WATER

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WATER SECTION OUTLINE

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- STRUCTURE OF A WATER MOLECULE
- WATER CHEMISTRY
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VII. CURRENT WATER ISSUES

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LEARNING OBJECTIVES

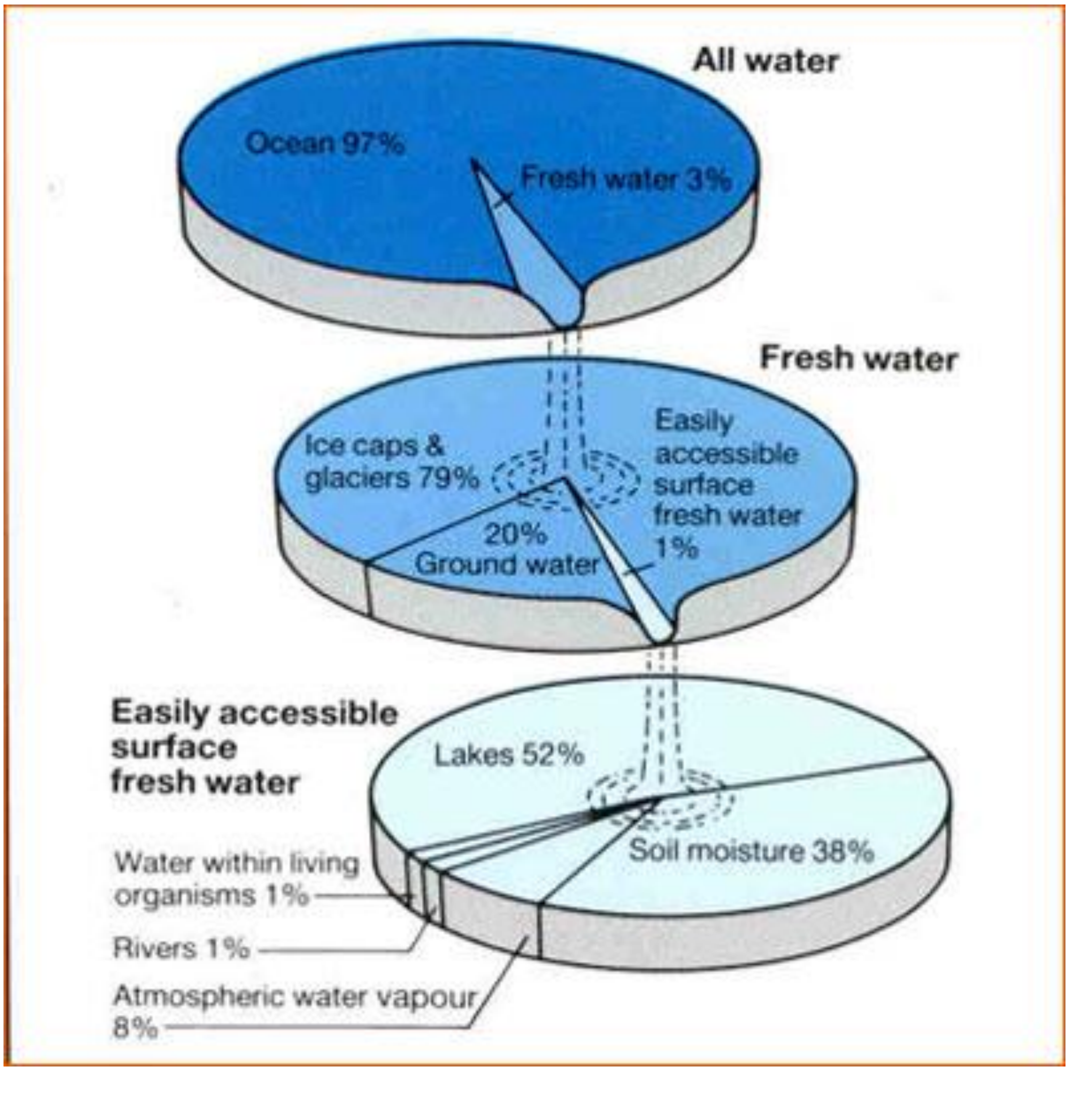
Team members will be able to:

- Identify the processes and phases of the water cycle.
- Describe the chemical and physical properties of water and explain their implications for freshwater and saltwater ecosystems.
- Analyze the interaction of competing uses of water for water supply, hydropower, navigation, wildlife, recreation, irrigation, industry and others.
- Discuss methods of conserving water and reducing point and non-point source pollution.
- Identify common aquatic organisms through the use of a key.
- Define a watershed and delineate a watershed boundary.
- Briefly describe the benefits of wetlands, including both function and value.
- Describe the benefits of riparian areas, including both function and value.
- Describe seasonal changes to a variety of aquatic ecosystems.
- Understand the various water quality parameters and use the water quality information to assess the general water quality of a body of water.
- Understand the pharmaceutical cycle and impacts to water resources and aquatic organisms
- Have a knowledge of climate change effects on surface water resources

I. WATER BASICS

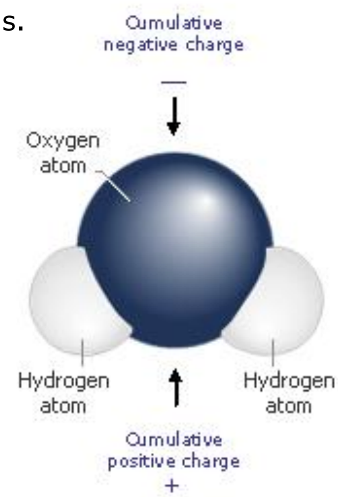
DISTRIBUTION OF THE WORLD'S WATER

Two-thirds of the planet Earth is covered by water. Most of that water is found in the oceans. Less than 1% is groundwater, surface moisture and soil moisture.



STRUCTURE OF A WATER MOLECULE

A water molecule consists of one oxygen atom and two hydrogen atoms that are covalently bonded. Covalently bonded means that each hydrogen atoms shares one outer shell electron with the oxygen atom and the oxygen atom shares an outer shell electron with each hydrogen atom. Covalent bonds only occur between two elements that are non-metals.



Water Molecule

Water has one of the highest heat capacities. Water can absorb a lot of heat energy before the temperature of the water will rise. A lot of heat energy is needed to break the hydrogen bonds that water molecules form with each other. Each water molecule is capable of forming four hydrogen bonds with adjacent molecules. This property is extremely important because water on the surface of the earth absorbs a lot of heat from the sun, which regulates the earth's climate.

Water has a strong surface tension. The water molecules at the surface of the water experience hydrogen bonds with adjacent molecules and molecules beneath them. The strong attractions experienced by the surface molecules enable them to withstand some pressure. Strong surface tension is also what enables bugs to skim across the surface of ponds. Due to water's unique molecular makeup, it has the ability to attract many different substances. It is known as the universal solvent because it can dissolve so many substances. The most common example of this is salt, since 97% of the earth's water is in fact salt water.

WATER CHEMISTRY

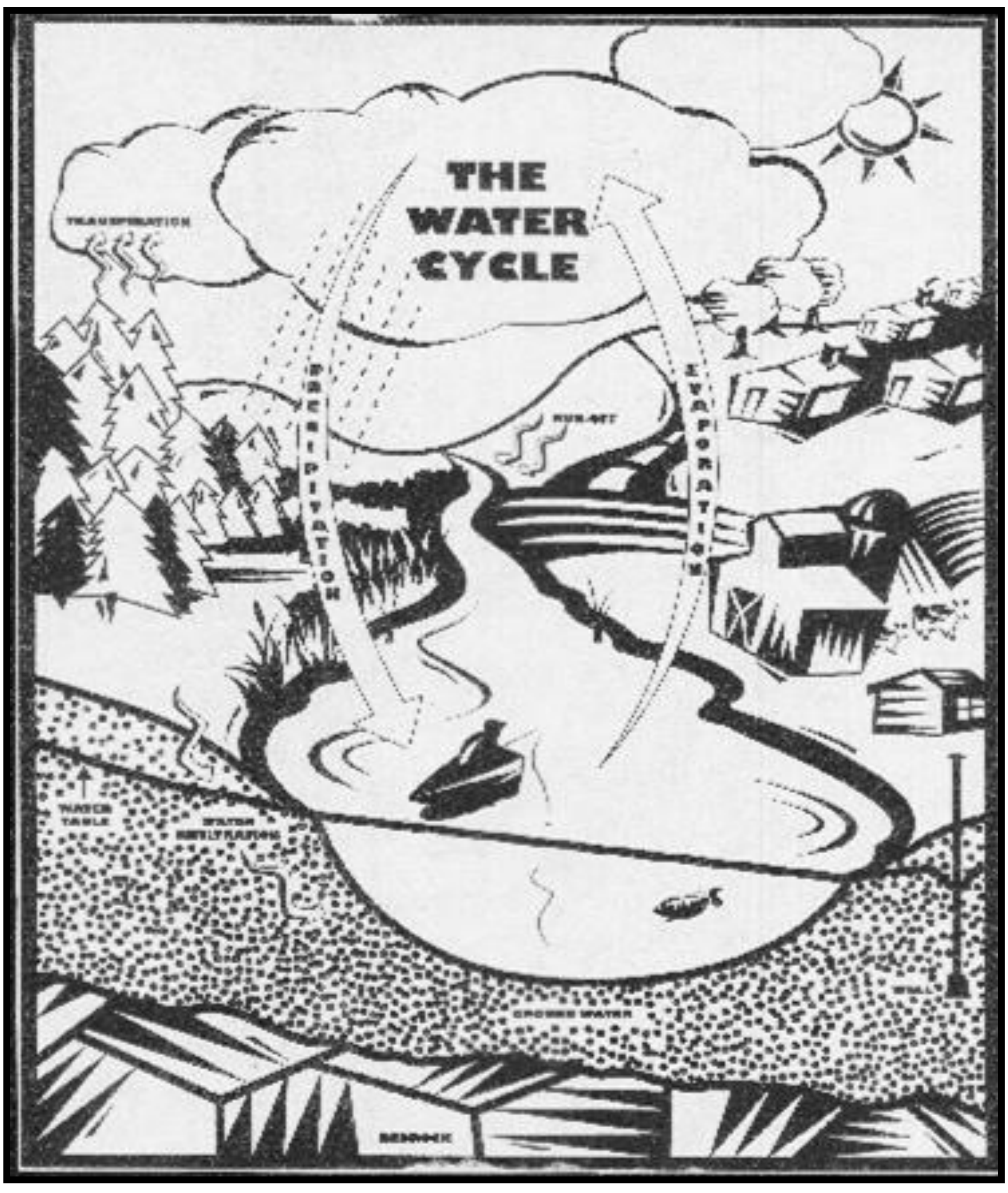
The chemistry of water will vary throughout the world. As water comes into contact with naturally occurring inorganic* substances, some of these substances will dissolve into the water. The types of dissolved substances and their concentration is dependent upon:

- the chemical composition of the precipitation* in that area
- the biological and chemical reactions occurring in that area
- the mineral composition of the geological material through which the water moves
- the length of time that the water spends in contact with the geological material through which it moves (Heath, 1998)

Water that spends a greater amount of time in contact with geologic materials will have a great concentration of dissolved inorganic substances. Water that spends only a short time in contact with geologic materials will have less dissolved inorganic substances. The concentrations of substances dissolved in water are referred to as the total amount of dissolved solids. The quality of water depends upon the total amount of dissolved solids and how these affect the characteristics of the water.

THE HYDROLOGIC CYCLE

The hydrologic cycle is the constant movement of water above, on and through the earth's surface. The diagram below shows the different paths that water may follow once it falls to the land in the form of precipitation. Water is returned to the atmosphere by evaporation*. Water may also be returned to the atmosphere by transpiration. Transpiration* is the loss of water vapor from the stomata (gasexchange pores) of plants and to a lesser extent, from the evaporation of water through plant cell tissue. The cycle starts over again when the evaporated water molecules fall to the earth in the form of precipitation.



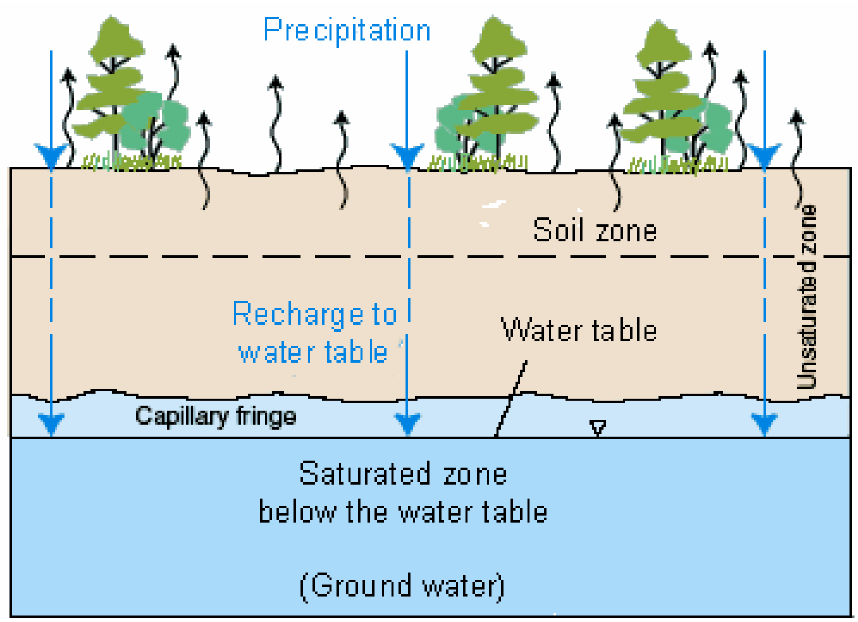
Magnificent Ground Water Connection, 1998)

II. GROUNDWATER

Groundwater is water that is located in the subsurface of the earth where all pore spaces or openings are saturated or completely filled with water. Pore spaces are the spaces in between soil and rock particles. To visualize this think of a jar of marbles. The marbles represent the soil or rock particles and the spaces in between them represent the pore spaces. Openings can also be fractures in a rock layer.

