Water: A Fragile Resource

Water is essential for 5 basic human needs

1. WATER IS HEALTH

7.5 liters/person/day
2 liters/day required for survival

Out of 7.2 billion people in the world
1 in 10 do not have access to clean drinking water

13% lack access to toilets

2. WATER IS URBANIZATION

- 54% world live in cities & 30% of them live in slums
- 90% of all wastewater in developing countries is discharged untreated directly into waterways

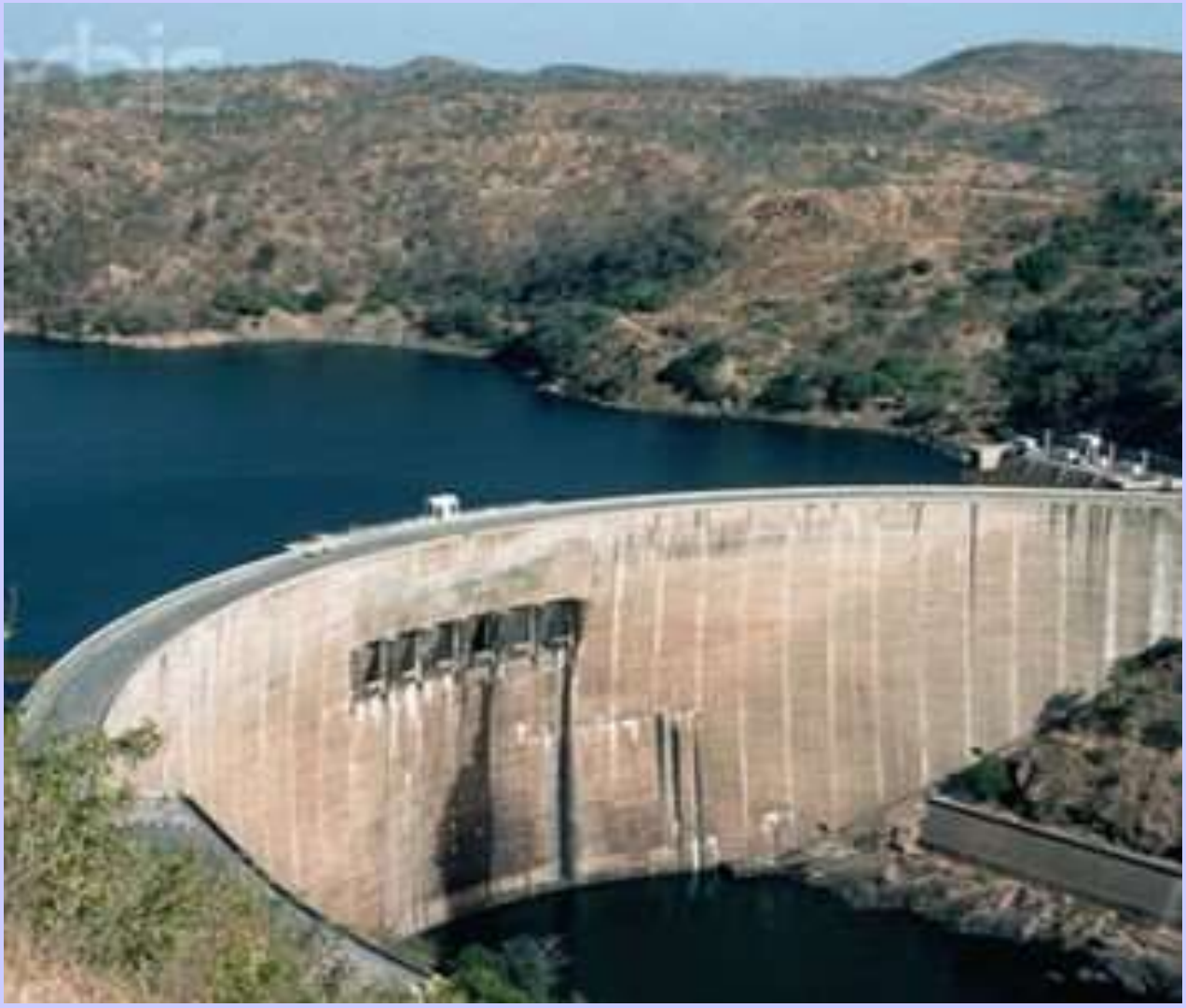
3. WATER IS INDUSTRY

- Some industries are more water-intense than others e.g.
- 10 liters of water are used to make one sheet of paper
- 3 liter water → 1 liter bottled water

4. WATER IS ENERGY

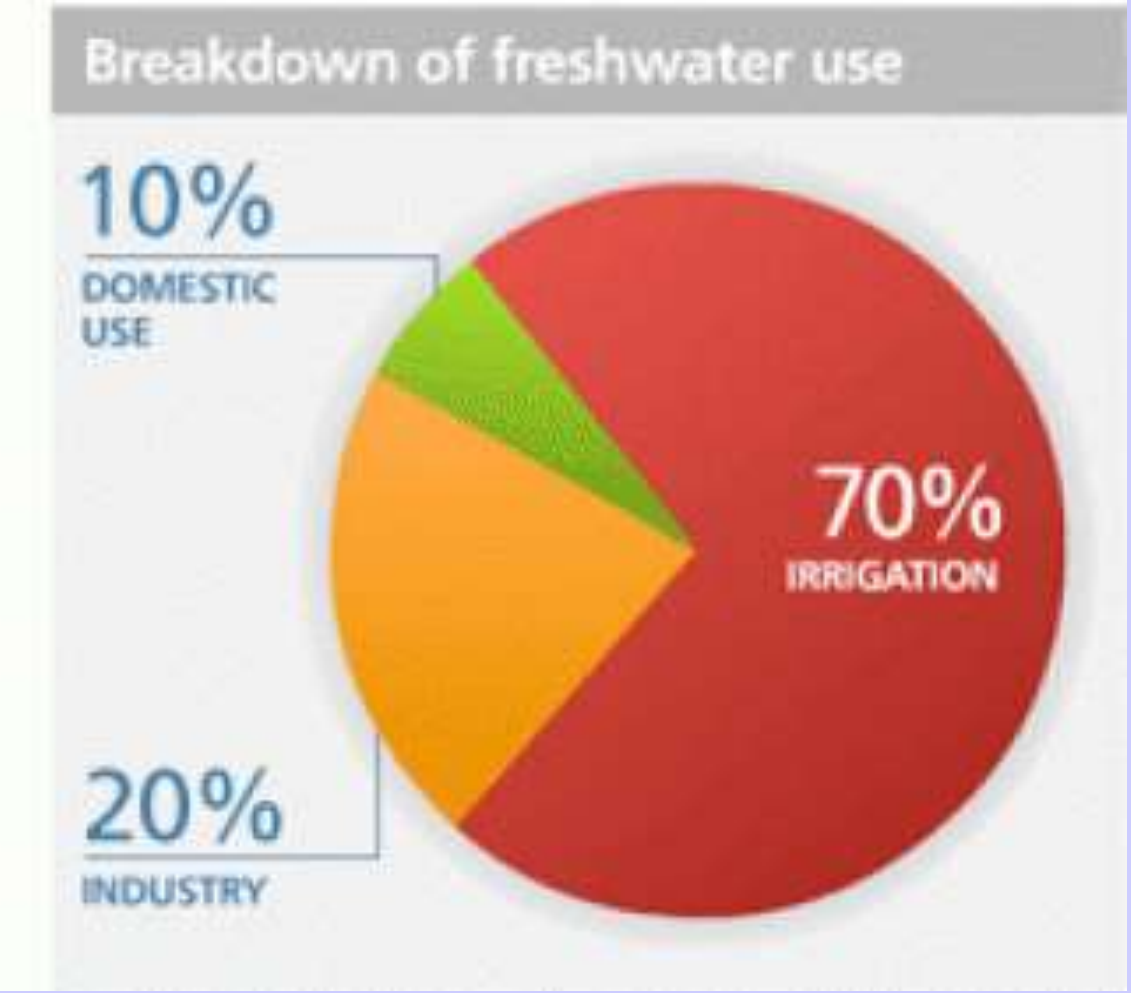
80% of power generation is by thermal electricity (heat →steam→ generator)

Hydropower accounts for 16% of global electricity production



5. WATER IS FOOD

Agriculture is the largest user of water, accounting for 70% of total withdraws



Meat and dairy require more water than vegetarian diets

Water need for food

For 1kg produced :

Apples	Potatoes	Cereals Bread	Soy beans	Eggs	Chicken	Pork meat	Cheese	Ox meat
700 L	900 L	1300 L	1800 L	3300 L	3900 L	4800 L	5000 L	15500 L

crop production — animal production

Source : Water Foot Print http://www.waterfootprint.org/?page=files/productgallery

Increased Industrial agriculture →

- Depletion of aquifers = tragedy of the commons
- Reduced river flows
- Degraded wildlife habitats
- Salinization

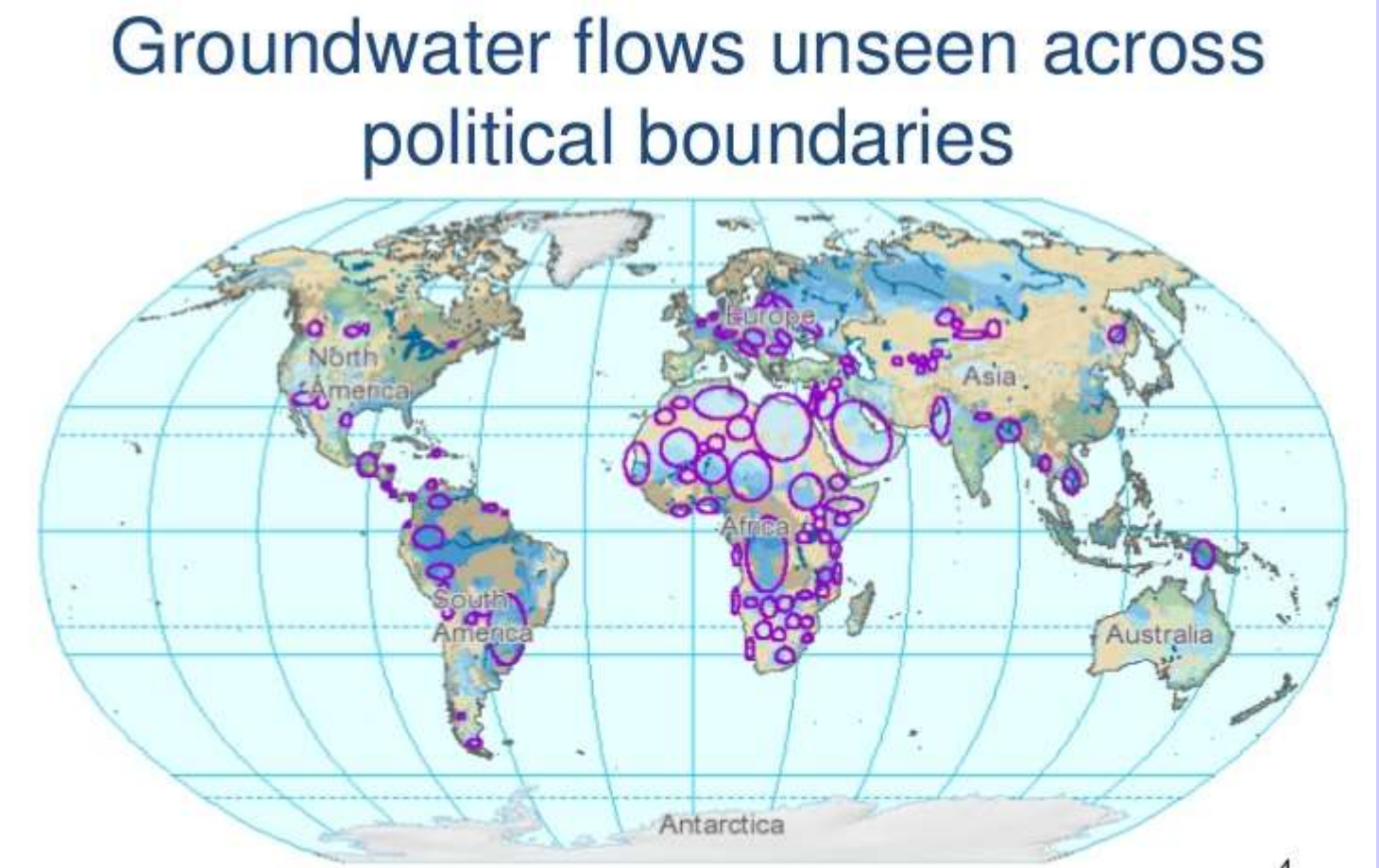
Lack of water is an environmental justice issue

- Powerless groups tend to be shut out of not just access to water but also the processes whereby allocation decisions are made

- http://www.cnn.com/2016/03/04/us/flint-update-five-months-later/
- https://www.nbcnews.com/nightly-news/video/drinking-water-crisis-in-flint--michigan--prompts-federal-investigation-59714259594 2

Lack of water is often a transboundary issue

- 158 of the world's 263 trans-boundary water basins lack cooperative management program



Syria's Water Cut off by Turkey Following McCain, Erdogan Meeting

By Whitney Webb

Global Research, March 06, 2017
Mint PressNews 3 March 2017

Region: Middle East & North Africa
Theme: Terrorism
In-depth Report: SYRIA

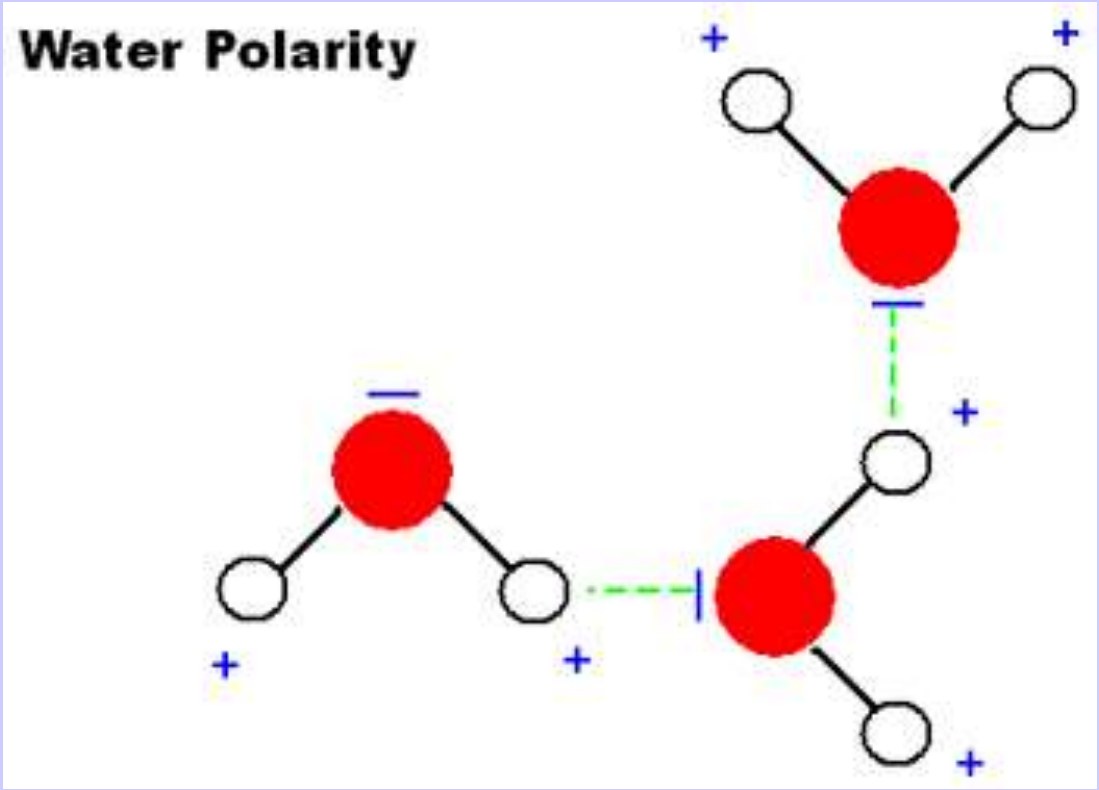
According to the Kurdish Hawar News Agency, Turkey cut water supplies to Syria around Feb. 23, which subsequently forced a hydroelectric plant at the Tishrin Dam to shut down while also significantly reducing water levels on its associated reservoir. The dam supplies both water and power to key parts of northern Syria, such as the city of Manbij and other parts of the predominantly Kurdish Kobani Canton.

ADAPTING TO CLIMATE CHANGE means dealing with changes in water availability

- Describe ways that climate change will affect water availability
  - Increased temperature → higher evaporation and transpiration → Increase drought and floods
  - Seawater intrusion in coastal aquifers
  - Higher water temperatures → oxygen depletion
  - Floods → Higher content of pollutants
  - Habitat changes → decrease biodiversity → loss of ecosystem services

Properties

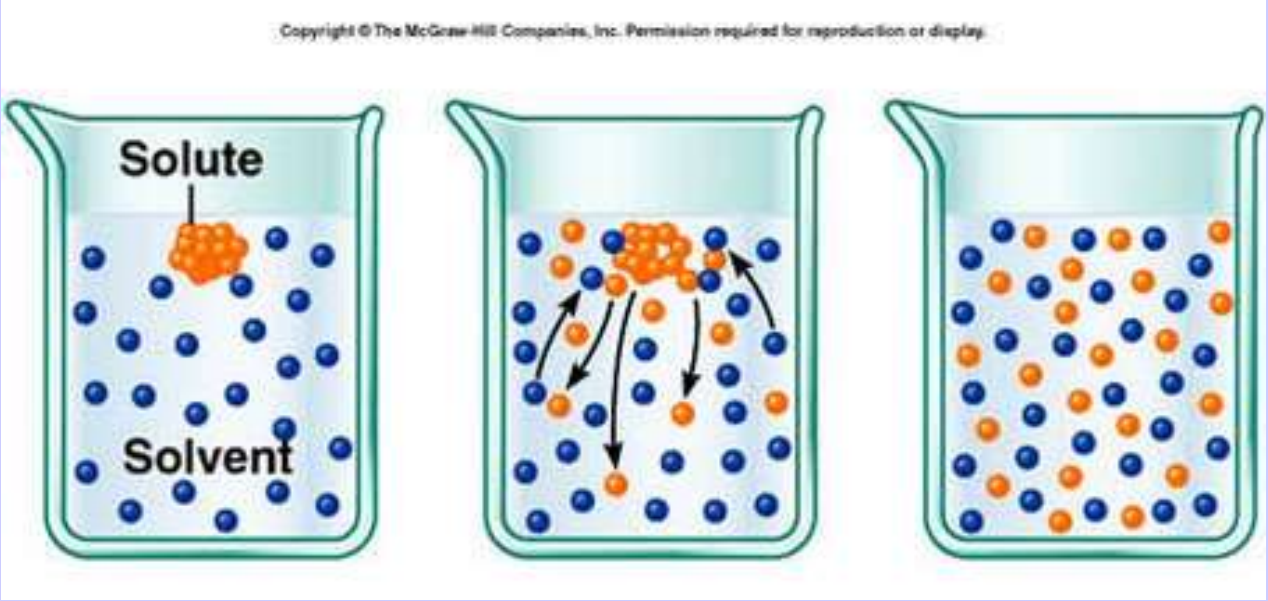
- Polar



http://www.utm.edu/staff/cerkal/electricity_files/image010.jpg

Properties

- Universal solvent
- Dissolves other polar substances



http://www.utm.edu/staff/cerkal/electricity_files/image010.jpg

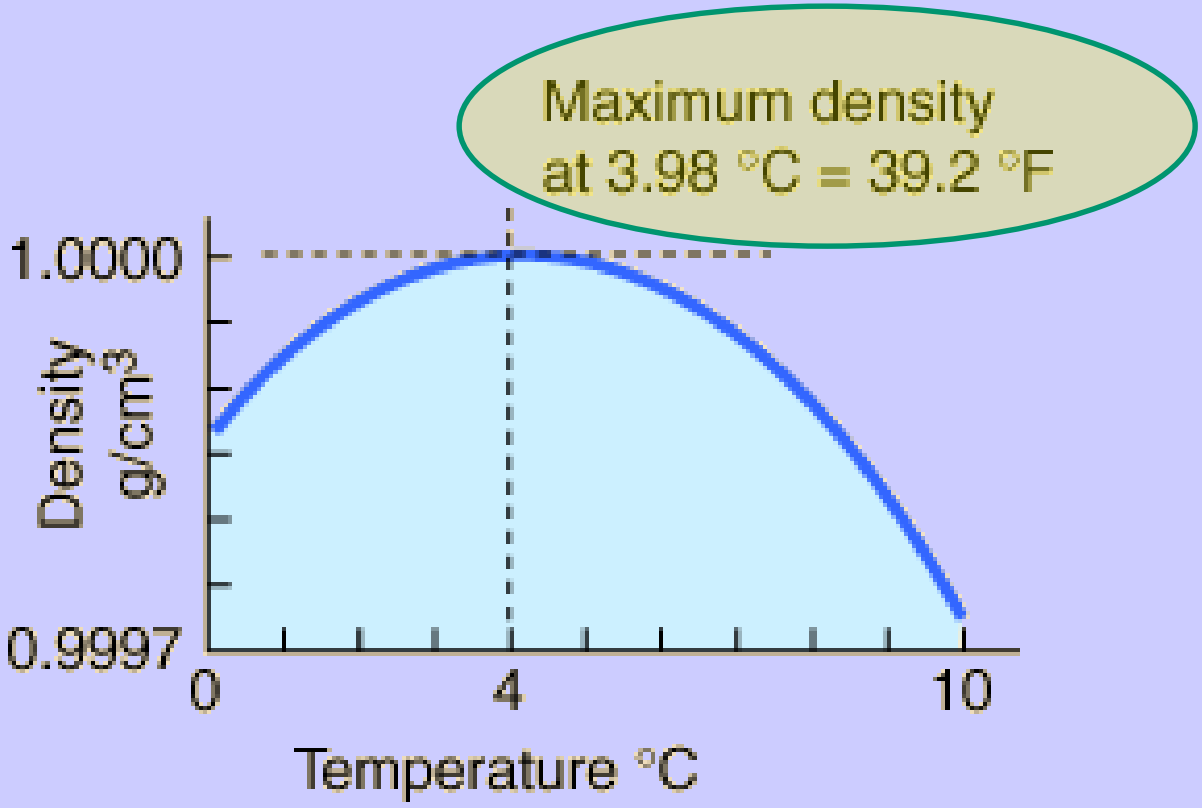
High heat capacity

- Helps organisms maintain constant body temps.
- Moderates climates
- Used as coolant for engines, power plants, and industry

More properties

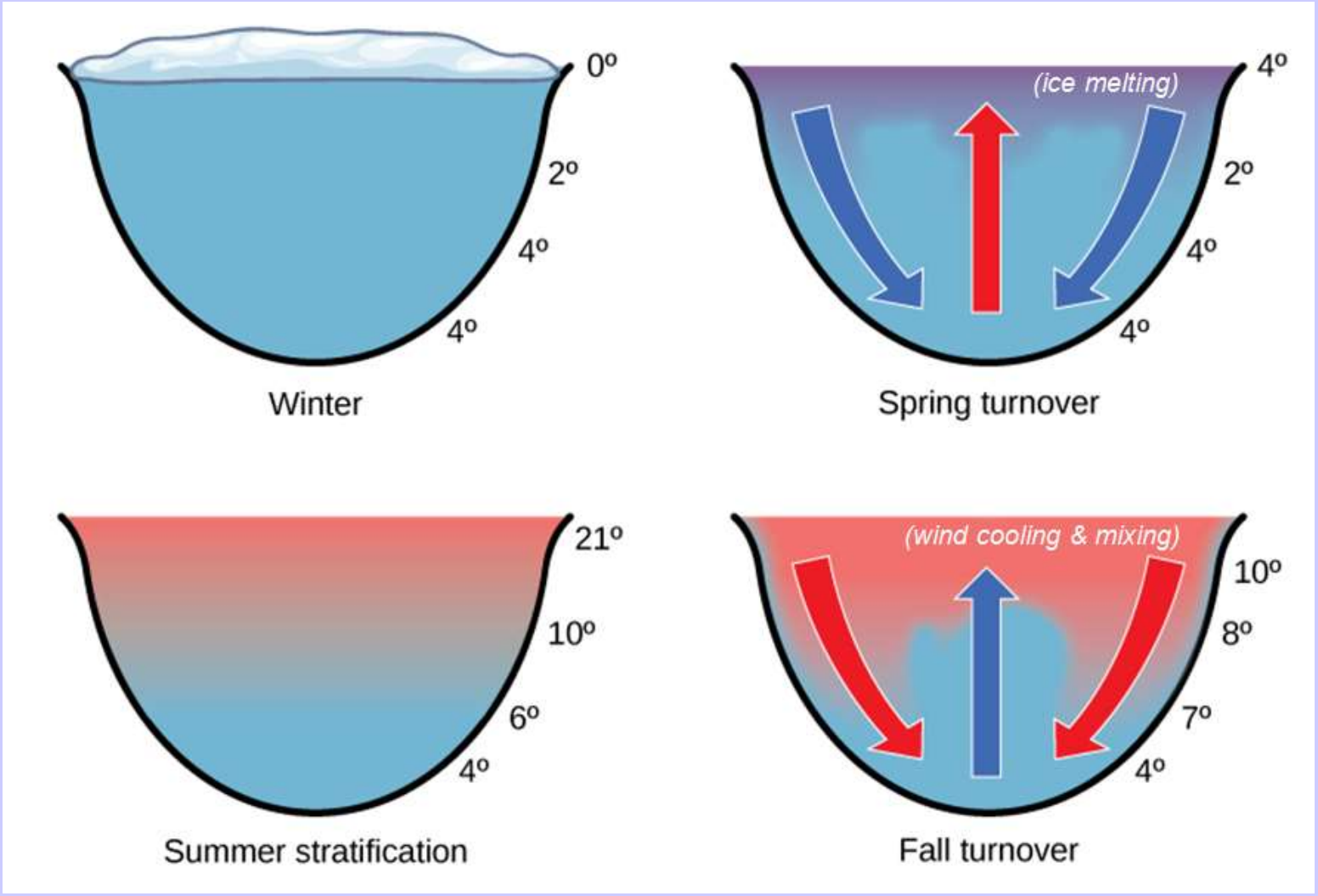
- Sublimates =
- solid to gas

Frozen water less dense than liquid



- Why is that important for life?

