Algae

Taste and Odor

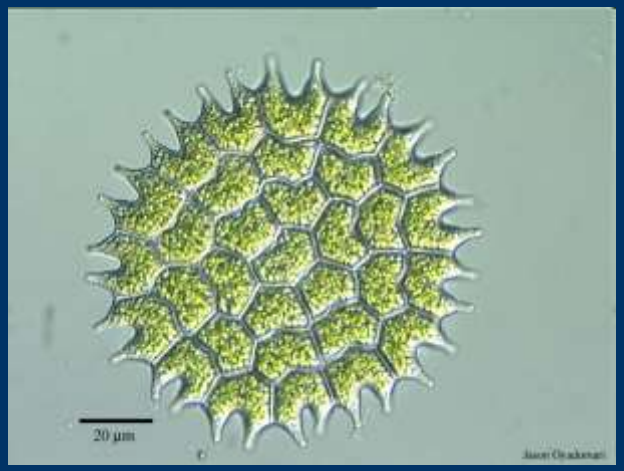
- **Dirty or Musty**
  - Geosmin and MIB (2-methylisoborneol)
  - blue-green algae, actinomycetes
- **Fishy, Cod liver Oil**
  - Chrysophyta, Pyrrhophyta
- **Septic Odor**
  - Pryyhophyta
- **Cucumber Odor**
  - Chrysophyta

Algal Toxins

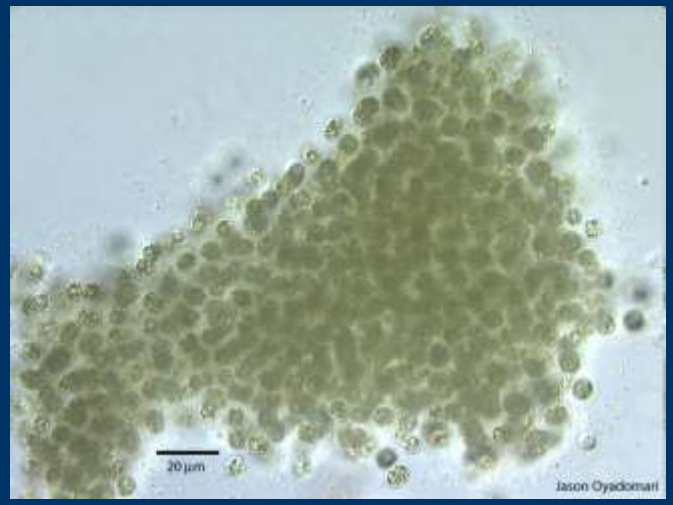
- **Anatoxin** (e.g. Anabaena)
  - Staggering, paralysis, gasping, convulsions, death
  - 200 µg/kg LD_{50}
- **Microcystin** (e.g. Anabaena, Microcystis, Oscillatoria)
  - Jaundice, shock, abdominal pain/distention. Weakness, nausea, vomiting, severe thirst, rapid/weak pulse, death
  - 300-600 µg/kg LD_{50}
- **Saxitoxin/Neosaxitoxin** (e.g. Anaphnizomenon)
  - Weakness, staggering, loss of muscle coordination, difficulty in swallowing, labored respiration, muscle paralysis, death, tingling around mouth or fingertips, slurred speech
  - 9 µg/kg LD_{50}
- **Hepatotoxin** (e.g. Gleotrichia)
  - Jaundice, abdominal pain/distention, weakness, nausea/vomiting
- **Cytotoxin** (e.g. Gleotrichia)
  - Skin irritation, gastrointestinal upset

Algae Divisions

- **Chlorophyta** (green algae)
  - Least harmful, generally considered benefical
  - Growth in reservoirs; mild taste and odor; some filamentous mat formers



- **Cyanophyta** (blue-green algae)
  - Prokayotes
  - Most significant concerns for water quality
  - Taste and odor problems; filter cloggers; oxygen depletion; toxicity



Images from http://www.keweenawalgae.mtu.edu

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***Chlamydomonas* sp.** (Chlorophyta, Green Algae)—Consist of spherical, ellipsoid, or ovoid cells, sometimes with one or two apical papillae, from which two flagella arise. Often it is found with a narrow or wide mucilaginous sheath. The chloroplast is a dense padded body that occupies the entire cell. The cell may contain 1 to many pyrenoids, which may be basal, or bilateral and scattered. Species of this genus have a habit of coming to rest, losing their flagella, and entering upon a quiescent phase. Vegetative cell division continues, ordinarily accompanied by the secretion of a mucilage, so that amorphous gelatinous masses are formed which contain many non-motile cells. This is known as the palmella stage. *Chlamydomonas* sp. Is capable of producing taste and odor in moderate concentrations. In large concentration, the odor may be fishy, medicinal, or septic. This alga is an indicator of fresh water pollution, and also sewage ponds.

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***Closterium* sp.** (Chlorophyta/Green Algae)- Cells are crescent shaped, variously bowed, but in some species nearly straight, without apical spines There is one axial chloroplast per semi cell, each with longitudinal ridges. Each cell may have few to many pyrenoids, which can be axial or scattered. The cells are either colorless or greenish brown. There is a terminal vacuole at the end of each cell (Prescott 1982). ***Closterium* sp** will produce a grassy odor in large quantities. The critical concentration for odor production is 20,000 cells/100 mls (AWWARF 1982).

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Isolated from the Coagulation Basin

***Cosmarium* sp.** (green)—There are thousands of species of this genera of algae, more than any other genera in the green algae (Prescott 1982). ***Cosmarium* sp.** will have two similar halves. Will produce a grassy odor in large concentration.

Cladophora glomerata

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Cladophora sp. *(*Chlorophyta/Green Algae)—Is a very common algae found in polluted streams and rivers. It is an attached algae, but in some species the adults can become free-floating. It forms feathery tufts on substrates. The branches are smaller than the main axis, or at least tapering slightly toward the apices. The cells are cylindrical or swollen with thick cell walls are lamellate in most places. Occasionally the walls are thin and firm. The chloroplast is a parietal reticulum, which sometimes becomes fragmented and appears as numerous discs. Pyrenoids are present. Species in this genus are indicators of high pH and are generally found in hard or semi-hard water.

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Isolated from Limnoecha- an eutrophic lake in Ecuador

Isolated from the Ohio River

Anabaena sp. (blue-green/cyanobacteria)-A few species of this genus are planktonic; others are epiphytic, or form gelatinous masses. Among the planktonic forms several are coiled (Prescott 1982). Some of the planktonic species are capable of producing lethal microcystin toxins in large concentrations. Anabaena sp. will produce a grassy, musty, or nasturium odor at moderate concentrations. A rotten, septic, or medicinal odor is possible with large concentrations. Critical concentration for odor production is 530,000 cells/100 ml. (AWWARF 1987)

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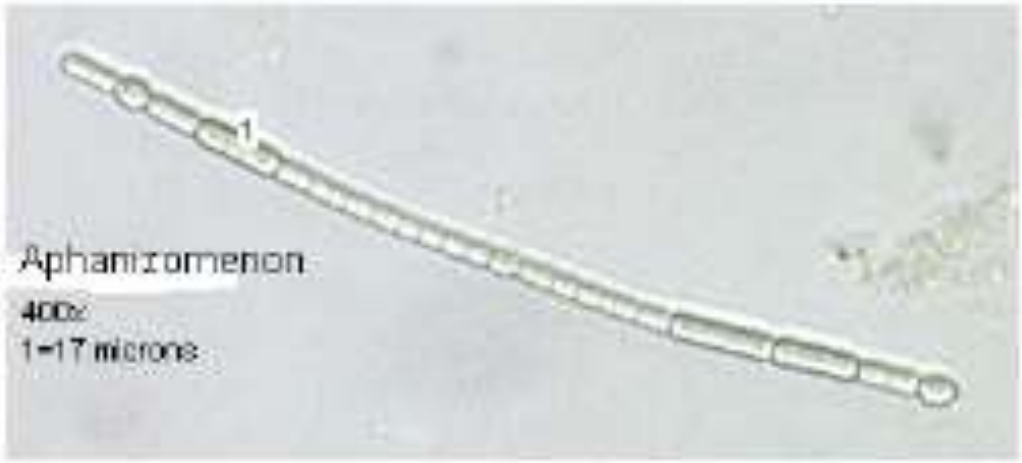
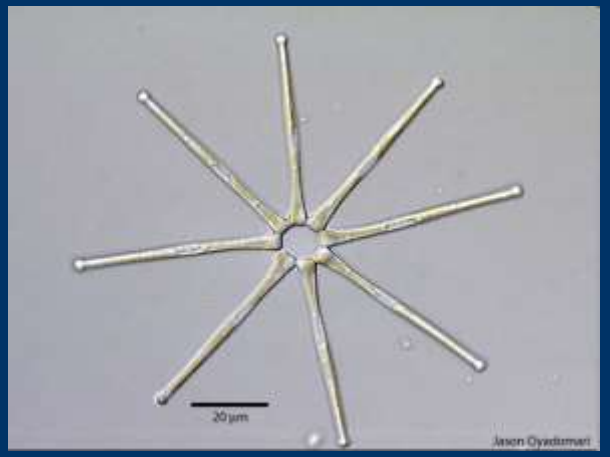


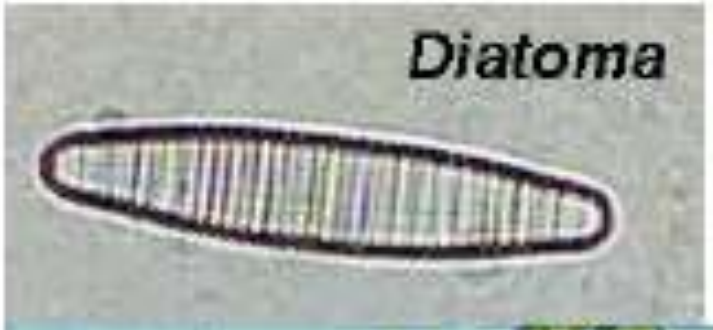
Isolated from the Ohio River

Aphanizomenon sp. (blue-green/cyanobacteria)-Species of this genus have trichomes that often lie parallel in bundles. The cells are short cylindrical or barrel-shaped and are the same diameter throughout except at the apices. Each trichome contains 1 heterocysts and one akinete (Prescott 1982). This spiecies is capable of producing taste and odor problems. Will produce a grassy, musty, or nasturium odor at moderate concentrations. A rotten, septic, or medicinal odor is possible with large concentrations. Critical concentration for odor production is 660,000 cells/100 ml or 20,000 colonies/100mls (AWWARF 1987). Microcystin toxins are also possible with this genera.

Algae Divisions

- **Ochrophyta (Chromophyta)**
  - **Chrysophyaceae** (Yellow-Green/Golden-Brown Algae)
    - Taste and odor problems; reservoir growth; filter cloggers
    - Frustules used for filtration
  - Bacillariophyaceae
    - Diatoms
- **Dinophyta (Pyrrhophyta, Dinozoa)**
  - Dinoflagellates
  - Taste and odor problems
  - Red tide problems





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Diatoma sp. (Diatom)—Frustules form zig-zag colonies that can be confused with *Tabellaria* when seen in girdle view. They are more common in running waters (rivers and streams) that in lakes or ponds.

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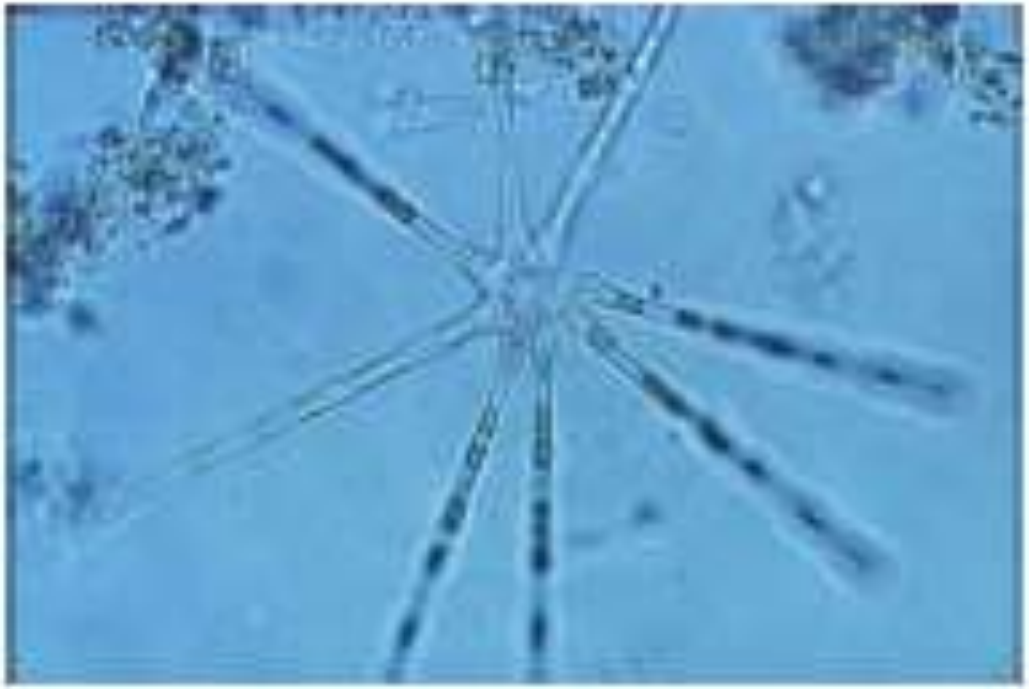
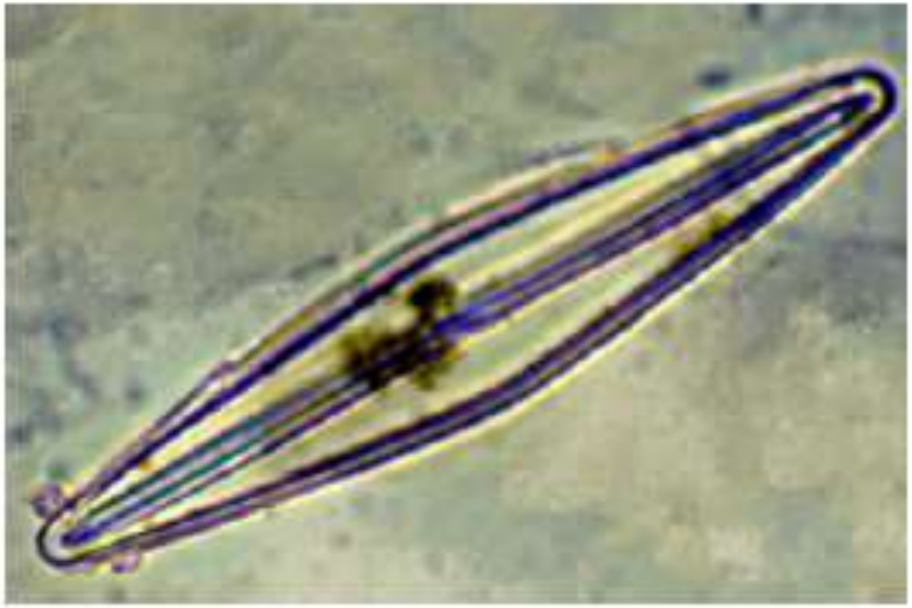
***Fragilaria* sp.** (diatom)—Frustules quadrate or rectangular in girdle view, attached side by side to form ribbons (rarely in chains); valve view fusiform, the poles narrowed from enlarged central region (Prescott 1982). May produce a grassy, spicy, or geranium odor in moderate quantities and a musty odor in large concentrations.



***Asterionella* sp.** (diatom)—Species of this genus are generally planktonic, often very abundant, and are readily identified by the spoke-like arrangement of the rectangular frustules about a common center. Some species may form a bloom in favorable habitats and are often involved in water spoilage. The common species are usually found in hard water lakes (Prescott 1982). May produce a spicy geranium odor in moderate concentrations and a fishy odor in large concentrations. Critical concentration for odor production is 100,000 cells/100 ml (AWWARF 1987).



