short cities
- Use water-saving toilets, showerheads, 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

Figure 12-17 Methods for reducing water waste in industries, homes, and businesses. Miller 2003

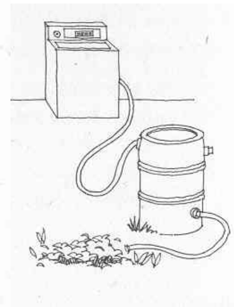
Richard Ducote

Council failed on water fees

55



Graywater



Irrigation

- Lining canals bringing water to irrigation ditches
- Leveling fields with lasers
- Irrigating at night to reduce evaporation
- Using soil and satellite sensors and computer systems to monitor soil moisture and add water only when necessary
- Polyculture
- Organic farming
- Growing water efficient crops using drought-resistant and salt-tolerant crop varieties
- Irrigating with treated urban waste water
- Importing water-intensive crops and meat

Figure 14-17 Methods for reducing water waste in irrigation.

=12-16; Miller, 2003 (other)

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Irrigation

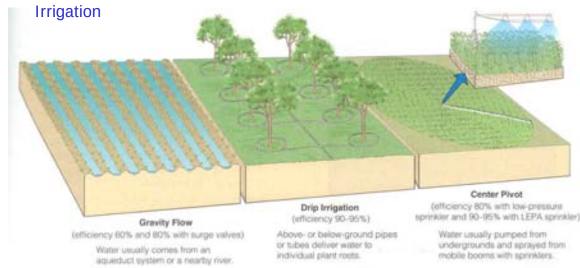

Figure 14-16 Major irrigation systems. Because of high initial costs, center-pivot irrigation and drip irrigation are used on only about 1% of the world's irrigated cropland each. However, this may change because of the development of new low-cost drip irrigation systems (Solutions, p. 341).

=12-15; Miller, 2003 (other)

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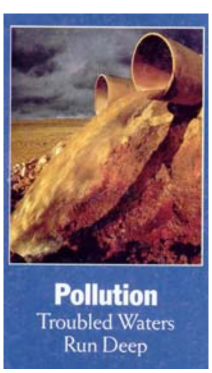
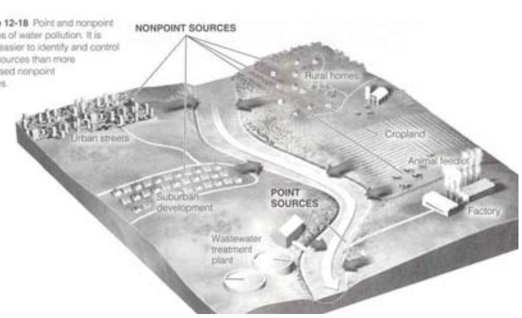


Point/Nonpoint

Point vs. Nonpoint

Figure 12-18 Point and nonpoint sources of water pollution. It is much easier to identify and control point sources than more dispersed nonpoint sources.



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Arsenic

Figure 14-27 Arsenic concentrations in groundwater of the United States in 1999. (Data from U.S. Geological Survey).

CANCER

=p.292; Miller, 2003 (other)

Ground Water Pollution

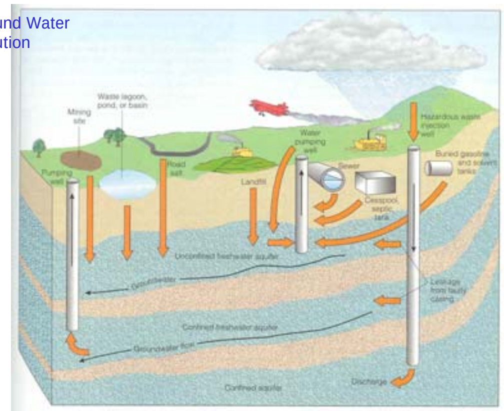


Figure 14-25 Principal sources of groundwater contamination in the United States.

=12-22; Miller, 2003 (other)

Table 14-1 Major Categories of Water Pollutants States =Table 19-1; Miller, 2003 (other)

INFECTIOUS AGENTS
Examples: Bacteria, viruses, protozoa, and parasitic worms
Major Human Sources: Human and animal wastes
Harmful Effects: Disease

OXYGEN-DEMANDING WASTES
Examples: Organic waste such as animal manure and plant debris that can be decomposed by aerobic (oxygen-requiring) bacteria
Major Human Sources: Sewage, animal feedlots, paper mills, and food processing facilities
Harmful Effects: Large populations of bacteria decomposing these wastes can degrade water quality by depleting water of dissolved oxygen. This causes fish and other forms of oxygen-consuming aquatic life to die.

INORGANIC CHEMICALS
Examples: Water-soluble **(1)** acids, **(2)** compounds of toxic metals such as lead (Pb), arsenic (As), and selenium (Se), and **(3)** salts such as NaCl in ocean water and fluorides (F^-) found in some soils
Major Human Sources: Surface runoff, industrial effluents, and household cleansers
Harmful Effects: Can **(1)** make freshwater unusable for drinking or irrigation, **(2)** cause skin cancers and crippling spinal and neck damage (F^-), **(3)** damage the nervous system, liver, and kidneys (Pb and As), **(4)** harm fish and other aquatic life, **(5)** lower crop yields, and **(6)** accelerate corrosion of metals exposed to such water.