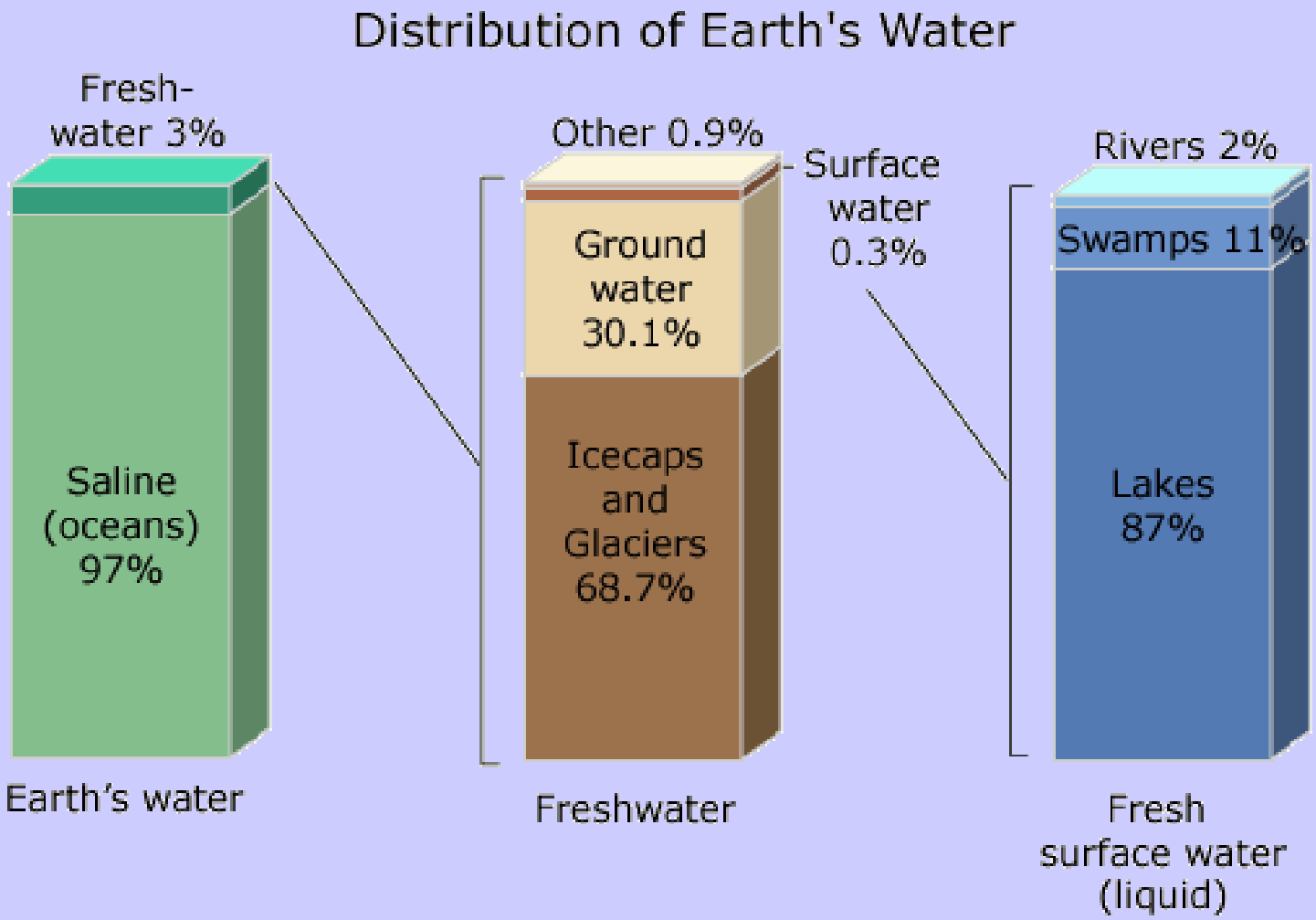
- What happens to a lake in spring when ice melts?



- How does this impact infrastructure and homes?

II. Water Availability

- 97 % of water is in the oceans
- 3 % is freshwater



http://ga.water.usgs.gov/edu/graphics/earthwheredistribution.gif

Uneven distribution of water

- Precipitation is unevenly distributed
- Increased population, irrigation, industrialization → shortages
- Global warming → disrupts hydrologic cycle

Water Vocabulary

- Surface water = freshwater found in streams, rivers, lakes, ponds, reservoirs, and wetlands

- Runoff = movement of water from precipitation to surface waters

Runoff in Cities

- Lots of impermeable surfaces →
- Increased runoff
- Decreased area for groundwater recharge
- Lots of oils, road salt, garbage in runoff

Case Study: Mirror Lake conductivity trends

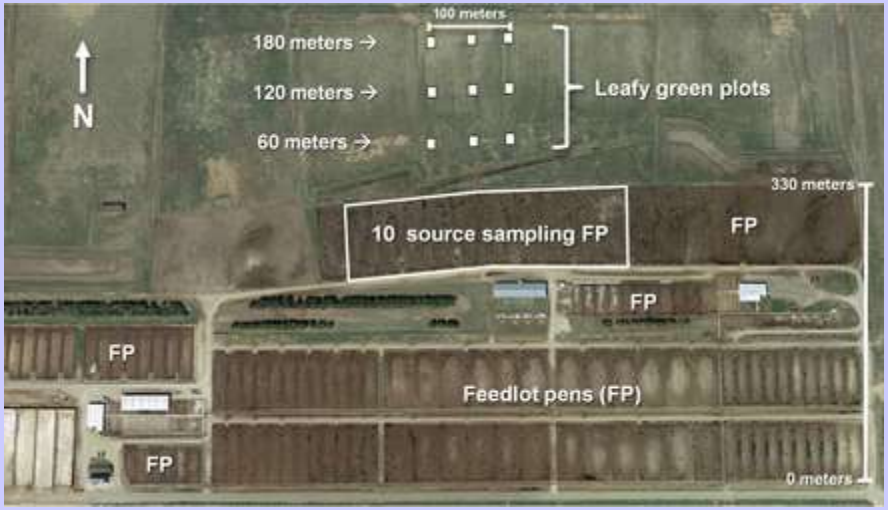
Adirondack Watershed Institute sampled 21 stormwater around Mirror Lake in 2015 and 2016.
Pictured above is a steward taking samples.

Runoff from agriculture

- Fertilizers → eutrophication → ____
- Pesticides → kill aquatic species

Manure → eutrophication and pathogens

Case Study: Effect of proximity to cattle feedlot on E.coli O157:H7 contamination of leafy greens



- High percentages of leafy greens contaminated with *E. coli* suggest great risk for planting fresh produce 180 m or less from a feedlot. What does this mean for produce growers? **It means that the current buffer zone distance guidelines of 400 feet (120 m) may not be adequate to reduce the risk of produce contamination near cattle feedlots,**

Freshwater wetlands

- Wetlands characterized by
  - Hydrology, Hydric soils, aquatic plants,
- Many ecosystem services:
  - recharge groundwater,
  - purify water (filter N, P, and sediments),
  - prevent flooding,
  - provide habitat…
- Many are privately owned therefore protection often involves **MITIGATION (trade-offs)**

Example of mitigation

About the Area

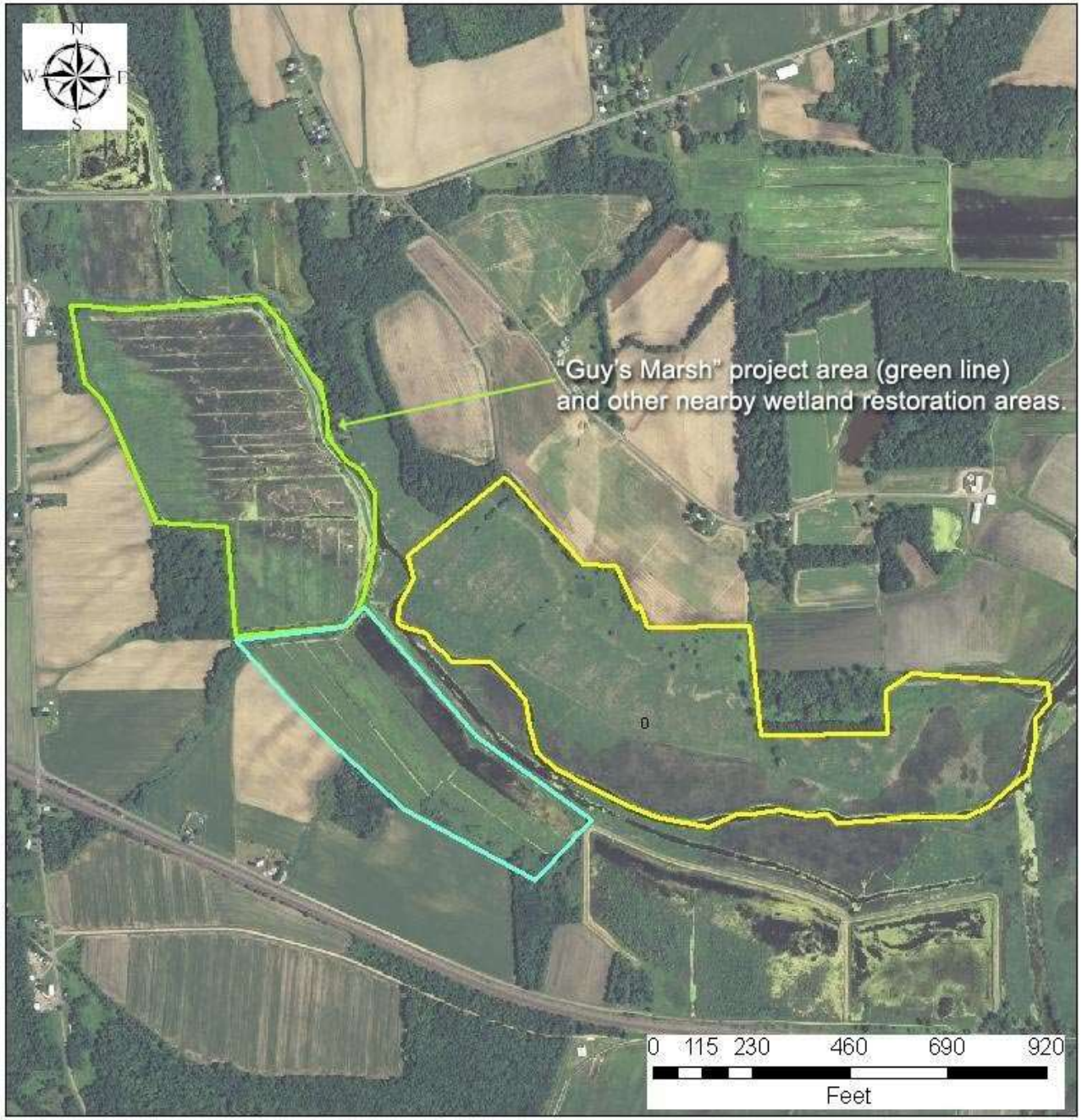
- Montezuma is located in central New York State (NYS)
- Prior to the 1900s the area held over 40,000 acres of wetlands[1]
  - Most was drained to support commerce and transportation, largely for the Erie Canal
  - Up to 70% of the wetlands was lost

Image courtesy of USFWS

Guy Andrew Baldassarre

February 14, 1953 - August 20, 2012

Distinguished Teaching Professor at SUNY College of Environmental Science and Forestry
for 25 years, where he specialized in ornithology and wildlife management



Legend

Cruso Creek
127 acres

Albino South
52 acres

Albino North
87 acres

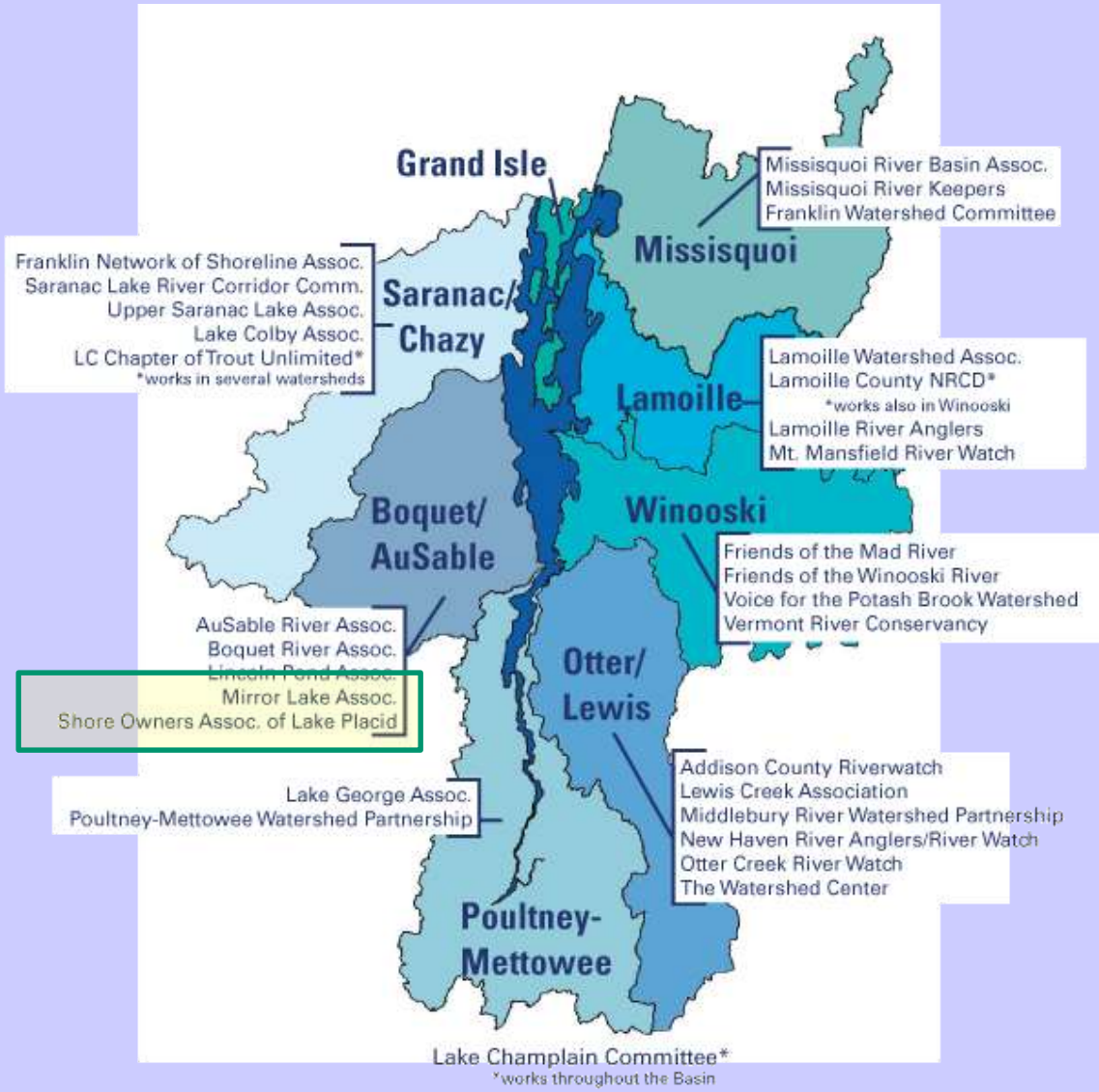
Figure 2. Albino Tory and Crusoe Creek Restoration Aerial Photo

DUCKS UNLIMITED
Mid-Atlantic Field Office
34 Defense Street, Suite 200
Annapolis, Maryland 21401

Watershed = Drainage Basin

- Area of land that is drained by a single body of water
  - Example: Lake Chaplain watershed

http://www.lcbp.org/watersheds/assoc.htm



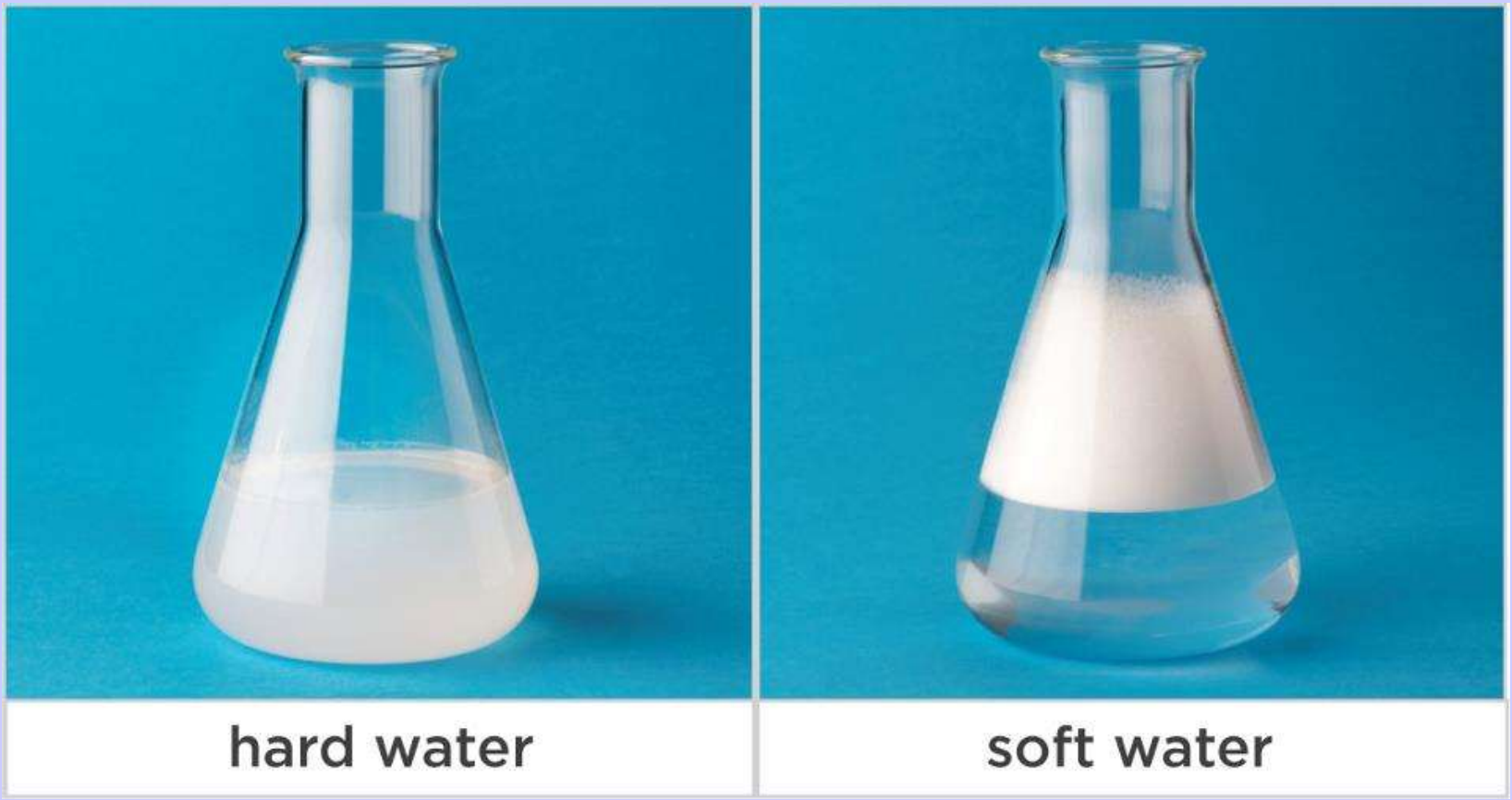
The Great Lakes
what is the shaded land called?

http://www.great-lakes.net/lakes/basinMap2.gif

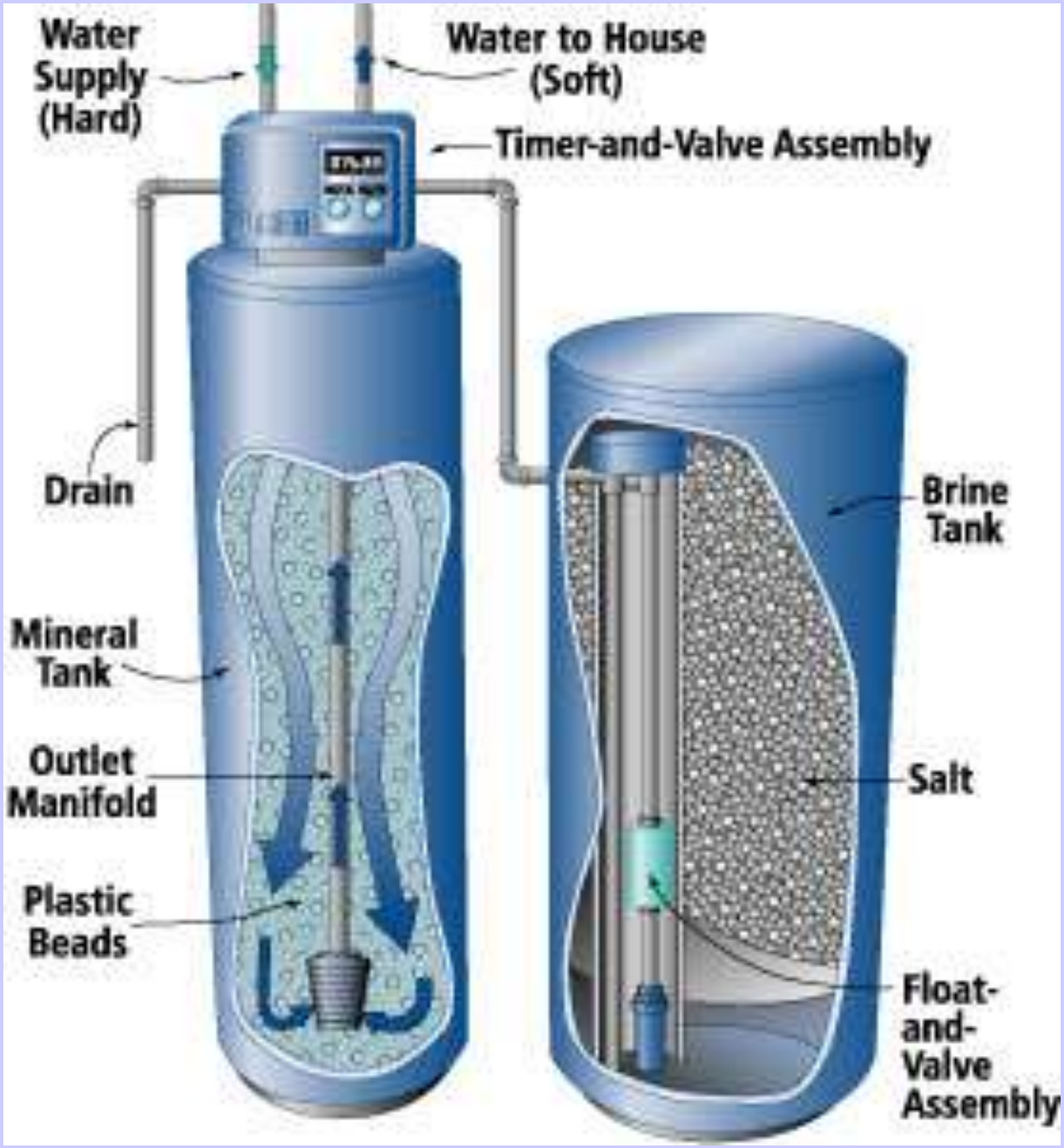
Water vocabulary

- Define hard water
- Hard water contains lots of dissolved salts (Mg, Ca, Fe)

Hard water → soap scum



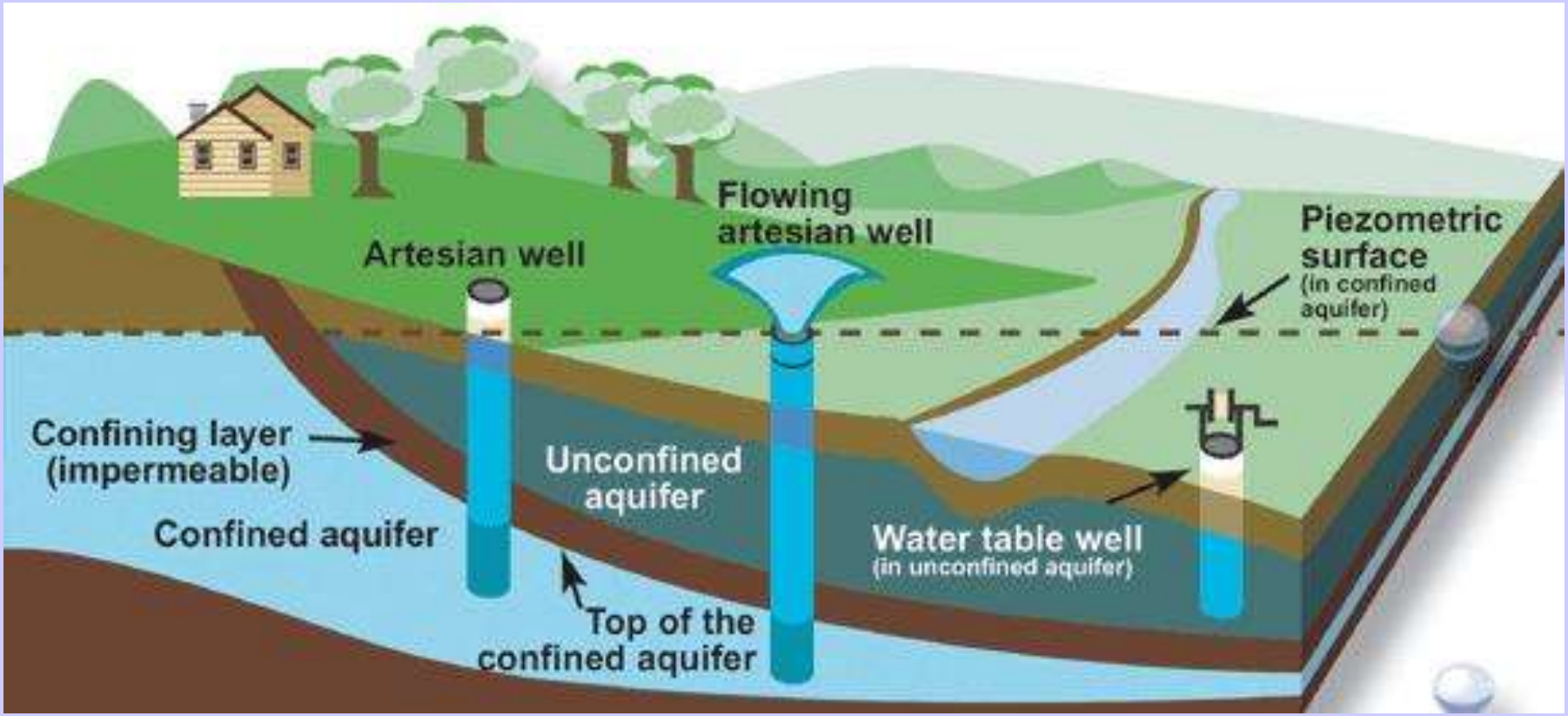
Hard water → mineral deposits in pipes


Water Supply (Hard)
Water to House (Soft)
Timer-and-Valve Assembly
Drain
Brine Tank
Mineral Tank
Outlet Manifold
Salt
Plastic Beads
Float-and-Valve Assembly

Water Vocabulary Cont.