WATER TABLE

The water table is the highest level of the groundwater. The level or height to which the water may rise or fall depends on how much water is present. Water tables are higher during rainy months and when there is less transpiration, and lower during drier months and when there is more transpiration. Above the water table the ground may contain some water, but the pore spaces or openings also contain air. This is known as the vadose zone or the unsaturated zone. Below the water table is the saturated zone. In the saturated zone all pore spaces or openings are completely filled with water. Directly above the saturated zone is the capillary fringe. The capillary fringe* contains a little water that is held in place due to dipole-dipole force of attraction between water molecules and between water molecules and other substances. When the water table intersects the surface of the earth, streams, lakes, springs, or swamps form.



USGS Water Science for Schools http://ga.water.usgs.gov/edu/index.html

AQUIFERS

Any geological structure that can yield a usable quantity of water is called an aquifer*. Examples of a geologic structure include a subsurface layer of sand, gravel, clay, till (a combination of sand, silt, clay and gravel), limestone, slate, shale, sandstone, or bedrock. In an aquifer water may be located in the pore spaces (the space in between the particles) or in the fractures of rock. If the water table is free to rise and fall in the geologic formation the aquifer is said to be an unconfined* aquifer. If an impermeable geologic formation, such as a clay layer, overlies an aquifer the aquifer is said to be a confined* or an artesian* aquifer.

POROSITY

Porosity is a ratio of the total openings to the volume of a geologic formation. This ratio is then expressed as a percentage. The percentage is the maximum amount of water that a particular geologic structure can contain in relationship to its total volume. For example, suppose that a section of sandstone aquifer had a porosity of 33%; meaning that when the aquifer was saturated, 33% of the total volume would contain water.

PERMEABILITY

The ability of the material to transmit a fluid is called its permeability. If a material allows water to flow through it easily, it has a high permeability. If a material does not allow water to flow through it easily, it has a low permeability. Permeability depends upon two factors: the size of the pore spaces in the material, and how well the pore spaces are connected. All porous materials are not permeable, because if the pore spaces in the material are not large enough for water molecules to pass through than no water can be transmitted through the material.

MOVEMENT OF GROUNDWATER IN THE SUBSURFACE

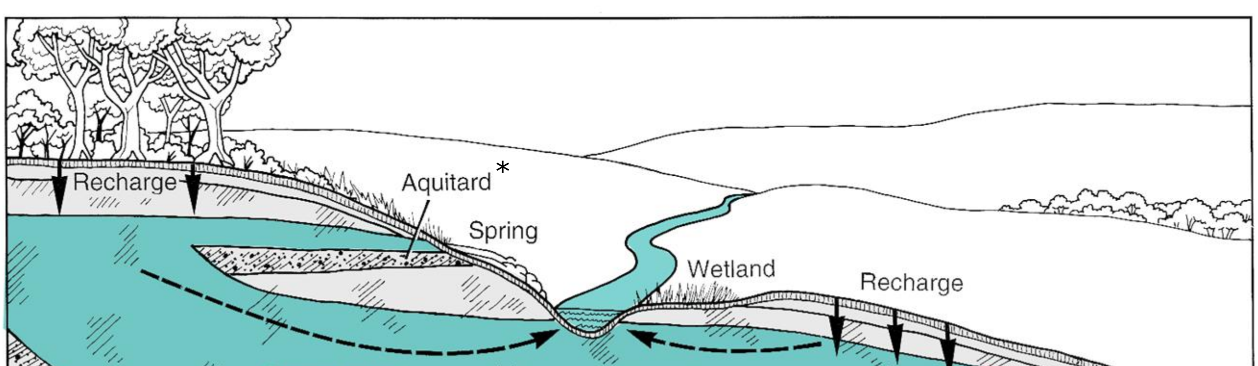
Water enters the subsurface by infiltration*. Once in the saturated zone water moves at a very slow rate, which can be measured in cm/day or meters/year. Groundwater flow is laminar*, meaning the water has a smooth, not turbulent* flow that allows very little mixing of adjacent layers. The height of the water table and/or the amount of pressure that is exerted on the groundwater by the overlying subsurface is the primary influence on the flow of groundwater.

Groundwater is also influenced by gravity. Groundwater will move from areas where the water table is high to areas where the water table is low. The water table is low in areas where it intersects the land surface such as lakes, ponds, springs, streams, or swamps. Some of the water molecules will travel the shortest path to the waterbody. Other water molecules will travel deeper into the subsurface, taking a longer path to the surface water body. Water will also move from areas of high pressure to areas of low pressure. An example would be the land area above an aquifer, where pressure is exerted on that aquifer by that land directly above it. This will cause the groundwater within the aquifer to seek out areas of lower pressure.

RECHARGE AND DISCHARGE AREAS

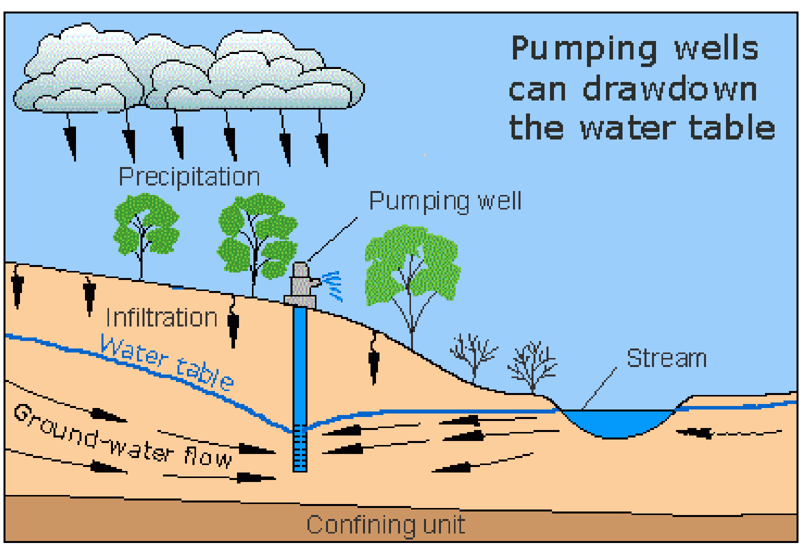
A recharge area is a section of land where groundwater is able to infiltrate the subsurface and enter the saturated zone* of an aquifer. In general, an unconfined aquifer has a greater recharge area than a confined aquifer since its saturated zone is not overlain by a confining layer such as the case in a confined aquifer. However some lakes, ponds, streams and rivers are also recharge areas. This means that water is able to infiltrate the subsurface and enter the saturated zone via the ground under the surface waterbody. A discharge area is where groundwater leaves the saturated zone of an aquifer and flows into an area of land or a surface water body such as a lake, pond, spring, stream, or river.

Some surface water bodies alternate between being a recharge area or a discharge area depending on the state of the water table. For example, if the water table is higher than the stream bed the stream will serve as an area of discharge for groundwater resulting in the stream gaining water. If the water table is lower than the stream bed, the stream serves as an area of recharge to the groundwater resulting in the stream losing water.



WELLS

A well is a vertical hole drilled in the earth to access water. Wells vary in length and diameter. Some wells, water supply wells, are pumped to bring the water to the surface. Other wells, observation or monitoring wells, are used for taking groundwater samples and measuring the depth to groundwater. When a well is pumped it will reduce the level of the groundwater. This is called drawdown. Drawdown creates a cone of depression around the pumping well that extends in all directions. Drawdown may even result in a shallow well becoming dry if a deeper well in the area has lowered the level of the water table.



Land subsidence* is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs. Land subsidence occurs in nearly every state of the United States. Over pumping of aquifers is the major cause of subsidence in the southwestern United States, and as ground-water pumping increases, land subsidence also will increase. In many aquifers, ground water is pumped from pore spaces between grains of sand and gravel. If an aquifer has beds of clay or silt within or next to it, the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The reduced water pressure is a loss of support for the clay and silt beds. Because these beds are compressible, they compact (become thinner), and the effects are seen as a lowering of the land surface. The lowering of land surface elevation from this process is permanent. Some problems from land subsidence include: changes in elevation and slope of streams and rivers; damage to bridges, roads, railroads, storm drains; and damage to private and public buildings. In some areas where ground-water pumping has caused subsidence, the subsidence has been stopped by switching from ground-water to surface-water supplies. If surface water is not available, then other means must be taken to reduce subsidence. Possible measures include reducing water use, enacting withdrawal limits and determining locations for pumping and artificial recharge that will minimize subsidence.

In Italy, groundwater withdrawal has caused the Tower of Pisa to lean and contributes to continued flooding in the canal-city of Venice.

DETERMINING GROUND WATER ELEVATION IN THE SUBSURFACE

It is important to know the elevation of groundwater in the subsurface, as this can aid in the drilling of water supply wells and in construction. Constructing a building where the water table rises close to the surface can cause problems, especially during the wet season where the water table can end up in your basement. Groundwater elevations are also used to determine the direction of groundwater flow. This is especially important if the water is contaminated*. If the flow direction of contaminated water is known, warnings can be issued and a treatment designed.

GROUNDWATER CONTAMINATION

Groundwater can become contaminated if rain water comes into contact with contaminated soil while seeping into the ground. It can also become polluted when liquid hazardous substances themselves soak down through the soil or rock into the groundwater. Some liquid hazardous substances do not mix with the groundwater but remain pooled within the soil or bedrock, acting as long term sources of groundwater contamination.

(this page is cropped)

Contaminants can be grouped into 3 general types: sinking, floating and compatible/soluble. Contaminants move with groundwater flow once into an aquifer (remember how slow it is moving?). As the contamination moves, it disperses and the concentration decreases as it moves farther away from the source of the pollution, much like pouring a packet of kool aid into a gallon of water. The darker color of kool aid (representing the most concentration) will occur where you are adding it, the color will get lighter (representing less concentration) as it flows through the gallon. The visual representation of the different concentrations is called a contamination plume. What the plume looks like depends on the type of contamination source, the specific contaminant(s), where the aquifer is, and different soils in the area.

Major sources of groundwater contamination include leaking underground storage tanks, like the ones you find at gas stations, leaking septic tanks, and industrial waste. Contamination amounts are measured in terms of concentration; parts per million (ppm), parts per billion (ppb), parts per trillion (ppt). Concentrations like these are hard to visualize because they are so tiny but to give you an idea, 1 drop of water in an Olympic size swimming pool is equal to 1 part per billion and 1 drop in a quart of water is equal to 1 part per thousand.

If you are interested in groundwater contamination and environmental law, research Love Canal, New York or watch the movie ***Erin Brokovitch*** or, an event that happened closer to home, ***A Civil Action***.

CERCLA (Comprehensive Environmental Response, Compensation and Liability Act of 1980) also known as the Superfund Act

Superfund or Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) is a United States federal law designed to clean up sites contaminated with hazardous substances and pollutants.

CERCLA was enacted by Congress in 1980 in response to the threat of hazardous waste sites, typified by the Love Canal disaster in New York, and the Valley of the Drums in Kentucky. The initial trust fund to clean up a site where a polluter could not be identified, could not or would not pay (bankruptcy or refusal) consisted of about $1.6 billion.

CERCLA authorizes two kinds of response actions:

1. Removal actions. These are typically short-term response actions, where actions may be taken to address releases or threatened releases requiring prompt response. Removal actions are classified as: (1) emergency; (2) time-critical; and (3) non-time critical. Removal responses are generally used to address localized risks such as abandoned drums containing hazardous substances, and contaminated surface soils posing acute risks to human health or the environment.