ORGANIC CHEMICALS
Examples: Oil, gasoline, plastics, pesticides, cleaning solvents, detergents
Major Human Sources: Industrial effluents, household cleansers, surface runoff from farms and yards
Harmful Effects: can **(1)** threaten human health by causing nervous system damage (some pesticides), reproductive disorders (some solvents), and some cancers (gasoline, oil, and some solvents) and **(2)** harm fish and wildlife

PLANT NUTRIENTS
Examples: Water-soluble compounds containing nitrate (NO_3^-), phosphate (PO_4^{3-}), and ammonium (NH_4^+) ions
Major Human Sources: Sewage, manure, and runoff of agricultural and urban fertilizers
Harmful Effects: Can cause excessive growth of algae and other aquatic plants, which die, decay, deplete water of dissolved oxygen, and kill fish. Drinking water with excessive levels of nitrates lowers the oxygen-carrying capacity of the blood and can kill unborn children and infants ("blue-baby syndrome").

SEDIMENT
Examples: Soil, silt
Major Human Sources: Land erosion
Harmful Effects: Can **(1)** cloud water and reduce photosynthesis, **(2)** disrupt aquatic food webs, **(3)** carry pesticides, bacteria, and other harmful substances, **(4)** settle out and destroy feeding and spawning grounds of fish, and **(5)** clog and fill lakes, artificial reservoirs, stream channels, and harbors.

RADIOACTIVE MATERIALS
Examples: Radioactive isotopes of iodine, radon, uranium, cesium, and thorium
Major Human Sources: Nuclear power plants, mining and processing of uranium and other ores, nuclear weapons production, natural sources
Harmful Effects: Genetic mutations, miscarriages, birth defects, and certain cancers

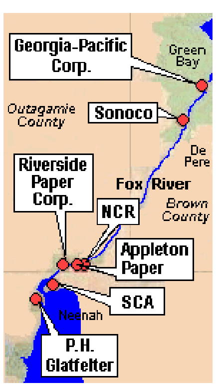
HEAT (THERMAL POLLUTION)
Examples: Excessive heat
Major Human Sources: Water cooling of electric power plants (Figure 19-20, p. 503) and some types of industrial plants. Almost half of all water withdrawn in the United States each year is for cooling electric power plants.
Harmful Effects: Lowers dissolved oxygen levels and makes aquatic organisms more vulnerable to disease, parasites, and toxic chemicals. When a power plant first opens or shuts down for repair, fish and other organisms adapted to a particular temperature range (Figure 4-13, p. 85) can be killed by the abrupt change in water temperature—known as thermal shock

Great Lakes Basin Pollution

Miller, 2003 (other)

Figure 14-24 The Great Lakes basin and the locations of some of its water quality problems. The Great Lakes region is dotted with several hundred abandoned toxic waste sites that are listed by the EPA as Superfund sites to receive cleanup priority (p. 389). (Data from Environmental Protection Agency)

http://www.foxriverwatch.com/index.html

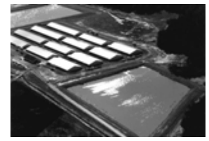


PCBs "polychlorinated biphenyls"
Dioxins
Etc.

AZDStar 28 March 2004

Factory Farms and Water Pollution

Factory Farms and Water Pollution



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Threats to human health

... The stench can be unbearable, but worse still, the gases contain many harmful chemicals. For instance, one gas released by the lagoons, hydrogen sulfide, is dangerous even at low levels. Its effects -- which are irreversible -- range from sore throat to seizures, comas and even death. Other health effects associated with the gases from factory farms include headaches, shortness of breath, wheezing, excessive coughing and diarrhea.

Animal waste also contaminates drinking water supplies. For example, nitrates often seep from lagoons and sprayfields into groundwater. Drinking water contaminated with nitrates can increase the risk of blue baby syndrome, which can cause deaths in infants. High levels of nitrates in drinking water near hog factories have also been linked to spontaneous abortions. Several disease outbreaks related to drinking water have been traced to bacteria and viruses from waste.

The widespread use of antibiotics also poses dangers. Large-scale animal factories often give animals antibiotics to promote growth, or to compensate for illness resulting from crowded conditions. These antibiotics are entering the environment and the food chain, contributing to the rise of antibiotic-resistant bacteria and making it harder to treat human diseases.

Threats to the natural environment

The natural environment also suffers in many ways from factory-farming practices. Sometimes the damage is sudden and catastrophic, as when a ruptured lagoon causes a massive fish kill. At other times, it is cumulative -- for example, when manure is repeatedly overapplied, it runs off the land and accumulates as nutrient pollution in waterways.

Either way, the effects are severe. For instance, water quality across the country is threatened by phosphorus and nitrogen, two nutrients present in animal wastes. In excessive amounts, nutrients often cause an explosion of algae that robs water of oxygen, killing aquatic life. One such algae type, *Pfiesteria piscicida*, has been implicated in the death of more than one billion fish in coastal waters in North Carolina.

Manure can also contain traces of salt and heavy metals, which can end up in bodies of water and accumulate in the sediment, concentrating as they move up the food chain. And lagoons not only pollute groundwater; they also deplete it. Many factory farms use groundwater for cleaning, cooling and providing drinking water.

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