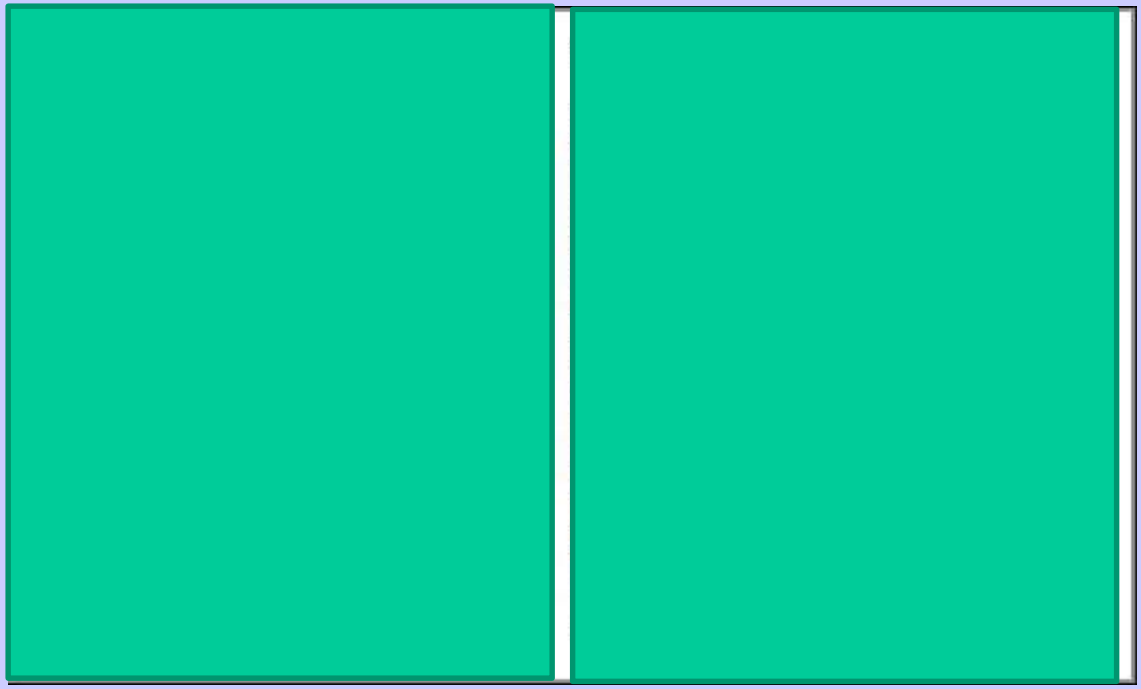
- Potable = drinkable

Groundwater percolates → aquifers

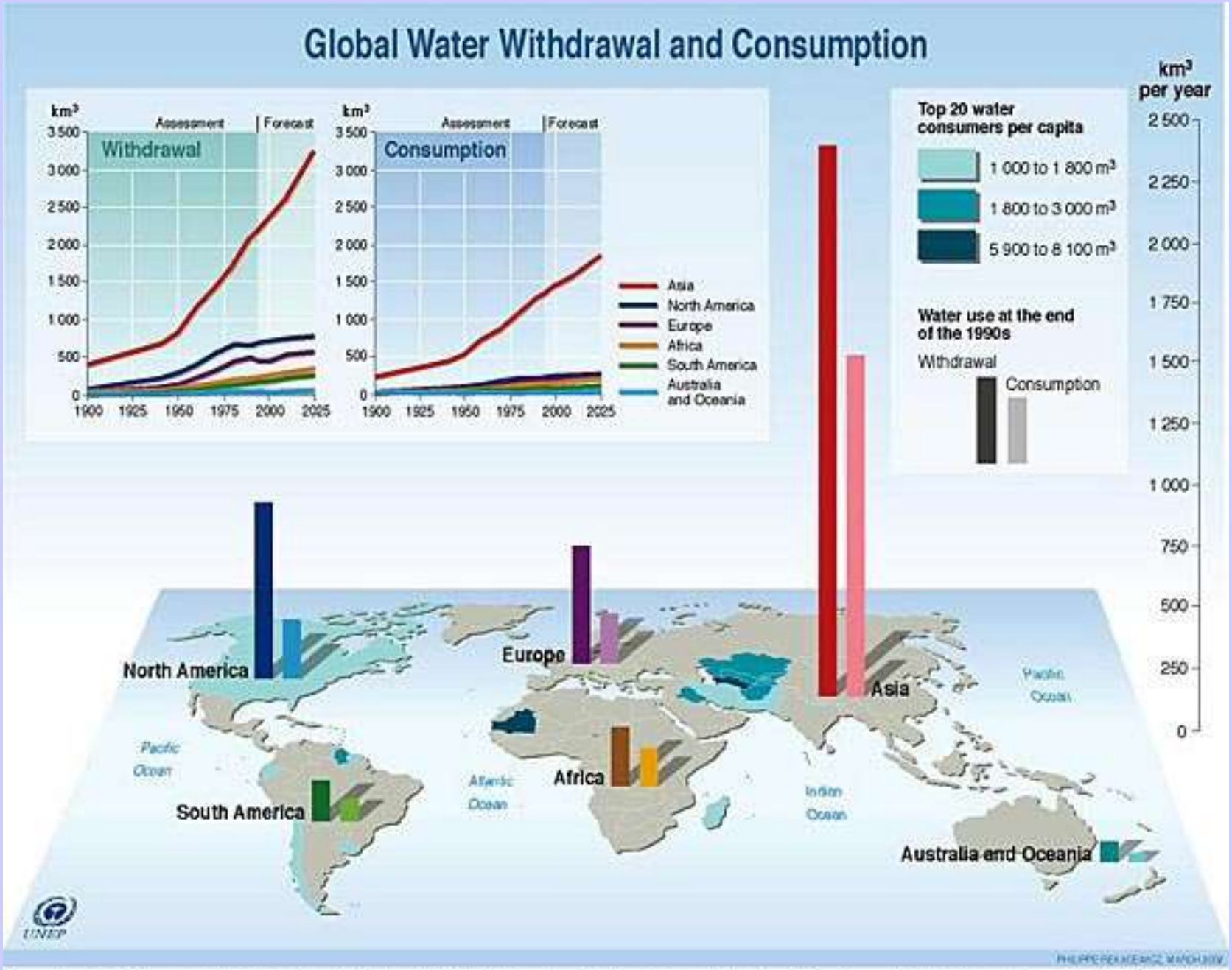


Aquifer = underground collection of water
2 types

- Unconfined aquifer = in between a permeable rock layer and an impermeable layer
- Confined (artesian) aquifer = trapped between 2 layers of impermeable rock (nonrenewable)



http://www.mahometaquiferconsortium.org/Edmats_1terms_0605_files/image002.jpg



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999, *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000; Paul Harrison and Fred Pearce, *AAAS Atlas of Population 2001*, American Association for the Advancement of Science, University of California Press, Berkeley.

What does it mean if withdrawl > amount consumed?

- Gets depleted
- Tragedy of the commons

Aquatic biomes

- Affected by salinity, pressure, light, tidal cycles, substrate, pH
- Light & nutrients limit biotic potential

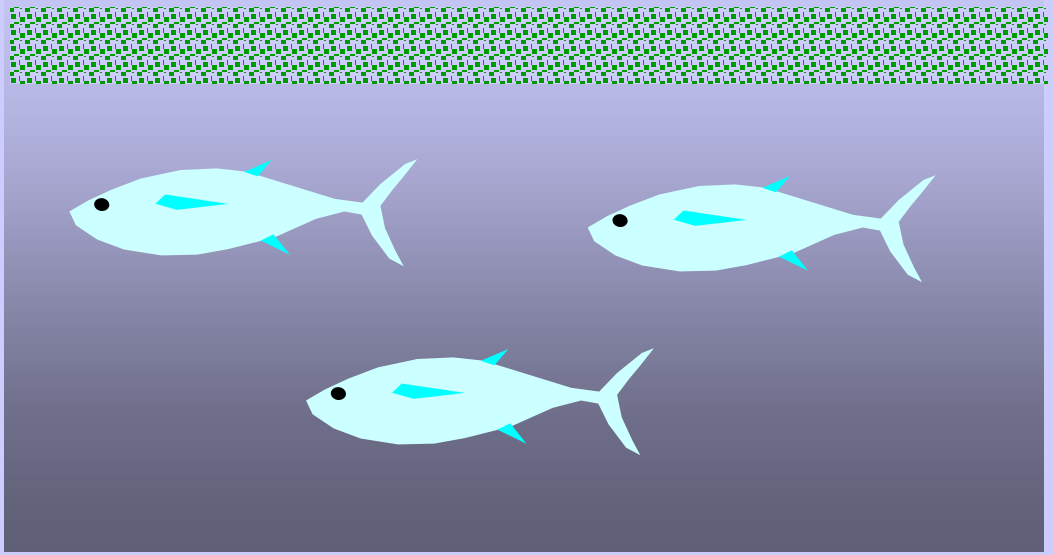
- Define biotic potential

Aquatic Food Chains

- Both fresh and saltwater ecosystems contain 3 categories of organisms:

Floating = plankton (zoo or phyto)

Swimming = Nekton



Bottom dwellers = benthos

Photic zone (light)

Aphotic zone


Benthic

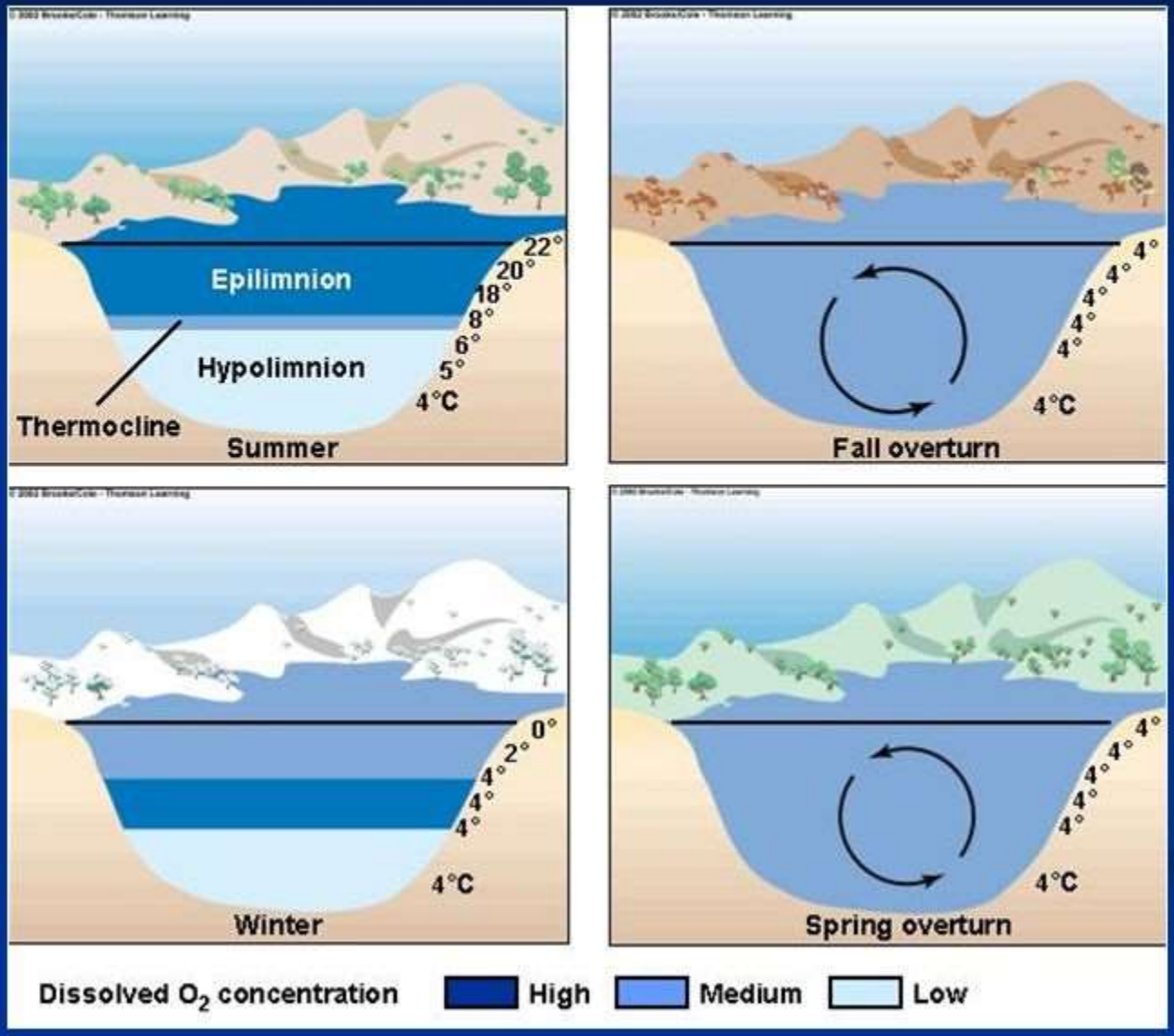
2 types of freshwater

- Lentic = standing water (lakes, ponds, wetlands)
- Lotic = flowing (streams, rivers)

Lakes = lentic depressions formed by

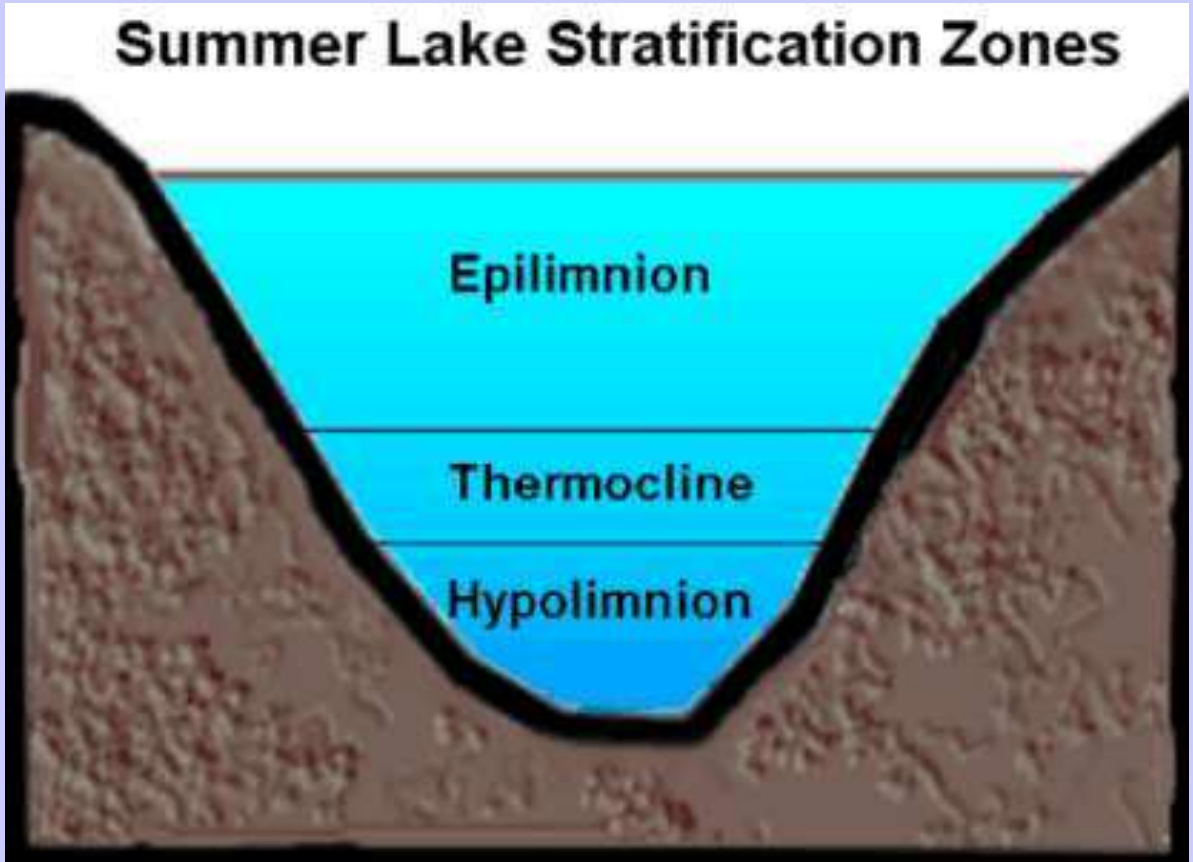
- Glaciers (ex: Great Lakes and Adirondack lakes)
- Crustal displacement (Lake Nyasa and Lake Victoria in Africa)
- Volcanic activity (Crater Lake in Oregon)

Seasonal changes in lakes

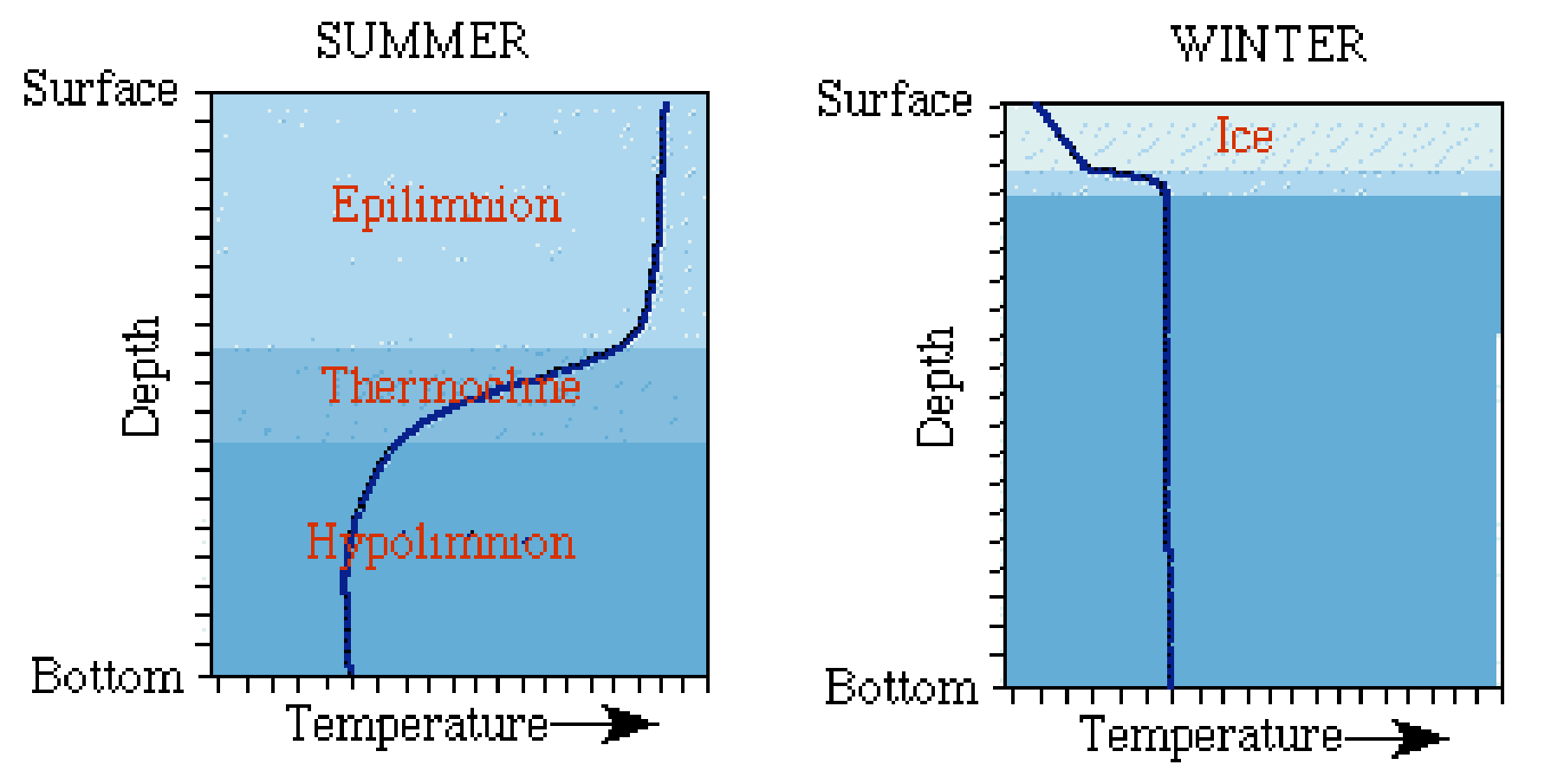


Summer and Winter

- Thermal stratification – layers of warm and cold water
- Thermoclines = abrupt temp difference between warm surface and colder layers



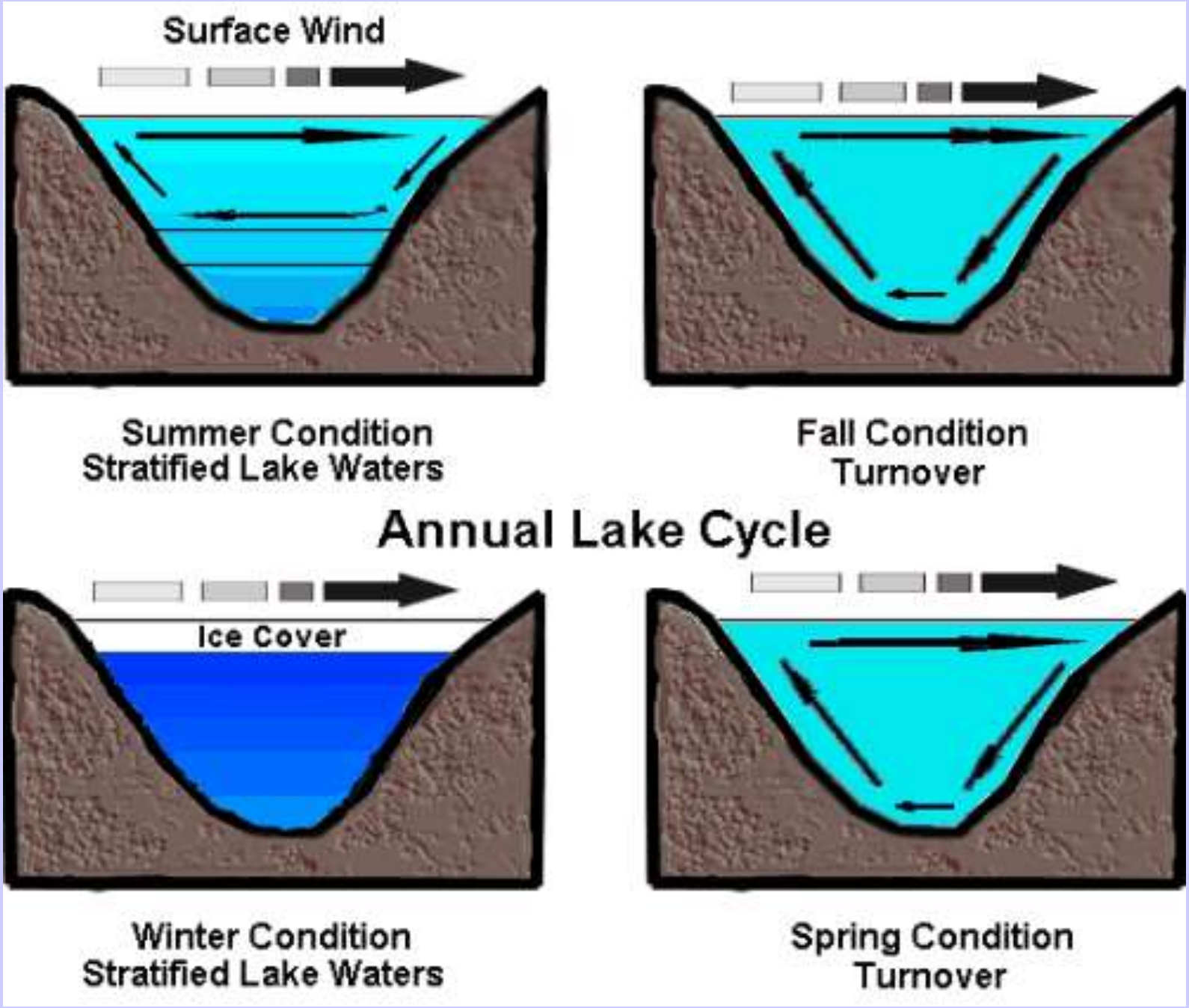
When is the thermocline the greatest and why



- Describe physical and chemical characteristics of the epilimnion,
  - Physical: Warm upper layer, light
  - Chemical: med-hi dissolved oxygen, low nutrients.

- Describe the physical and chemical characteristics of the hypolimnion
  - Physical: Cold, deep, dark water w/high pressure
  - Chemical = low-no oxygen high in nutrients.

- Why are lakes and rivers brown in the spring and blue in the summer?