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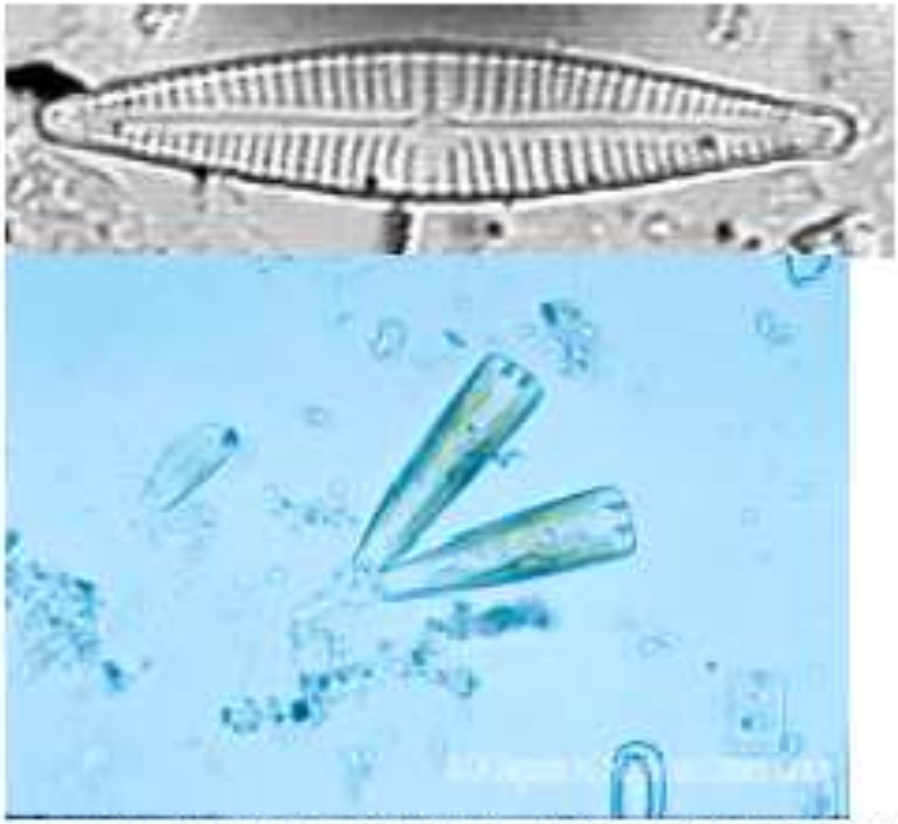
***Frustulia* sp.** Cells single, with raphe on both valves, usually rhomboidal or lanceolate, with straight to undulate margins. Raphe contained in a median rib extending most of the length of the valve. At the apices, the raphe rib has the appearance of a pencil tip. Striae are fine. ***Frustulia* sp.** seems to prefer oligotrophic to somewhat dystrophic waters with low to neutral pH.



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***Gomphonema* sp.** (diatom)—This epiphytic diatom is asymmetrical on the transverse axis. The striae are composed of puncta in a single series. The central striae usually ends with one isolated puncta. It is frequently attached on branched stalks (Prescott 1982).

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***Ceratium* sp.** (Dinoflagellate). This is one of the most common freshwater dinoflagellates and frequently—occurs as dominant phytoplankter in ponds, lakes and rivers. The horn-like extensions and transverse groove from which the 2 flagella arise are distinctive of the genus. It is a taste and odor producing algae.

Algae Divisions

- **Euglenophyta** (protozoan-like algae)
  - Indicators of pollution
  - Filter cloggers
- **Crytptophyta** (crytomonads)
  - Taste and odor problems
- **Rhodophyta** (red algae)
  - Growth on reservoir walls and irrigation ditches

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***Euglena* sp.** (Euglenophyta). Cells often changing shape when swimming. Numerous disc shaped chloroplasts are usually green but one species sometime is colored red because of a pigment (Haematochrome). The red pigment seems to be produced in response to intense light. Ponds may have a bright red film over the surface caused by Euglena blooms. This algae is found in eutrophic waters with high levels of organic material. It is a pollution indicator.

Hydrologic Cycle/Water Sources

ENV H 440/545

Suggested Reading:

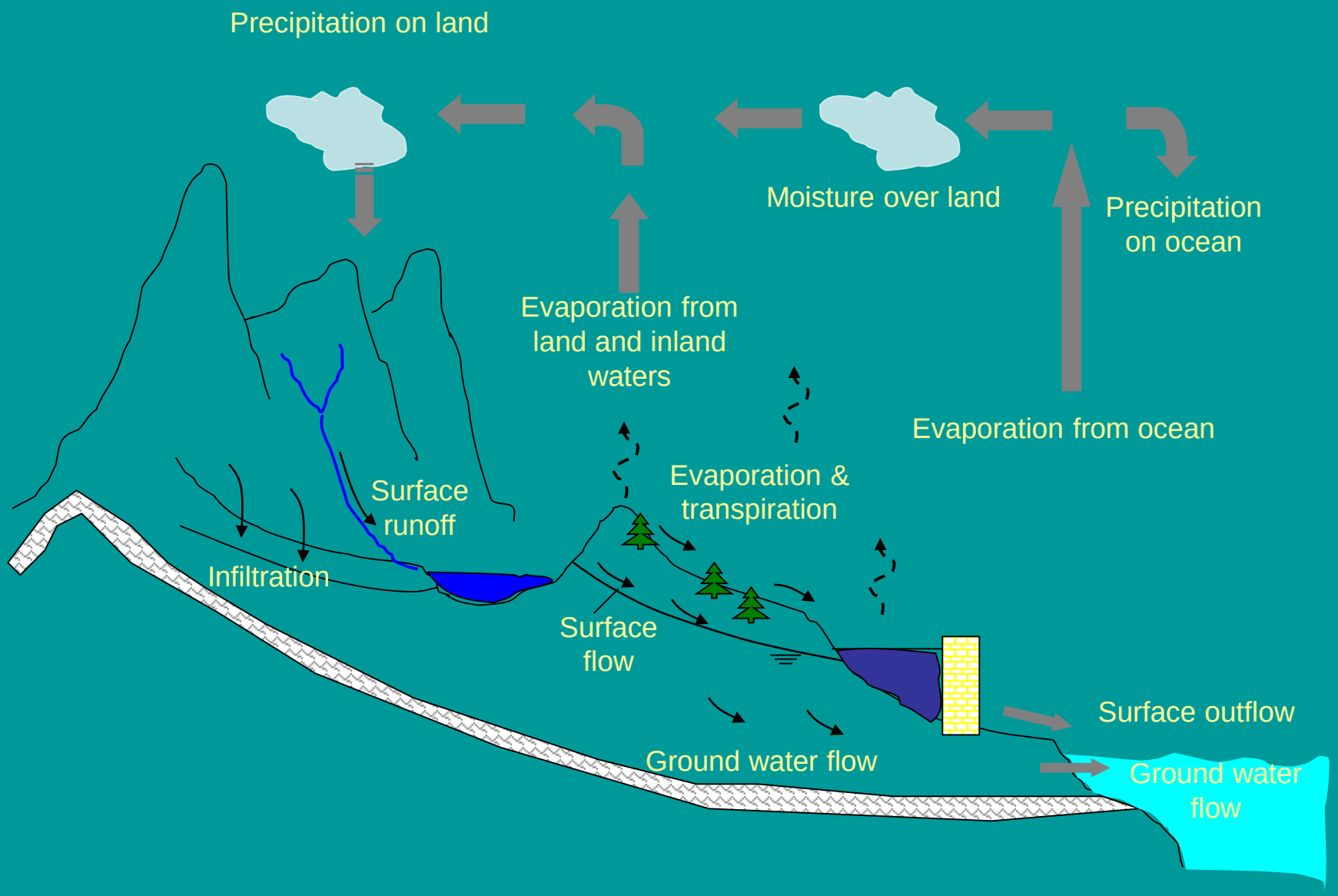
Hammer and Hammer, Water and Wastewater Technology.

- Chapter 1
- Chapter 4: 4-12 through 4-14

Water Sources

- Surface water
  - River or stream
  - Lake
  - Reservoir
- Ground water
  - Water table well
  - Artesian well
    - Flowing
    - Non-flowing
  - Springs

Basic Hydrologic Cycle



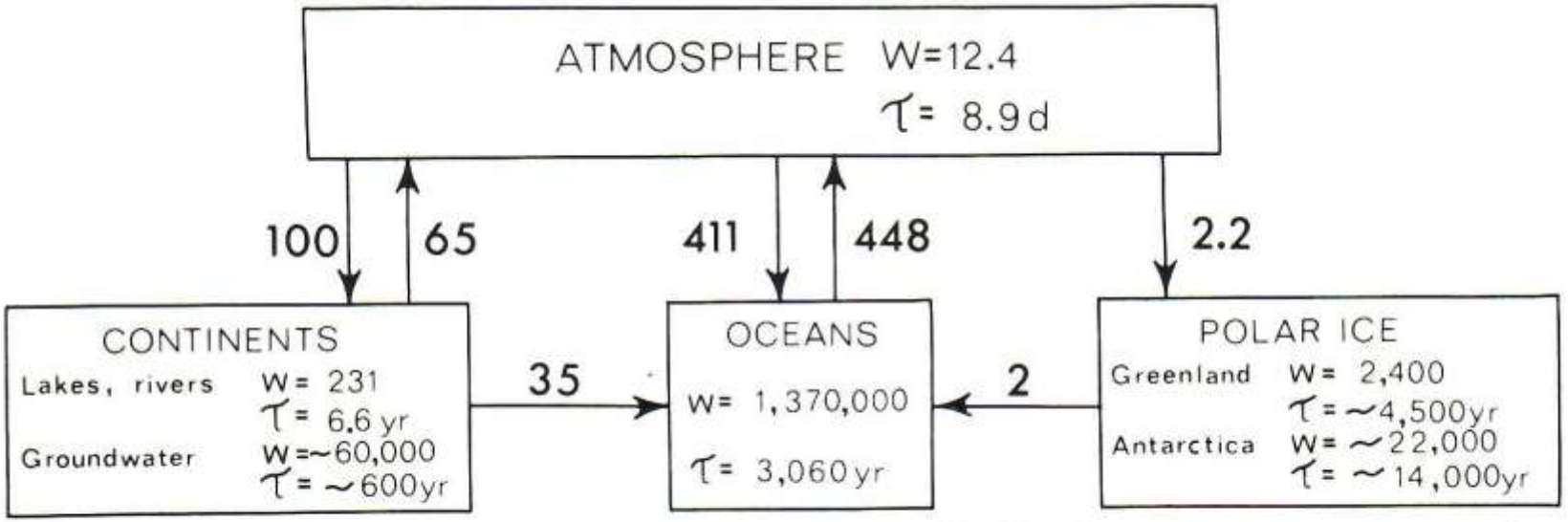
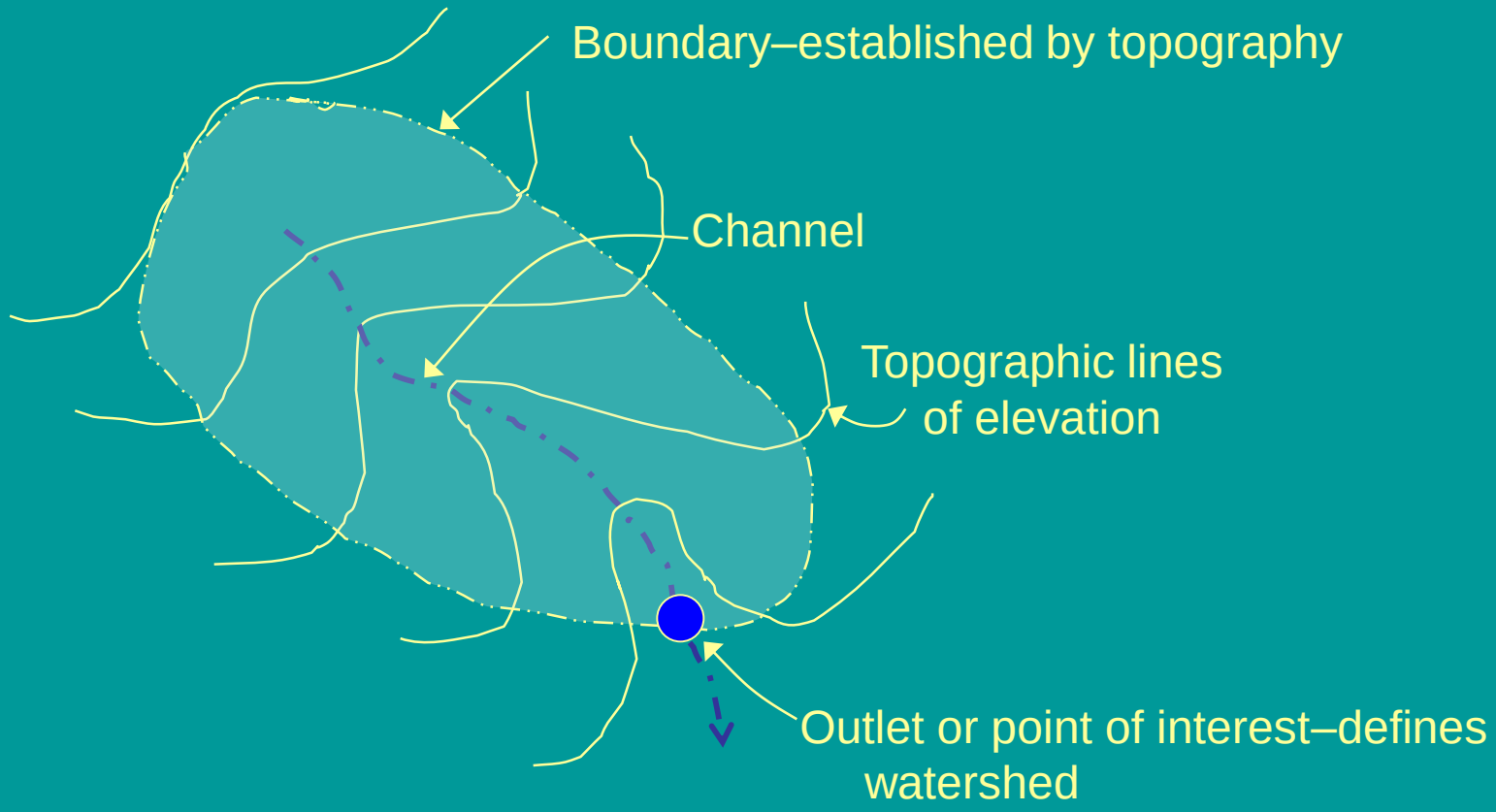


Figure 4-2 Global water balance. W = water content in 10^3 km^3, values on arrows = transport in 10^3 km^3 yr^{-1}, and τ = retention time. Estimate of ground water is to a depth of 5 km in the earth's crust; much of this water is not actively exchanged. (Modified from Flohn, 1973, after Lvovitch.)