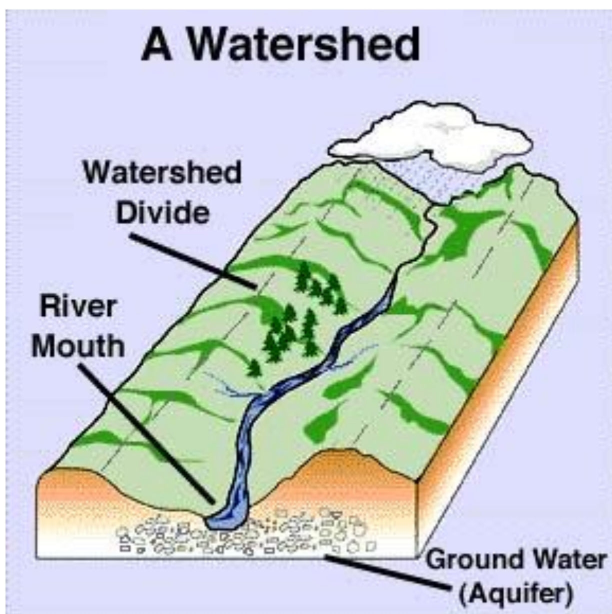
2. Remedial actions. These are usually long-term response actions. Remedial actions seek to permanently and significantly reduce the risks associated with releases or threats of releases of hazardous substances, and are generally larger more expensive actions which may include such measures as preventing the migration of pollutants with containment, or preferably removing and/or treating or neutralizing toxic substances. These actions can be conducted with federal funding only at sites listed on the EPA National Priorities List (NPL) in the United States and the territories. Remedial action by responsible parties under consent decrees or unilateral administrative orders with EPA oversight may be performed at both NPL and non-NPL sites, commonly called Superfund Alternative Sites in published EPA guidance and policy documents.

III. SURFACE WATER

Water that occurs on the surface of the earth is termed surface water. Surface water includes rivers, streams, wetlands, lakes, ponds, reservoirs, estuaries and oceans.

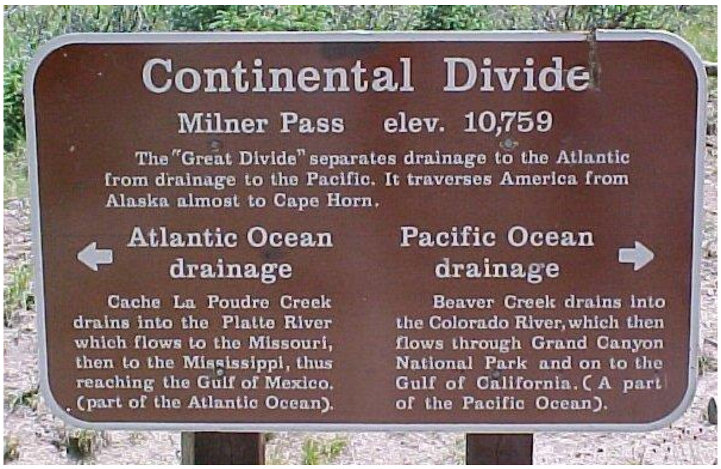
WATERSHEDS

The land contains water both on the surface and under the surface, and gravity forces all of this water to a main course (stream/river), or holding area (lake/pond/reservoir). A watershed consists of all the land that drains to a particular waterbody. It's the land that water flows across or under on its way to a river, lake, or reservoir.



Kentucky Division of Water

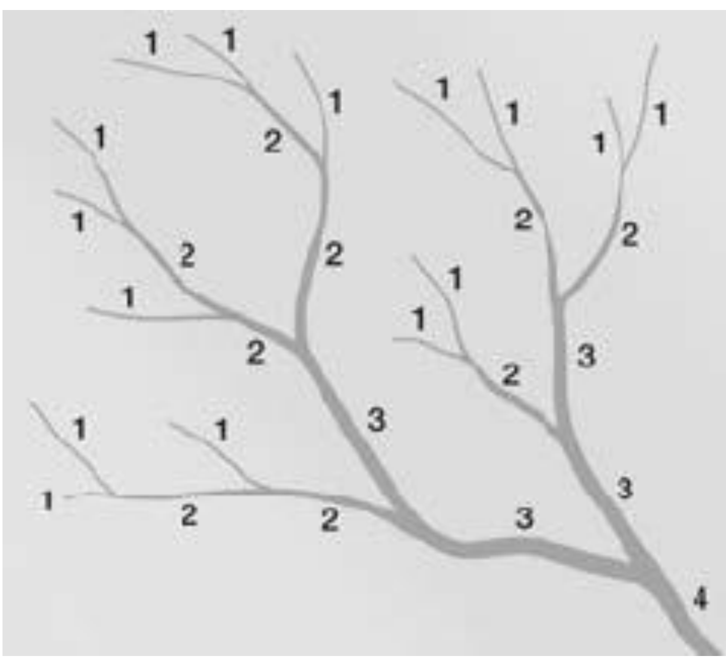
Every watershed has boundaries which are defined by the highest elevations around a given waterbody. Ridges and hills serve as watershed boundaries or divides. Surface water will always flow down hill. Water that falls on the top of a ridge or a hill may flow down either side. Water that flows down one side will enter into one watershed while water flowing down the opposite side will enter into a different watershed. Thus, the high points in elevation form watershed boundaries by separating the flow of water into two or more watersheds. One of the most well known divides is the Continental Divide, running north to south through North America. Water that falls west of the Continental Divide flows to the Pacific Ocean. Water that falls east of the Continental Divide flows to the Atlantic Ocean.



STREAMS AND RIVERS

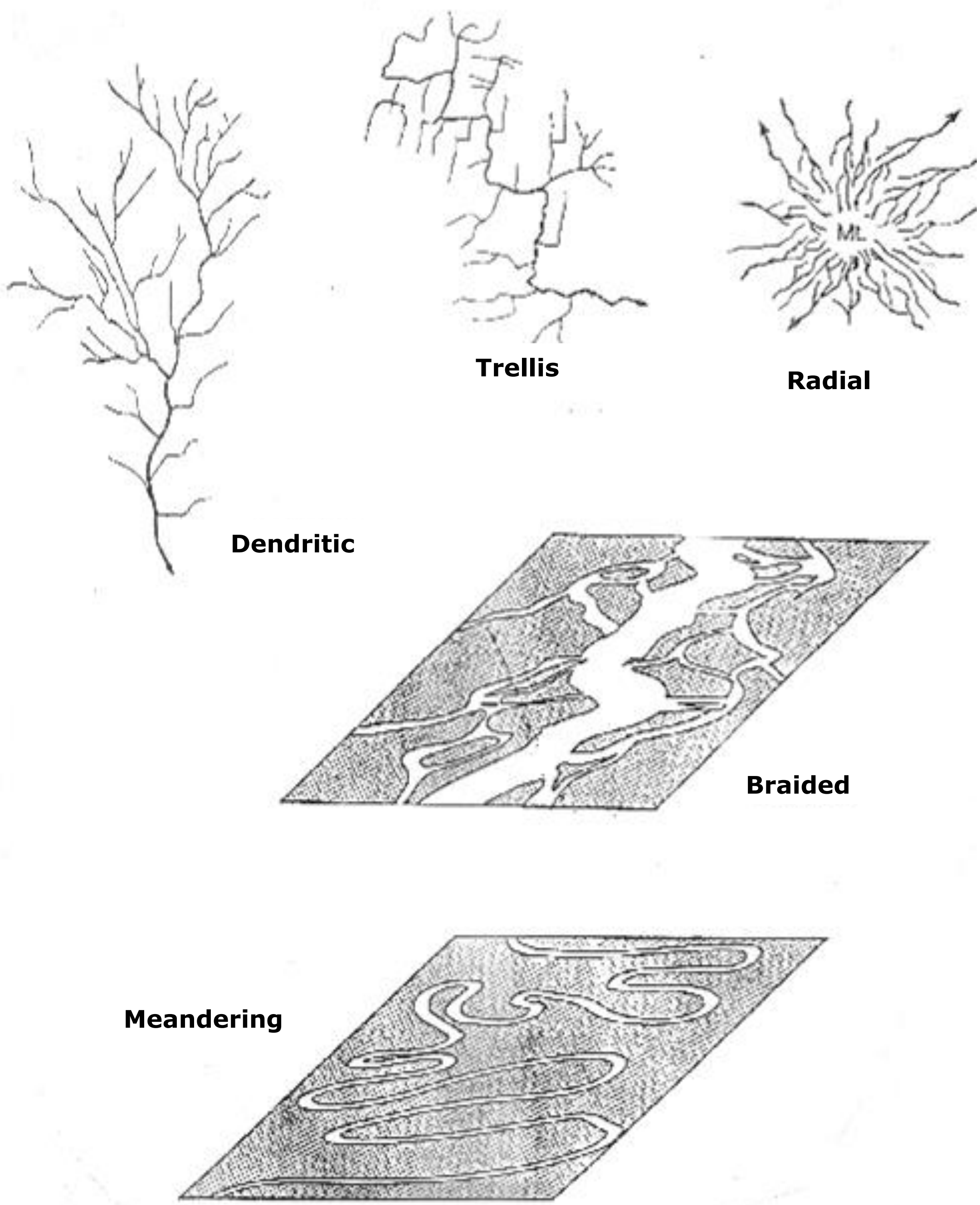
Streams and rivers within a watershed are classified by orders. The orders are defined below:

- **First-order stream** – known as headwaters (the beginning of the stream, the uppermost reaches of the stream); no other tributaries are connected to it.
- **Second-order stream** - the resulting stream from a first-order stream joining with another first-order stream.
- **Third-order stream** - the resulting stream from a second-order stream joining with another second-order stream.
- Orders increase (four, five, and beyond) with the increasing size of the stream or river.



Marsh 1998; www.chesapeake.towson.edu

Streams form different patterns. Five patterns are shown above. Note that when looking at a map of a dendritic stream pattern you can figure the direction of stream flow. Look for a "V" on the map. This is the joining of two streams. The bottom of the "V" points in the direction of stream flow.

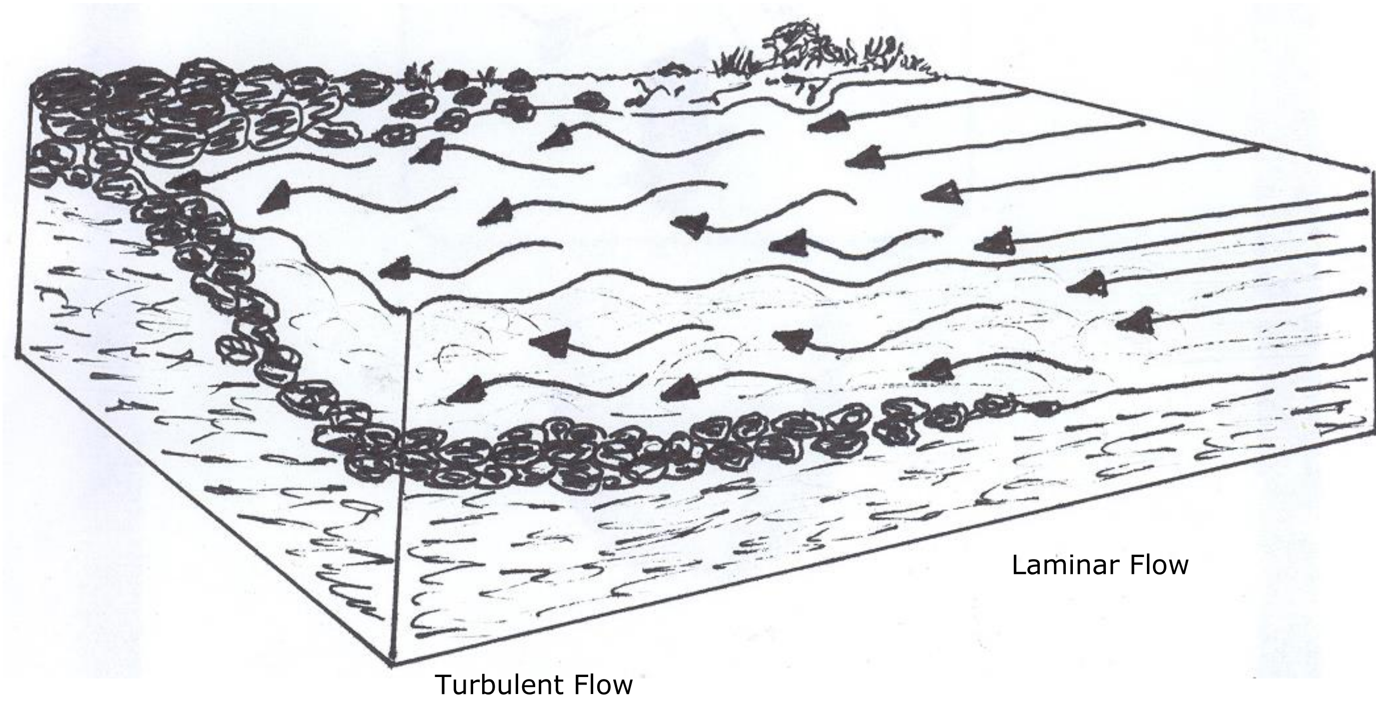


Firehock, 1995

Streams can be further classified as perennial or intermittent. A perennial stream flows all year long as opposed to an intermittent stream that only flows when the water table is high. Intermittent streams can be found in later spring, early summer and after heavy rains.

FLOW

The flow in a river/stream can be turbulent or laminar. Flow depends on the velocity of the water and on the nature of the stream bed. Turbulent flow is when the water moves erratically downstream and stirs the sediment as it moves. Turbulent flow usually occurs when the stream bed is rocky. This type of flow can cause scour. Scour is the erosion of the channel by the suspended sediments and particles in the turbulent flow. Laminar flow is when the water moves steadily and there is minimal mixing of the sediment. The bottom is usually smooth and flat for laminar flow to occur.