Surface Wind
Summer Condition
Stratified Lake Waters
Fall Condition
Turnover
Annual Lake Cycle
Ice Cover
Winter Condition
Stratified Lake Waters
Spring Condition
Turnover

Aging of Lakes

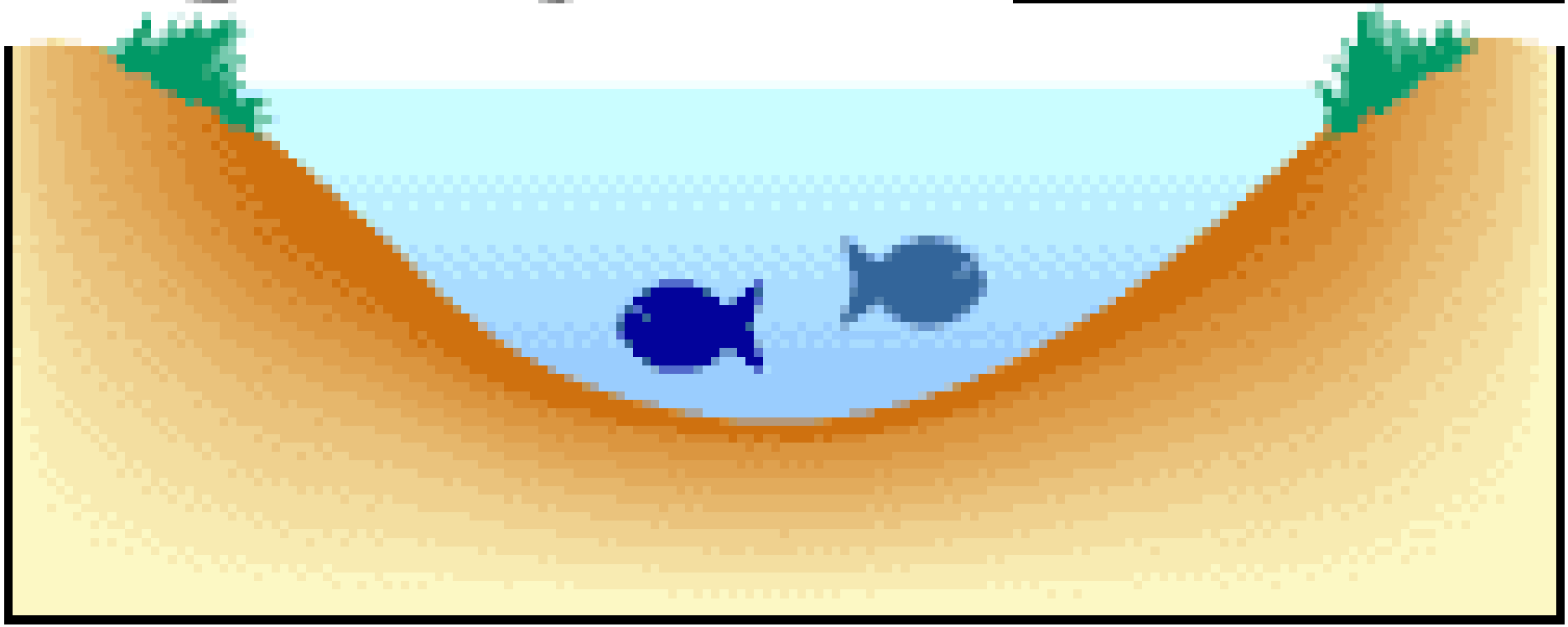
Nutrient content and DO (dissolved oxygen) → 3 types of lakes

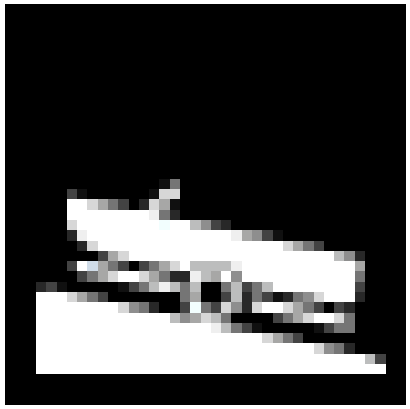
Nutrient content and DO (dissolved oxygen)→ 3 types of lakes

- Oligotrophic
  - Deep, cold, steep banks
  - Young
  - Low organics and low nutrients
  - Trout, bass
  - Ex: Lake Placid

http://www.hillsborough.wateratlas.usf.edu/shared/learnmore.asp?toolsection=lm_tsi

Oligotrophic



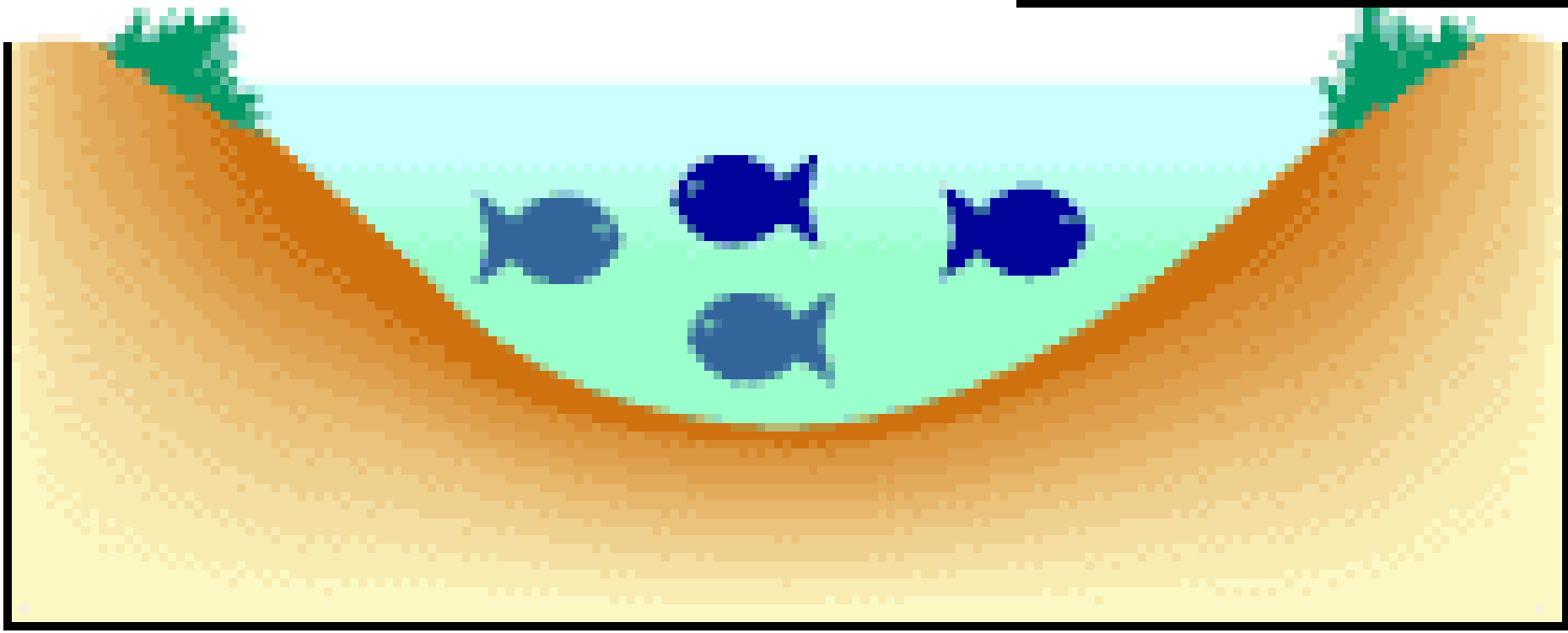


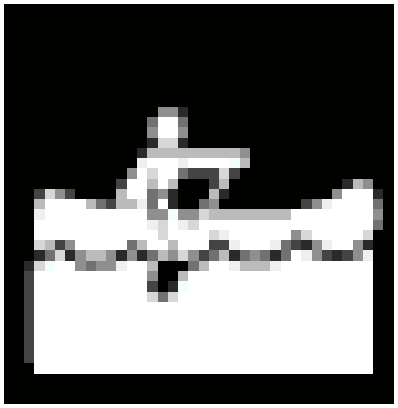
Chlorophyll	<3 µg/L
Phosphorus	<15 µg/L
Nitrogen	<400 µg/L
Clarity	>13 feet

Mesotrophic

- Warmer, middle-aged lake
- medium amt. of nutrients and organics,
- higher npp,
- less oxygen,
- Inc. phytoplankton (esp. cyanobacteria) → perch sunfish, bass)
- Ex: Mirror Lake

Mesotrophic



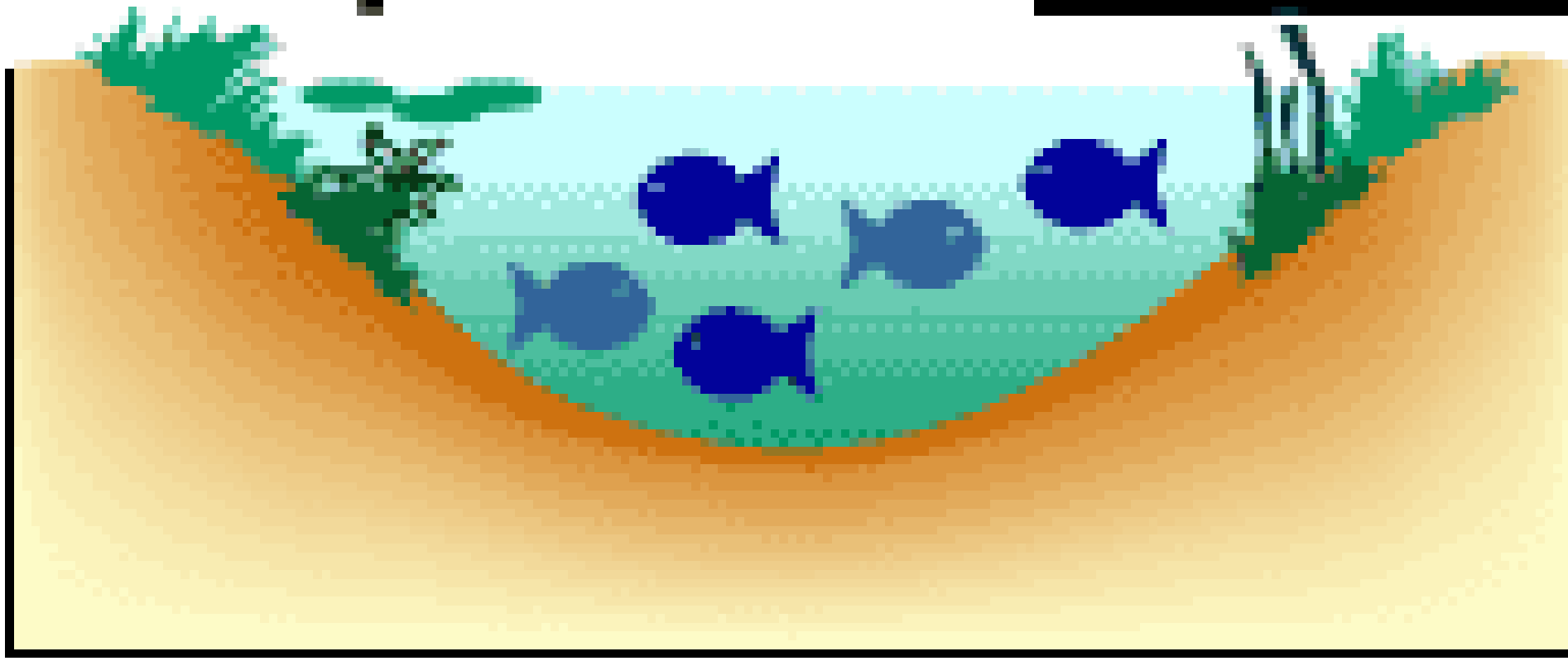


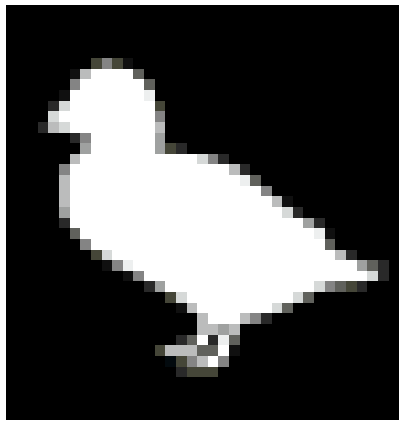
Chlorophyll	3-7 µg/L
Phosphorus	15-25 µg/L
Nitrogen	400-600 µg/L
Clarity	8-13 feet

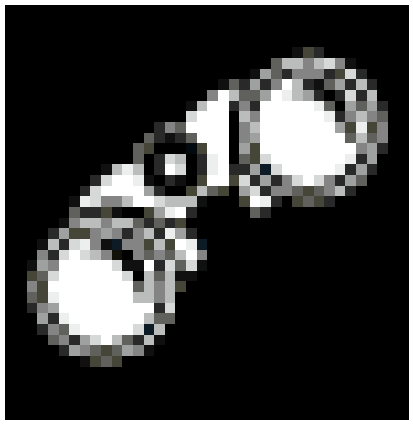
Eutrophic

- High nutrients and organics
- Very little oxygen
- Lots of decomposition
- Older lake

Eutrophic







Chlorophyll	7-40 µg/L
Phosphorus	25-100 µg/L
Nitrogen	600-1500 µg/L
Clarity	3-8 feet

Aging of lakes (Eutrophication)

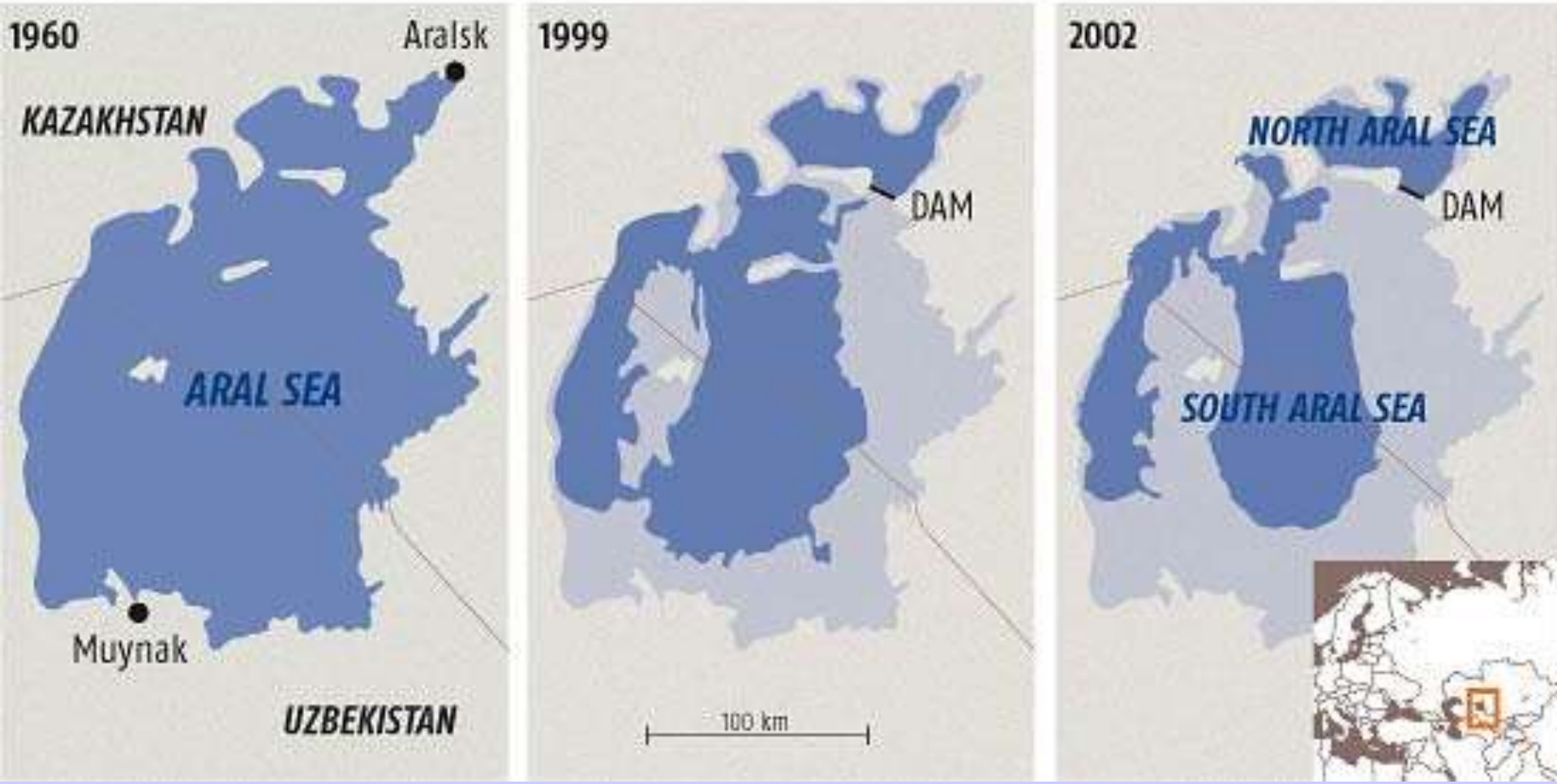
- Occurs naturally = succession
  - Oligotrophic → eutrophic
- Cultural eutrophication occurs when humans increase the rate
  - Ex: fertilizer runoff, sewage contamination
  - Inc. nutrients → increased plant growth → increased decomposition → dec. oxygen

5 Largest Lakes in the World (area)

1. Caspian Sea (Eurasia)
   143,244 square miles
2. Lake Superior (US) 31,700 square miles
3. Lake Victoria (Africa) 26,828 square miles
4. Aral Sea (Asia) 24,904 square miles
   (water diversion → shrinking)
5. Lake Huron (US) 23,000 square miles

THE SHRINKING SEA

The changed shape of the Aral Sea since 1960

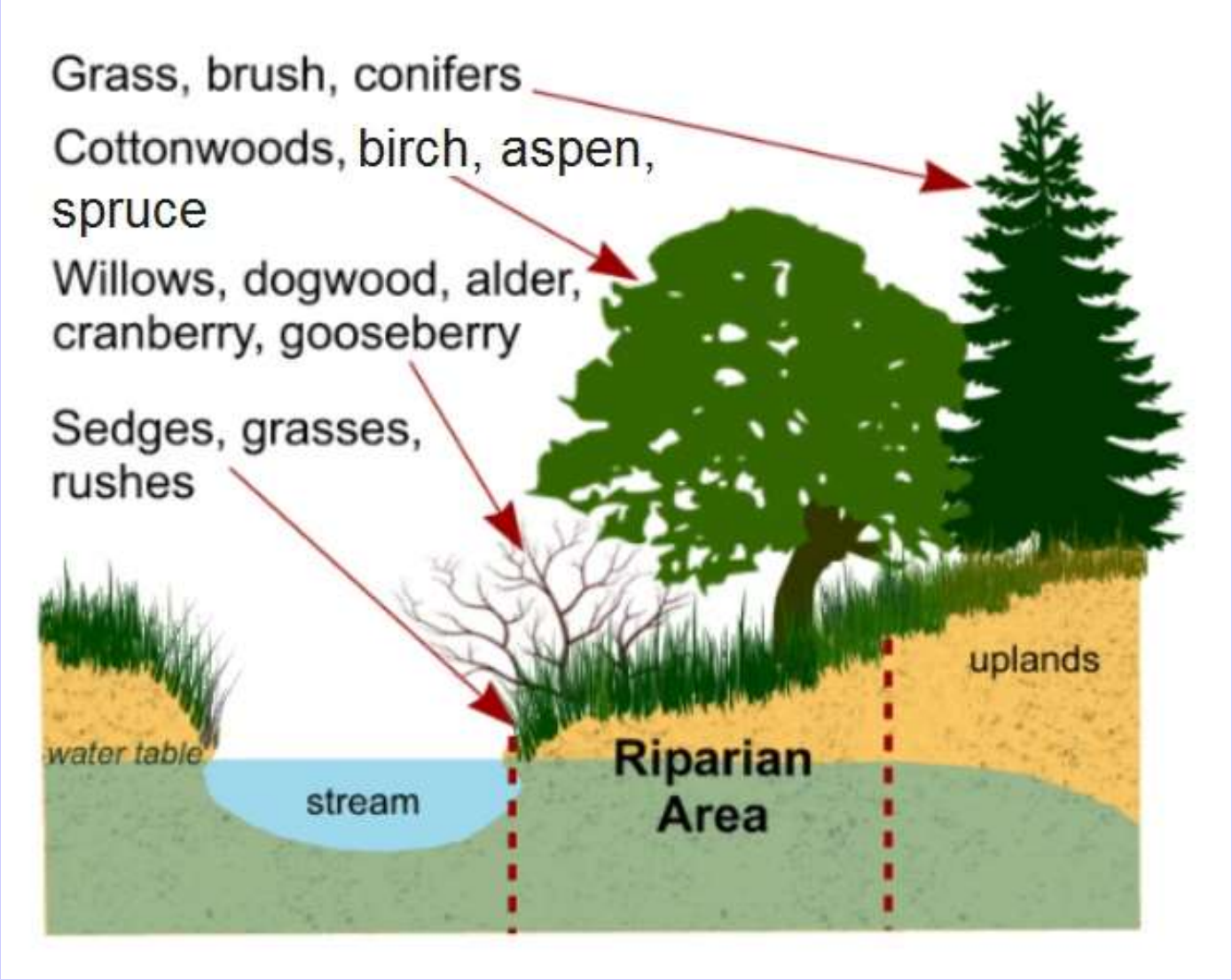


1989 - 2014

Rivers

- Lotic (flowing)
- Mouth = where rivers meet oceans
- Delta = soil deposits at mouth
- Head waters describe a rivers source
- Riparian zone = shoreline
- Floodplain = area bordering river subject to flooding

Riparian Zone



Rivers and Streams

- narrow, swift, clear, cold, nutrient poor, and highly oxygenated

- Tend to be wide, slow, cloudy, warm, nutrient rich, and less oxygenated

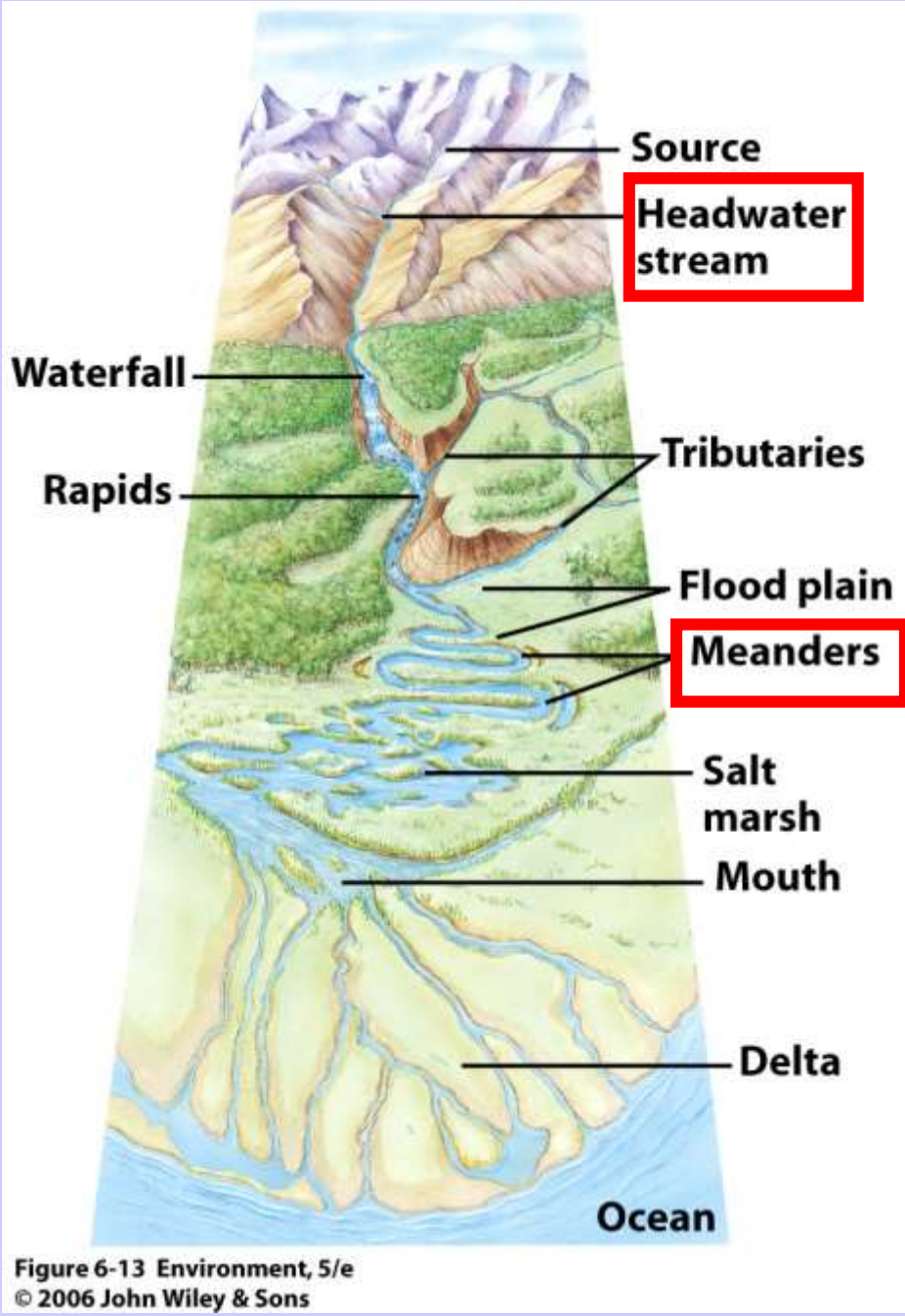


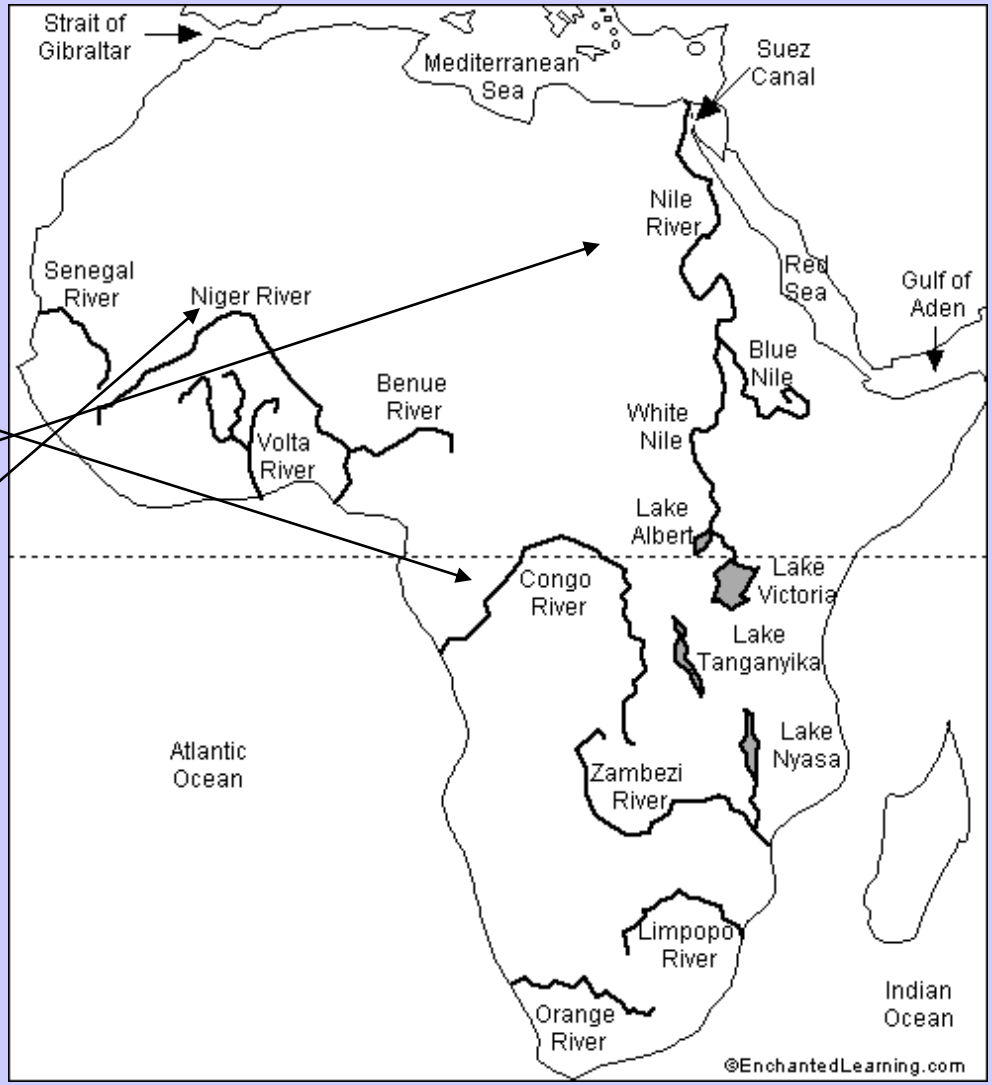
Figure 6-13 Environment, 5/e

World's 10 largest watersheds

- North America
  - Mississippi
- South America
  - Amazon
  - Parana

http://www.mantleplumes.org/images/SAmerica_350.gif

- Africa
  - Congo
  - Nile
  - Niger



- Asia
  - Ob (Siberia)
  - Yenisey (Mongolia, Russia)
  - Lena (North and Central Russia)
  - Yangtze (China)

Longest rivers in the world

River	Country	Miles
Nile	Egypt	4,145
Amazon	Brazil	4,000
Yangtze	China	3,964
Mississippi / Missouri river system	US	3,740
Yenisea / Angara river system	Russia	3,442

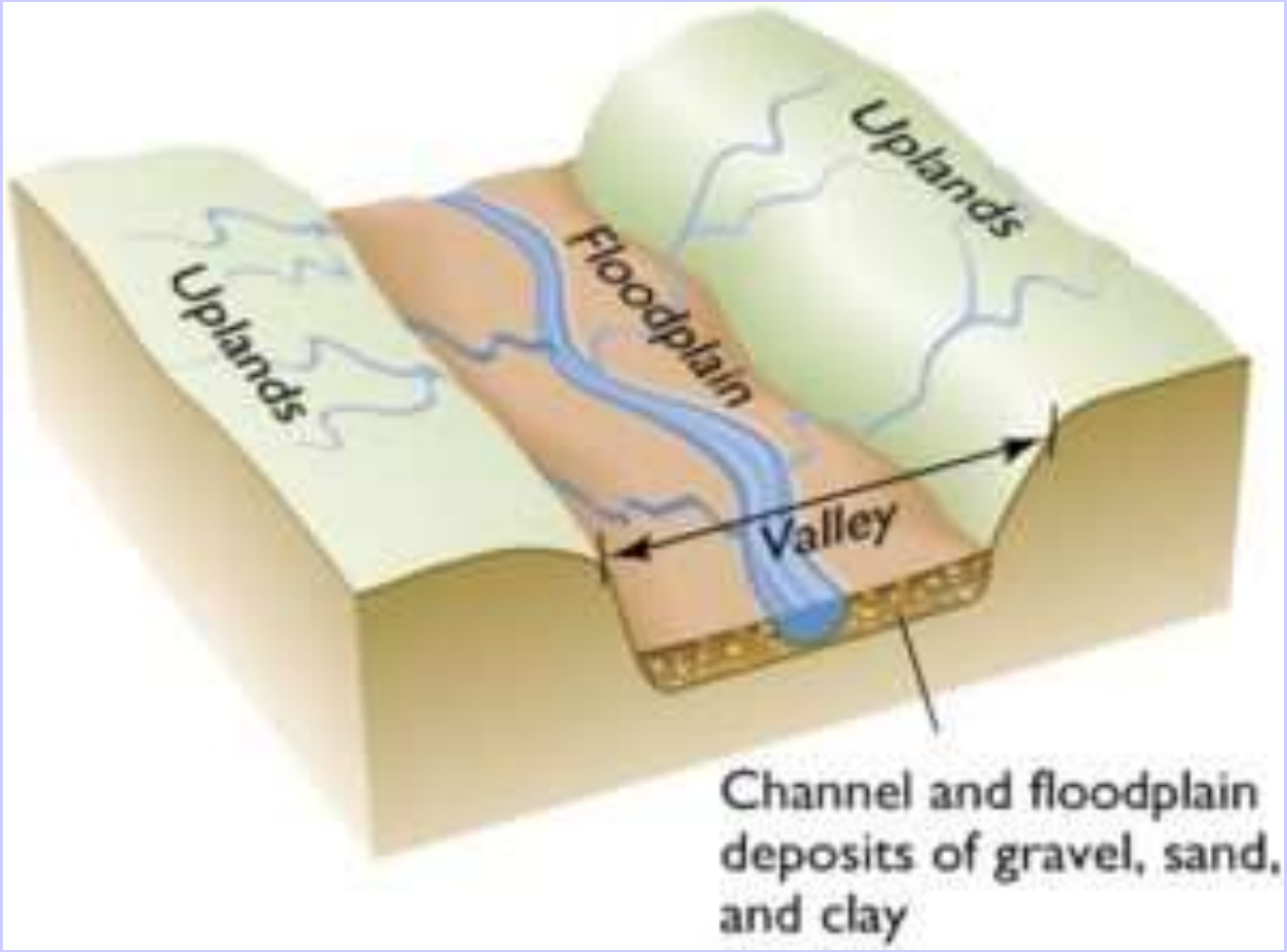
Human impacts on Rivers

- Hydroelectric dams and water diversion projects change natural course of rivers

- ex: Hoover Dam in Nevada controls Colorado River → river runs dry

The six-million-year-old Colorado River is one of the hardest-working rivers on the planet. It supplies water to 40 million people, irrigates four million acres of farmland, and serves as the lifeblood of native tribes, seven National Wildlife Refuges and 11 National Parks. It generates an annual $26 billion recreation economy and employs a quarter of a million Americans. Due to prolonged drought, diversions and dams across the river, and increased water demand from the seven U.S. states through which it flows, the Colorado River dries 70 miles before reaching its delta plain in the Gulf of California.