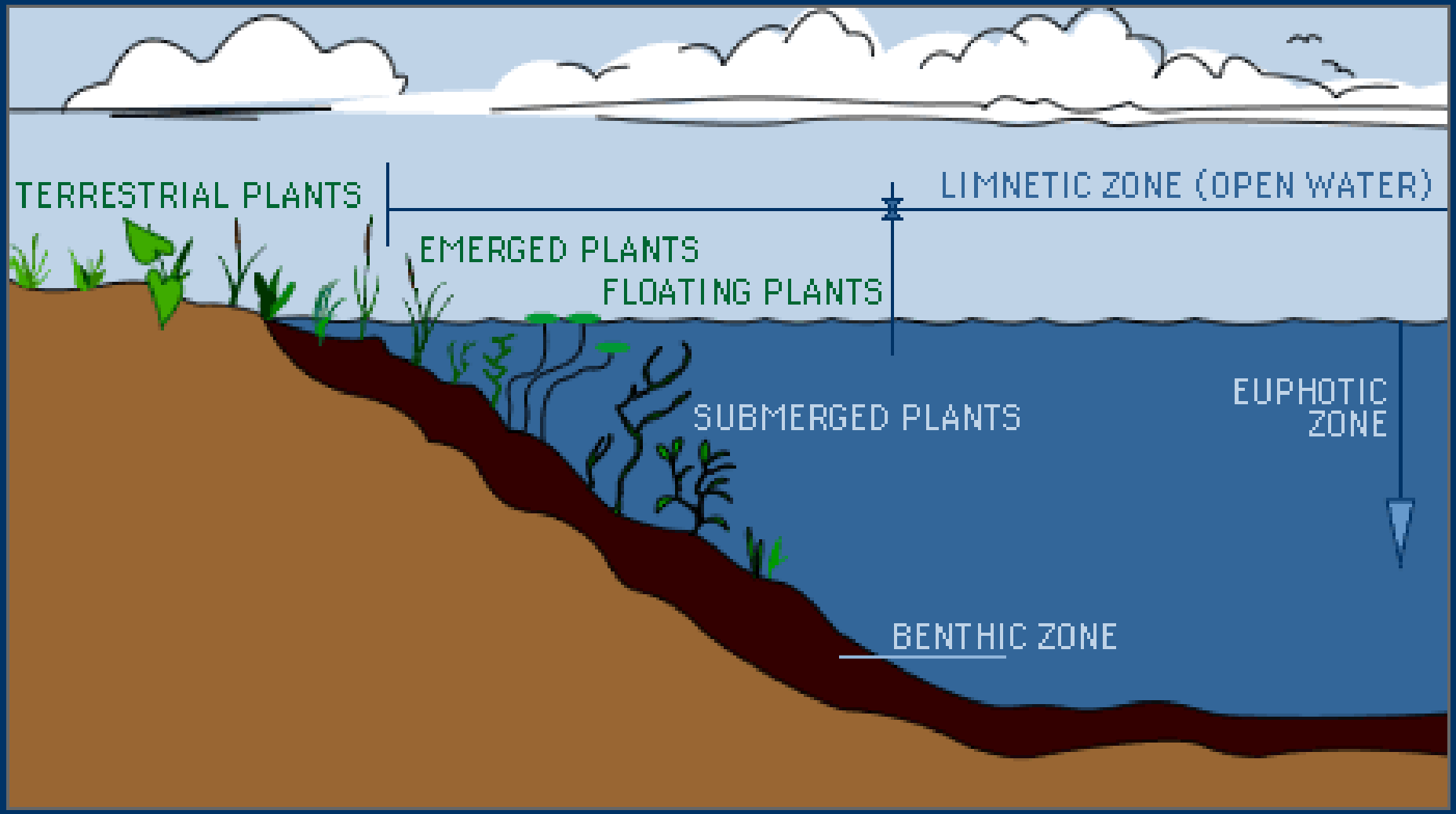
Watershed

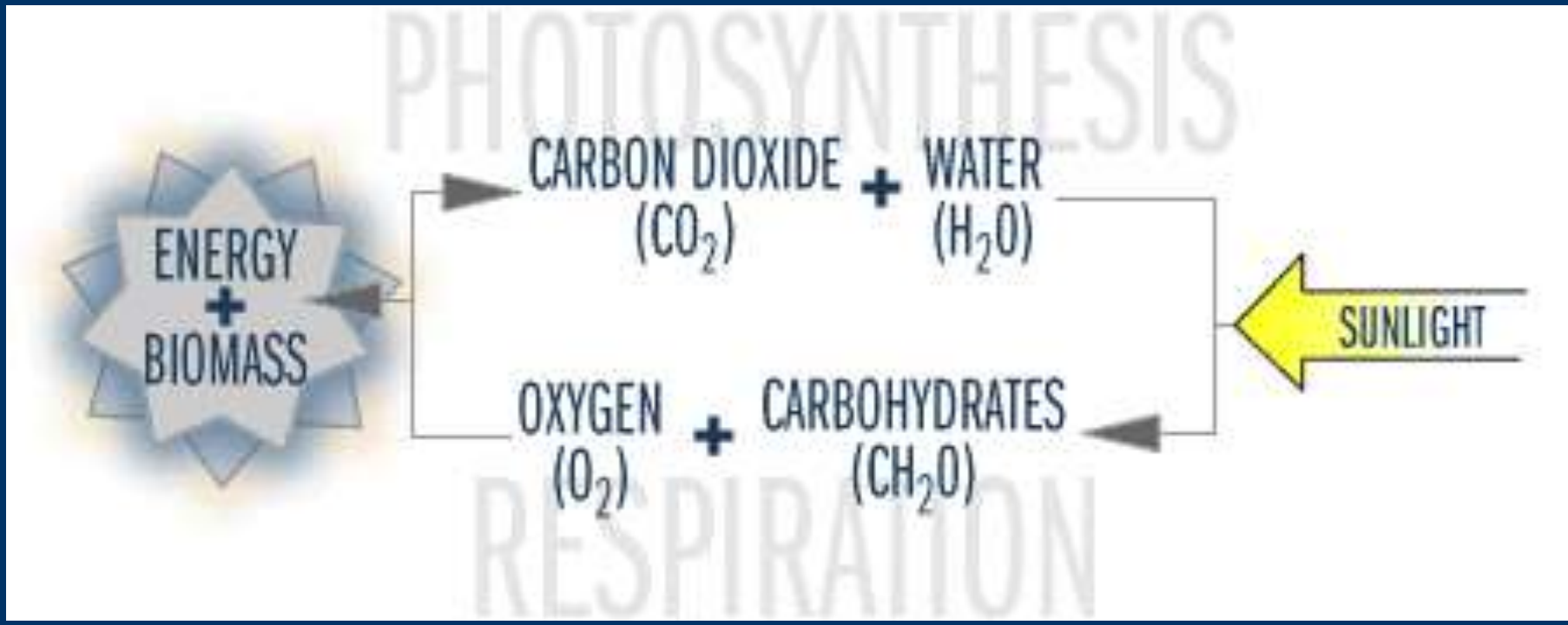

Boundary–established by topography
Channel
Topographic lines of elevation
Outlet or point of interest–defines watershed

Cedar River Watershed

Source: Seattle Public Utilities

http://www.shorelandmanagement.org//index.html


TERRESTRIAL PLANTS
LIMNETIC ZONE (OPEN WATER)
EMERGED PLANTS
FLOATING PLANTS
SUBMERGED PLANTS
EUPHOTIC ZONE
BENTHIC ZONE


PHOTOSYNTHESIS
ENERGY + BIOMASS
CARBON DIOXIDE (CO_2) + WATER (H_2O)
SUNLIGHT
OXYGEN (O_2) + CARBOHYDRATES (CH_2O)
RESPIRATION

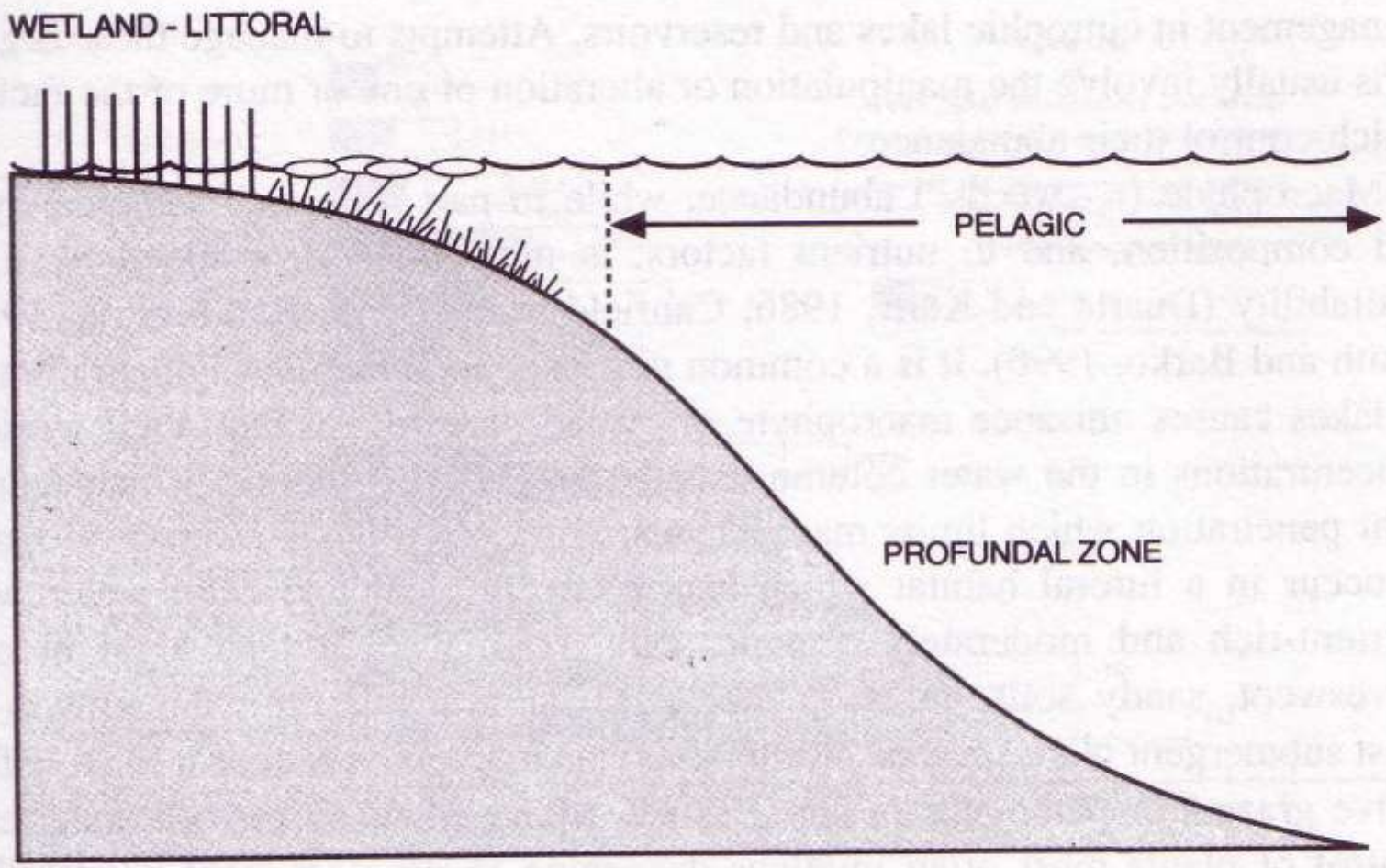
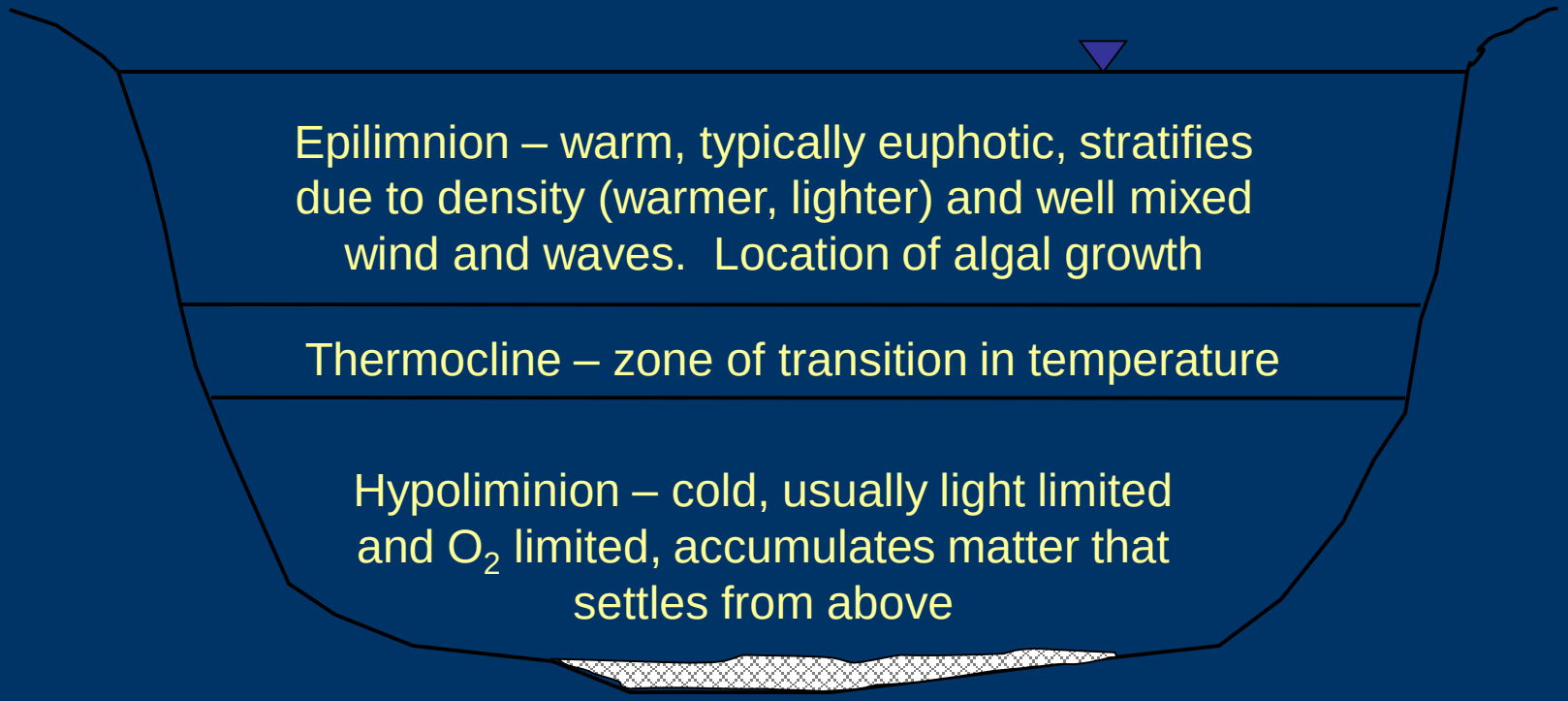


Figure 2-5. Biotic communities in lakes and reservoirs.