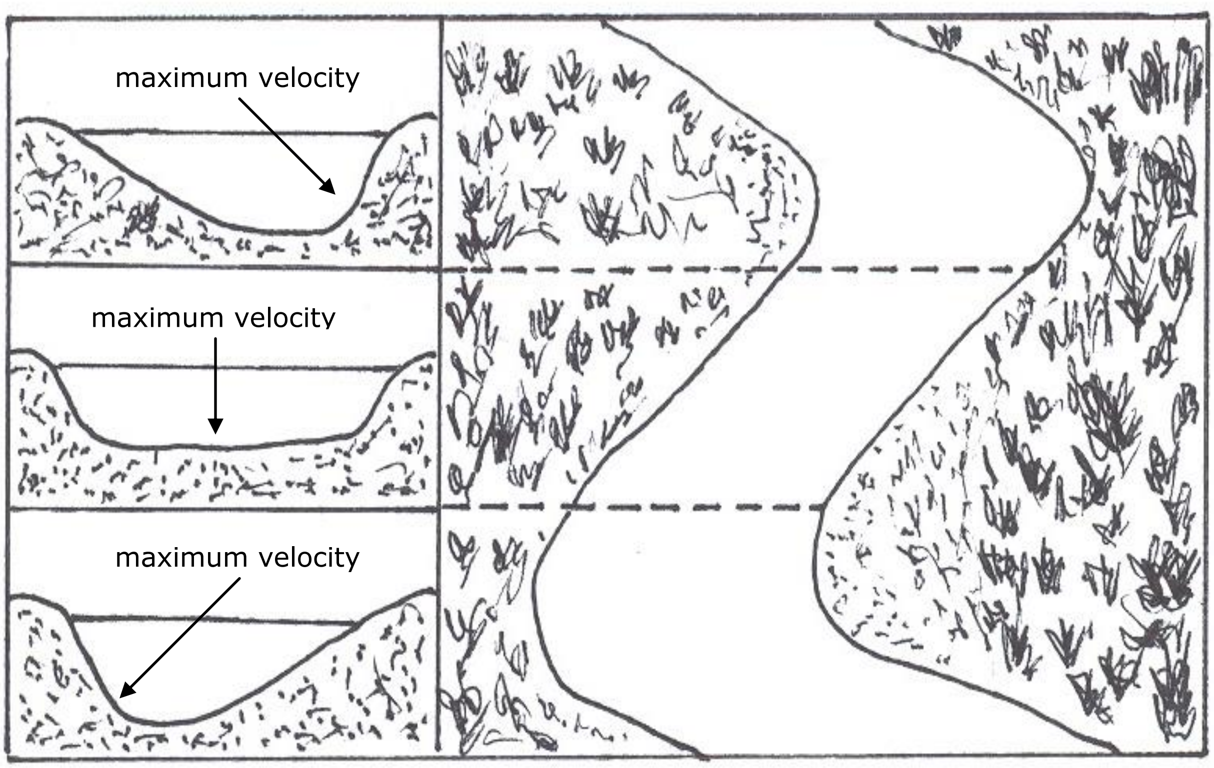


Hewitt et al 1994; Redrawn by Jim Lafley, MA DCR

DISCHARGE IN A RIVER OR STREAM

The discharge is the volume of water that flows past a given point in a channel per a given unit of time. The velocity of a stream is dependent upon the stream's gradient. The gradient of a stream is the ratio of the vertical drop to the horizontal distance for that drop. The greater the gradient, the greater is the velocity. The size and shape of the channel also affect the velocity. The greater the contact area of the water with the land, the greater is the friction and the slower the velocity. The maximum velocity of the flowing water in a stream depends upon the shape of the stream channel. The maximum velocity of the flowing water in a straight channel stream is in the middle of the channel and close to the surface. The maximum velocity in a stream channel that has bends in it is toward the outside of each bend and slightly below the surface of the water. Erosion* occurs where the stream velocity is greatest and deposition* occurs where the stream velocity is slowest.

Erosion of cut bank



Hewitt et al. 1994; Redrawn by Jim Lafley, MA DCR

ALTERATIONS TO WATERSHEDS

As the land becomes more and more developed, diking, damming, straightening, and underground piping are altering waterways within our watersheds. Dams are used for many different purposes. They provide hydro-electrical power, recreation, irrigation, or traps for sediment from agriculture or construction activities. Although dams are beneficial in some situations, they are detrimental in others. While the water is behind the dam, it is being heated by the sun. A three degree rise in Celsius can cause thermal pollution and depletion of oxygen. Warmer water can not hold as much oxygen. Without enough oxygen to meet the biological oxygen demand the plant and animal life become stressed and could die. Damming a river also restricts the flow of water downstream, resulting in a disruption to the balance of the ecosystem* (ex. the loss of shallow wading habitats).

When the natural vegetation in the riparian zone* is removed erosion can take place. The roots of the vegetation help to hold the soils in place. Without the vegetation holding the earth in place, the surface water run-off can become high in suspended sediments. Extra sediment can cloud the water reducing the amount of photosynthesis by aquatic plants, clog the gills of aquatic animals, and smother macroinvertebrates*. If the sediments increase to the point where the river becomes too shallow for boat traffic, dredging must take place. Dredging is a solution for deepening the river but it also disrupts the established ecosystem and suspends the sediment.

Proper sediment management during agricultural activities and construction can save the streams. Silt fences and straw bales can help to contain sediments in construction areas. Alternating crops with rows of grass will also help to filter the runoff and reduce the amount of sedimentation in the water. Preserving vegetation along stream beds and especially in the riparian zones will also prevent extra sediments from entering the water.

When streams are in the way of development they are piped underground. Once underground they are often connected to the city's storm water drainage system. Underground streams in cities have been redesigned to carry away all the storm water, and whatever the storm water can carry, such as oil and animal wastes. In some cities, the storm water drainage system is also used as an overflow for the city's sewage. Companies have been known to illegally connect to the storm water drainage system to discharge manufacturing by-products.

EUTROPHICATION

Eutrophication is the evolution, or natural aging process of a waterbody. A lake or pond is created from a catastrophic event, typically glaciers, volcanoes, or earthquakes, then slowly evolves from a pristine low nutrient waterbody to dry land over time. This usually takes thousands of years to occur, although human activities can speed the process up significantly. The process begins with nutrients, like nitrates and phosphorous, slowly building up in the waterbody. Plants and algae utilizing these nutrients grow, providing a good environment for aquatic life. Aerobic * (oxygen consuming) bacteria break down the organic wastes from this aquatic life. The decaying organic material and respiring algae cause the oxygen levels to drop. This will eventually reach a point where the waterbody no longer has enough oxygen to support life, and aquatic animals like fish begin to die. Without oxygen aerobic bacteria will no longer be able to break down the organic wastes, so the nutrients will stay trapped in these wastes within the waterbody. Anaerobic bacteria* (non-oxygen consuming) begin to break down the organic waste very slowly over time producing foul smelling gases. After hundreds of years, the waterbody will fill up with plants, becoming a wetland, then eventually dry land, most likely a forest.

As stated above, humans can greatly increase the process of eutrophication, this is sometimes known as cultural eutrophication. Sewage, agricultural runoff, and over-fertilization can severely impact both our salt and fresh water ecosystems, and cause an increase in plankton and encourage the growth of aquatic plants. The effects are most obvious in bays, coves, and estuaries as they are often shallow and sheltered.

WETLANDS

A wetland is defined as land that is saturated by water for at least part of the year, with characteristic hydric (saturated) soils, and having one of a number of distinct vegetation types (Art 1993). It was once common practice to drain and fill wetlands. It is now known that wetlands are much more valuable in their natural state. Wetlands are able to degrade moderate amounts of contamination (rendering these substances harmless), and trap sediments, preventing them from entering a stream. Wetlands can be a recharge or a discharge area for an aquifer, or alternate between the two. Wetland vegetation can store and slow the release of water, which helps to control flooding. Wetlands provide food and shelter for 45% of endangered animals and 26% of endangered plants (Gralla, 1994).

Swamps*, bogs*, marshes*, fens*, and vernal pools* are all types of wetlands. When they formed, the water table was at or near the surface of the earth. Swamps remain wet for part of the year and dry for the other part. The trees in a swamp are often dormant. Swamps are characterized by certain types of trees such as: oaks, willows, alders, tupelo gums and bald cypresses. Bogs have spongy, moist ground with only shallow waters visible. Bogs are characterized by spongy peat deposits, acidic waters and a floor covered by a thick carpet of sphagnum moss. Bogs receive all or most of their water from precipitation rather than from runoff, groundwater or streams. As a result, bogs are low in the nutrients needed for plant growth, a condition that is enhanced by acid forming peat (a highly organic material found in marshy or damp regions, composed of partially decayed vegetable matter mosses). Bog soils are oxygen and nutrient poor, and are much more acidic than other soils. The unique and demanding physical and chemical characteristics of bogs result in the presence of plant and animal communities that have many special adaptations to low nutrient levels, waterlogged conditions, and acidic waters, such as carnivorous plants. Because bogs are so low in oxygen, they result in extraordinary preservation for anything that might get into them, including butter (yes, butter), and bodies (yes, bodies)! Try a

Google search for these. Marshes are wet the entire year. Grasses will grow in a marsh but trees will not. Cattails, bulrushes, and water lilies may be found in a marsh. Vernal pools are common in shallow lowland areas following spring runoff or high precipitation.
Vernal pools are unique because they dry up for a period of time during the year (or at least every few years); therefore, you might find an occasional fish, but will never find a fish population in a vernal pool. Because there are no fish, they allow the safe development of amphibian and insect species unable to withstand competition or predation by fish. Fairy shrimp, spotted salamander and blue spotted salamander are a few examples of vernal pool species.

The Massachusetts Wetlands Protection Act (1972) protects Wetland Resource Areas. It prohibits removal, fill, dredging or alteration of any coastal or freshwater (inland) wetland covered by the act without the filing of a Notice of Intent (NOI) with the local Conservation Commission. This Act was amended in 1996 to include a new resource area called the Riverfront Area. With this amendment, any work taking place within 100 feet of a wetland or 200 feet of a perennial river or stream or 100 feet from an intermittent river or stream must get approval from the local Conservation Commission.

LAKES & PONDS

Lakes and ponds are classified as lentic* (still water) systems, in contrast to streams and rivers which are lotic* (flowing water) systems. There is no clear definition between a lake and a pond. There are several interpretations over which the science community likes to argue. Generally a lake is a much larger system, loosely defined as a body of fresh water that is deep enough to prohibit rooted aquatic plants from growing all the way across the bottom (Art 1993). A pond is a smaller shallow system that can potentially support rooted aquatic plants throughout. Again these are not hard fast definitions, but should help you to understand that a lake and a pond are different systems. Some of the ways that lakes and ponds have formed include: glacial scouring from ice events (this is how most waterbodies in the northeast were formed), shifting of the earth's surface to create basins, and rivers changing course over time leaving behind ox-bow ponds, or lakes.

Lakes are divided into successional, or developmental stages. This has to do with a lakes trophic level (how nutrient rich or poor it is), which has a lot to do with how old the lake is, how much sediment has settled into the lake, and how much organic and inorganic matter the lake has been exposed to. This successional process is known as ontogeny*.

There are two major developmental stages of a lake, these are:

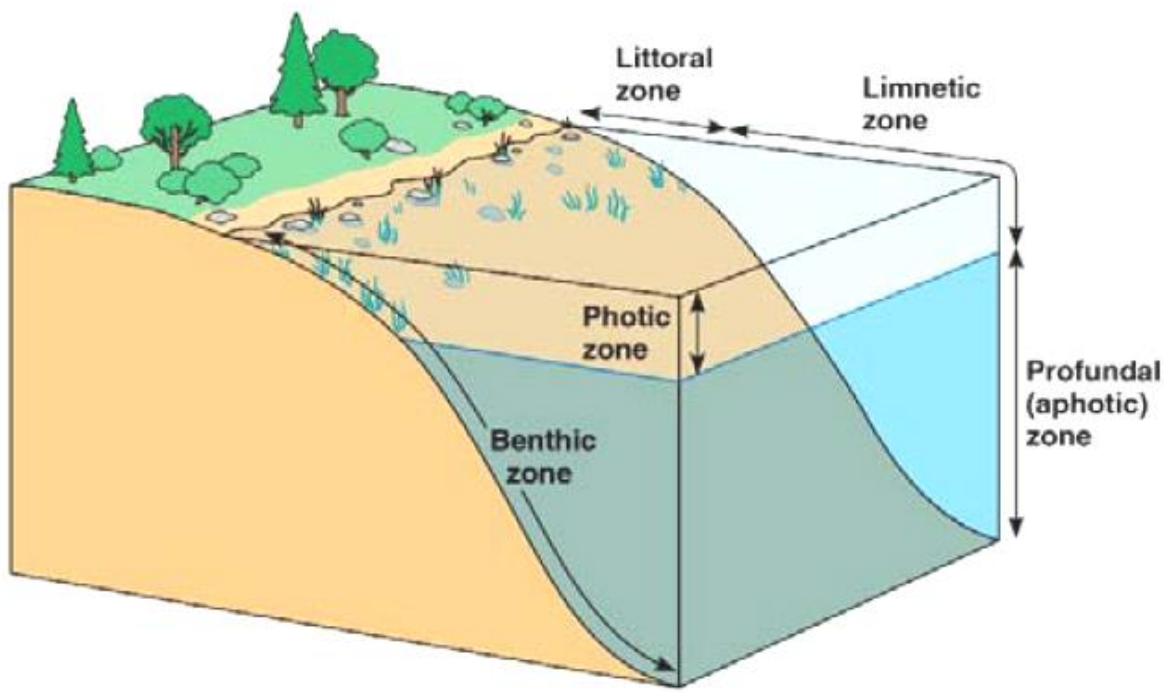
- **Oligotrophic** – A lake that is fairly young developmentally. These water bodies are extremely nutrient poor, and contain little organic matter. Oligotrophic lakes have a much clearer appearance than eutrophic lakes, and the bottom is comprised mainly of rock and sand. Most New England lakes are far removed from this oligotrophic stage, as these waterbodies were created during the last glacial event roughly 12,000 years ago. Reservoirs (man-made waterbodies) are considered oligotrophic as most were created within the past 100 years.