Floodplain


Uplands
Floodplain
Uplands
Valley
Channel and floodplain deposits of gravel, sand, and clay

Developing on floodplains and riparian zones → increased flooding and erosion

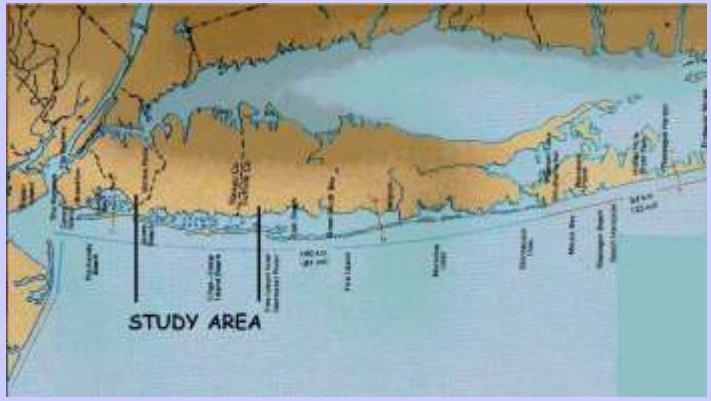
Saltwater Ecosystems

- Tides = due to gravitational pull of moon and sun

Highest tides in world = Nova Scotia's Bay of Fundy

Barrier islands

- Sandbars that have become islands
- <u>Protect an estuary from full force of ocean</u>
  - Ex:
    - Cape Hatteras, NC
    - Miami beach, FL
    - Jones Beach and Fire Island, NY



Estuaries

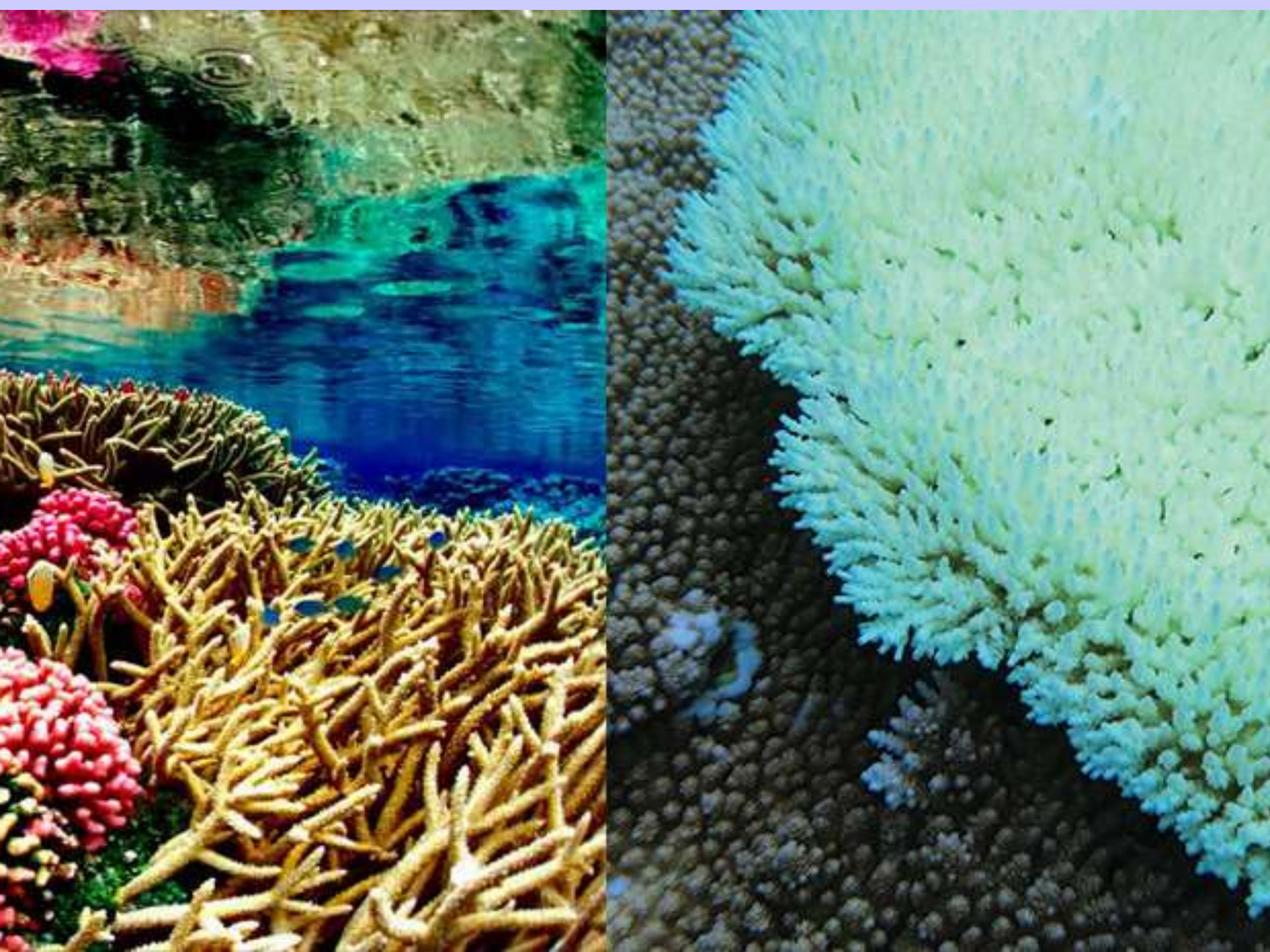
- Where salt and freshwater meet (ecotone, brackish water)
  - Salt marshes = hi gpp, tall grasses, act as nurseries
  - Mangrove forests = found in deltas, tree roots hold soil in place, adapted to brackish water (mangrove tree roots have salt filters) found in warm tropical regions
    - Florida
    - Argentina
    - African coasts
    - Australia
    - Threatened by logging, mining, agriculture, and development

Mangroves

http://www.ozestuaries.org/indicators/Images/rhiz_mangrove.jpg

Coral reefs

- Coral – colony of polyps (stinging cells similar to anemone)
- Symbiotic relationship between algae (zooxanthellate) and polyp → colors
- Relationship required to → secretion of $CaCO_3$ → hard skeletal-like structure for the colony to grow on = reef
- Acidification caused by global warming → blanching of coral (algae move out) → decrease in reef development → decrease in aquatic species diversity



Deep Ocean Communities

- Chemosynthetic producers found near hydrothermal vents support whole communities of organisms

- Avg NPP in open ocean is low except where upwelling occurs

Human impacts

- Overfishing
- Loss of biodiversity = loss of stability
- Pollution –
  - Great Pacific garbage dump (plastics enter food chain)
  - Oil spills
  - Ghost nets (abandoned fishing nets – continue to threaten wildlife)

Laws and Management

- NOAA (National Oceanic and Atmospheric Administration)
- 4 Laws
  - Clean Water Act (1972) – bans discharge of pollutants from stationary point sources into navigable waters
  - Marine Protection, Research and Sanctuaries Act **(Ocean Dumping Act)** (1972)– EPA regulates ocean dumping of industrial, sewage sludge and other wastes and bans dumping of radioactive, biological and chemical warfare agents

Laws and Management Continued

- The Oil Pollution Prevention, Response, Liability and Compensation Act (1989) –
  - vessel owners responsible for oil spill clean-up
  - Requires double hulls on tankers
  - Sets up a fund → quicker spill response
- Coastal Zone Management Act (1972)
  - Coastal states must manage nonpoint sources in an effort to protect estuaries (includes Great Lakes)

Water management

- Predict what happened when over 50 trees were removed from this slope

List ecosystem services of trees on hillsides

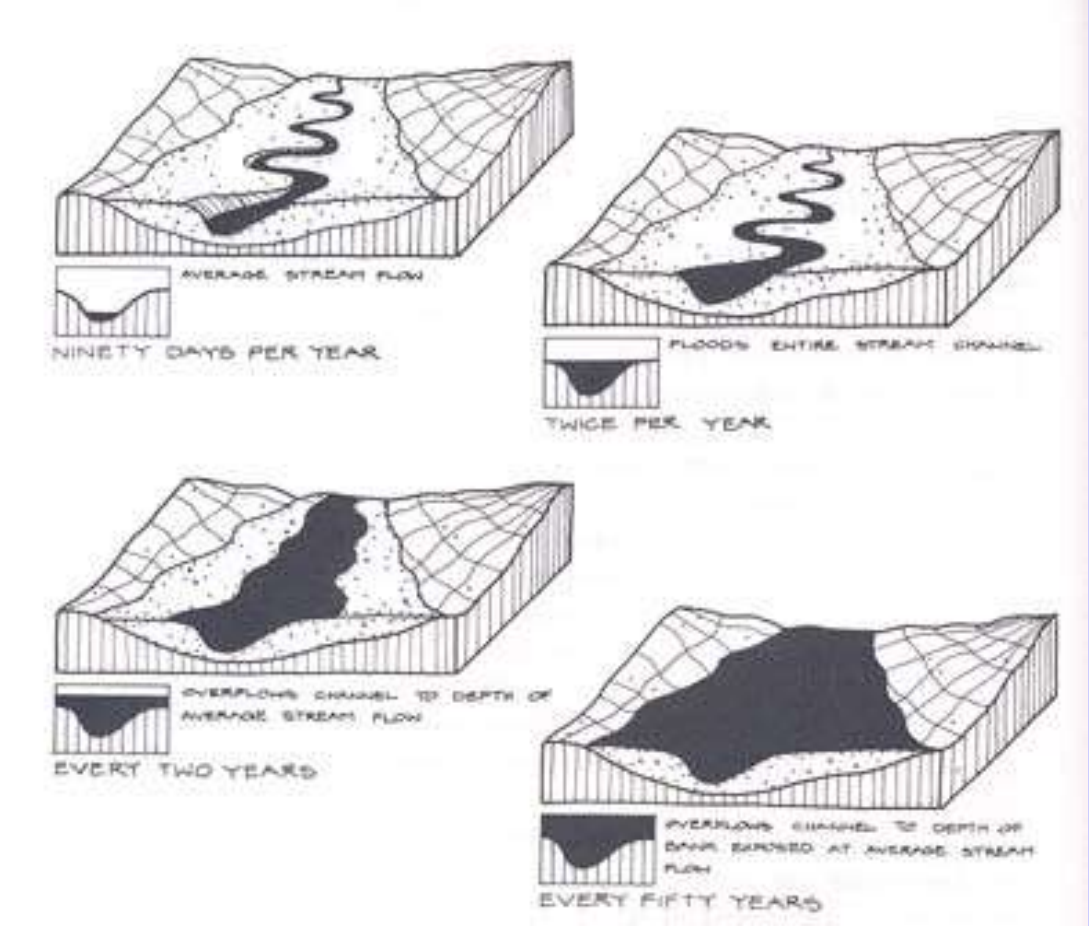
- Prevent erosion
- Prevent flooding downstream
- Absorb/hold 50-100gallons water / day
- Moderate climate
- Build and hold soils
- Carbon sink
- Clean water by absorbing N and P

Too much water →Flooding (causes)

- Natural
  - From heavy rains
  - Spring thaw
- Humans increase severity of floods by
  - Cutting trees on hillsides
  - Removing vegetation from shores (riparian zone)
  - Draining wetlands
  - Building levees
  - Climate change impacts

Too Much

- Flood Plain = areas surrounding a river that flood seasonally



http://web.mit.edu/wplp/course/f98stud/bw/images/1-2topo/diagrams/floodplaindynamics.jpg

Ecosystem services of floodplains

- Very fertile → productive → high biodiversity
- Remove sediment → increase water quality
- Prevent flooding downstream
- Recharge groundwater

Negative side of flooding

- Can destroy homes and businesses
- Damage crops
- Kill people and livestock
- Loss of money
- Spread invasive species
- Water pollution

Flooding (Solutions and more problems)

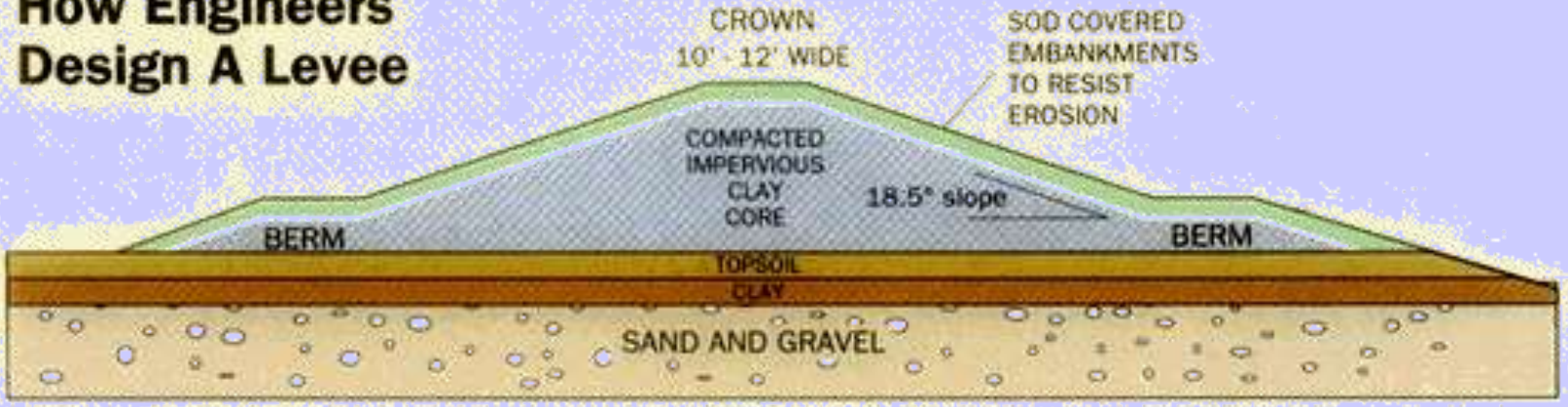
- Channelization = force water to go in 1 direction
- Pros =
- reduce upstream flooding
- Cons =
- inc. erosion, can increase downstream flooding, disrupts ecosystems, prevents build-up of nutrients in flood plains

http://www.epa.gov/maia/images/md-page27.jpg

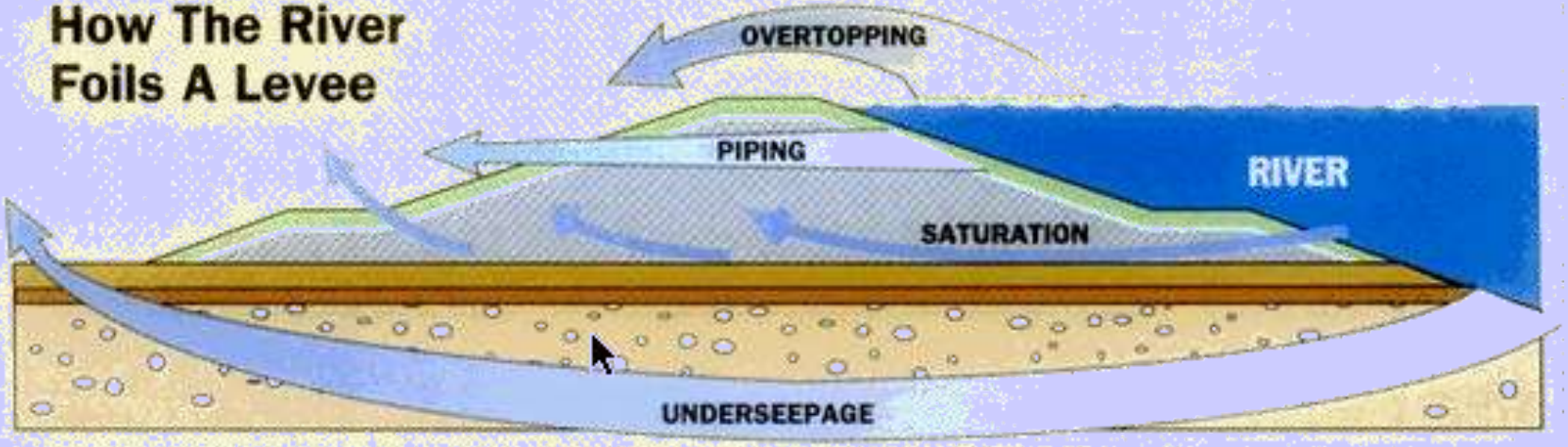
Building levees = walls to hold water back

- Pros
  - Protect cities and towns from flooding
- Cons
  - When they fail → large devastating floods

How Engineers Design A Levee



How The River Foils A Levee



Overtopping: The river flows over the levee's crown, quickly eroding the landward slope.

Piping: The river finds its way through animal burrows or through canals formed by roots; it soon eats away at the levee's innards.

Saturation: The river gradually permeates the levee material, leaving the levee too weak to hold up its own weight.

Underseepage: The river pushes through a loose layer of sand beneath the levee and breaks through the ground on the other side, weakening the ground the levee sits on.

http://www.earthsci.unimelb.edu.au/Thomas/lteng/engeimg/enge1327a.GIF

Flooding (example)

- Hurricane Katrina devastated New Orleans and parts of Mississippi (Aug. 2005)
  - Strong winds, heavy rainwater, storm surge → failure of the Lake Pontchartrain levees
  - Severe flooding
  - Massive water pollution
  - Deaths
  - Destroyed ecosystems
  - http://www.cnn.com/videos/tv/2015/08/[illegible]never-stopped.cnn/video/playlists/hurricane-katrina-10-years-later/

Flood control Dams

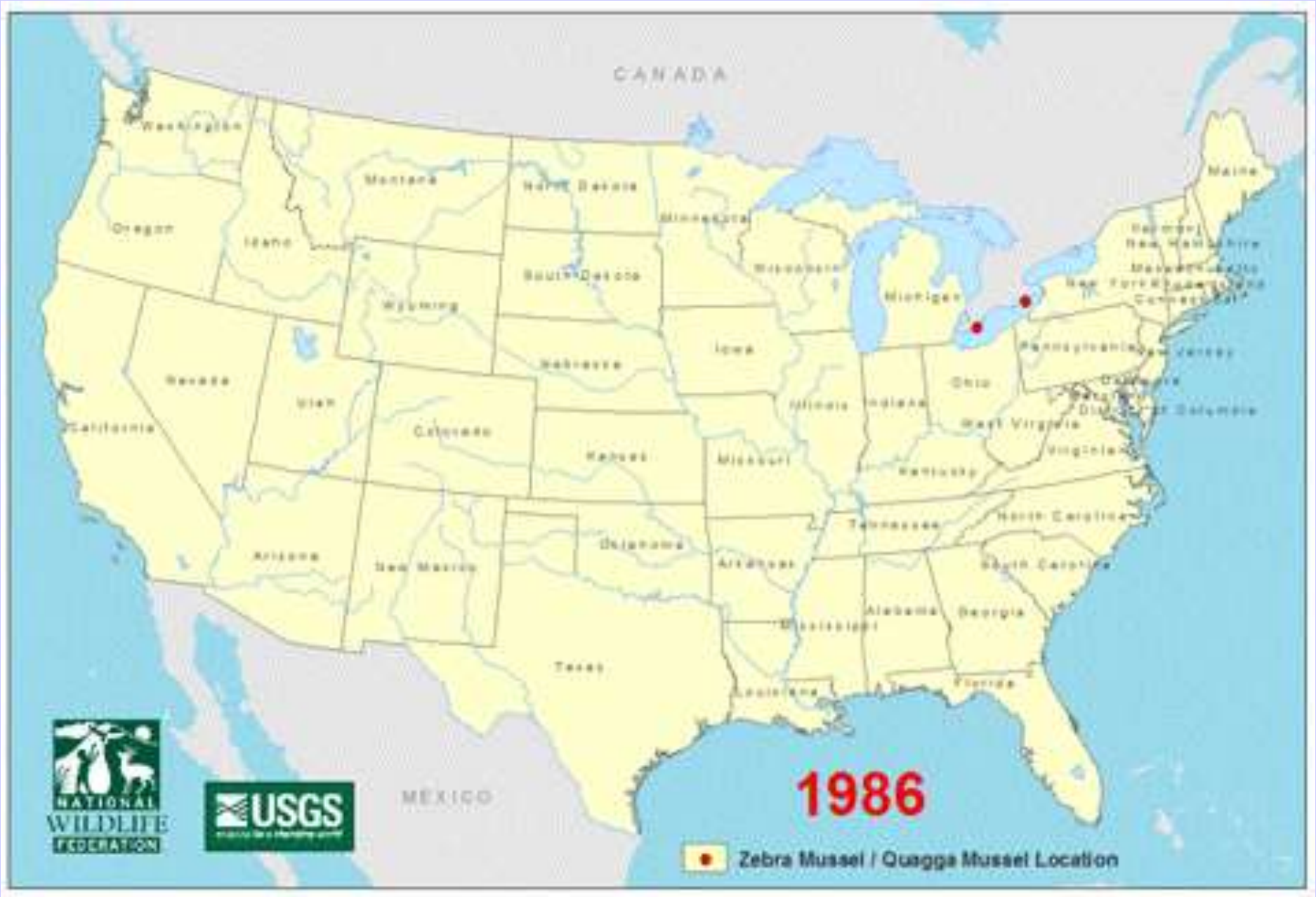
- Store water in a reservoir and release gradually
- Pros
  - Hydroelectric power,
  - Reservoir can be used as a water source
  - Can decrease local flooding downstream
- Cons
  - Displaces people and animals
  - Can → seismic activity
  - Can increase diseases (ex:cholera, schistosomiasis)
  - Affect fish populations
  - Cause droughts downstream

Flooding (examples in US)

- 1993 Mississippi River flooded affecting 9 states
  - Property damage
  - Washed pesticides into Gulf of Mexico
  - Spread invasive species (like zebra mussels)

http://www.fws.gov/r5crc/invasive_species.htm

http://www.calstatela.edu/dept/geology/G158images/1993Flood(2).jpg


CANADA
MEXICO
1986
Zebra Mussel / Quagga Mussel Location
NATIONAL WILDLIFE FEDERATION
USGS

Aftermath

- US Flood Plan Management Task Force reassessed flood policies
- Recommend
  - letting rivers meander
  - Smaller levees farther away from rivers edge
  - Wetland protection and restoration

Human health impact of flooding

III. Too Little

- Causes of water shortages
  - Dry climate and climate change
  - Drought
  - Deforestation and overgrazing

Ways to increase water supply to a region

1. Build dams and reservoirs
    - List pros and cons

2. Transfer or bring in surface water from another area = (use tunnels, aqueducts and pipelines)

- Ex: California Water Project
  - 75% Ca. population = south of Sacramento
  - 75% Ca. rain falls in the north


California Department of Water Resources
State Water Project
Reservoir
Aqueduct or canal
Hydroelectric station
Pumping station
Purple indicates shared features with the federal Central Valley Project (CVP)
Light blue indicates other federal or private facilities
Only principal features are shown
Redding
Antelope Lake
Frenchman Lake
Upper Feather Watersheds
Lake Davis
Lake Oroville
Oroville Thermalito Hydroelectric Complex
Feather
Sacramento
Sacramento
NORTH BAY AQUEDUCT
Delta Cross Channel
NEVADA
CALIFORNIA
San Francisco
Clifton Court Forebay
SOUTH BAY AQUEDUCT
Lake Del Valle
Modesto
San Jose
Gianelli Pumping-Generating Plant
O'Neill Reservoir
San Luis Reservoir
San Luis Canal
Fresno
Salinas
CALIFORNIA AQUEDUCT
COASTAL BRANCH
Bakersfield
Kern River intertie
Edmonston Pumping Plant
Tehachapi Forebay
Lake Cachuma
Pyramid Lake
EAST BRANCH
CCWA EXTENSION
Castaic Power Plant
Castaic Lake
Santa Barbara
WEST BRANCH
Silverwood Lake
Devil Canyon Power Plant
Los Angeles
Lake Perris
Lake Skinner
Pacific Ocean
San Diego
UNITED STATES

California Water Project

- Pros = support agriculture and population
- Cons
- Threatens fisheries in north
- Reduces flushing action that normally cleans San Francisco Bay
- Irrigation in arid regions → salination

3. Withdraw groundwater

- Draining water faster than recharge = loss of a shared resource =
- Tragedy of the commons.