Stratification in Lakes/Reservoirs

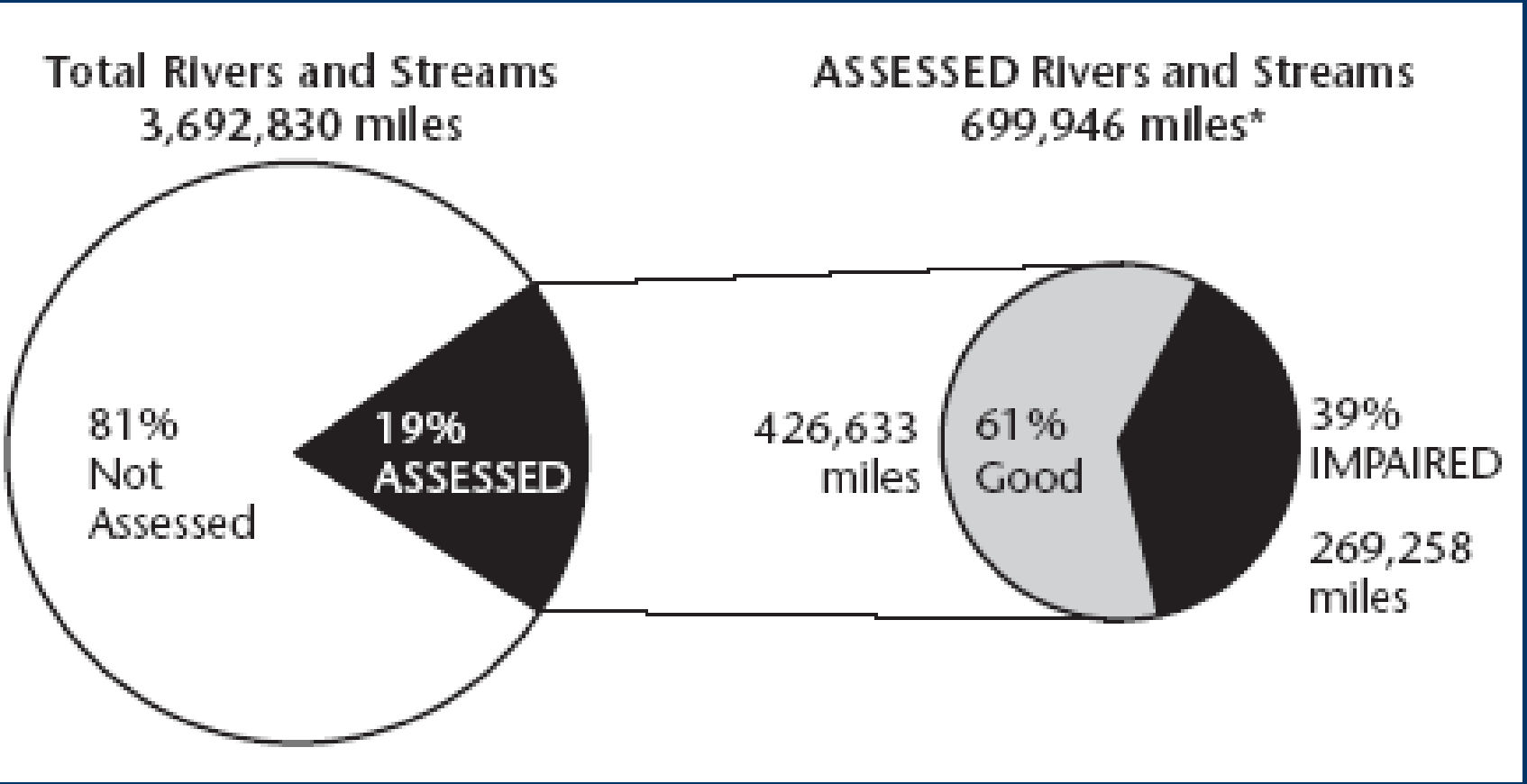


Turnover in Lakes

- Temperature & stratification events lead to compartmentalization of nutrients & O_2 in deep lakes
- In temperate climates, turnover occurs in fall and spring

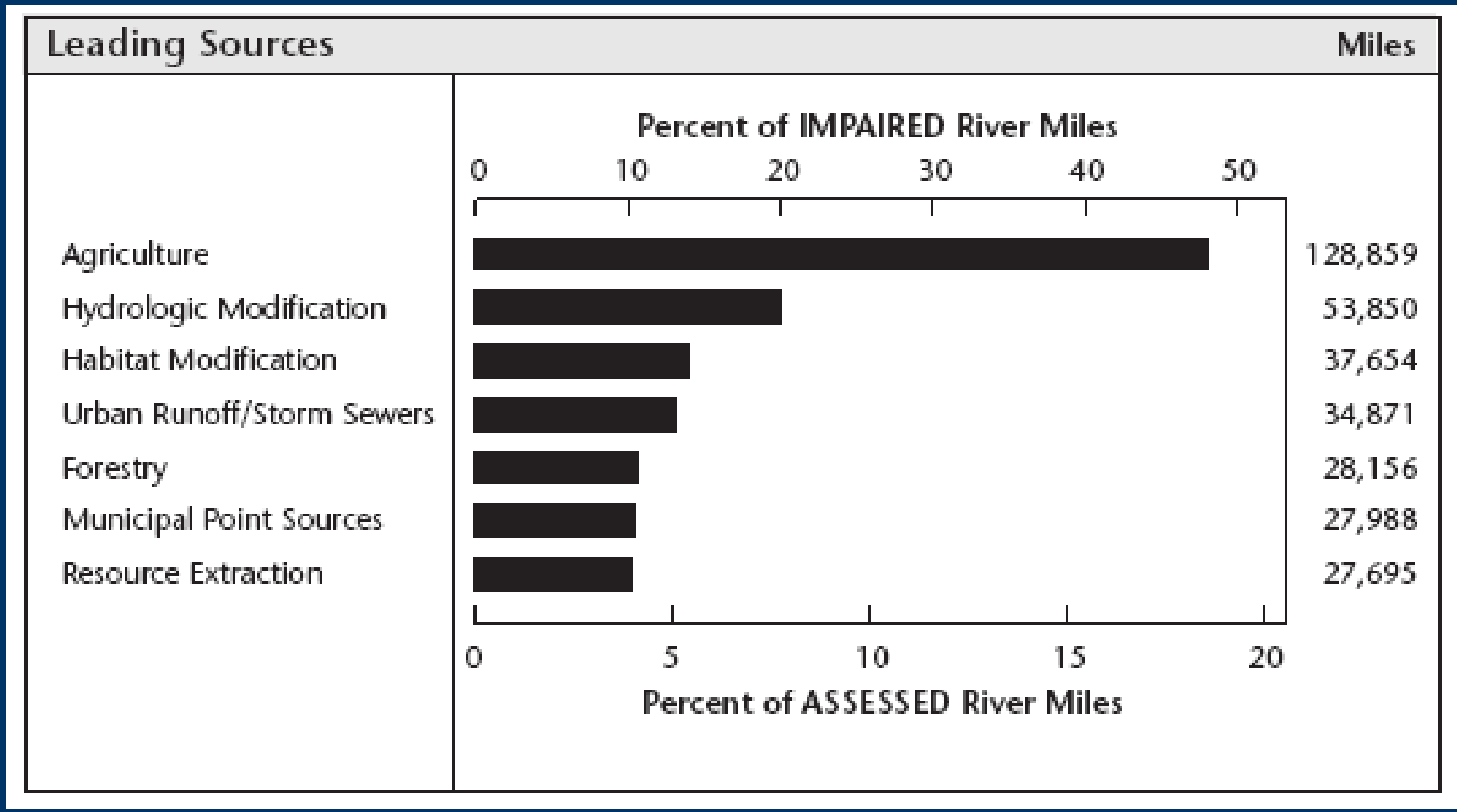
Ex. In fall top layer cools, and when water reaches same temperature or lower of thermocline & hypolimnion, water sinks. Large up-welling of N & P from below can occur. If surface water temperature drops below 4°C a spring overturn occurs when epilimnion temperatures increase to that of the lower layers, allowing complete mixing to occur.

Condition of Assessed Rivers & Streams in 2000 Water Quality Inventory



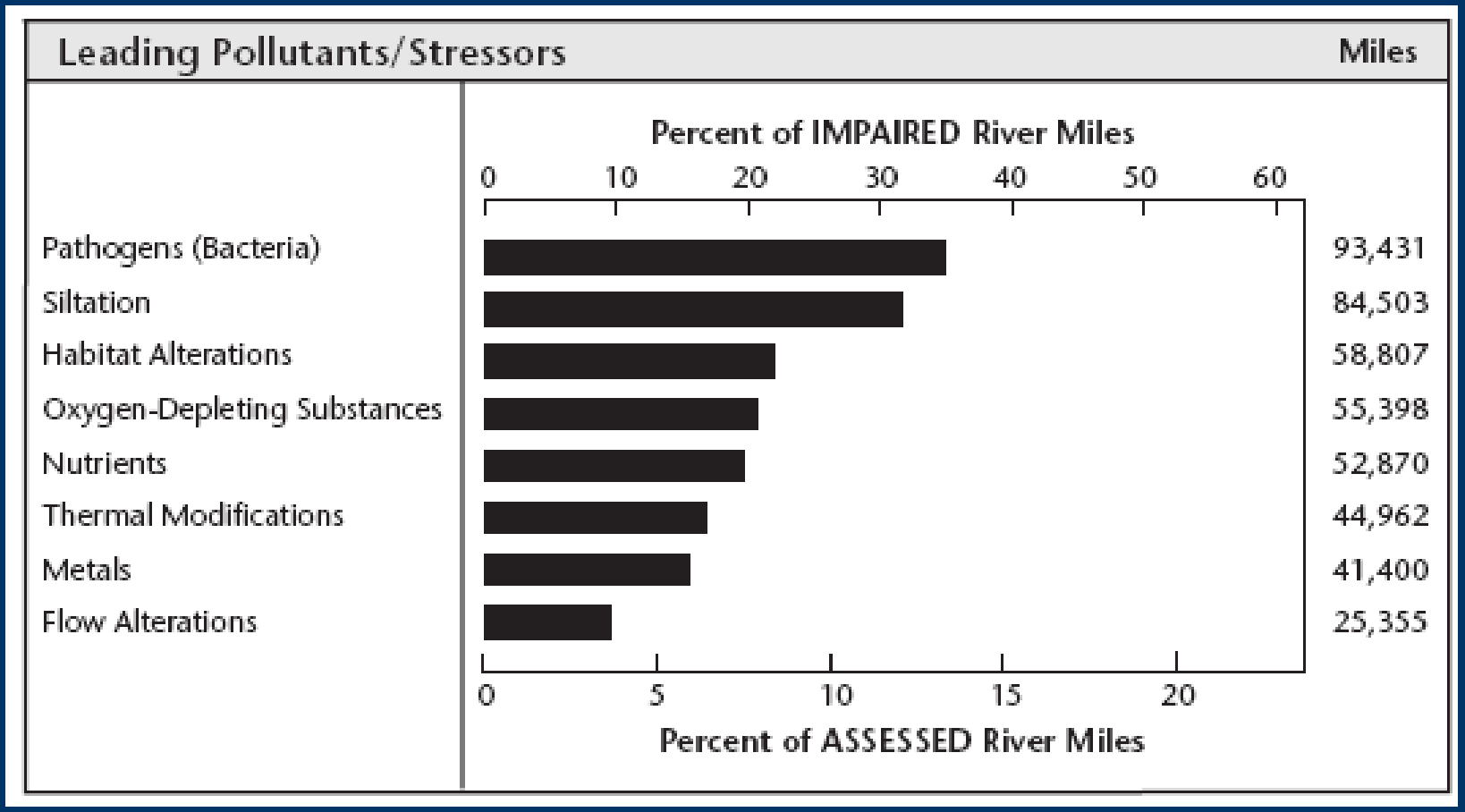
Source: USEPA. National Water Quality Inventory 2000 Report, EPA 841-R-02-1, August 2002.
http://www.epa.gov/305b/2000report

Leading Sources Contributing to River & Stream Impairment



Source: USEPA. National Water Quality Inventory 2000 Report, EPA 841-R-02-1, August 2002.
http://www.epa.gov/305b/2000report

Leading Pollutants/Stressors in Rivers & Streams

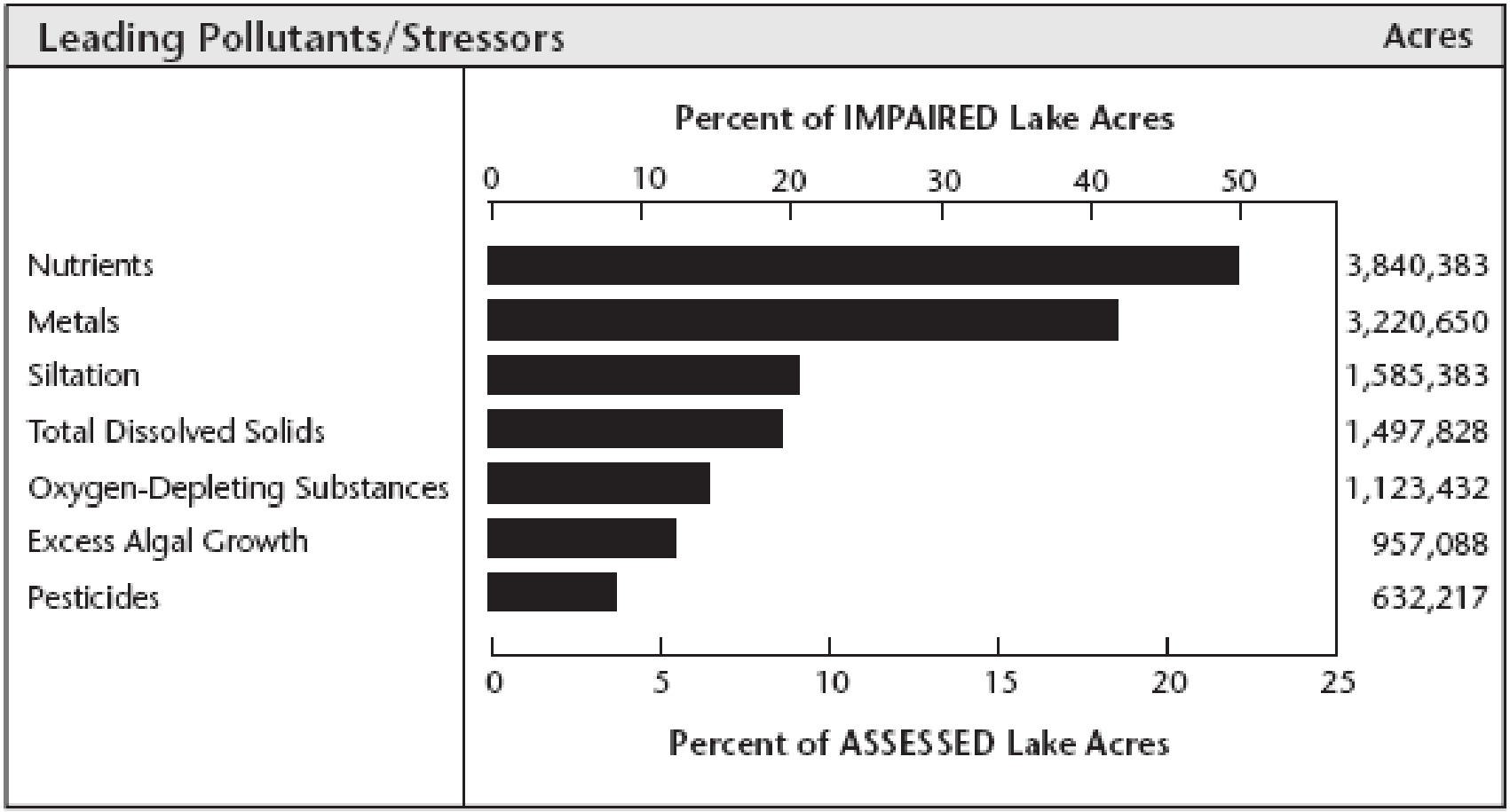


Source: USEPA. National Water Quality Inventory 2000 Report, EPA 841-R-02-1, August 2002.
http://www.epa.gov/305b/2000report

Stresses on Lakes and Reservoirs

- Eutrophication
- Hydrologic and Physical Changes
- Sedimentation
- Exotic Invasive Species
- Acidification
- Contamination by Toxics

Leading Pollutants/Stressors in Lakes



Source: USEPA. National Water Quality Inventory 2000 Report, EPA 841-R-02-1, August 2002.
http://www.epa.gov/305b/2000report

Water Quality in Lakes

- Algal growth typically controls the cycle (aquatic plants can also be major contributors)
  - N & P usually the limiting nutrients
  - Fixed carbon usually limiting for bacteria
- Additions of N or P can unbalance the cycle
  - N as organic nitrogen, NO_3, NH_3
  - P as PO_4
  - Some cyanobacteria fix N_2, so P then limiting

Lake & Reservoir Eutrophication

N+P→ light rxn, algal growth (fixed carbon & algal products)