- **Eutrophic** – A lake which is rich in organic matter and vegetation. The water is much less clear than an oligotrophic lake, and is often considered murky. A eutrophic lake is much more evolved than an oligotrophic lake due in large part to an increased sediment load, and a higher nutrient (organic and inorganic) content. Eutrophic lakes are always more productive biologically, which simply means an increase in aquatic life. Most New England waterbodies are either eutrophic, or well on their way.

Lake and pond succession is a natural event, where nutrients and sediments from the surrounding land wash into and accumulate in the waterbody. An oligotrophic lake will eventually turn into a eutrophic lake. As a eutrophic lake accumulates nutrients and sediments it will eventually evolve into a wetland. These successional processes evolve over extremely long periods of time, often thousands of years.

A lake can be divided into six different zones:

- **Littoral zone** - The area of the lake that is closest to shore. The water here is usually shallow and vegetation will grow in this area.
- **Pelagic zone** - the open water in the middle of the lake
- **Limnetic zone** - the depth to which sunlight can penetrate the water of the lake
- **Photic zone**- Sunlit upper waters extending from the surface down to where light dims to about 1% of that at the surface.
- **Profundal zone** - the deep water below the level of light penetration
- **Benthic zone** - The bottom of the lake. This is where anaerobic microorganisms live in the silt and sediments. They break down the decaying vegetation and organic matter in the lake.



Jepson: http://www.ent.orst.edu/jepsonp/2000lecture1

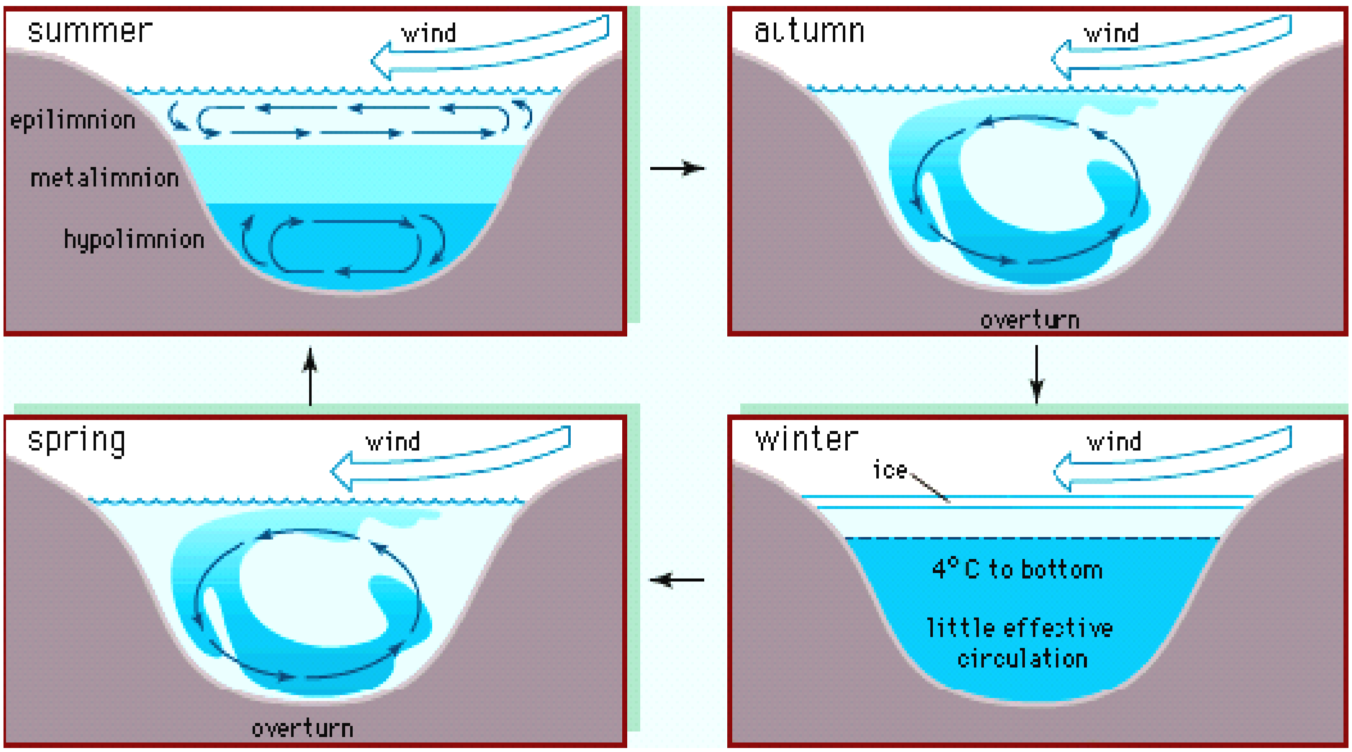
LAKE TURNOVER & STRATIFICATION

Temperate lakes go through two periods of thermal mixing each year, one in the spring, and one in the fall. This thermal mixing occurs when the entire water column becomes one temperature. This process is also known as turnover. If a lake turns over twice a year it is known as dimictic. In other lakes around the world this turnover occurs more or less frequently, depending upon elevation, differences in climate, and lake morphometry*. To understand how lakes change it is important to know what happens to water at different temperatures. Water, like most substances, becomes lighter when warmed, and heavier when cooled. Water does have a unique property however, when it cools below 39 degrees F (4 degrees C), it becomes lighter. This is because water reaches maximum density at 39 degrees F. This results in the lake's bottom water being warmer than the surface water during winter. It also explains why ice, at 32 degrees F (0 degrees C), being less dense than water, floats.

Following these turnover events a lake begins to set up distinct temperature zones. These zones get larger and more distinct with prolonged periods of warm (summer) or cold (winter) weather. An upper warm water layer called the epilimnion, a cooler middle layer called the metalimnion, and a deeper colder water layer called the hypolimnion characterizes summer stratification*. A thermocline, or rapid drop in water temperature with respect to depth defines the metalimnion. If you have ever jumped into a lake in the middle of summer you probably have pushed through this layer (thermocline) and experienced this rapid drop in temperature. During the winter months these layers of stratification will again set up, but in reverse. As the temperature of the water reaches the point of maximum density surface ice will begin to form. Inverse stratification then occurs, where colder less dense water lies over warmer more dense water. During this time water temperatures throughout the depths of the water column will only be a few degrees different. They will stay this way until the spring turnover period.

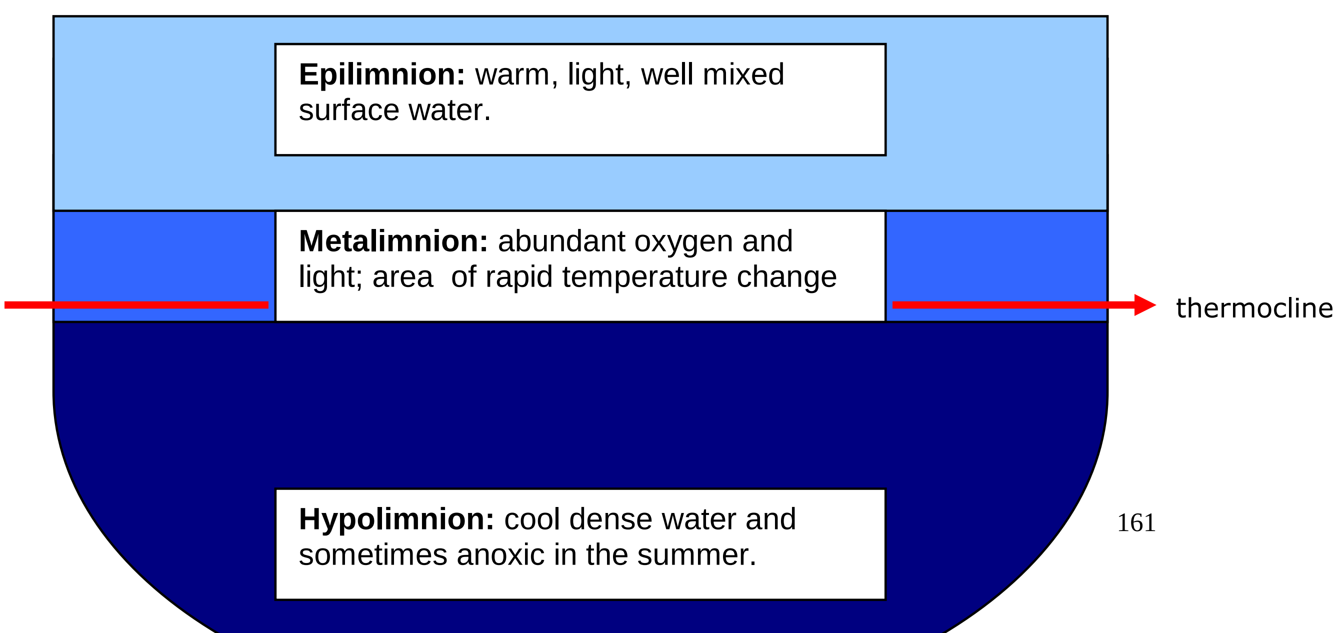
Turnover, whether in spring or fall, is triggered by air temperature. Fall turnover is triggered by a decrease in air temperature, while spring turnover is triggered by an increase in air temperature. Wind also helps to churn the water column, and plays a big role in both seasons. Basically air temperature and wind act to break up stratification. In the fall, cooler air temps and gusty winds cool the upper layers, and eventually mix the entire water column to one temperature. In the spring, the warming air temperatures and winds melt and break up the icy top layer, and again, eventually mix the entire water column to one temperature.

Turnover is extremely beneficial to the lake because the lower layer needs to mix with the upper layers to become reoxygenated and release accumulated noxious gases. The lower water layer often has lost all of its oxygen due to the lack of contact it has had with the atmosphere during stratification. A build up of methane and hydrogen sulfide can also occur during stratification. These noxious gases have accumulated as by-products during the decay of organic matter at the bottom of the pond or lake. If turnover occurs early and rapidly (a few hours) due to a severe storm and high winds, the lower layer will not have had sufficient time to reoxygenate. This means that a small volume of oxygenated water will mix with a large volume of deoxygenated water, resulting in an insufficient amount of oxygen to sustain animal life.



Ohio State University

Layers in a Stratified Lake



ESTUARIES

An estuary is where fresh water from rivers mixes with salt water from oceans. Estuaries contain a great diversity and number of life forms because they are rich in nutrients brought by the flow of fresh water from rivers. Some animals that live in estuaries can tolerate both fresh and salt water. Bays, mudflats and salt marshes are all examples of estuaries. Estuaries are tidal, meaning that a part of the land under the water may be exposed to air at low tide.

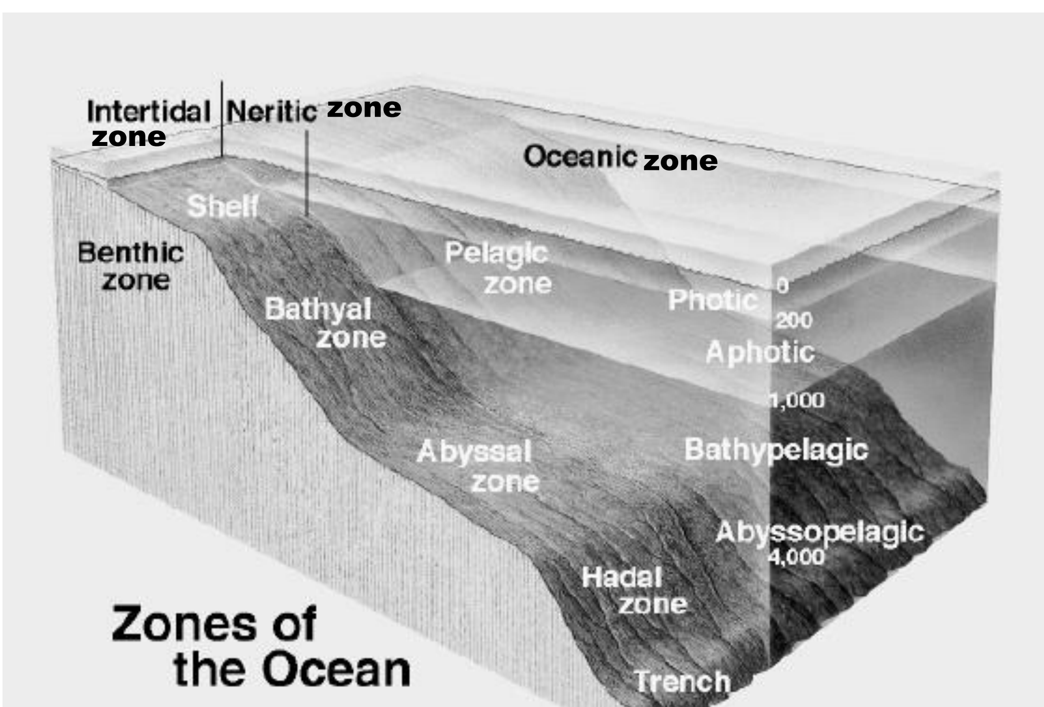
Due to the beauty and recreational activity estuaries provide, people like to develop the land that surrounds it. Currently, approximately 60% of the world's population lives near the coast (Gralla, 1994). Unfortunately the closer people live to the water the easier it is for pollution from lawn products, industry, sewage, and storm water drainage systems to come in contact with the water. Shellfish and other filter feeders ingest different kinds of contamination and bioaccumulate* it in their systems. This poisons both the animals, and the people who eat these animals.