WA
OR
CA
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KY
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WV
GA
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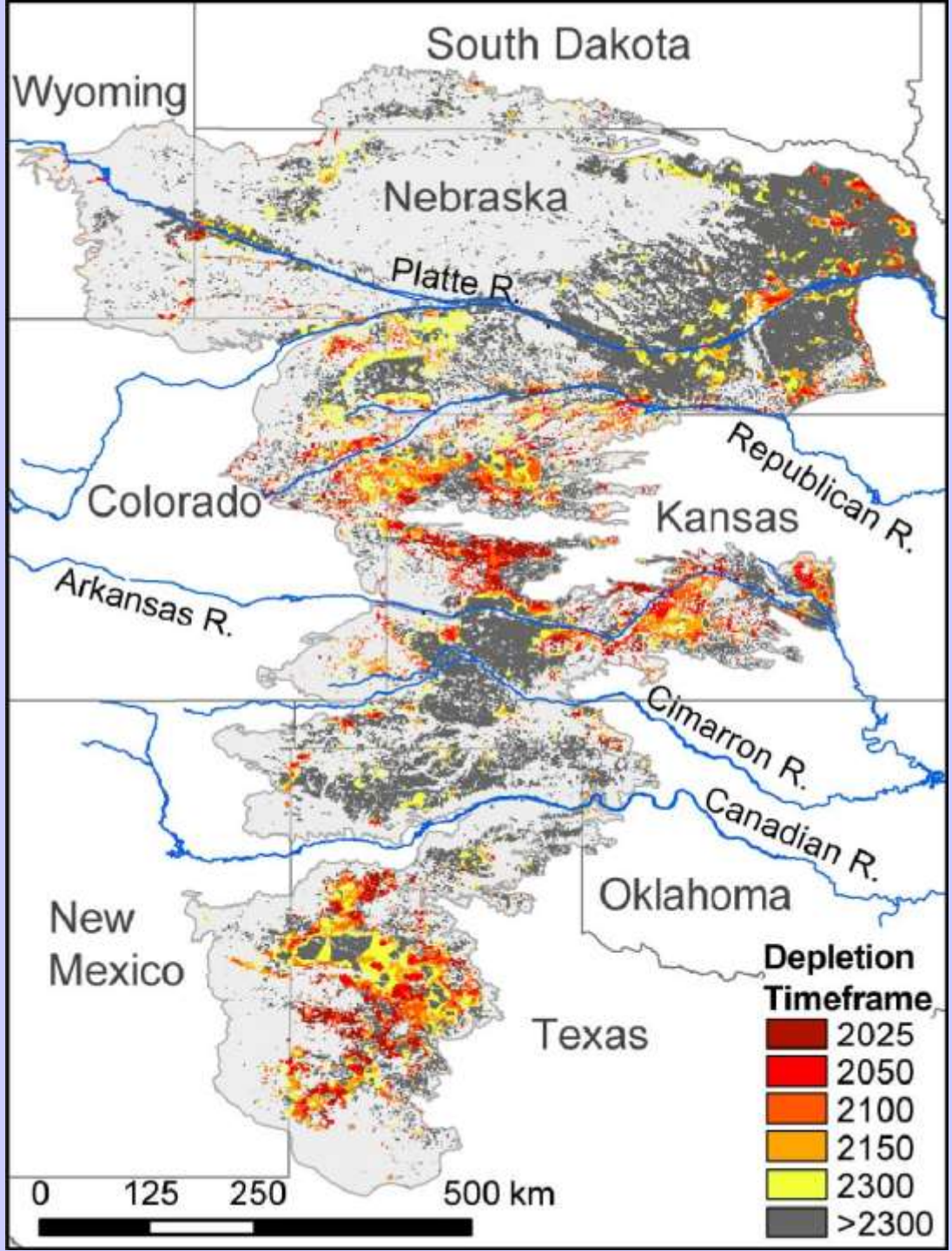
ME
OGALLALA
AQUIFER
USGS
science for a changing world

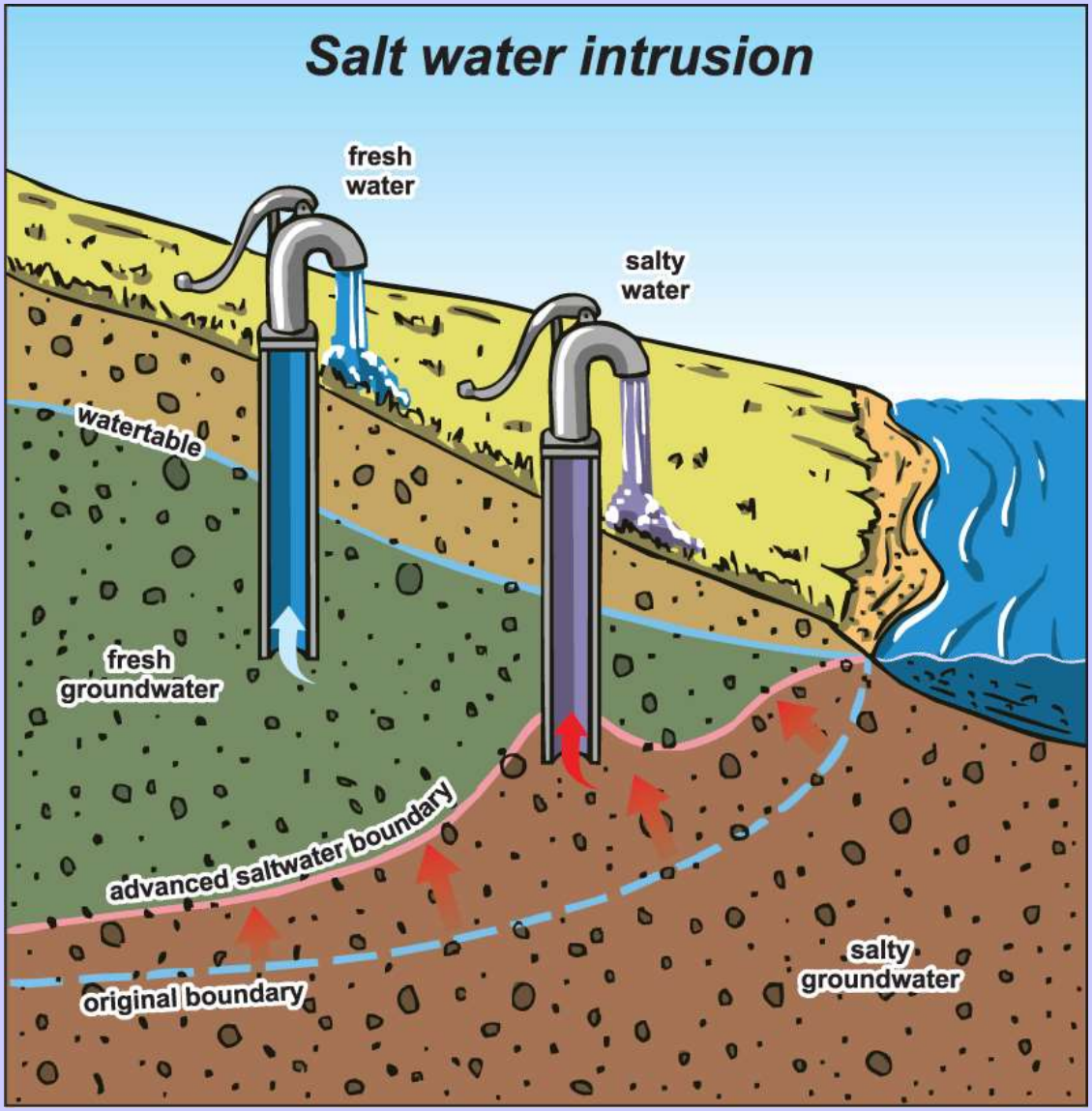

South Dakota
Wyoming
Nebraska
Platte R.
Republican R.
Colorado
Kansas
Arkansas R.
Cimarron R.
Canadian R.
Oklahoma
New Mexico
Texas
Depletion Timeframe
2025
2050
2100
2150
2300
>2300
0
125
250
500 km

Problems with groundwater depletion →

- <u>Subsidence</u> = sinking of land due to aquifer depletion

http://iml.jou.ufl.edu/projects/Spring04/Paquet/saltwaterintrusion.html

- Saltwater intrusion = saltwater fills into depleted aquifers to fill the void → brackish water



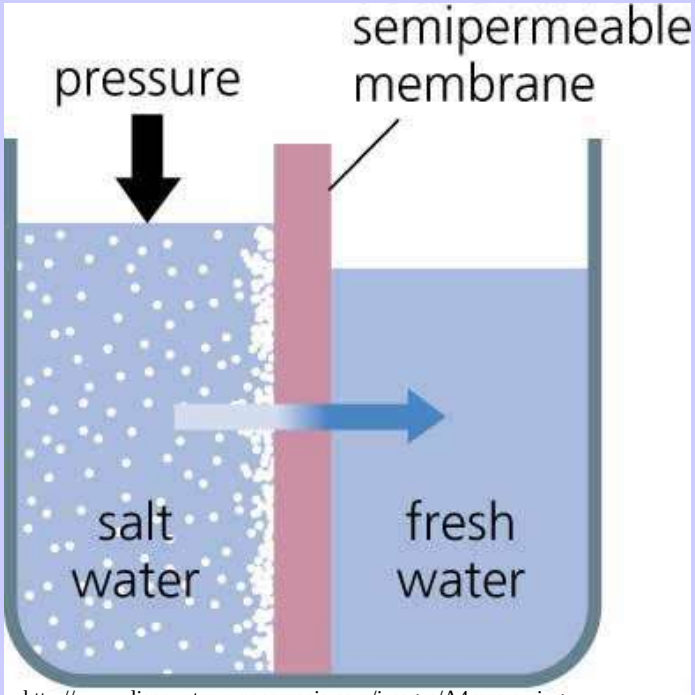
4. Desalination = change saltwater into freshwater

- Huge industry in Middle East where freshwater supplies are limited (esp. in Saudi Arabia)
- Arizona adds desalted water to the Colorado River (→ helps supply residents of Arizona and Mexico with fresh water)

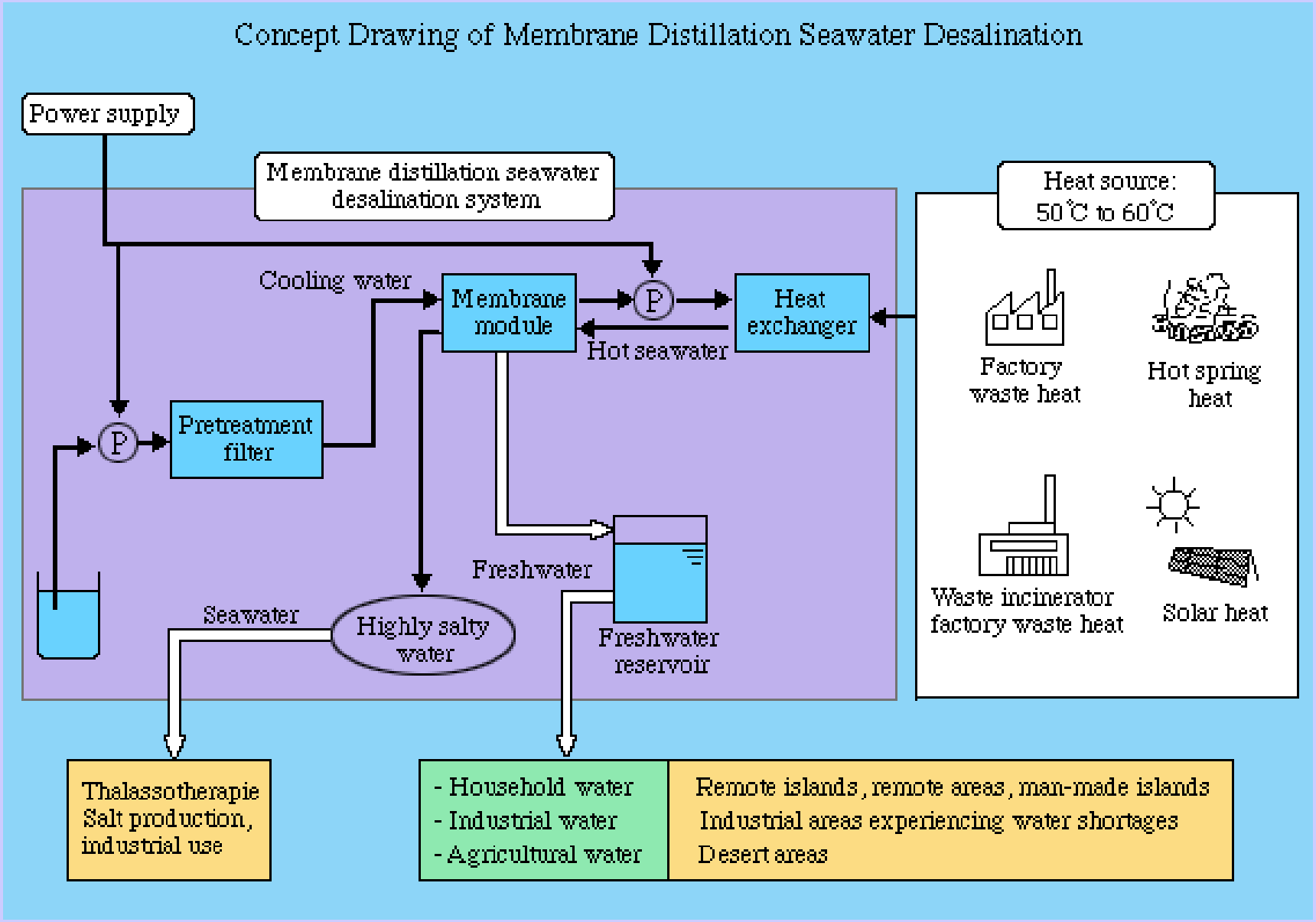
2 types of desalination

1. Distillation = heat to evaporate, cool and collect (requires energy)

2. Reverse Osmosis = force water through filter membranes (requires energy)



http://www.discountreverseosmosis.com/images/A4reosmo.jpg



http://www.takenaka.co.jp/takenaka_e/techno/n02_kaisui/gif/02_04.gif

$850 million seawater desalination plant
Saudi Arabia operates on crude oil

More ways to get freshwater

5. Cloud seeding and towing icebergs
   - Adding things like silver iodide will induce precipitation
   - Both → legal issues and technical difficulties

http://www.athropolis.com/arctic-facts/fact-berg-tow.htm

6. Conservation

- Worlds water consumption
  - 68.3% → agriculture
  - 23.1% → industry
  - 8.6% → domestic and municipal supplies

http://comet.lehman.cuny.edu/keenl/vietnampix/101_0189.JPG

Conservation in agriculture

- Terrace and contour plowing

Using less water in agriculture

- Grow drought resistant crops (fruits, vegetables, flowers require less water than corn, grain)

and

- Decreased meat consumption

http://www.hort.ifas.ufl.edu/pies/control/usse1fa.jpg

Drip irrigation

http://www.waterencyclopedia.com/images/wsci_03_img0398.jpg

Central Pivot sprinklers

http://www.technet.pnl.gov/sensors/physical/projects/images/physical12a.jpg

Soil moisture detector

Tells you when to water

Note: Flood irrigation = least effective → evaporation and salination

http://caticsuf.csufresno.edu/Images/Flood%20Irrigation/73630030.jpg

- Use gray water from sewage treatment plants or digesters for non food crops

Conservation in industry

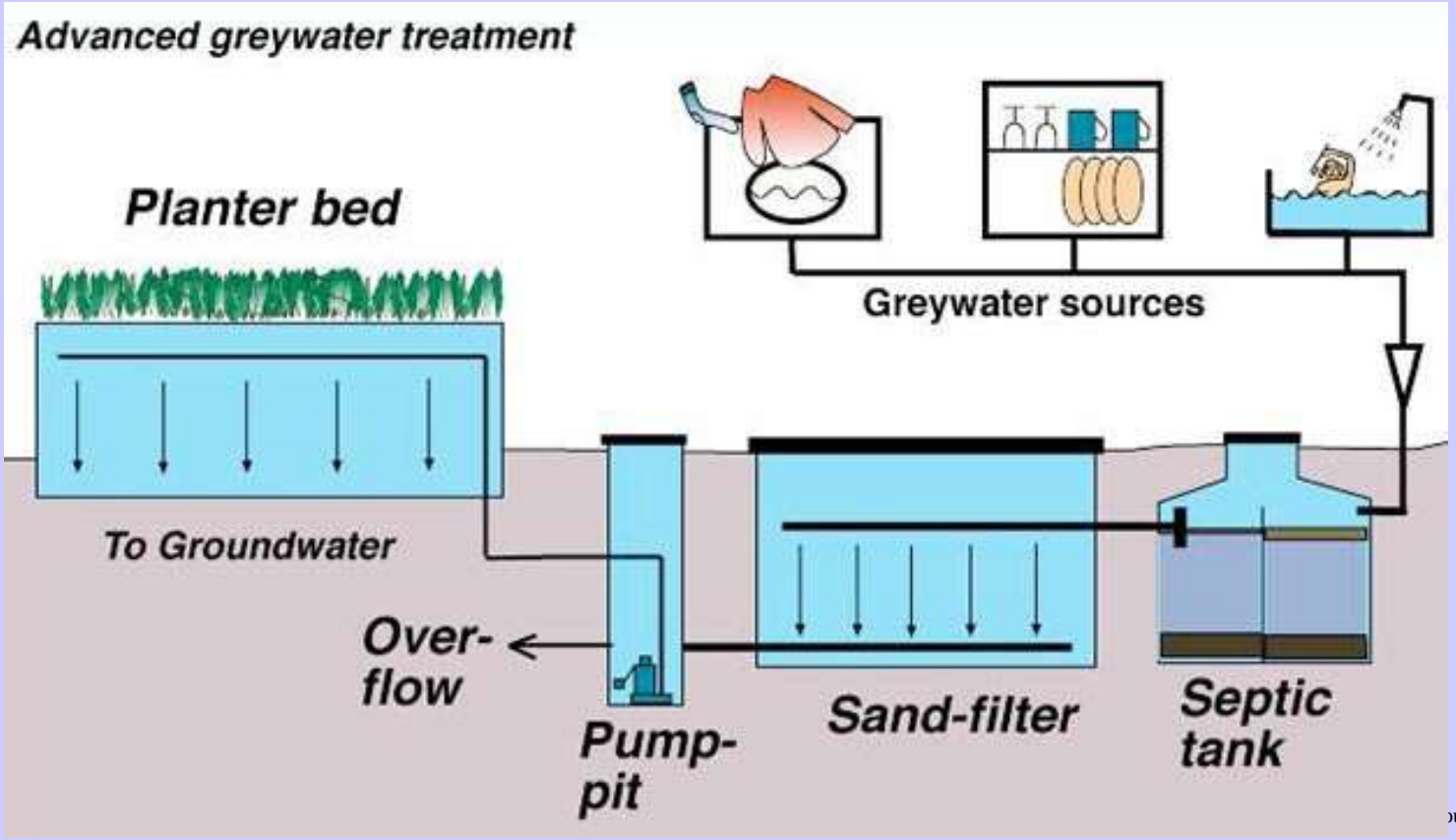
- Redesign manufacturing processes → less water
  - Ex: recycling aluminum = less water than starting with virgin ore (bauxite)
  - Ex: recycle waste water

Conservation in homes and businesses

- Rainwater collection

Conserving homes and business

- Recycling grey water to irrigate landscapes (ex: use water from showers and washing machines)



our.htm

Conservation in homes and businesses

- Zeriscaping = <u>replacing green lawns with drought tolerant native plants and stones</u>

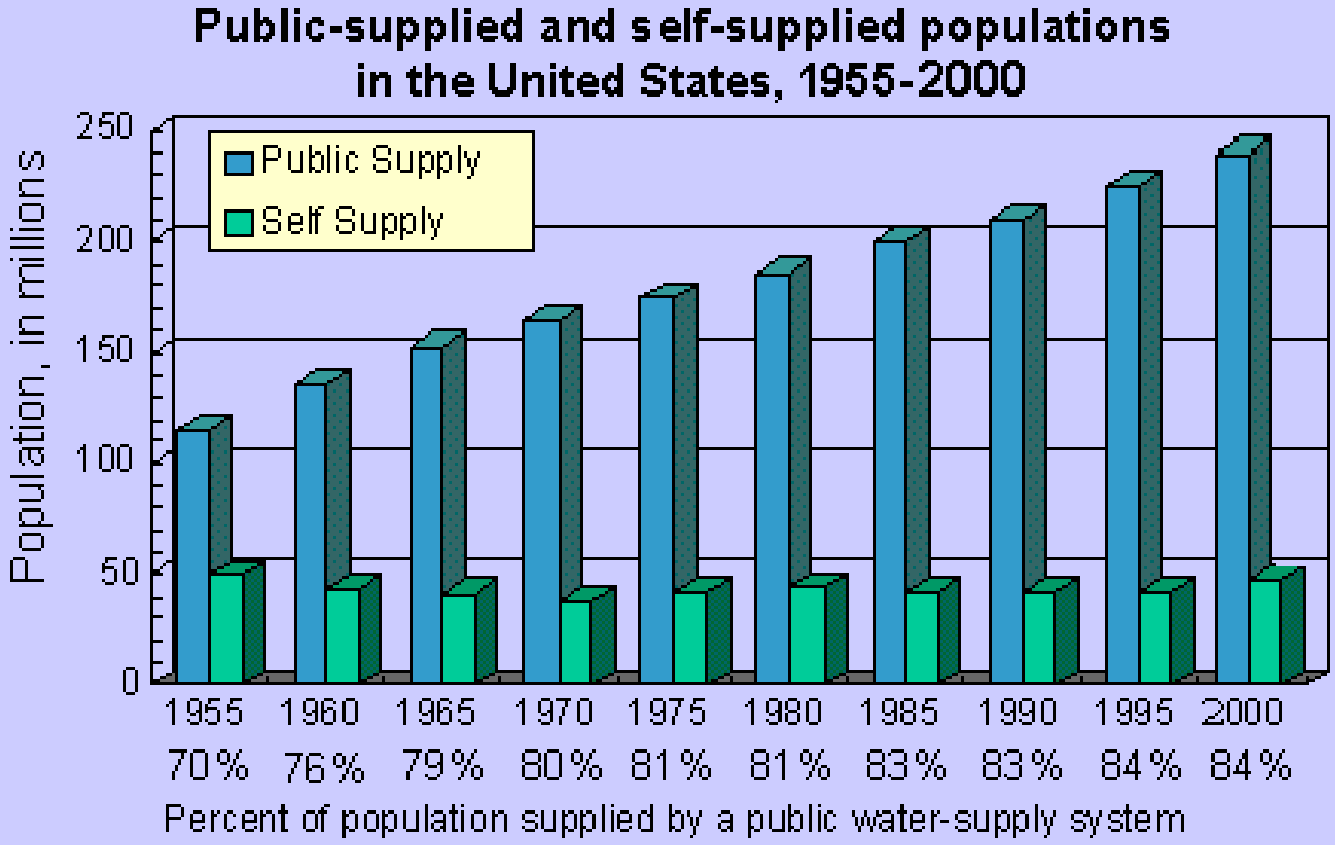
Conserving in industry and home

- Drip irrigation to water gardens and vegetation
- Fixing leaks
- Using water meters and charge for municipal water use

Conserving in industry, home and business

- Low flow toilets and showerheads
  - Before the 90s = 3.5 to 5 gallons
  - Low-flush toilets = 1.6 gallons
  - Energy Policy Act of 1992 (Public Law 102-486) requires that all new toilets produced for home use must operate on 1.6 gallons per flush or less
- Front loading washing machines

Domestic water use



http://ga.water.usgs.gov/edu/wudo.html

US consumption

- In the US each person uses about 80-100 gallons of water per day
- That is about 6 times more than the average person in a developing nation.
- 40% = toilets
- 20% = faucets and showers

Water Pollution

(*physical or chemical changes to water → adverse effects on living organisms*)

2 types of pollution

- Point source = direct (highly regulated by Clean Water Act)

- Nonpoint = runoff (harder to control)

8 Categories of water pollutants

1. Sewage
2. Sediment
3. Inorganic plant and algal nutrients
4. Organic compounds
5. Inorganic compounds
6. Radioactive substances
7. Thermal
8. Disease causing agents

1) Sewage = point source

- Wastewater from homes and businesses
- Contains
  (human waste, soaps, detergents, pathogens, motor oil, sand, sediment, pharmaceuticals…)

What’s in it?

Sewage contains N and P

- Environmental impact =
  - enrichment = eutrophication
- Measure with
  - chemical indicators

The Mississippi dumps~ 1.5 million metric tons of N into the Gulf of Mexico

68% of N = agricultural runoff,
Rest = wastewater plants and urban runoff

http://www.pca.state.mn.us/artwork/mnenvironment/hypoxia.jpg

Sewage contains pathogens

- Environmental impact =
  - disease
- Measure with
  - Fecal colilform test

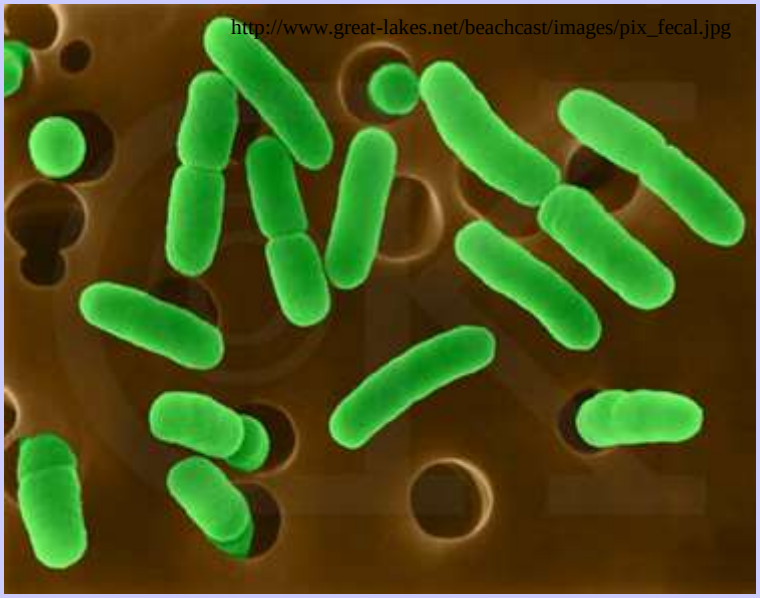
Pathogens → disease

- Disease causing organism in sewage = pathogens
- Cholera
- Dysentery
- Typhoid
- Hepatitis
- Polio
- Parasitic worms (schistosomiasis)

Measure with Fecal coliform test

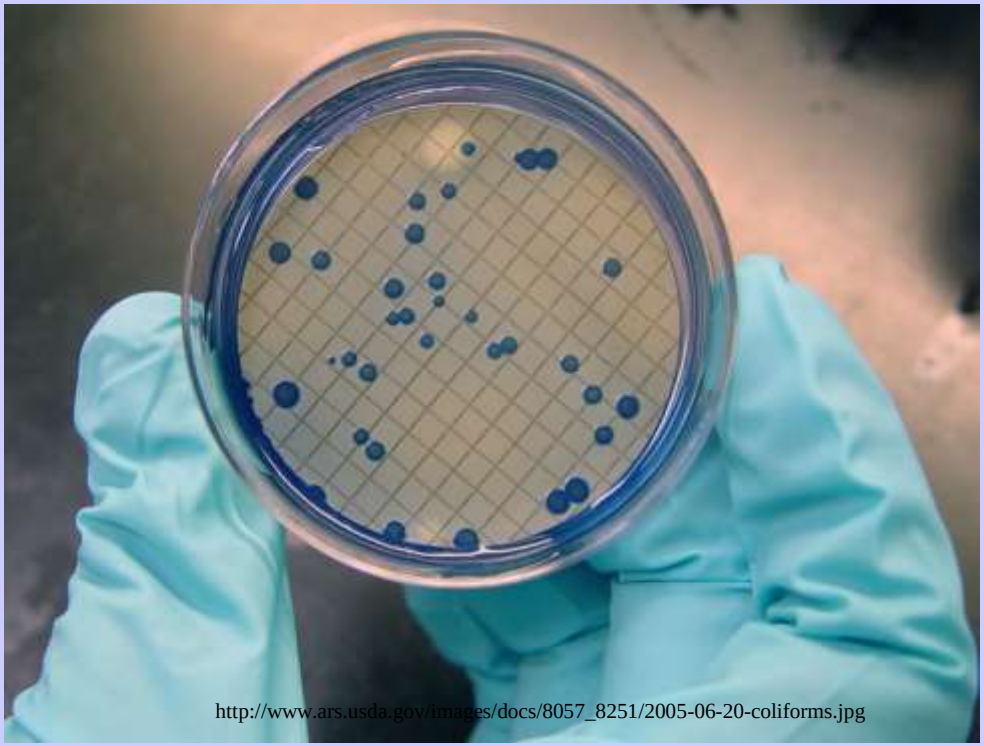
- Pass water through a filter
- Add nutrient solution, incubate.
- Count any E. coli colonies that form.