O_2

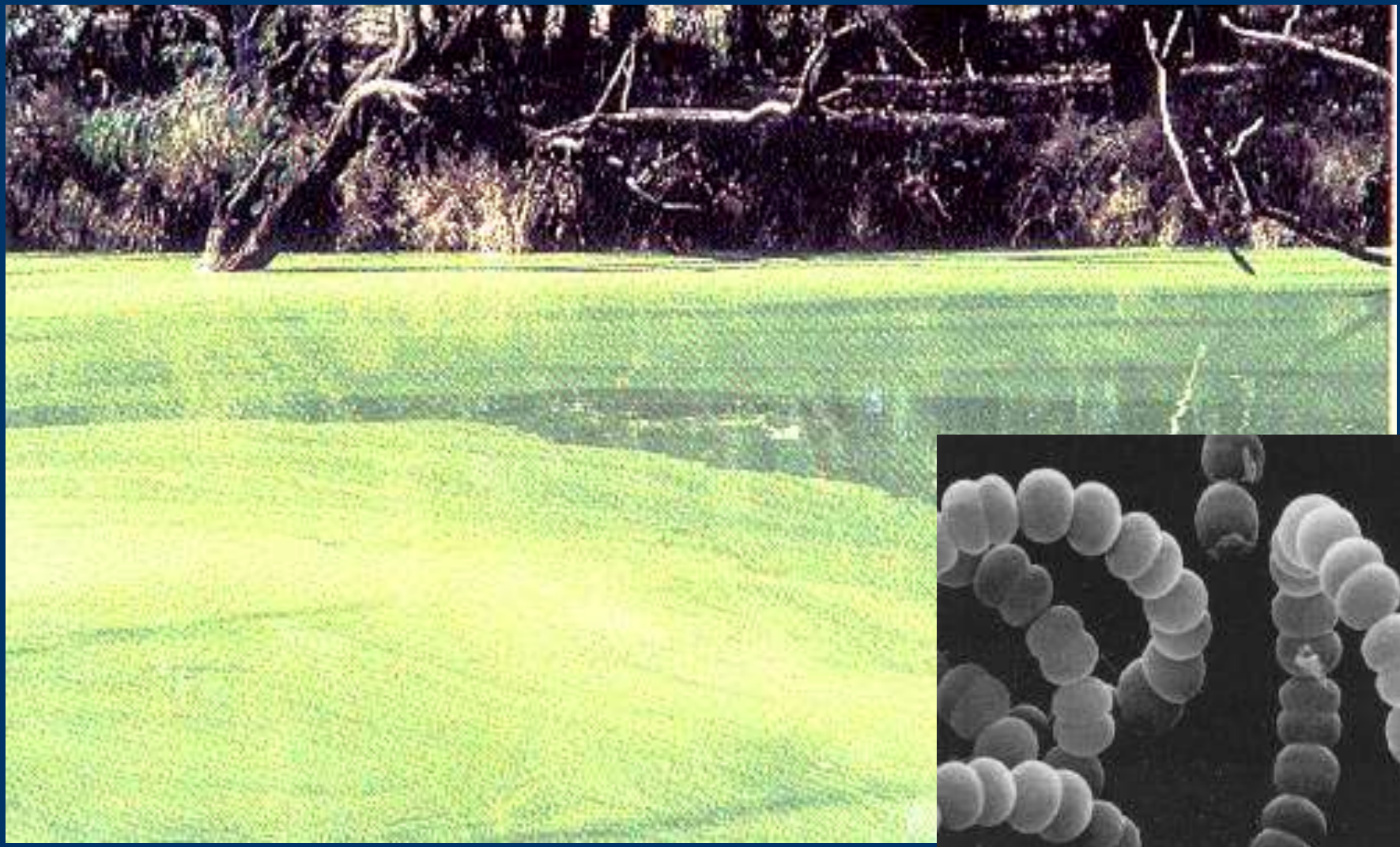
Dark rxn, produce algal biomass

bacterial, aerobic heterotrophs - growth

SO_4^{2-}, CO_2

Anaerobic – bacterial biomass + products (H_2S, CH_4, etc.)

O_2 production > respiration: euphotic zone
O_2 production < respiration: profundal zone



Anabaena Bloom

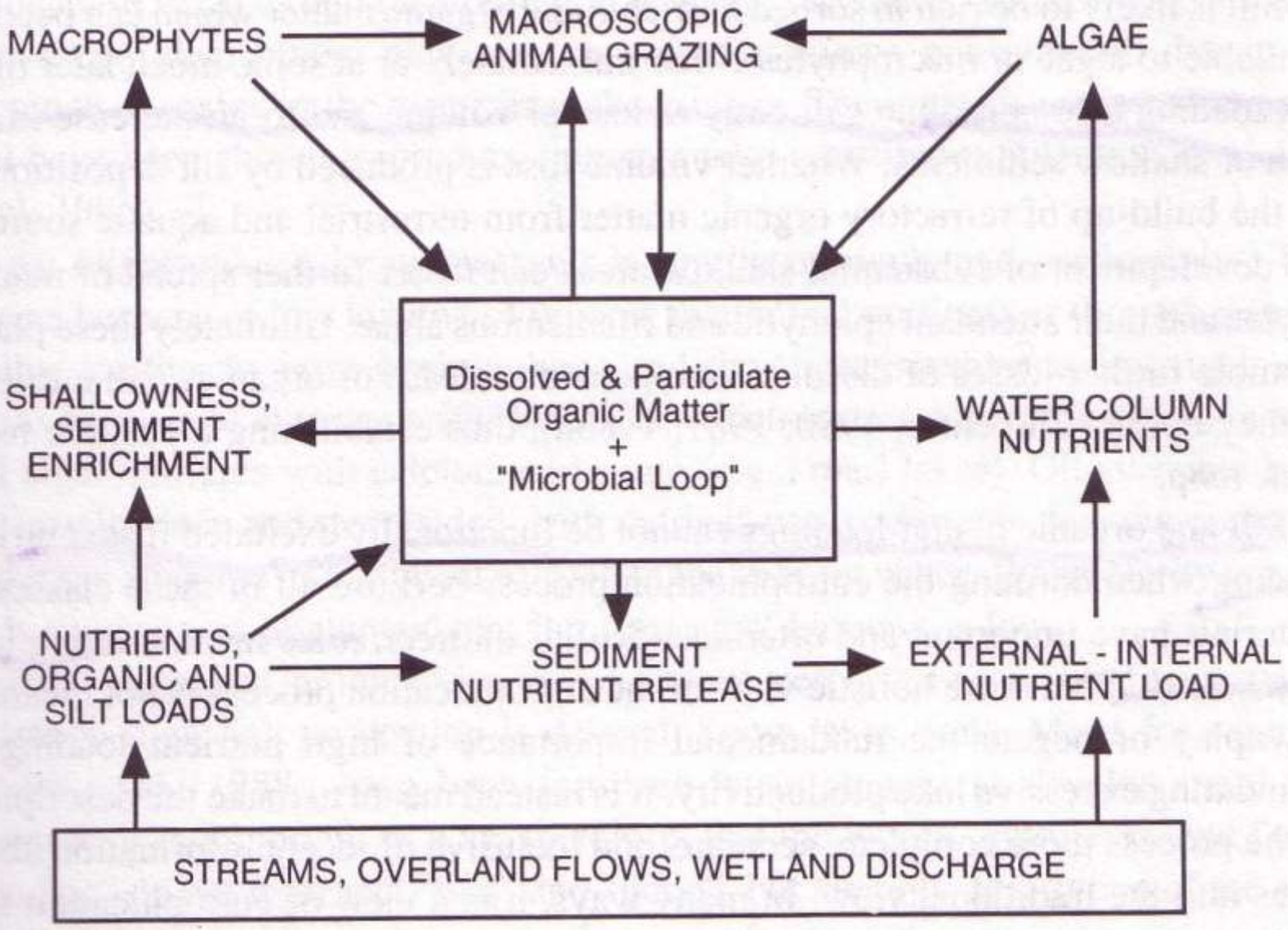


Figure 2-7. Loadings and primary interactions in lakes and reservoirs.

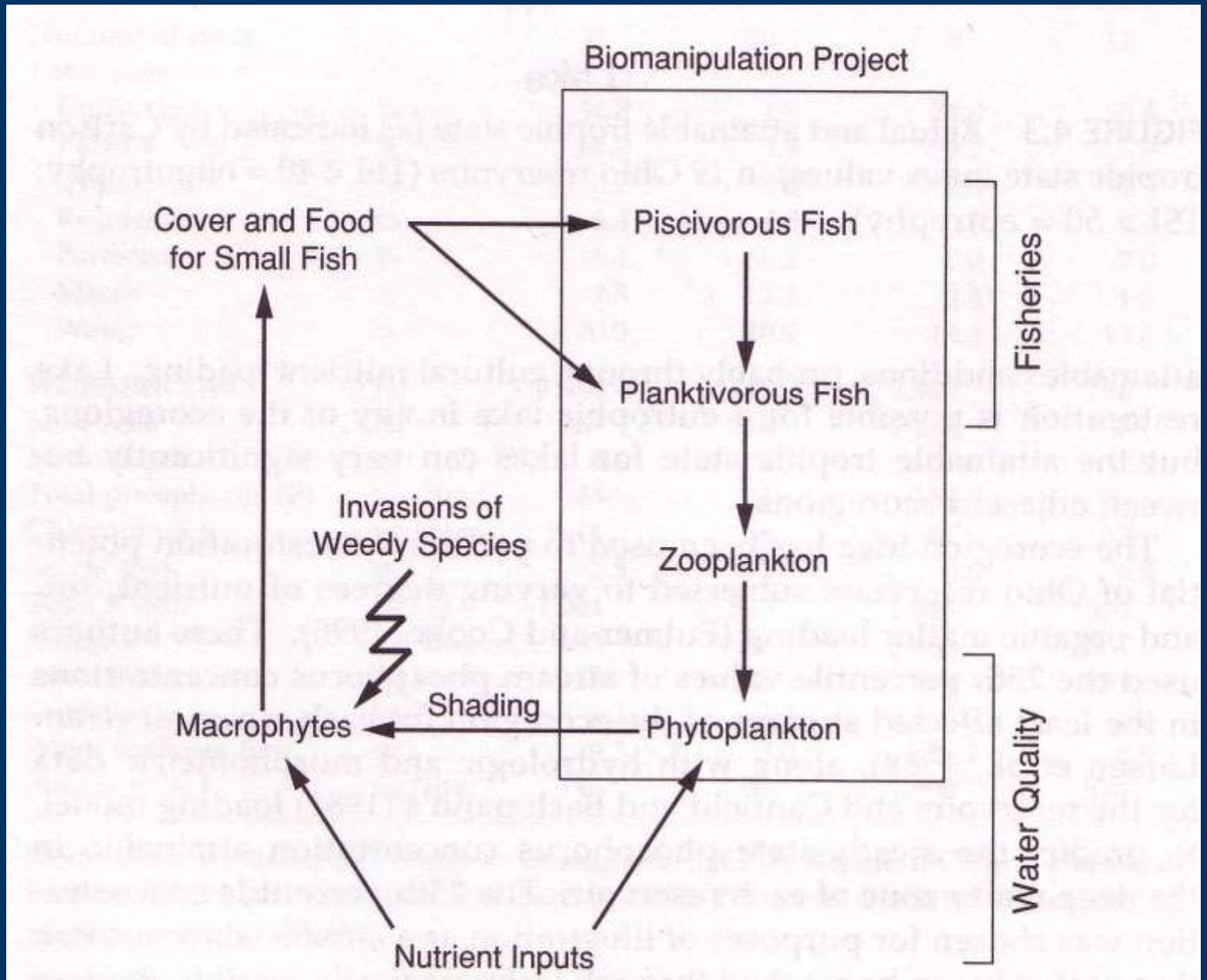


FIGURE 4.4 Linkages of algae, macrophytes, and fisheries in lakes.

Acidification of Lakes

- Caused by acid deposition (SO_2 and NO_x)
- Decay of organic matter slowed
- Affects solubility of metals and nutrient cycles

- Carbonate system provides buffering capacity so that addition of acid will not lower pH of lake

$$CO_2(aq) + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^- \Leftrightarrow H^+ + CO_3^{2-}$$

  - CO_3^{2-} & HCO_3^- react with added H^+ (acid)
  - pH > 6.3, then HCO_3^- is effective buffer
  - pH 5 – 6, pH sensitive to H^+ addition
  - pH < 5, addition of H^+ makes lake chronically acid

Control of Eutrophication

- Control of Algal Blooms
  - Nutrient Source Reduction
    - Diversion
    - Product Modification
    - Tertiary Waste Water Treatment
    - Interception of NPS Nutrients
    - BMPs
  - Dilution
  - In-Lake Methods of Nutrient Removal
    - Alum Treatment
    - Sediment Skimming
    - Sediment Oxidation
    - Deep Water Discharge
  - Management of Symptoms
    - Biomanipulation
    - Artificial Ciruculation
    - Algicides

Control of Eutrophication

- Control of Aquatic Macrophytes
  - Biological agents
  - Waterlevel Drawdown
  - Harvesting
  - Herbicides
- Low Dissolved Oxygen
  - Hyolimnetic Aeration
  - Artificial Circulation
  - Winter Aeration

Control of Sedimentation

- BMPs
- Dredging

Control of Exotic Species

- Biomanipulation
- Rotenone/Herbicides

Control of Acidification

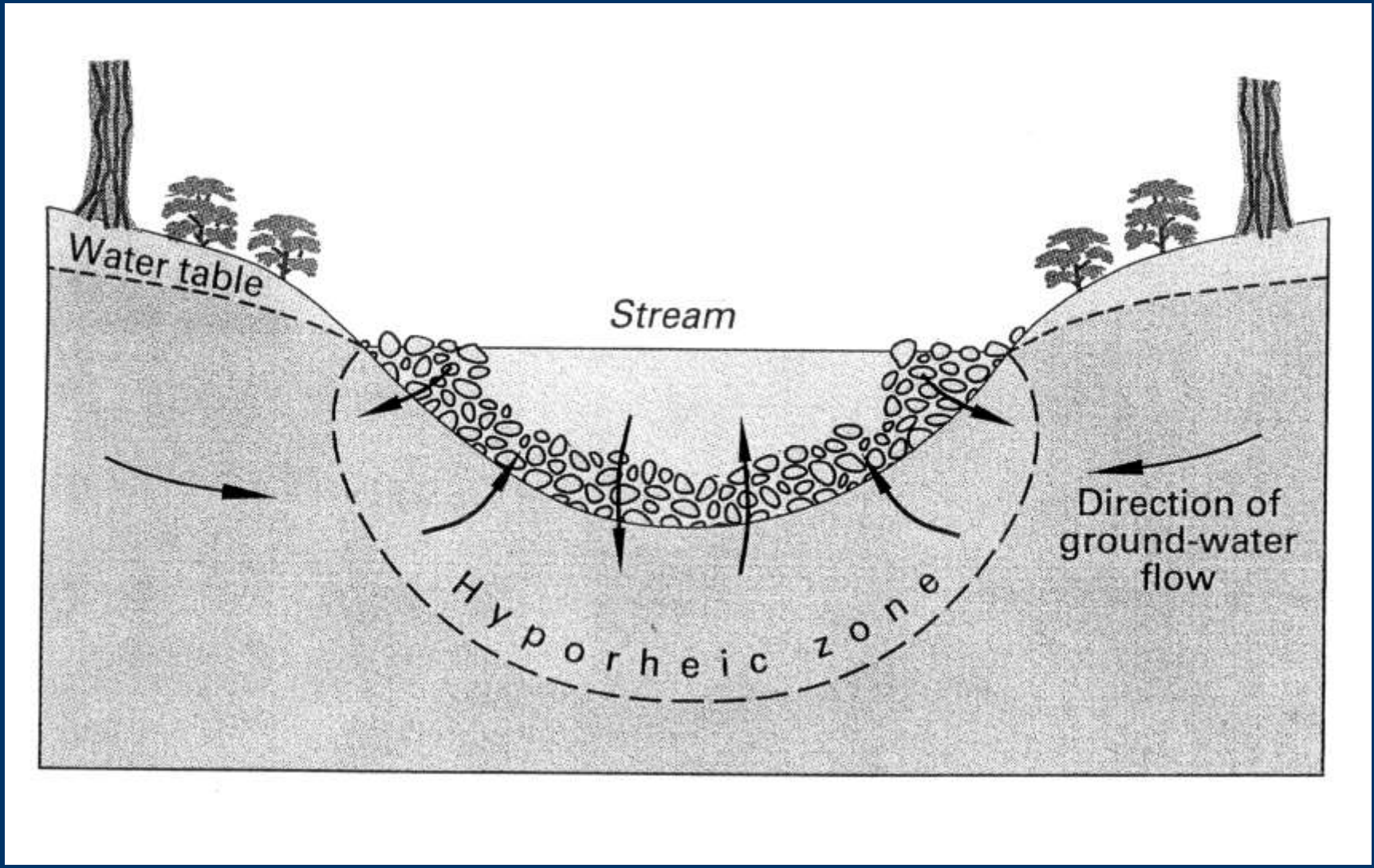
- Decrease sulfur and nitrogen oxide emissions
- Liming (calcium carbonate, calcium oxide, calcium hydroxide)