OCEANS

Oceans cover two-thirds of the world. Oceans gave birth to the first living organisms over 4 billion years ago. Oceans have an average depth of 2.3 miles (3.7 km) but can be as deep as 7.14 miles (11.5 km) (Towel, 1991). Some of the largest mountain ranges in the world are found in the oceans. These ranges are called Midocean Ridges. The salinity content of the oceans is approximately 3.5% (Towel, 1991). Most of the salt is sodium chloride (NaCl).

The ocean can be divided into seven zones:

- **Pelagic zone** - the open ocean.
- **Neritic zone** - The part of the pelagic zone that extends over the continental shelf. The continental shelf is a flat plane or terrace that boarders the land and slopes down into the ocean. The size of the continental shelf varies. The seaward limit of the shelf is defined by a dramatic change in the slope of the land. This zone supports the largest amount of marine life due to its nutrient rich waters from the accumulation of sediment and organic debris from the land and the upwelling of nutrients from the ocean bottom.
- **Oceanic zone** - the part of the pelagic zone that is not over the continental shelf and is defined as the deep water of the open ocean
- **Photic zone** - The area of the ocean that sunlight is capable of penetrating. This zone extends to a depth of approximately 656 feet (200 meters) from the surface of the water.
- **Aphotic zone** - the area of the ocean that receives no sunlight
- **Benthic zone** - the bottom of the ocean
- **Intertidal zone** - the area of land where the tide rises and falls



Temperature, salinity, hydrostatic pressure (the pressure exerted by a static column of water), light, currents and nutrients affect the ecosystem of the ocean. The base of the food web is phytoplankton*. Through photosynthesis and the ingestion of nutrients, phytoplankton are able to reproduce in great numbers. Zooplankton* feed upon phytoplankton. The term zooplankton refers to a variety of life forms such as krill (tiny shrimp-like organisms) and larvae. Zooplankton are consumed by small surface feeding fish such as anchovies and sardines. The small fish are in turn fed upon by larger fish and marine mammals. Scavengers such as crabs feed on the dead plants and animals on the bottom. Micro-organisms* degrade the remains left by the scavengers, producing nutrients, which are brought up from the bottom during periods of upwelling.

The only ecosystem that does not rely on the sun for survival is located in the ocean. At the bottom of the open ocean are hydrothermal vents, which emit a continuous fountain of hydrogen sulfide gas. Hydrogen sulfide gas is poisonous to humans. Bacteria in the area of the vent are capable of converting this gas into energy, which allows them to reproduce and form the base of the food chain. The creatures that the bacteria support at the hydrothermal vent are extremely different. Giant clams, albino blind crabs and worms 4 meters in length have been found.

The oceans provide us with a source of precipitation due to the large amount of evaporation of water. Oceans also help to regulate our climate due to water's high heat capacity. One-half to one third of our oxygen comes from phytoplankton in the ocean. These one celled plants take in carbon dioxide and produce oxygen that humans and animals need to survive. This process occurs during photosynthesis. Another benefit to this process is the regulation of carbon dioxide, a known greenhouse gas.

Humans have not been entirely kind to our oceans, pollution from land is carried to the sea via rivers, and sometimes the oceans are used as a receptacle for our garbage. Over-harvesting certain species of marine wildlife has upset the ecological balance, at times pushing other species to near extinction.

IV. WATER POLLUTION

EXAMPLES

There are numerous ways that pollution can enter water supplies. Below are a few;

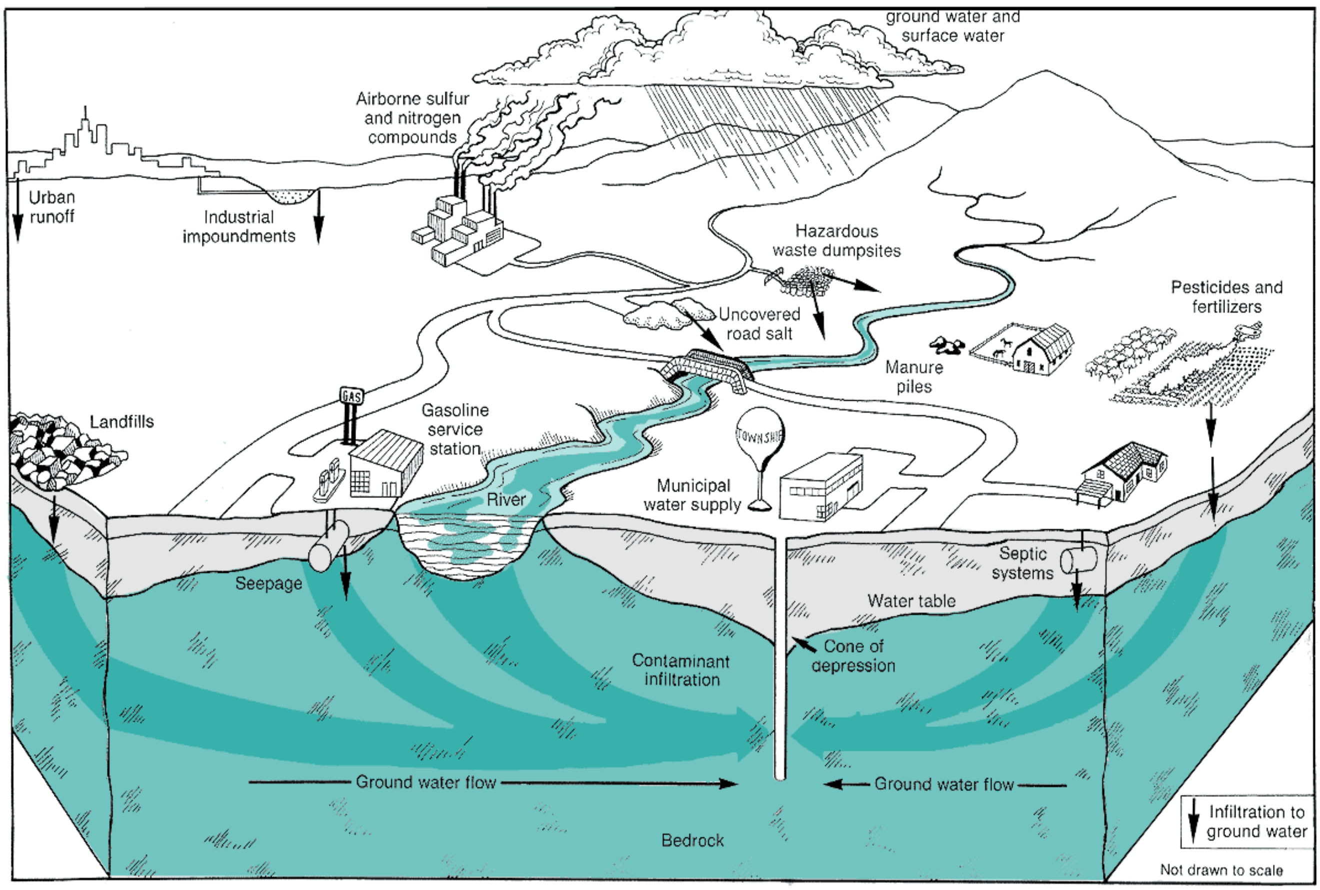
- Industry can discharge waste by-products directly into waterways. Many industries have permits to discharge a specific quantity of by-product but exceed their limit and pollute the water. Illegal or accidental discharge of chemicals into the ground can also contaminate the water and subsurface. Both are examples of point source pollution. Point source pollution means that the exact geographical location of the source of contamination can be located. Non-point source pollution means that the exact geographical location of the contamination can not be located. An example of a non-point source pollutant is agricultural erosion that can't be identified like a discharge pipe which releases a specific contaminant.
- Some power plants discharge hot water into a water body, changing the natural temperature of the water, and upsetting the established ecosystem. This is known as thermal pollution.
- Chemical storage tanks or underground storage tanks are known to leak. Chemicals may leak from tanks located on the surface or in the subsurface and contaminate the environment. This contamination can flow with the surface water run-off and enter rivers or other surface waterbodies, and/or infiltrate the subsurface and enter the groundwater just as water does.
- Out-dated septic systems may leak, or animal waste may be washed

overland into the water, allowing disease-carrying bacteria, called pathogens, to enter the water supplies. Boaters who empty their sewage into the water instead of using an approved pump out station at a marina also contribute to this problem.

- Pesticides, fertilizers, and other agricultural chemicals can enter groundwater by infiltration, or can be washed off crops and flow with the surface water run-off entering rivers or other surface waterbodies.
- Leachate* from landfills or garbage dumps may carry contaminants to water supplies.
- Phosphates and nitrogen can cause an excess growth of bacteria in lakes or ponds. These bacteria use all the available oxygen in the water, leaving the water with an insufficient amount of oxygen to support its ecosystem.
- Oil tankers may run aground or have leaking hulls, allowing large quantities of oil to spill in the oceans.
- At times the ocean is used as a dump for garbage or a place to pump treated sewage.
- Motor boats and jet skis pollute by adding oil and gasoline by-products to the water.
- Polychlorinated bi-phenyls (PCBs) from the production of electrical transformers have entered rivers and bays. The PCBs adsorb to the sediments in the water. Once the fish ingest the contaminated sediments, the PCBs bioaccumulate in their tissues. Since PBCs are known carcinogens* the fish become toxic and can not be eaten.
- Mining produces wastes that are harmful to the environment. An example of this is acid mine drainage. Run-off at mining sites turns acidic due to the oxidation of pyrite and iron disulfide by exposure to the air and water. The oxidation process produces ferrous ions and sulfuric acid, which enters the surface water run-off. Acid mine drainage can also infiltrate the land and pollute the groundwater.
- Acid precipitation is formed when the gases, sulfur dioxide and nitric oxide (produced by the burning of fossil fuels) mix with water in the atmosphere

to form rain, snow, fog, frost, sleet, and cloud moisture with a pH of 2.0 or less. Normal uncontaminated rain has a pH of about 5.6. This precipitation erodes buildings, and leaches heavy metals out of the soils, which can end up in surface water. Depending on how acidic the water, it can be toxic to animal life. If the pH levels are low enough fish and amphibians can not reproduce, and immature fish (fry/larvae) can die.

- In coastal areas, if too much water is withdrawn from a water supply well that is close to the ocean, saltwater intrusion* can occur. This occurs when saltwater is drawn into the well by pumping. It is estimated that two thirds of all aquifers in the Untied States are underlain by salt water (Winter et al., 1998). This is especially a problem in coastal areas where fresh rainwater infiltrating the ground floats on top of salt water in the aquifer. Salt and freshwater do not mix (differing densities) unless too much fresh water is being withdrawn from the well.



Ground and Surface Water Contamination Sources
Dauphin County (PA) Conservation District Dauphin County Conservation District

THE MOVEMENT OF CONTAMINATION IN THE SUBSURFACE

Once contaminants infiltrate the subsurface and enter the groundwater, it is important that hydrologists* be able to predict the direction of movement of the contamination. To predict this, the density of the contamination relative to the groundwater must be known.

REMEDIATION

Remediation is the process of removing contamination from the environment. Passive remediation or active remediation may remove contamination. Passive remediation refers to the adsorption, dilution, and dispersion of the contaminant by the environment. These processes do not rid the environment of contamination, only lessen the concentration of the contaminant by spreading it throughout the environment. Another form of passive remediation is bioremediation. This occurs when naturally occurring bacteria in the ground break apart the molecules of the contamination. The bacteria derive energy by breaking down the molecules. This can rid the environment of toxic substances because the bacteria can eventually change a toxic contaminant into to a non-toxic substance. Active remediation refers to any activities conducted by people to clean up the contamination. Forms of active remediation include:

- Using a trench to catch and divert contaminated water.
- Installing an underground wall or barrier to stop the flow of contaminated water.
- Pumping groundwater to the surface by using a well and either, treating the water and returning it to the subsurface, or collecting the water and removing it from the subsurface. Forms of treatment may include the addition of chemicals to cause the contamination to precipitate out of the groundwater, filtration of the water, and/or aeration* to volatilize* contaminates out of solution. With aeration care must be taken to capture and treat the volatiles.
- The physical removal of contaminated water and soil is done by absorbing the contamination with booms or collecting it in 50-gallon drums. This option is used when an oil spill occurs in the ocean.