- Note E.coli is only found in fecal matter therefore it is used as a bio indicator.



Escherichia coli only found in feces

Describe a Fecal Coliform Test

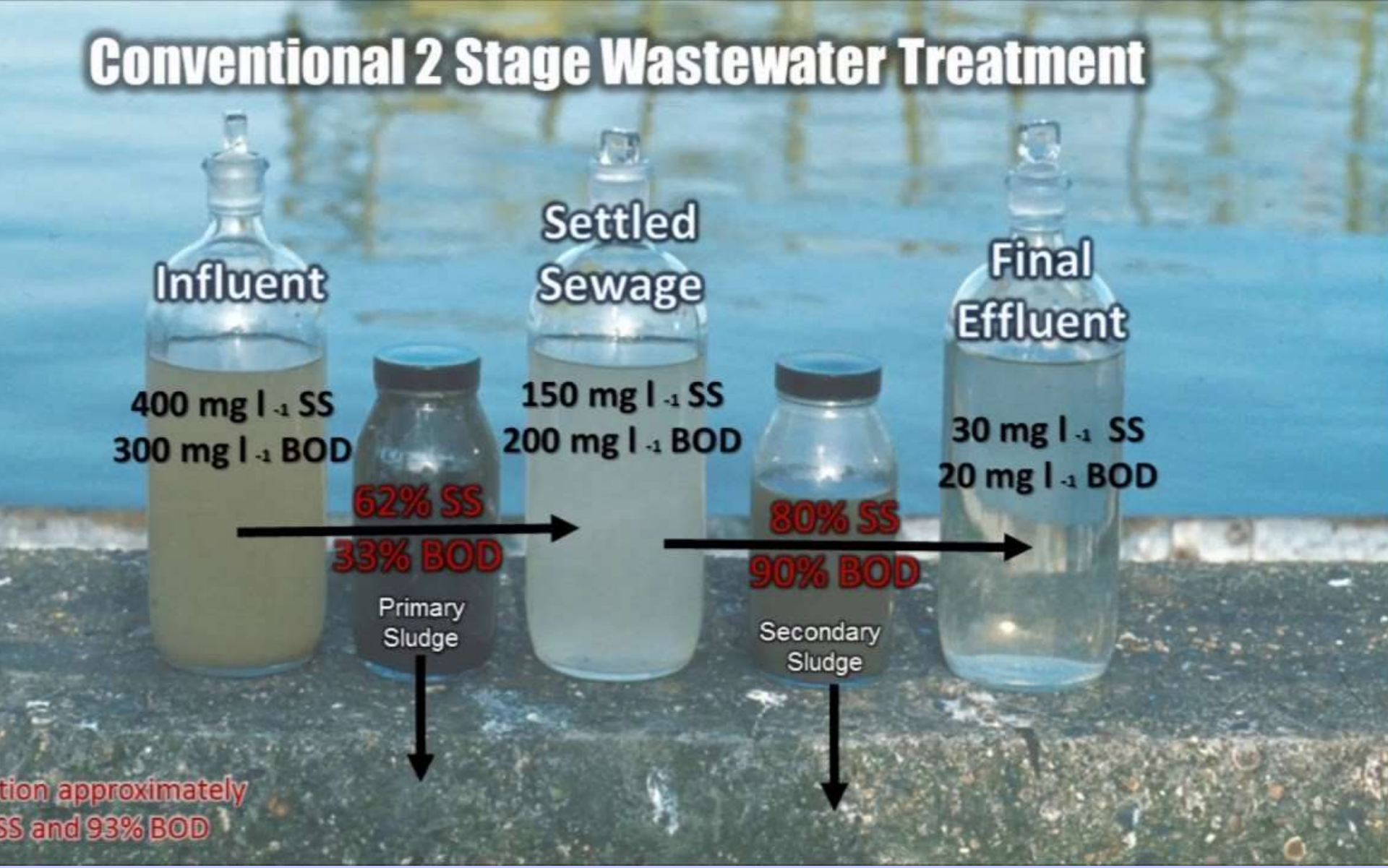


Sewage contains acids

- Environmental impact =
  - Decrease in low tolerant species
  - Increase solubility of heavy metals
- Measure with
  - Bioindicator species
  - pH indicators

Sewage contains organic material (fats, oils…)

- Environmental impact =
  - Increased decomposition →
  - Decrease in dissolved oxygen
- Measure by determining
  - BOD = biological oxygen demand



More sewage = higher BOD

Testing sewage

- BOD = biological oxygen demand
- Fecal coliform test = determine if water has E. coli (bio-indicator of fecal matter)

2. Sediment Pollution increased by

- Sand from urban runoff
- Mining
- Agriculture and overgrazing
- Degraded stream banks (development of riparian zones)

2. Sediment Pollution

- What's in it
- Sand, silt, clay
- Env impact
- Decreased photo and clog fish gills
- How to measure
- Take samples and let it settle out
- Remove by slowing the flow → settling

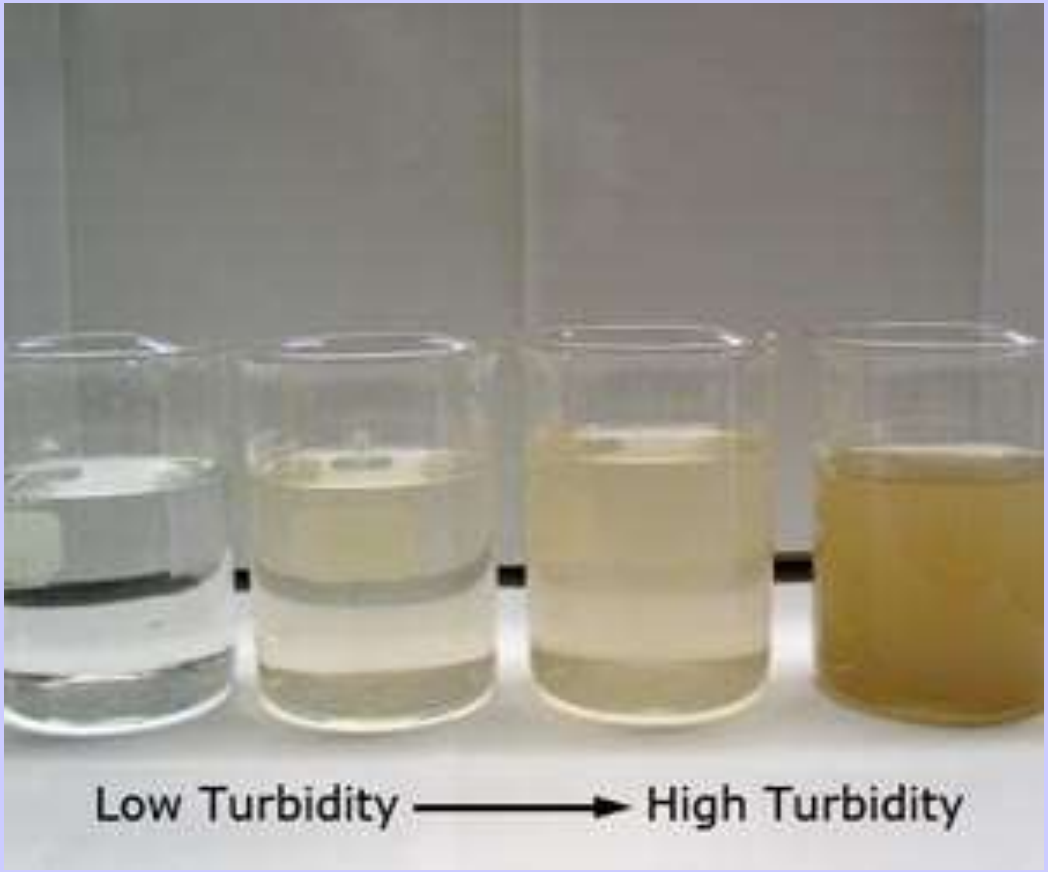
Sediment measured by

- Using secchi disk (measures water clarity)

Sediment

- What's in it
- Heavy metals and toxins
- Env impacts
- Bioaccumulate
- How do we measure it
- Blood testing in organisms

Increase in total suspended solids = measure of turbidity



Sediment pollution increased by

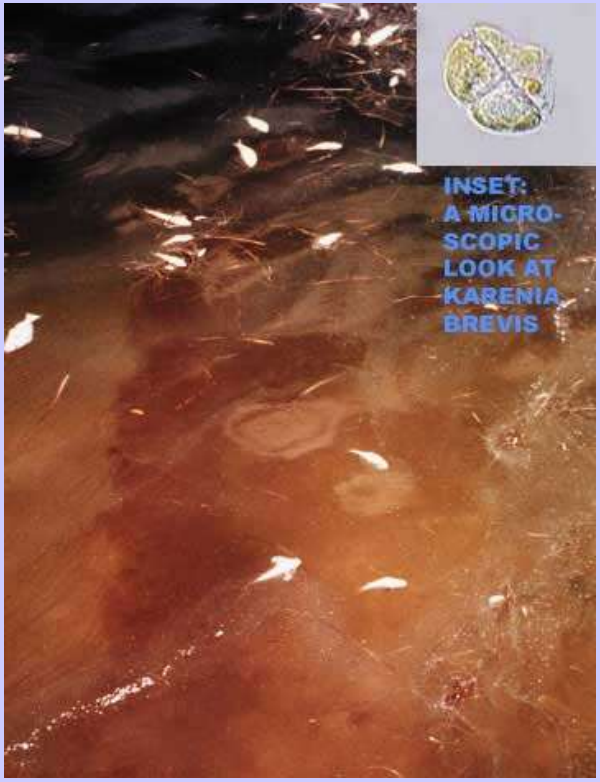
- Heavy rain events
- Loss of plant material

3. Inorganic plant and algal nutrients *(nitrogen, phosphorus,…)*

- Sources
  - Sewage
  - Animal wastes
  - Plant residue
  - Fertilizer runoff
  - Atmospheric pollution
- Essential in moderate doses
- Too much → enrichment and eutrophication

Enrichment → toxic algal blooms

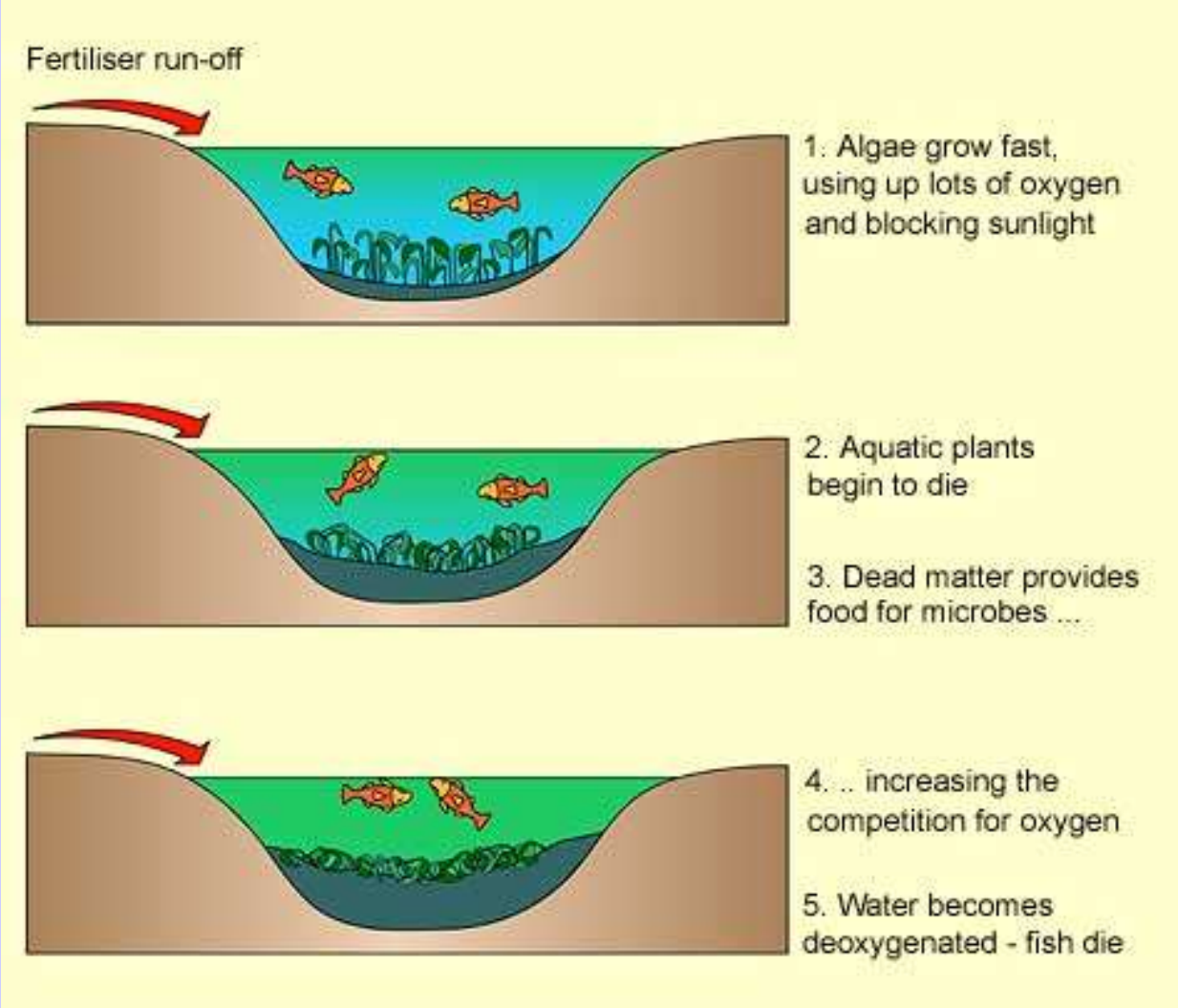
- Ex: red tides are marine algae → neurotoxins that kill fish



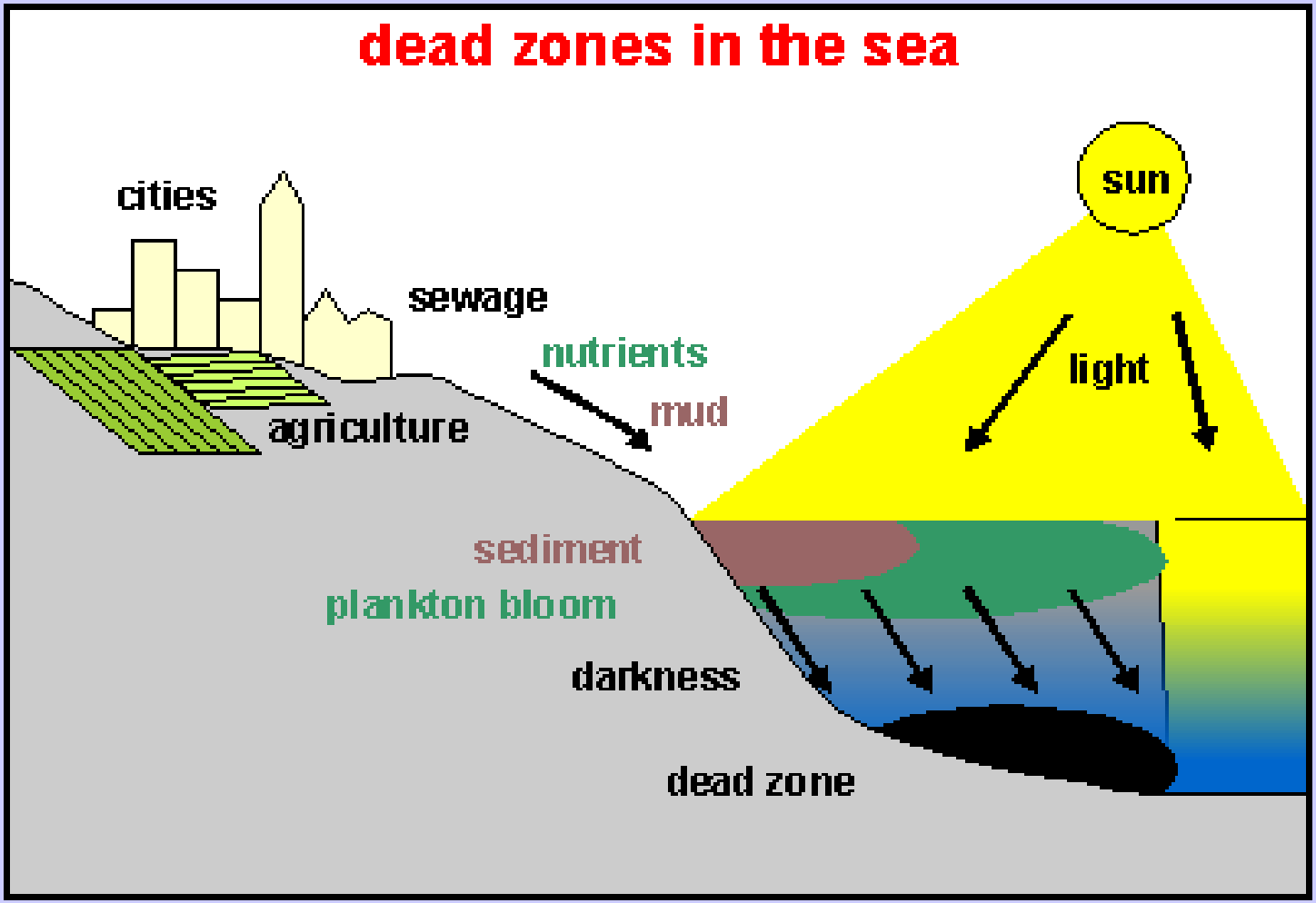
Florida Red Tide Bloom of Karenia Brevis, Karenia Brevis Under a Microscope (inset)
Credit: Woods Hole Oceanographic Instititute/NOAA and NOAA/CHBR

http://earthobservatory.nasa.gov/Newsroom/NasaNews/ReleaseImages/20040831/01_REDTIDE-composite.jpg

Enrichment → <u>High BOD → decreased O_2</u>



http://www.bbc.co.uk/schools/gcsebitesize/img/bieutrophication.jpg



http://www.seafriends.org.nz/issues/cons/cons42.gif

Solutions

- Regulate sewage output of N and P
- Modify farming methods → fewer fertilizers (ex: crop rotation, plant legumes (nitrogen fixing plants) in off season)
- Restore former wetlands (plants absorb N and P)

4. Organic compounds

- Synthetic carbon containing compounds (used in pesticides, solvents, industrial wastes, plastics)
- Examples:
  - Benzene (industry)→ leukemia
  - Dioxins (from herbicides) → cancer
  - Polychlorinated biphenyls (PCB's) (from industry → developmental problems)
- Seep into groundwater from landfills
- Often toxic and bio-accumulate

5. Inorganic Compounds

- Non-carbon containing compounds
- Ex: (salts, acids, heavy metals)
- Not easily degraded (persist in environment)
- Seep into groundwater from industry, mines, irrigation runoff, landfills
- Examples:

Lead

- Natural sources = volcanoes and wind blown dust
- Used in paint until 1978
- Released into atmosphere from burning lead containing gasoline prior to 1986 > soil contamination along roadsides
- Old lead pipes or lead solder of new pipes
- Found in some pesticide and fertilizer residue on produce
- From food cans soldered with lead

Lead poisoning

- Hypertension
- Miscarriages
- Skin rashes
- Mental and physical problems and learning disabilities in children
- Accumulates in bones and can be measured

Mercury

- Can vaporize at room temperature
- Released by coal burning and incinerators
- Found in batteries, paints, and plastics
- Used in fluorescent lights (see CFL EPA article)

Mercury contamination

- Accumulates in muscles of top marine predators (tuna, shark, swordfish)
- Causes
- Neurological problems
- kidney, nervous, and cardiovascular system disorders

6. Radioactive Substances

- Naturally occurring (radon) = produced in the Earth's crust
  - Most is in the air but some is dissolved in water
  - Radon → increased risk of lung cancer
  - Possible long term effects of drinking water contaminated with radon over time

Manmade sources of radioactive substances

- Can seep into groundwater from
  - Mining and processing of radioactive minerals (ex: uranium and thorium)
  - Nuclear waste facilities
    - Power plants
    - Nuclear weapons industry
    - Medical and research facilities

Radioisotopes in Japan's water supply

- Ei Yoshida, head of water purification for the Tokyo water department
  - " I^{131} had been detected in water samples at a level of 210 bq/L. The recommended limit for infants is 100 bq/L"

Iodine - 131

- 8 day half life
- Linked to thyroid cancer
- Ex: Contaminated milk near Chernobyl → 6,000 cases of thyroid cancer

7. **Thermal Pollution** (heat)

- Many industries use water as a coolant
- Heated is allowed to cool a little before returning to waterways but often still warmer
  - Chemical effects =
    - Dissolves more minerals
    - Speeds up decomposition → O_2 depletion
  - Biological effects =
    - Speed up metabolism (fish need more food to survive)
    - Affects reproductive, digestive, and respiration rates

8. Disease causing organisms

(pathogens)

- Viruses, bacteria, protozoa, and worms can act as pathogens (disease causing organisms) and parasites (organisms that live on or off of another organism)

8) Disease causing organisms (pathogens)

Bacterial	**Viral**	**Other**
Cholera → diarrhea, cramps	Hepatitis → liver problems	Amoebic dysentery (protozoan)
Dysentery → diarrhea, bloody stools and pain	Polio → paralysis	Schistosomiasis (fluke)
Typhoid → headache, fever, sometimes hemorrhaging		Giardia (protozoan) → "beaver fever"

Solution

- UV radiation
- Add ozone to water
  - (remember ozone in troposphere = toxic, in stratosphere = protection from UV rays)
- Add Chlorine (bleach)

3 Major sources of surface water pollution

1. Agriculture → 72%
2. Municipal water pollution (highly regulated under Clean Water Act)
3. Industrial wastes (highly regulated under Clean Water Act)

Agricultural pollution

- Fertilizers
  - enrichment
  - nitrates in drinking water → nitrites which reduce ability to carry O_2 → blue baby syndrome problem in well water in some rural areas
- Animal wastes and plant residues
  - Enrichment
  - High BOD
  - pathogens

Agriculture

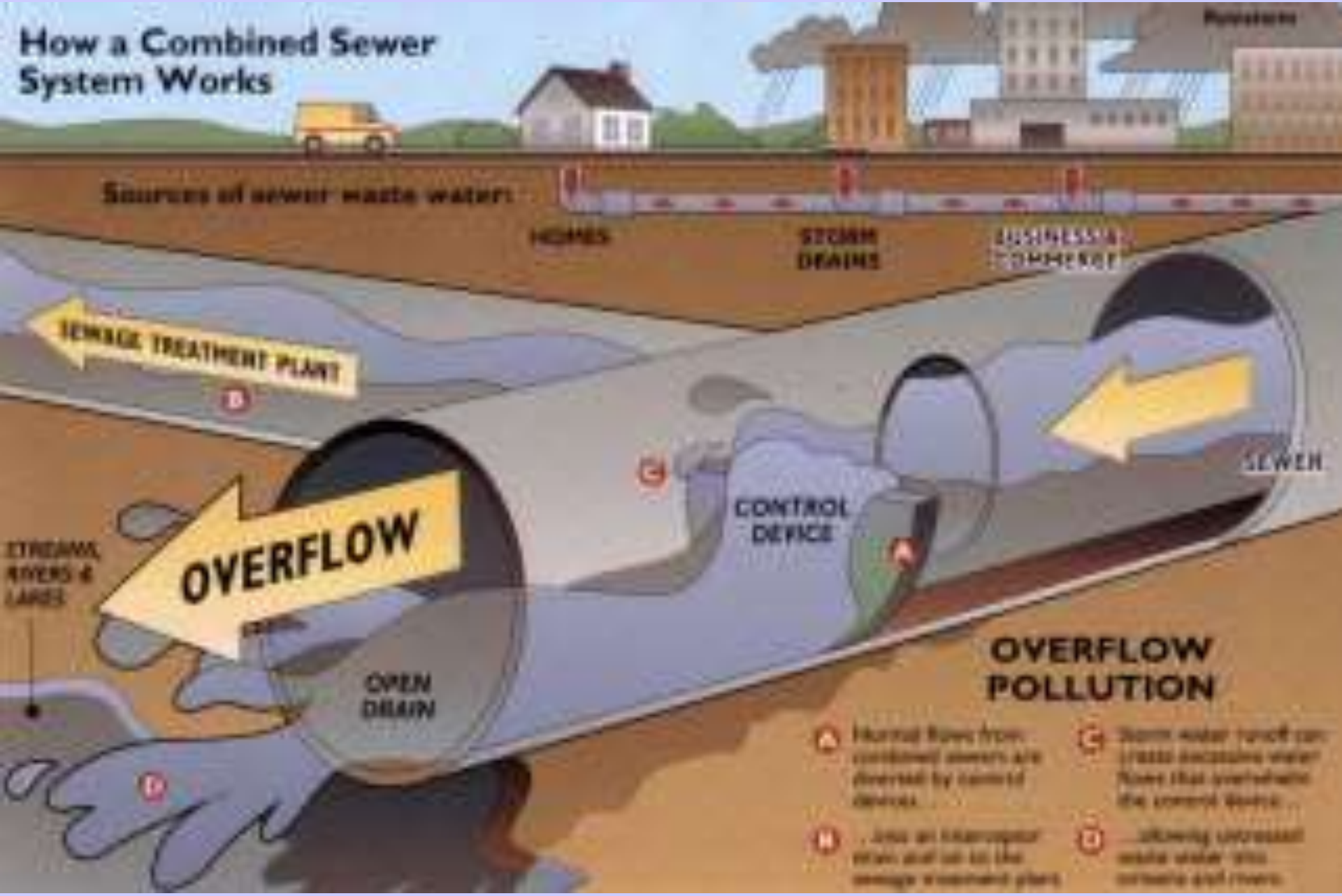
- Toxic pesticides and herbicides
  - Can contain endocrine disruptors (reproductive problems)
  - Dioxins → linked to cancer
  - Trace metals (lead, mercury, arsenic)