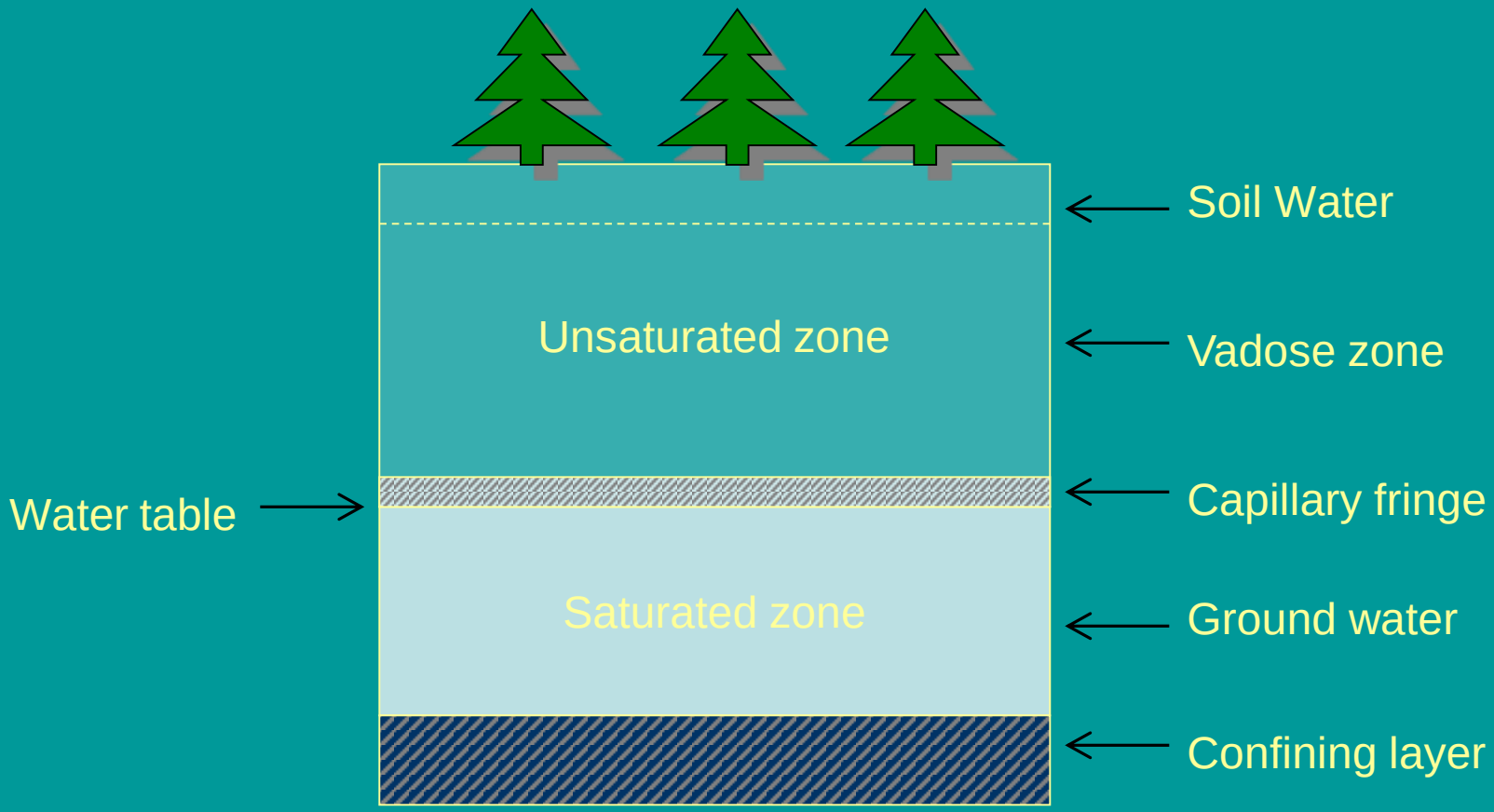
Control of Toxics

- Input reduction (point and non-point)
- Dredging
- Bioremediation

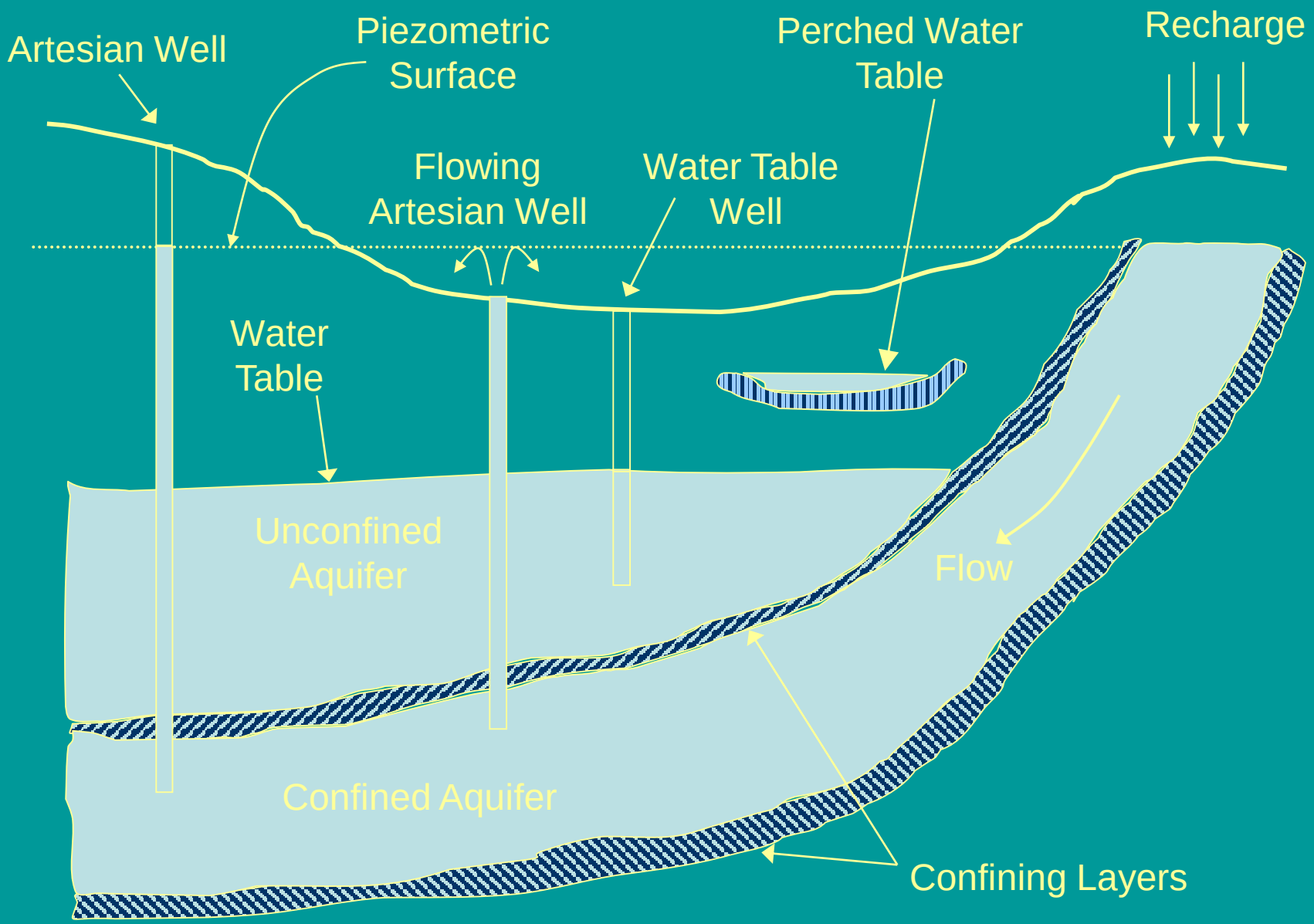
Ground Water

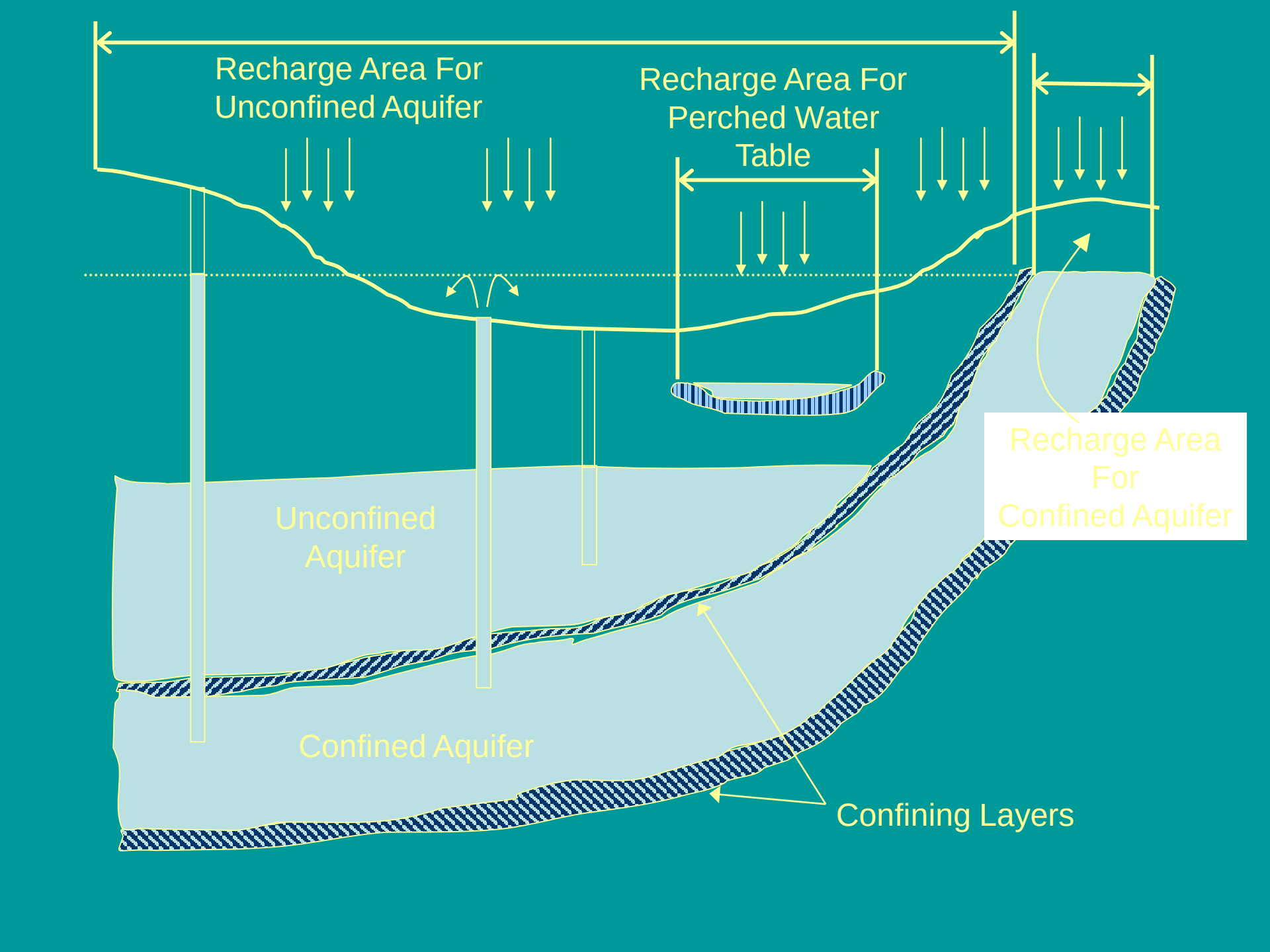
Hyporheic Zone





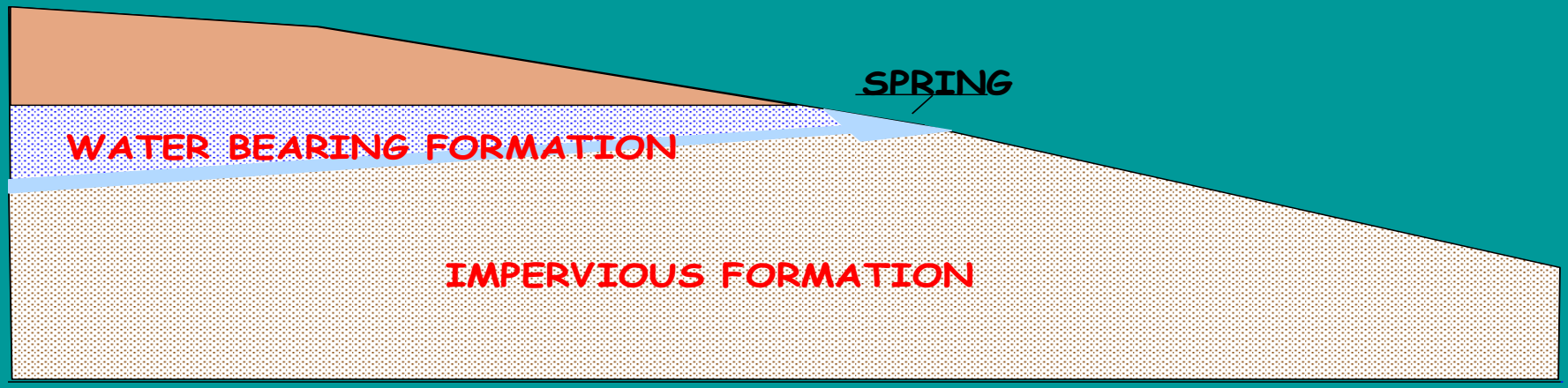
Vertical Section


Artesian Well
Piezometric Surface
Perched Water Table
Recharge
Flowing Artesian Well
Water Table Well
Water Table
Unconfined Aquifer
Flow
Confined Aquifer
Confining Layers


Recharge Area For Unconfined Aquifer
Recharge Area For Perched Water Table
Recharge Area For Confined Aquifer
Unconfined Aquifer
Confined Aquifer
Confining Layers