V. WATER QUALITY MANAGEMENT

Every life form on the planet depends on water for its survival. When the quality / or quantity is compromised, these life forms have problems surviving. Maintaining water quality and quantity, therefore, is essential to maintaining life on earth. Almost everything we do affects water quality. Our individual use of water at home and our use as a society can have a significant impact.

AT HOME

- If we use water wastefully, we are contributing to the depletion of the region's water supply, whether you get your water from a private well, or a municipal supply. Sound water conservation practices go hand in hand with sound water quality programs.
- Lawn and garden chemicals (fertilizers/herbicides/pesticides) can run off into storm drains and local waterways during storms.
- Household hazardous wastes such as solvents, paints, waste oils, and cleaning chemicals flushed down the drain or poured into storm drains can make their way into either surface water or groundwater.
- Improperly maintained or overused septic systems or cesspools allow excess nitrogen and bacteria to enter regional water supplies. Sewer systems are designed to handle sewage (human and domestic waste products) not hazardous waste.

IN SOCIETY

- Larger scale lawn and garden chemical runoff from parks, golf courses, and crop lands, enters regional water supplies during storms, raising the level of nutrients, such as nitrogen or phosphates, altering the pH, or contributing toxic chemicals, such as pesticides, that might harm the environment.
- Each rainfall washes road debris, such as oils, bits of tire rubber, and gasoline into local waterways. This debris adds hydrocarbons and sediment to the water, which can often raise the turbidity levels.
- Industrial pollution threatens our waterways, adding a variety of contaminants, often in high concentrations, to regional water supplies.

DETERMINING WATER QUALITY

There are many factors that affect the water quality of a river, stream, lake, pond, or reservoir. Conditions can fluctuate over time making it necessary to measure water quality on a regular basis. Quality is also dependent on the water's specific use. Water may be safe for one use but completely unacceptable for another. Some examples of use categories are: water supply for domestic and industrial use, recreation for total body contact like swimming, partial body contact like fishing, hunting, trapping, and boating, protection of wildlife, agricultural uses such as livestock watering, irrigation, and spraying, and commercial uses like navigation, and hydroelectric power.

To determine the water quality of a given river, lake, pond, or reservoir, there are many tests to identify specific areas of concern. There are nine parameters* that make up what is called the water quality index (WQI)*. This index was set up to compare rivers throughout various parts of the country. The nine parameters are: temperature, pH, dissolved oxygen, biochemical oxygen demand, total coliform, total phosphorous, nitrates, turbidity, and total solids. After completing the nine tests a formula is used to determine the overall WQI #.

The overall WQI ranges are as follows:

- 90 – 100 Excellent
- 70 - 90 Good
- 50 – 70 Medium
- 25 - 50 Bad
- 0 – 25 Very Bad

A body of water could have an overall WQI in the good range, but one of the parameters, say fecal coliform, could exceed the state standards, which would then make the waterbody unusable for an activity such as swimming. So the overall score can be deceptive.

Here is a closer look at the parameters that make up the WQI:

Temperature – The temperature of a waterbody is very important. Physical, biological, and chemical characteristics are influenced by temperature. *Dissolved oxygen* levels are higher in colder waters, because gases, like oxygen, dissolve more readily at lower temps. Fish have temperature preferences, for example trout need colder water, while bass, and carp seek out warmer environs**.** Temperature also affects the rate of photosynthesis by aquatic plants, as well as the metabolic rates of other aquatic organisms**.**

pH - This test indicates the number of hydrogen ions present in a substance. A value of 7.0 is neutral, meaning there is an equal number of hydrogen (H+) ions, and hydroxyl* (OH-) ions. A number less than 7.0 indicates that there are more hydrogen ions than hydroxyl ions, making the substance acidic. If the number is greater than 7.0, there are more hydroxyl ions present and the substance is alkaline. The pH scale goes form 0.0 to 14.0. The scale is logarithmic, meaning each one-digit change in the scale indicates a ten-fold change in the acidity or alkalinity (example: a substance with a pH of 5.0 is 10 times more acidic than a substance with a pH of 6.0, and 100 times more acidic than a substance with a pH of 7.0).

There are many factors that influence pH, a few of these are:

- Decomposition of organic materials releases carbon dioxide. As carbon dioxide mixes with water, it forms carbonic acid, lowering the pH.
- Alkaline materials like limestone buffer acidic waters, unfortunately limestone is not present everywhere. It is scarce in the northeast.
- Fresh water is more susceptible to changes in pH than salt water as the minerals in saltwater act as buffering agents.
- Some human practices have an affect on pH values. Modern industry has contributed such noxious releases as sulfur dioxide, oxides of nitrogen, and carbon dioxide into the atmosphere. These compounds go through a

series of changes in the atmosphere and eventually return to earth as acid precipitation. Acid precipitation is responsible for increasing acidity in many lakes of the northeast, where there is limited buffering capacity. Many of these lakes have a crystal clear, almost pristine appearance. Ironically, this look is due to an almost total lack of life. Fortunately over the past 20 years much has been done to clean up these industrial practices, bringing back from the dead many of these water bodies.

Dissolved Oxygen (DO) – A measure of the amount of oxygen dissolved in water. Oxygen is essential to most all life, and water is capable of holding a large volume of oxygen. Water movement and aquatic plants are the two main ways oxygen enters a waterbody. There are minimum levels of oxygen necessary to support life. Most aquatic animals can withstand DO levels as low as 2.0 parts per million (ppm) for very short periods of time, but these levels are certainly not healthy. In general DO levels greater than 5.0 ppm is considered relatively healthy, supporting most aquatic animals. DO levels are influenced by salinity, temperature, and pollution; a higher percentage of oxygen can dissolve in water with lower temperature and low salinity.

Several factors affect the amount of oxygen in water. Some of these factors are:

- **Salinity** – the less of this, the more DO
- **Agitation and Turbulence** – the more contact with atmospheric oxygen the higher the DO
- **Temperature** – the lower the temperature the higher the DO
- **Minerals** – the higher the mineral content the lower the DO
- **Plant Life** – Photosynthesis (green plants utilizing sunlight, chlorophyll, water, and carbon dioxide to produce water, complex carbohydrates, and oxygen) occurs during the daylight, so DO levels can be quite a bit higher during this time than at night. So more photosynthesis equals higher DO.
- **Organic Wastes** – Certain aerobic bacteria that decompose organic wastes (feces, detritis) consume oxygen, so more wastes equals lower DO.

Biochemical Oxygen Demand (BOD) – Basically this is a measure of the oxygen-consuming life in the water. Organic materials (leaves/sewage/dead animals/etc..)

are decomposed by bacteria that live in the water. The amount of oxygen consumed by the bacteria over a certain period of time in a controlled environment indicates the amount of this organic matter in the water. That measure (amount of oxygen) is called the biochemical oxygen demand (BOD). A high BOD might indicate the presence of pollution in the waterbody, whereas a low BOD can be an indicator of clean water. BOD serves as an important clue as to a water bodies health.

Interpreting BOD results:

- 1 – 2 ppm = very clean water w/little organic decay
- 3 – 5 ppm = moderately clean water, some organic decay (probably from plant life)
- 6 – 9 ppm = much organic decay (possibly from algae blooms)
- 10+ ppm = very unhealthy levels of organic decay (often from untreated sewage)

Nitrates – A common nutrient abundant in aquatic ecosystems, and essential for plant growth. Plants do not utilize nitrogen in its pure state, rather they use it in the form of nitrates, and ammonia. Bacteria initially break tissue down into ammonia, which is then oxidized by other bacteria into nitrites and nitrates, thus completing the cycle. Nitrate contributors include animal excrement, fertilizers, and sewage**.**

Total Phosphorous – Includes organic phosphorous and inorganic phosphates. Organic phosphorous is attached to organic matter composed of once-living plants and animals. Inorganic phosphates include ions bonded to soil particles, and phosphates present in laundry detergents. In most waterbodies phosphorous is the growth-limiting element, in other words, plant growth is limited by the phosphorous available within it's environment. Since very little phosphorous is necessary for aquatic plant and algae growth, excess phosphorous can thus produce extensive plant growth and algae blooms (pea-green colored water). This is the classic symptom of cultural eutrophication*. A few sources of phosphorous include: human and animal wastes, industrial pollution, wastewater treatment plants, residential septic systems, agricultural practices, as well as residential and commercial application of lawn fertilizers.

Total Solids – Includes both dissolved solids (portion of material in water that passes through a filter), and suspended solids (portion retained by a filter). Dissolved solids include a wide range of substances like calcium, sodium, phosphorous, iron, sulfate, carbonate, nitrates, and chloride to name a few. A constant level of these substances is essential for maintaining aquatic life. Suspended solids include silt and clay particles from soil runoff, plankton*, industrial waste, and sewage. High concentrations of total solids can diminish water quality and cause water balance problems for individual organisms. Low concentrations may limit growth of aquatic life, and may also restrict some aquatic organisms from surviving in water.

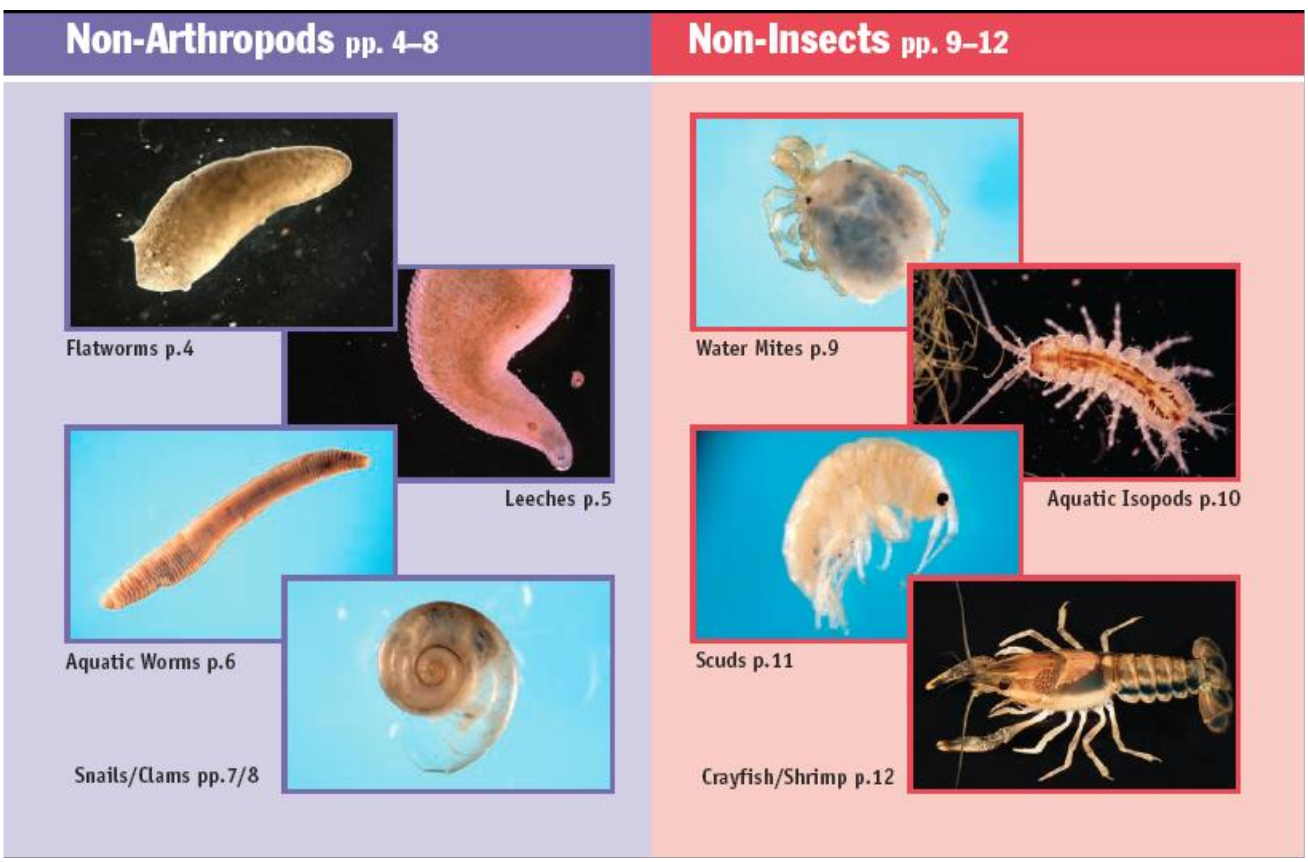
Turbidity – The measure of a water's relative clarity, or cloudiness resulting from suspended solids in the water that reduce the transmission of light. These solids may be microscopic plankton, stirred up organic materials, eroded soil, clay, sand, industrial wastes, or sewage. High turbidity may be a symptom of other water quality concerns. A few effects of turbidity include, diffusing sunlight, which in turn reduces photosynthesis, raising water temperatures (due to the ability of the solids in the water to absorb and hold the sun's heat), clogging the gills of fish and other invertebrates, which stunts growth and decreases disease resistance, creating breeding grounds for pathogenic bacteria that live within the organic materials that cause higher turbidity, and industrial processes, where turbid water can clog machines and interfere with making food and beverages.