- Increased sediment from soil erosion
  - can be minimized by soil conservation methods

Municipal water pollution

- Combined sewer system = human and industrial wastes are mixed with urban runoff before going to sewage treatment plant →

- Combined sewer overflow = excess water from spring runoff and heavy rains often flows directly into a body of water without being treated (Note: this is illegal under the Clean Water Act of 1972)


How a Combined Sewer System Works
Sources of sewer waste water:
HOMES
STORM DRAINS
SEWAGE TREATMENT PLANT
SEWER
CONTROL DEVICE
OVERFLOW
OPEN DRAIN
OVERFLOW POLLUTION

Communities with combined sewage overflow systems

- ~ 860 communities in US / 40 mil people
- Most in the Northeast and Great Lakes regions
- Most have populations < 10,000
- Some large cities like New York, Philadelphia, and Atlanta

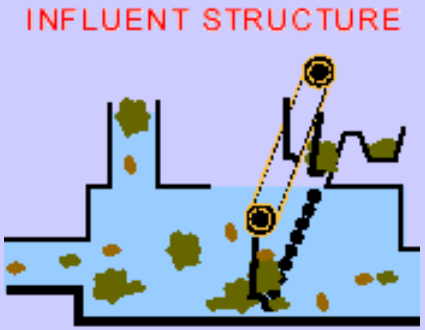
Sewage treatment plants

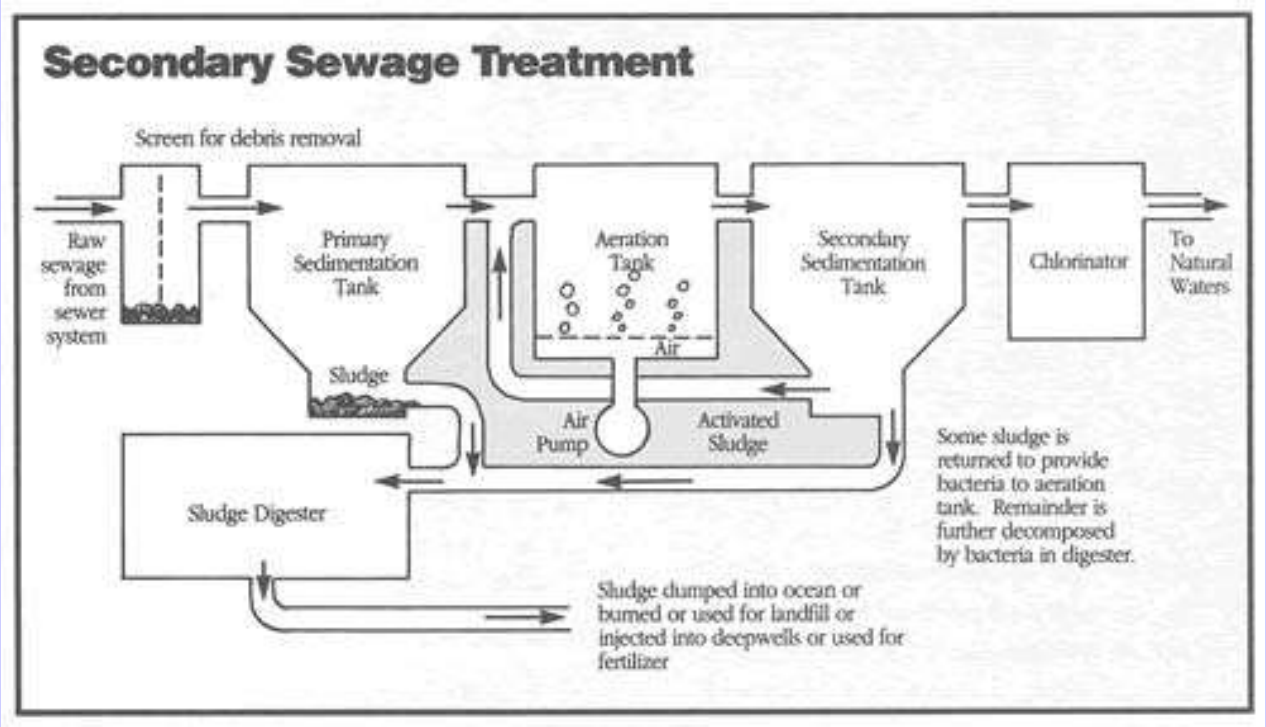
Preliminary treatment

Primary treatment =

- physical separation of solids using screens and settling tanks→ primary sludge (sludge = solid matter)

Primary = physical separation of solids from liquids (screens and settling tanks)





http://www.filtronics.com/images/secondary_sewage_chart.jpg

http://www.city.palo-alto.ca.us/depts/pubworks/waterquality/images/tour/anim/primary/influentstructure.gif

- Secondary Treatment = biological treatment= use bacteria to breakdown organic matter

Ex: aeration tank

Secondary treatment included aerating

- Aeration tanks or trickle systems

http://ec.dupageco.org/publicworks/images/06_AerationTank.jpg

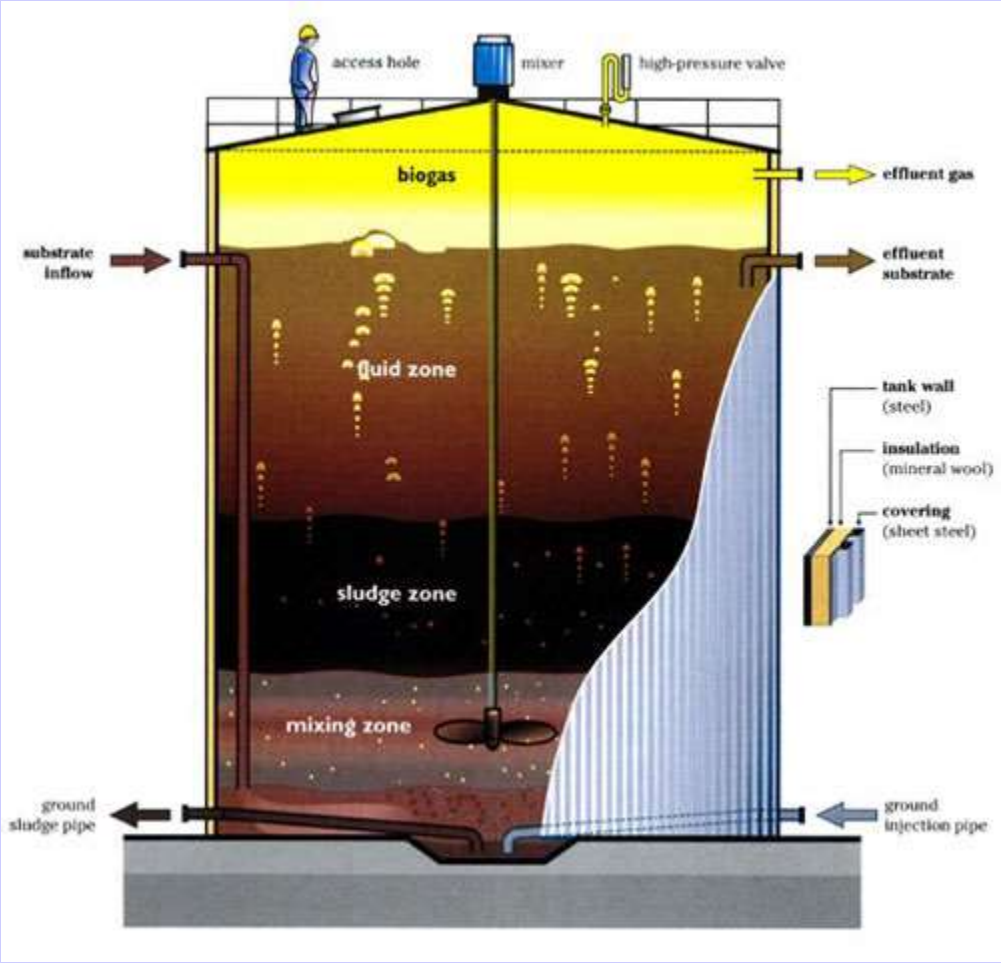
http://www.lifesciences.napier.ac.uk/aem/smaefiles/wlinton-broughton/bacteriabed.jpg

Sewage treatment plant

- Secondary treatment involves creating perfect environment for aerobic decomposers (right temperatures and aerate by adding oxygen) Ex:
  - Pump air into the tank
  - Have water trickle over a bed of rocks to aerate
- Treated water then moves to a secondary settling tank where secondary sludge settles out and is removed

Secondary treatment is followed by secondary settling tanks

Sludge can go to an anaerobic digester



Sludge = Biosolids

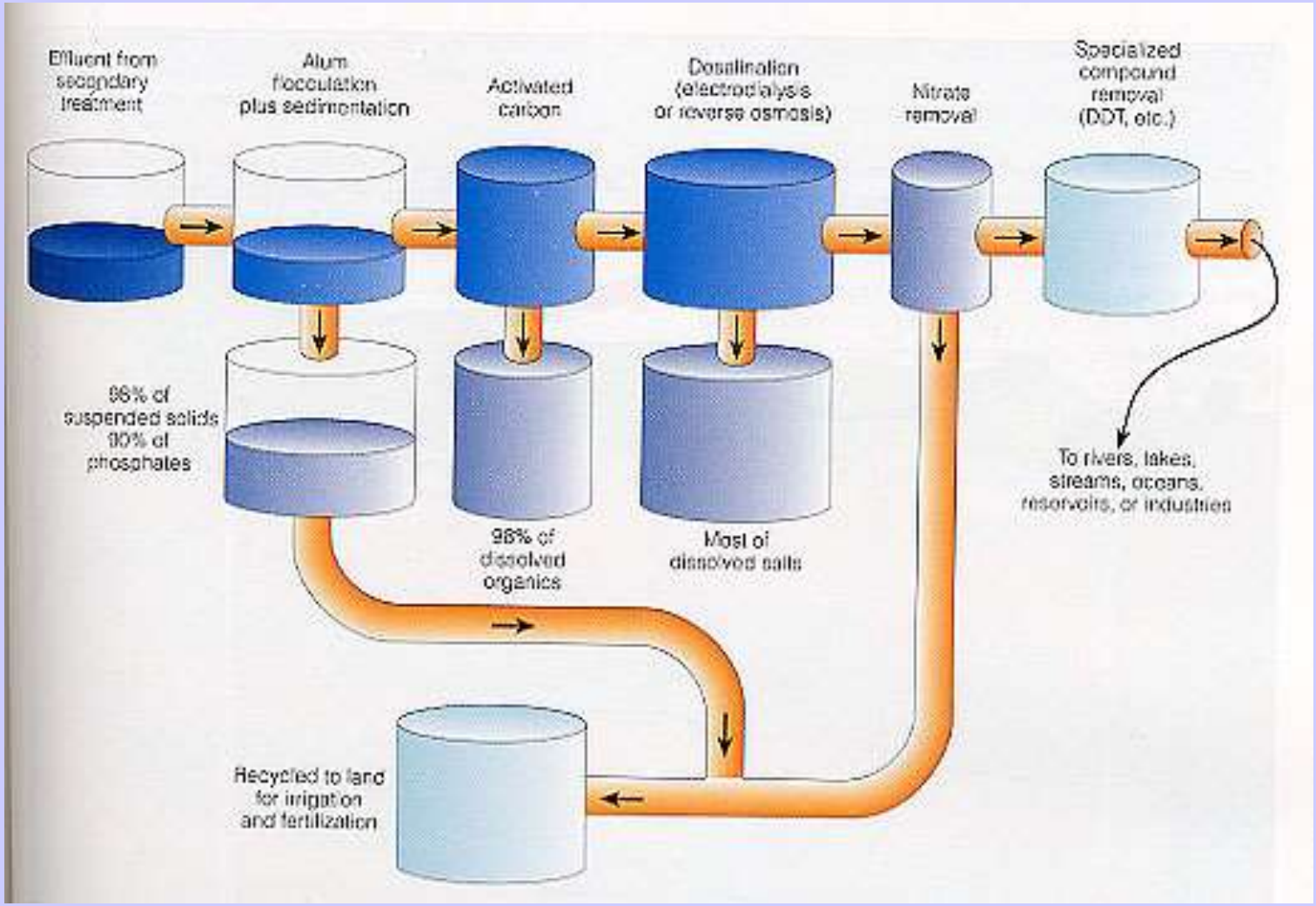
- Solids are removed along the way and sent to anaerobic digester or landfill
  - Anaerobic bacteria = require little to no oxygen, produce gases (including methane)
  - Gases can be burned → energy
- Can be used as fertilizer
  - As long as it is produced using temps high enough to kill pathogens
  - May contain heavy metals if industrial wastes were added to the system

Tertiary treatment

- Chemical treatment (to remove nitrogen and phosphorus containing compounds and to purify)
  - Ex: add alum to remove phosphorus (Note: Most cost effective ways to deal with nitrogen and phosphorous = irrigate golf courses or fields or plant wetlands to absorb nutrients)

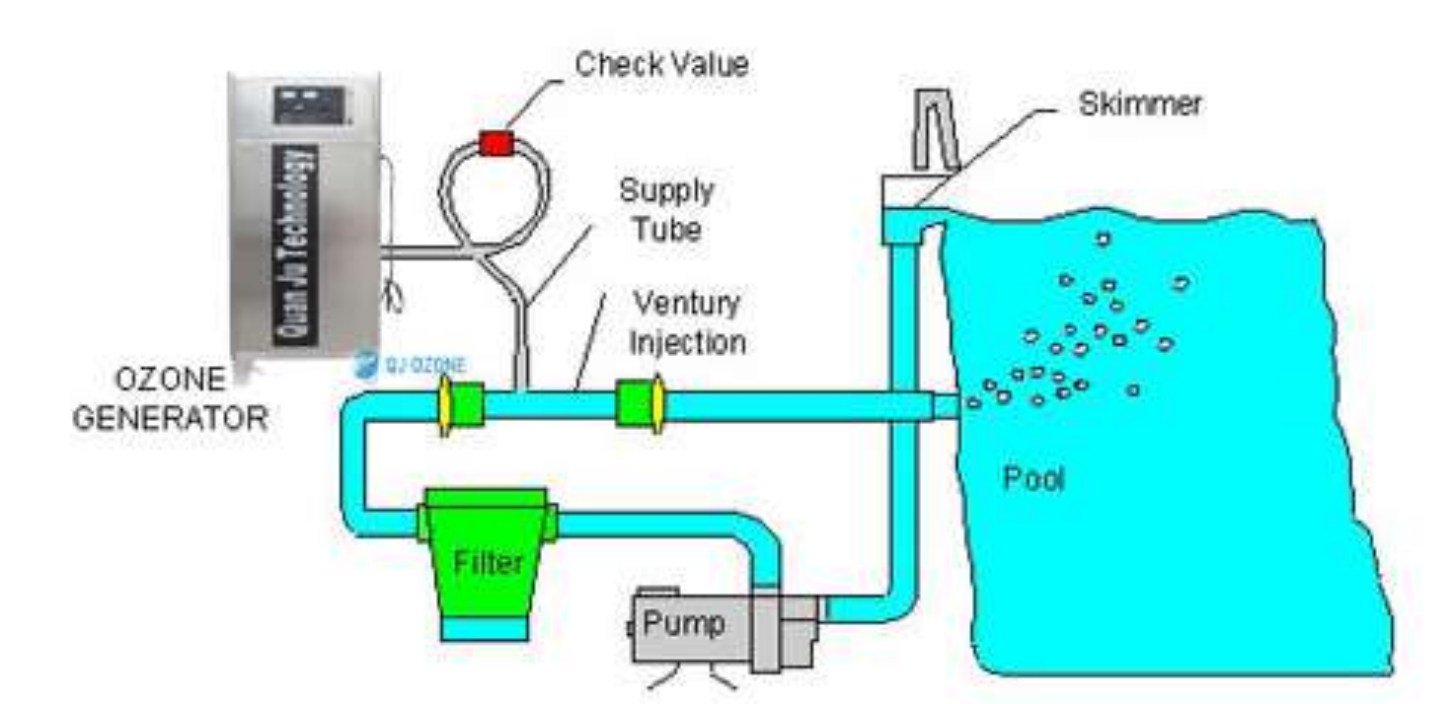
- Purification = killing bacteria (several ways:
  - Chlorine
  - UV radiation
  - ozone

Examples of Tertiary treatment



http://www.tarleton.edu/~biology/tertiarytreat.jpg

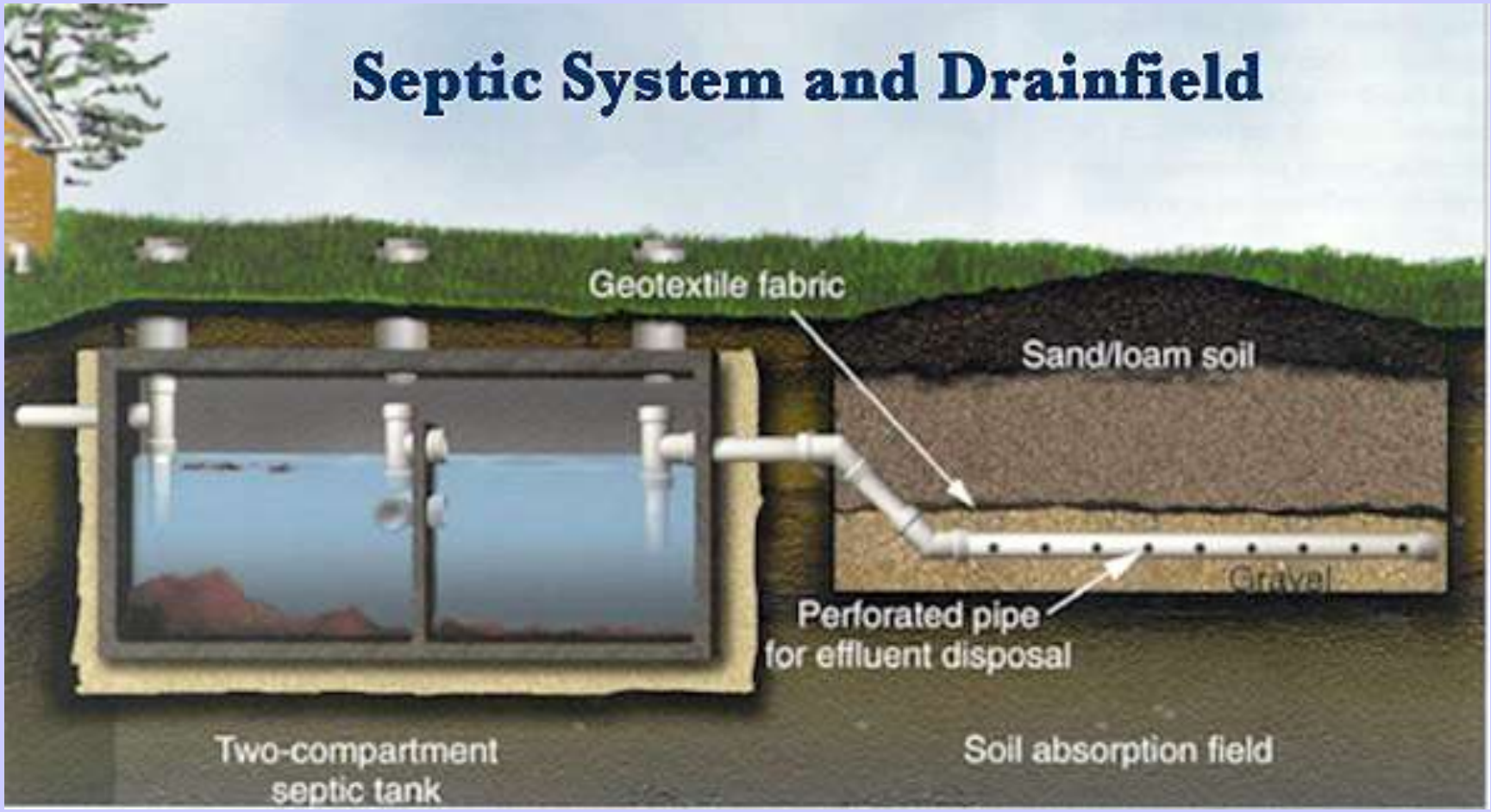
Ozone treatment



UV treatment

Septic systems

- Where municipal treatment is not available household sewage is piped into septic tanks
- Grease and oils → scummy layer (decomposed by bacteria)
- Wastewater flows to drainage field (perforated pipes surrounded by crushed stone → aerobic decomposition)


Septic System and Drainfield
Geotextile fabric
Sand/loam soil
Gravel
Perforated pipe
for effluent disposal
Two-compartment
septic tank
Soil absorption field

3. **Industrial Wastes** *(highly regulated in US)*

- Food processing industries > organic wastes (high BOD and enrichment)
- Pulp and paper industry > toxic compounds, bleaches, inks, and sludge
- Electronics industries > metals (Cu, Pb, Mn…) PCB's, inorganic solvents
- Mining > acids, toxic metals, lots of sediment

Drinking water

- Chlorination (chlorine) added to most municipal water supplies
  - Pros: decrease in water borne diseases
  - Cons: may be linked to other problems (possible rectal, pancreatic and bladder carcinogen)(increased risk of miscarriages and rare birth defects)
  - 1994 EPA suggests that water treatment facilities reduce Cl levels in drinking water
    - Replace with UV light, activated carbon filtration (both more expensive)

Drinking water

- Fluoridation (adding fluoride to prevent tooth decay) (began in mid 1940's)
  - Pros =
  - may help prevent tooth decay
  - Cons =
  - might not prevent tooth decay (dose received may be too low to be effective)
  - Cause fluorosis = yellow teeth.
  - Fluoride is found in toothpastes and mouth rinses.

Pollution of Groundwater

- Seeps in from landfills, underground storage tanks, and agricultural operations
- Currently most US groundwater supplies are good
- Because cleanup is so difficult it is important to avoid the problem in the first place

Water Pollution Laws

1. Clean Water Act of 1972
   - EPA monitors national emission limitations on point sources such as
     - Sewage treatment plants
     - Factories
   - Requires discharge permits from all point sources
   - Includes provisions to reduce polluted runoff from urban areas and animal feeding operations
   - Establishes best managements practices to reduce pollution and best management plans to fix polluted waters
   - funding → improvements, education and training

Water pollution laws

2. 1974 Safe Drinking Water Act → EPA determines maximum contaminant levels of pollutants
   - 1996 > Municipal water suppliers must tell consumers about the levels and risks of any pollutants in their water

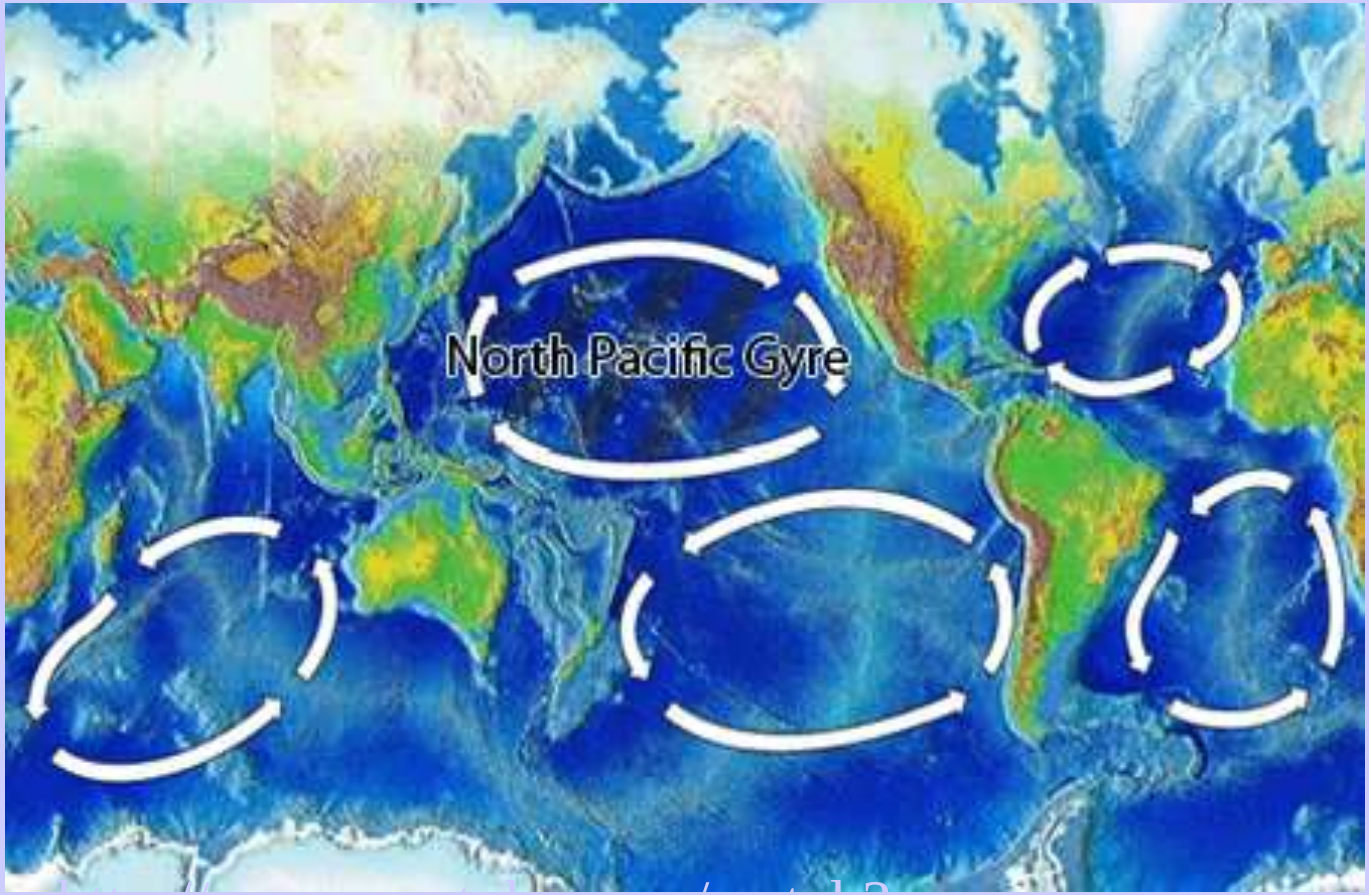
Plastics in the ocean

Plastics =
- petroleum based polymers containing many toxins (ex: phthalates and BPA = endocrine disruptors)

http://beachcare.org/_img/pollution/plastic/Boat-sea-plastic-krichim.jpg

North Pacific Gyre

aka Pacific Trash Vortex



Water pollution laws

3. Resource, Conservation, and Recovery Act
    3. Deals with storage and disposal of hazardous wastes and helps protect groundwater
4. 1988 Ocean Dumping Ban Act
    – Prevents dumping of garbage, sewage sludge, and industrial waste in the ocean. (as a result NYC sludge usually ends up in landfills)

Fixing contamination

- Phytoremediation = use plants to absorb pollutants
- Bioremediation = use bacteria
- Disinfection (chemical, UV, ozone)
- Dredging (can clean sediment)
- Filtering (ex: reverse osmosis = desalinate)
- Distilling

Problems and solutions

- https://www.youtube.com/watch?v=VIaw5mCjHPI

Congratulations you are now Water Wise!!

Did you know that 80% of your brain is water! The follow up saying is “use your water wisely”