SUGGESTED DETAILS FOR SPRING DEVELOPMENT IN ALLUVIAL FORMATIONS

UNDEVELOPED SPRING



DEVELOPED SPRING

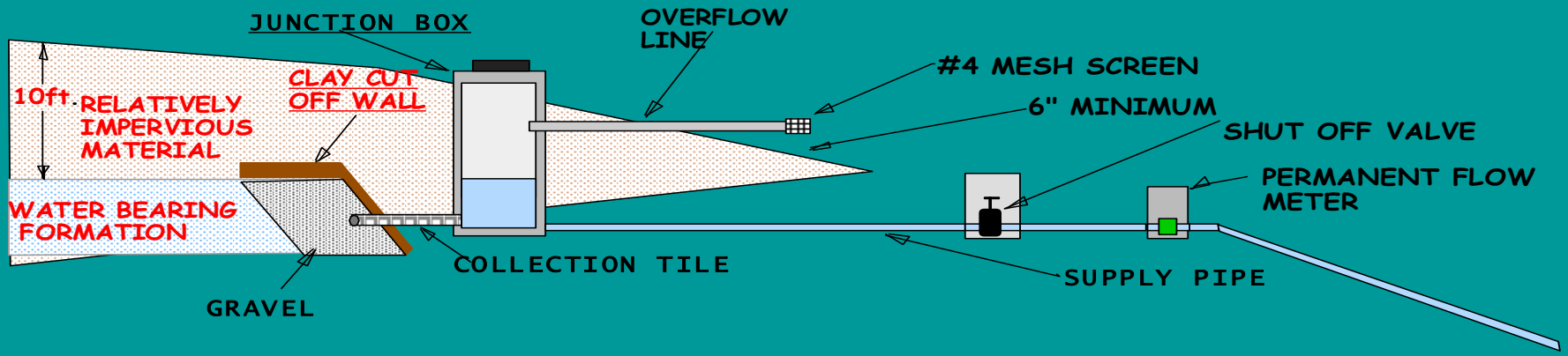
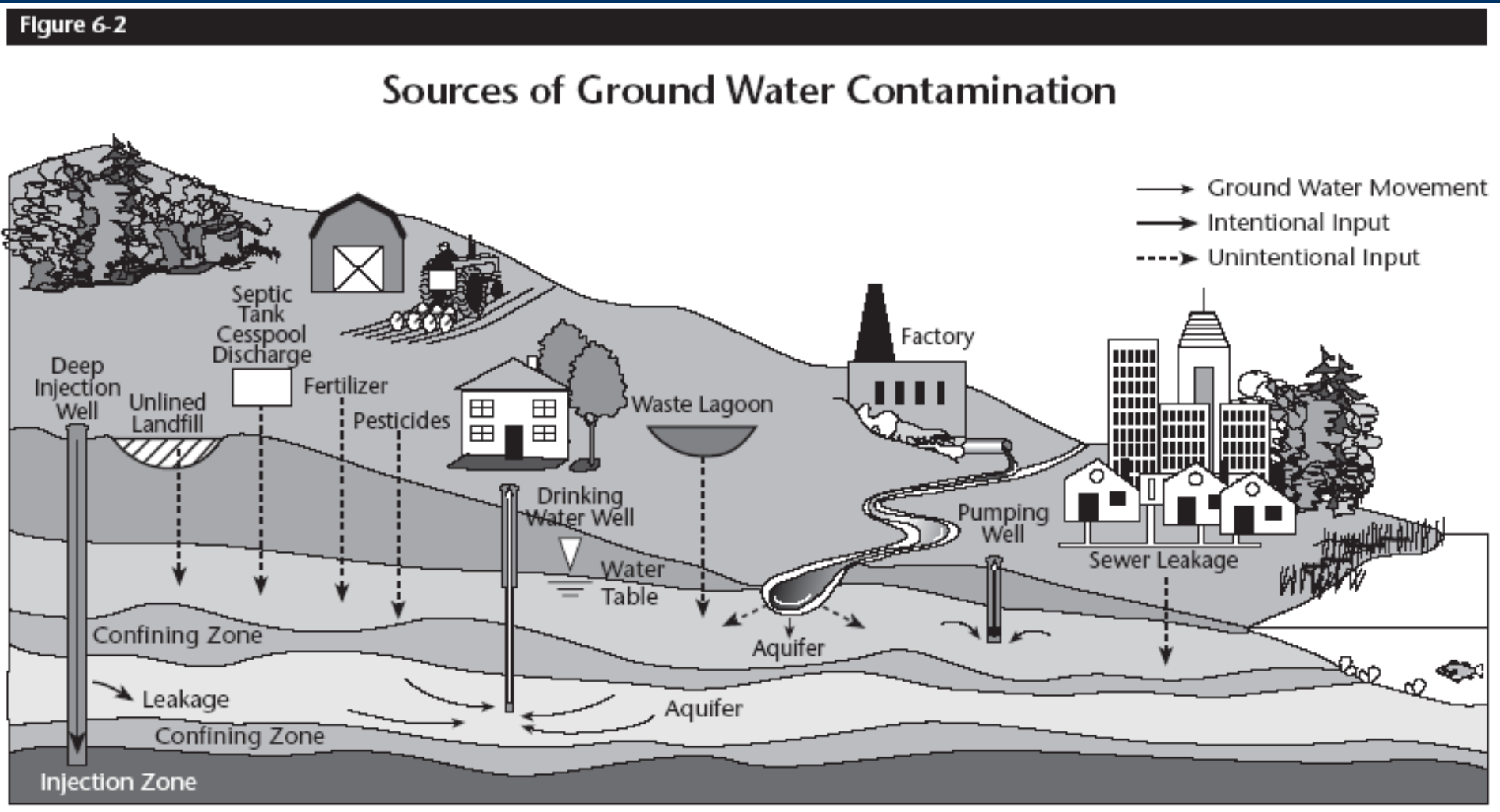


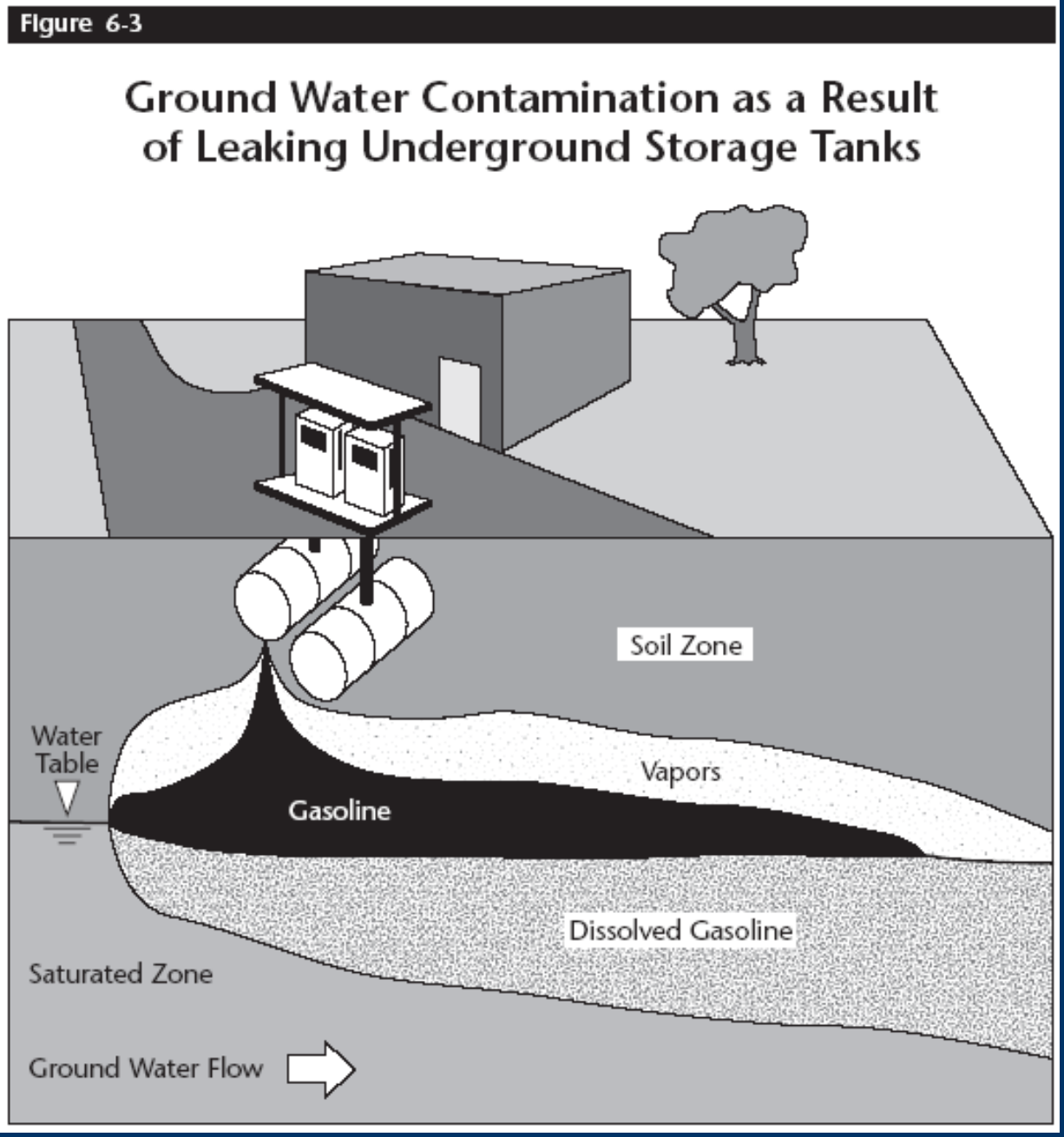
DIAGRAM 6-4

Figure 6-2



Source: USEPA. National Water Quality Inventory 2000 Report, EPA 841-R-02-1, August 2002. http://www.epa.gov/305b/2000report

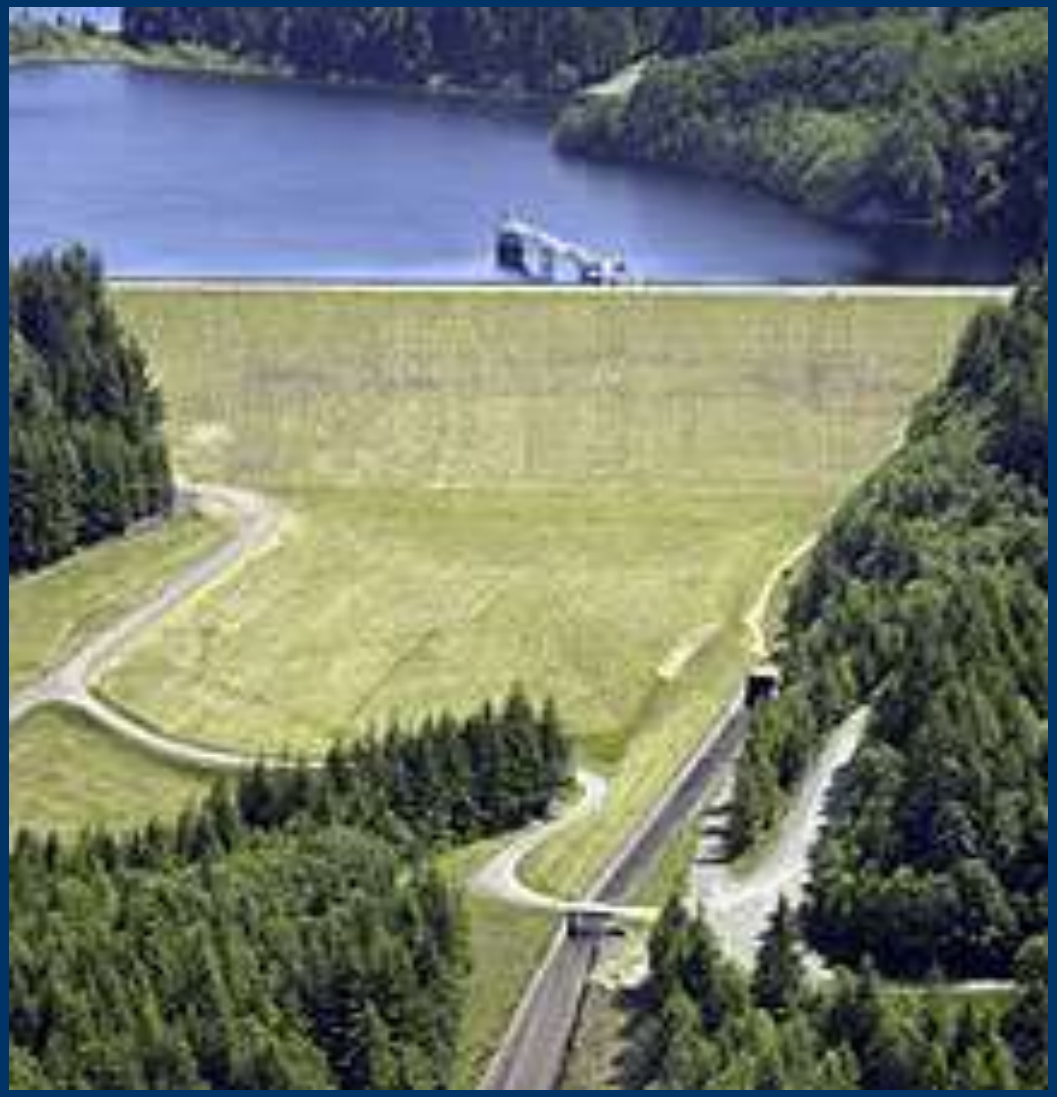
Figure 6-3



Source: USEPA. National Water Quality Inventory 2000 Report, EPA 841-R-02-1, August 2002. http://www.epa.gov/305b/2000report

Water Storage

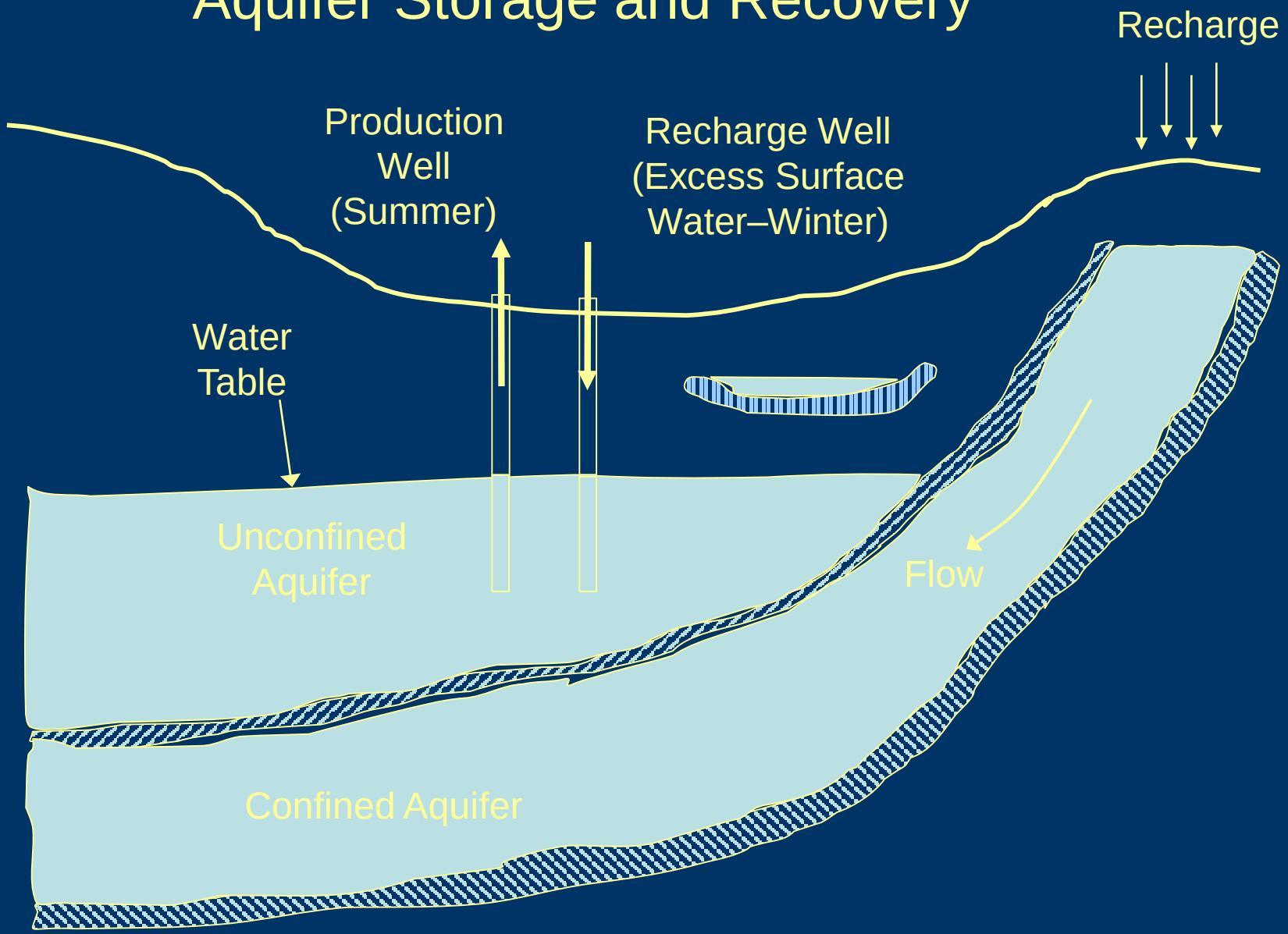
- Purpose–augment supply during high water demand season, e.g., precipitation or streamflow are less than water demand
- Major Types
  - Man-made impoundments
  - Aquifer recharge (and storage)



Tolt Reservoir and Dam
City of Seattle Public Utilities

Source: Seattle Public Utilities

Aquifer Storage and Recovery



Source Water Protection

Safe Drinking Water Act - Protecting America's Public Health

MULTIPLE RISKS REQUIRE MULTIPLE BARRIERS

Safe drinking water is essential to the health of American citizens and the economic health of our communities. However, drinking water is vulnerable to contamination from many potential threats. There are programs and activities that when operated effectively form a protective web of multiple barriers to ensure the safety of our drinking water. The success of these barriers relies on the involvement and vigilance of local, state and federal officials, the private sector, public interest groups and nervous citizens.

This poster identifies examples of:

1. Surface and groundwater sources of drinking water (in blue),
2. Potential threats to those drinking water sources (in red), and
3. The multiple barriers that together protect our nation's public health (in green).

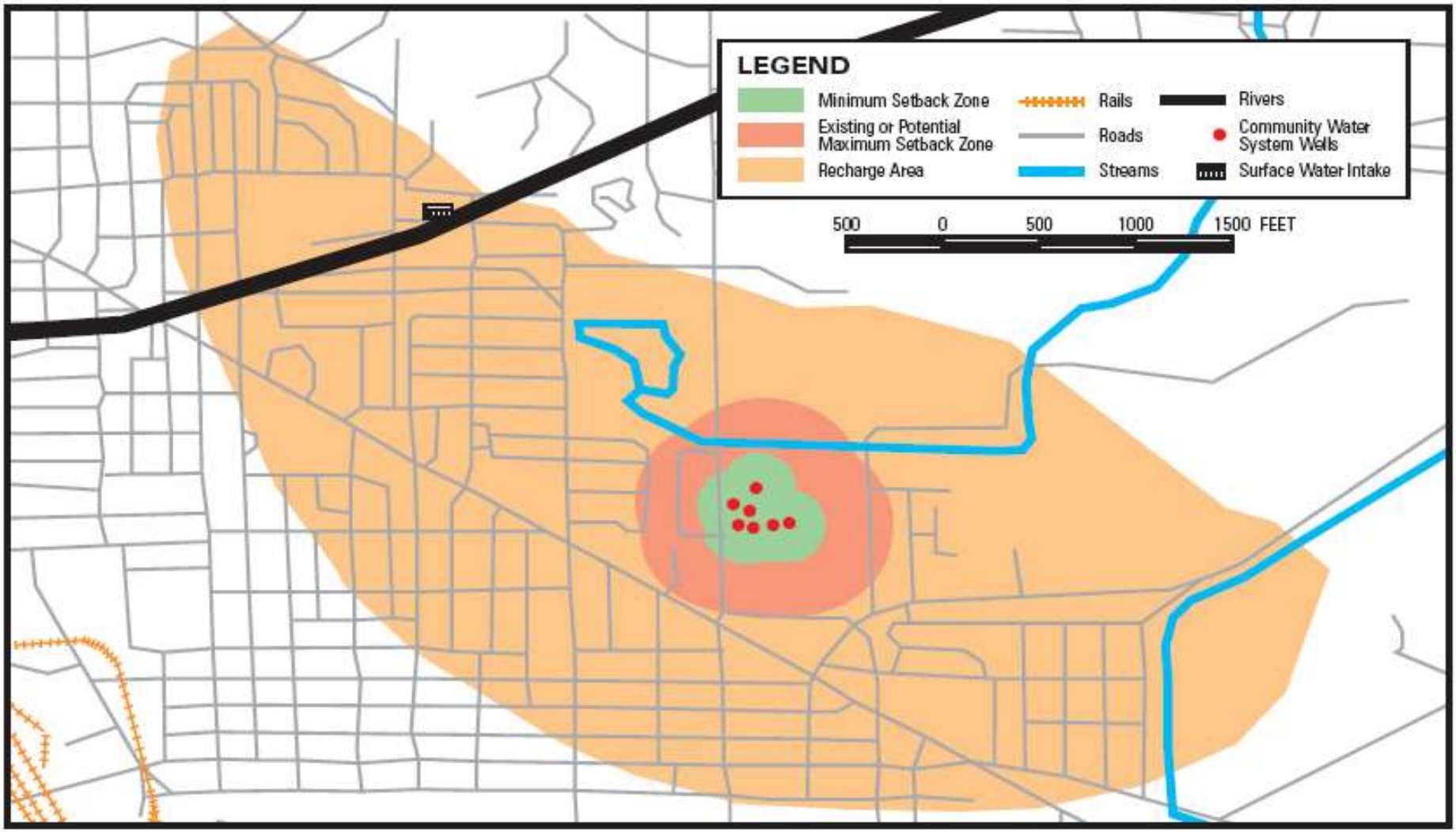
EPA

Safe Drinking Water Hotline – (800) 426-4791 Safewater Web Site – www.epa.gov/safewater

Typical Steps Involved In Development of Source Water Protection Program

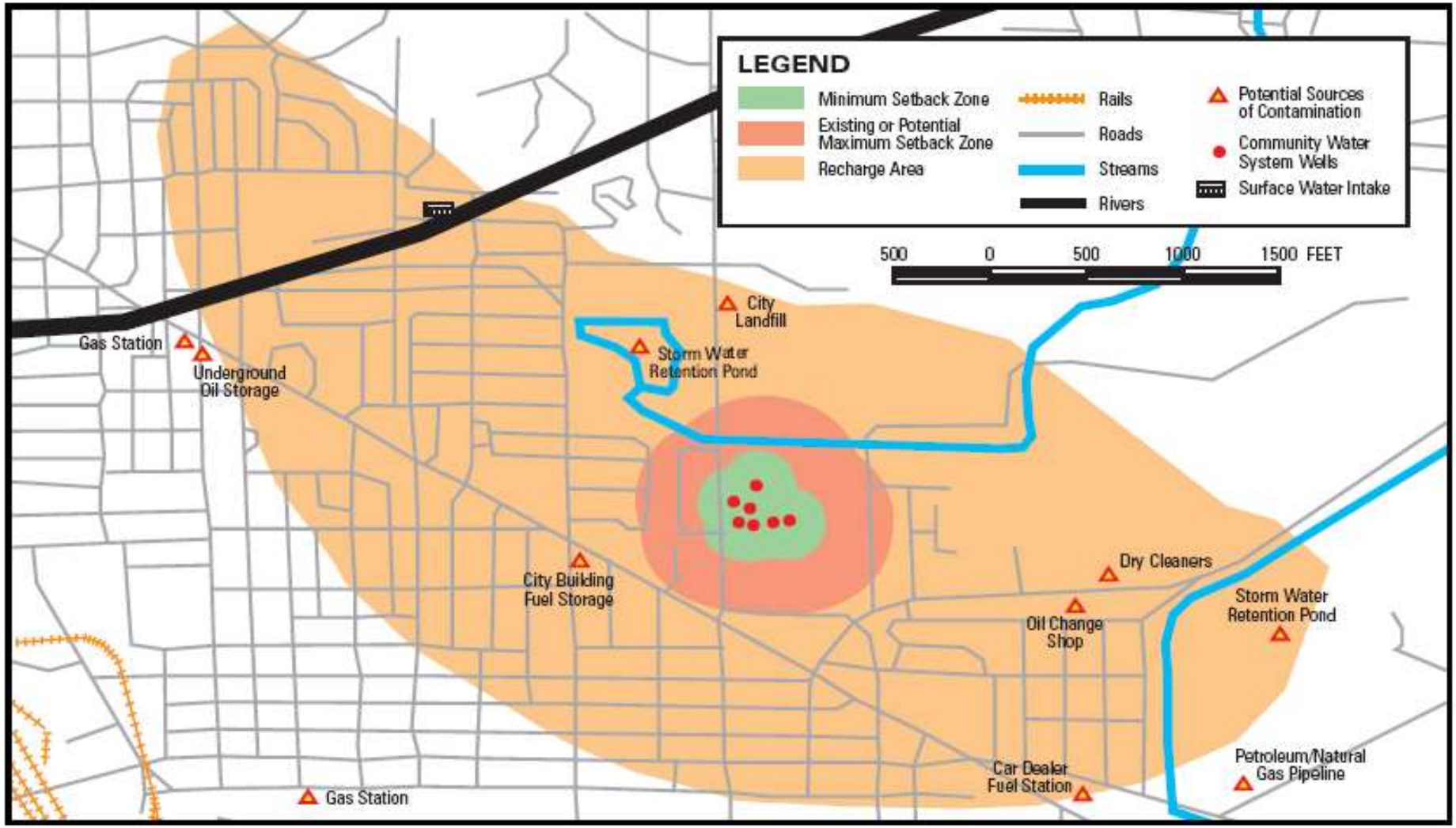
- **DELINEATE** your drinking water source protection area
- **INVENTORY** known and potential sources of contamination within these areas
- **DETERMINE THE SUSCEPTIBILITY** of your water supply system to these contaminants
- **NOTIFY AND INVOLVE THE PUBLIC** about threats identified in the contaminant source inventory and what they mean to their PWS.
- **IMPLEMENT MANAGEMENT MEASURES** to prevent, reduce, or eliminate threats
- **DEVELOP CONTINGENCY PLANNING STRATEGIES** to deal with water supply contamination or service interruption emergencies

Source: USEPA. Consider the Source – A Pocket Guide to Protecting Your Drinking Water, EPA 816-K-02-002, 2002.



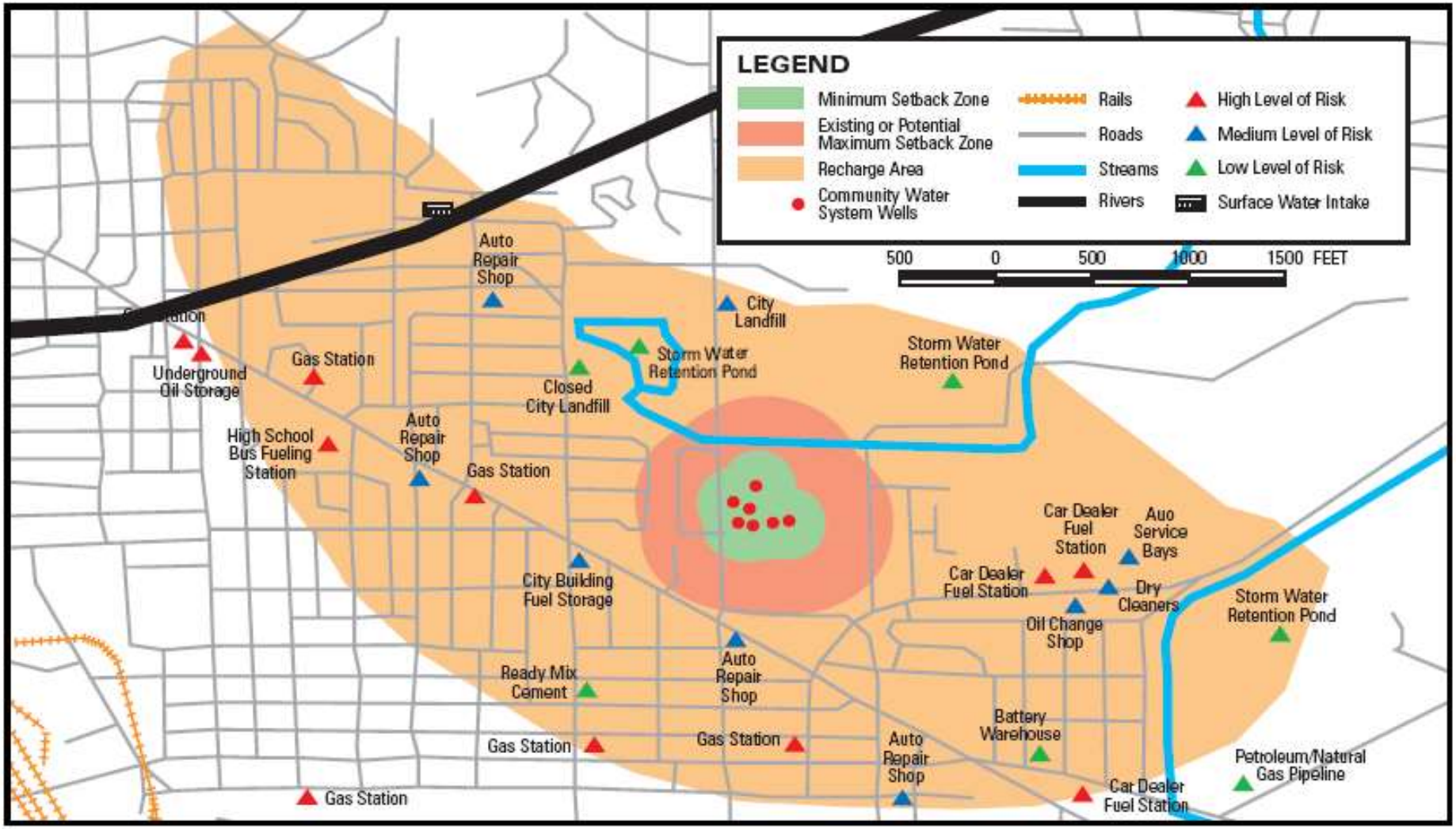
This map shows the delineation of a Source Water Protection Area.

Source: USEPA. Consider the Source – A Pocket Guide to Protecting Your Drinking Water, EPA 816-K-02-002, 2002.



This map inventories known and potential sources of contamination.

Source: USEPA. Consider the Source – A Pocket Guide to Protecting Your Drinking Water, EPA 816-K-02-002, 2002.



This map rates the susceptibility of a PWS to inventoried threats.

Source: USEPA. Consider the Source – A Pocket Guide to Protecting Your Drinking Water, EPA 816-K-02-002, 2002.

Example of Best Management Practices for Source Water Protection

Category, Activity, or Threat	Impacts, Implications, or Risk	Possible BMPs Available
Septic Systems	Improper siting, maintenance and use may contaminate both surface and ground water by percolation or runoff. Bacteria, protozoa, and viruses present in sanitary wastewater can cause gastrointestinal illness, cholera, hepatitis A and typhoid if consumed.	• Establish proper siting criteria • Specify appropriate design and construction criteria • Establish operation and maintenance protocols ("Septic System Ground Water Protection" EPA, July 1986 GPO 1991-517-003-28046) • Analyze assimilative capacity of soils and receiving water to

Source: USEPA. Consider the Source – A Pocket Guide to Protecting Your Drinking Water, EPA 816-K-02-002, 2002.

Other Possible Categories, Activities or Threats

- Lawn and garden fertilizer
- Pet and wildlife waste
- Pesticide application (large & small scale)
- Turfgrass/Agricultural fertilizer application
- Livestock, horse and poultry waste
- Above ground storage tanks
- Sanitary and Combined Sewer Overflows
- Injection wells
- Storm water runoff
- Vehicle washing
- Small quantity chemical use
- Underground storage tanks (USTs)
- Highway and/or airport deicing operations