Total Coliform Bacteria – A group of generally non-pathogenic (non-disease causing) bacteria that live throughout the environment. One type of coliform that live in the intestinal tract of warm blooded animals to aid in digestion is known as fecal coliform. It's not harmful all by itself, but the presence of it serves as an indicator that other viruses or parasites may be present. Some of these others might however cause disease (pathogenic). In water with a high total coliform count, about 10% of the coliform will be fecal. Coliform bacteria are easy to test for, and usually occur with other pathogens. That is why people who monitor water quality use this group as an indicator. Sources of coliform bacteria include sewage treatment plant wastes, storm water, agricultural runoff, and improperly working septic systems.

BENTHIC MARCOINVERTIBRATES

Beyond the chemical and physical testing of water to determine its quality, scientists can also use benthic macroinvertebrates. Macroinvertebrates are animals with no backbones that can be seen without the aid of a microscope. Benthic macroinvertebrates spend at least part of their lifecycle in or on the bottom of a body of water. They can include aquatic insects such as mayflies, stoneflies, caddis flies, midges and beetles, as well as worms and crustaceans such as crayfish, clams and snails.

The invertebrates are good indicators of water quality because they differ in their sensitivity to water pollution. They are not very mobile so they can not avoid pollution events or other forms of stress that some sampling methods might miss. If water quality is poor or if a pollution event occurred within the past several months, it will be reflected in the macroinvertebrate population. Some of these animals, such as stoneflies and mayflies, can't tolerate much pollution at all. If a sample is dominated by these organisms it would signify good water quality.



Page from "A Guide to Stream Benthic Macroinvertebrates" http://sacsplash.org/streams/BMI%20Booklet.pdf

VI. CLIMATE CHANGE, GLOBAL WARMING AND SURFACE WATERS

Global warming refers only to the rising surface temperature of the entire planet, while climate change includes the increase in the planet's temperature and the "side effects" of warming—like melting glaciers, heavier rainstorms, lack of snowfall or more frequent droughts. Global warming is one symptom of the much larger problem of human-caused climate change.

Ice storms, tornados, droughts, blizzards on Halloween, heat waves. Our weather pattern is changing, there is no doubt about that. With our changing climate, the water cycle is also expected to undergo significant change. For example, a warmer climate causes more water to evaporate from both land and oceans; in turn, a warmer atmosphere can hold more water – roughly four percent more water for every 1ºF rise in temperature. Changes like this are expected to lead to specific, and in many cases negative, consequences. Some parts of the U.S. – in particular, the Northeast and Midwest – can expect increased precipitation and runoff, especially in winter and spring, leading to increased flooding. Other areas – notably the Southwest – can expect less precipitation, especially in the warm months, and longer, more severe droughts as storm tracks shift northward leaving arid areas increasingly dry (Union of Concerned Scientists).

Expected changes include decreased snow cover amount and duration, reductions in streamflow, accelerated coastal erosion and salt intrusion into coastal aquifers, changes in magnitude, timing of ice freeze-up/break up and possible spring flooding, shifts in fish species distributions and migration patterns.

If warming temperatures continue to melt the glaciers in the polar regions, the supply of freshwater might actually decrease. First, freshwater from the glaciers will mingle with salt water in the oceans and become too salty to drink. Second, the increased ocean volume will cause sea levels to rise, contaminating freshwater sources along coastal regions.

What we know right now backed by science from EPA's Climate Change Indicators In the United States, 2014 (Third Edition):

- The rate at which glaciers are losing mass has accelerated over the last decade

- Lakes in Northeast are freezing later than they did in the past and ice break up has been earlier in the Spring
- Total snowfall has decreased in many parts of the country, more winter precipitation is falling as rain
- The trend for snow cover (amount of land in North America covered by snow) is decreasing
- Annual average stream flows in the Northeast have increased
- Nearly half of the streams studied show inter-spring runoff happening more than 5 days earlier than in the mid 20th century
- Ocean carbon dioxide levels have risen in response to increased carbon dioxide in the atmosphere, leading to an increase in acidity (decrease in pH)
- It has been more difficult for certain ocean organisms to build and maintain their skeletons and shells
- Roughly 20 square miles of dry land and wetland were converted to open water along the Atlantic coast between 1996 and 2011
- Sea surface temperature increased over the 20th century and continues to rise- sea surface temperatures have been higher during the past three decades than at any other point in time!

Impacts to water quality will certainly be a consequence to climate change. Warmer stream temperatures lead to a reduction in dissolved oxygen, higher intensity and shorter duration summer storm events lead to more contaminants entering our surface waters.

The increased standing water from flooding events can lead to an increase in mosquitoes, thus an increase in human disease caused by mosquitoes like West Nile Virus (WNV), Eastern Equine Encephalitis (EEE), and a newer one, the Zika Virus. This is when the public starts to demand that mosquitoes be chemically sprayed, and larvae be chemically treated. Since larvae are found in standing water, a lot of the time chemicals are added to storm drains- and we all know where these storm drains go to!

It is also expected that waterborne infectious diseases will rise as a result of climate change, resulting in public health crisis.

VII. CURRENT WATER ISSUES

PPCPs.

PPCPs stands for Pharmaceutical and Personal Care Products. PPCPs represent a vast group of compounds manufactured in large quantities that are frequently used by humans (and domesticated animals) worldwide and are not commonly monitored for or regulated. Pharmaceutical and personal care products enter the environment through a variety of pathways, including human excretion, the disposal of unwanted or expired medication or cosmetics, agricultural runoff, landfill leachate, and direct release to open waters via washing, bathing, and swimming. Wastewater treatment systems and septic systems were not designed to remove, and have not caught up with, the advances in new and improved products and chemicals, therefore releasing traces of these compounds back into our environment. At this time, ecological impacts have been observed but there is no scientific evidence that they have an impact on human health.

Microbeads.

A significant number of personal care products such as scrubs and toothpastes are known to contain thousands of minuscule balls of plastic called microplastics, or more specifically, microbeads. Over the years, microbeads have replaced traditional, biodegradable alternatives such as ground nut shells, and salt crystals.

The microbeads used in personal care products are mainly made of polyethylene (PE), but can be also be made of polypropylene (PP), polyethylene terephthalate (PET), polymethyl methacrylate (PMMA) and nylon. Where products are washed down the drain after use, microbeads flow through sewer systems around the world before making their way into rivers and canals and ultimately, straight into the seas and oceans, where they contribute to the plastic pollution. Typically, microplastics are defined as: plastic pieces or fibres measuring less than 5 mm. The microbeads found in personal care products are almost always smaller than 1 mm. A single cosmetic product can contain up to 300,000 non-biodegradable microbeads!

Because microbeads are so tiny, they look like fish eggs which is food for aquatic organisms and other fish. There is concern that microbeads are becoming a part of the food web.

In 2015, the United States Congress passed the Microbead-Free Waters Act. This new federal law (which amended the Federal Food, Drug, and Cosmetic Act prohibits the manufacture of products containing microbeads as of July 1, 2017.

Cyanobacteria

Cyanobacteria are aquatic and photosynthetic, that is, they live in the water, and can manufacture their own food. Cyanobacteria can be found in almost every terrestrial and aquatic habitat—oceans, fresh water, damp soil, temporarily moistened rocks in deserts, bare rock and soil. Aquatic cyanobacteria are known for their extensive and highly visible blooms that can form in both freshwater and marine environments. Blue-green algae reproduce rapidly in lakes and ponds with adequate amounts of sunlight, air/water temperature and nutrients like phosphorus and nitrogen. These blooms will most likely become more common due to climate change. The blooms can have the appearance of blue-green paint or scum or thick pea soup. Some kinds of blue-green algae produce natural toxins or poisons which can be hazardous to humans in high levels and can be noxious, if not fatal, to pets. When these algae die and break down, toxins can be released into the water. Exposure to the algae from swallowing water while swimming or via the skin can cause nausea, diarrhea, skin or throat irritation and breathing difficulties.

Aquatic Invasive Species (AIS)

Aquatic invasive species (AIS) (sometimes called exotic, invasive, nonindigenous or non-native) are aquatic organisms that invade ecosystems beyond their natural, historic range. Their presence may harm native ecosystems or commercial, agricultural, or recreational activities dependent on these ecosystems. Invasive aquatic plants are introduced plants that have adapted to living in, on, or next to water, and that can grow either submerged or partially submerged in water. People have helped spread species around the globe for centuries either intentionally or unintentionally. Intentional introductions involve the deliberate transfer of nuisance species into a new environment. An example of this would be someone who dumps the contents of their home aquarium into a lake. Unintentional introductions occur when invasives are transferred accidentally. For instance, zebra mussels can be spread when ballast water used for ship stability is exchanged.

In fact, aquatic nuisance species can be spread many ways including ships, boats, barges, aquaculture, aquatic recreation (fishing, hunting, boating, diving, etc.), water gardening, seaplanes, connected waterways and many other pathways. Through these and other means, thousands of terrestrial and aquatic invasive species have been introduced into our country, costing us billions annually.

Examples of aquatic nuisance species include:

- zebra mussels,
- Chinese mitten crabs,
- hydrilla,
- Eurasian watermilfoil,
- nutria,
- sea lamprey,
- Asian carp, and
- New Zealand mudsnail.

Some of these organisms seem to have little impact while others are devastating.

Economics

What happens when a community or State relies on money received from recreational use of lakes and ponds but these areas are closed because of Aquatic Invasive Species, or high bacteria levels? They lose that money, and if that money was being used for a different cause, it will have to be made up elsewhere.

What happens when a large farm does not have the required rain to water it's vegetables and fruits? Sometimes it requires staff to hand water, or maybe they will have to install irrigation systems or rely on groundwater wells. All of these will cost the consumer (us) more to purchase those strawberries or tomatoes. And think about what will happen when there is a lack of the groundwater that the farmer has to revert to, like in extreme drought situations? There is no water and the crops don't grow. The farmer loses money, and maybe has to get rid of some of their staff; putting people out of work.

Public drinking water supplies are especially vulnerable to water quality impacts and changes. For example, in order for your home to have safe water, the water is treated, at a cost to your city or town. These costs are passed down to you in the form of water rates. If the public water supply needs additional treatment for high bacteria (climate change impacts, stormwater pollution) or becomes unusable due to a cyanobacteria bloom (climate change, stormwater pollution) and an alternate supply must be found, it is going to cost the city or town more money. This will, in turn, cost you more money, leaving less for the fun things you like to do or buy. Buying less causes the store to lose money, and raise their prices to make up for the lost money. Much like the water cycle, the money cycle will continue, over and over.

So what does this mean? In addition to clean water being a vital resource for life and recreation, it is important that attention is paid to ensuring that it is kept clean for the money benefits.

VIII. SOME IMPORTANT WATER LAWS

Clean Water Act

Primary federal law in the US governing surface water quality (NOT drinking water)
• Establishes standards for water meeting needs for human recreation by setting maximum permissible amounts of water pollutants that can be discharged into waterway
• Goal: to make surface waters swimmable & fishable

The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1972.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The Safe Drinking Water Act (SDWA) is the federal law that protects public drinking water supplies throughout the nation. Under the SDWA, EPA sets standards for drinking water quality and with its partners implements various technical and financial programs to ensure drinking water safety.

Water Resources Planning Act (1965)

Provided plans to formulate & evaluate water related land resource projects & to maintain a continuing assessment of adequacy of water supplies in US.

Ocean Dumping Ban Act (1988)

Bans ocean dumping of sewage sludge and industrial waste.

IX. REFERENCES & RESOURCES

Envirothon students are not required to study from the references and resources listed below.

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Resource Professionals

- Kelley Freda, Environmental Analyst, DCR Division of Water Supply Protection, 180 Beaman Street, West Boylston, MA. 01583 (508) 792-7806 ext. 205
  Kelley.freda@state.ma.us
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Additional links can be found at http://massenvirothon.org/areas-of-learning/ecostations/water/

X. GLOSSARY

Acid – a substance with a pH value below 7. It will be sour in taste or corrosive in nature.

Acid Deposition – wet and dry atmospheric fallout with a very low pH that results from the combination in the atmosphere of water vapor with sulfide or nitrous compounds released during the combustion of fossil fuels.

Aeration – expose water to the circulation of air for purification.

Aerobic – occurring, acting, or living in the presence of free oxygen, either as atmospheric gas or dissolved in water.

Alkaline – having a pH greater than 7, the opposite of acid. Alkaline soil or water is able to neutralize acid precipitation or discharge.

Anaerobic – occurring, acting or living in the absence of oxygen.

Aphotic Zone – the zone in a body of water where light cannot penetrate. Photosynthesis cannot be supported here.

Aquifer – a geologic structure composed of porous or permeable rock or sand that can yield a usable quantity of water.

Artesian Aquifer – see Confined Aquifer.

Bedrock – a general term for the solid rock that underlies the soil or unconsolidated surface material.

Benthic Zone – the section of a water body near the bottom.

Bioaccumulate – storing chemicals in an organism in higher concentrations than are normally found in the environment.

Biological Oxygen Demand – a measure of the dissolved oxygen consumed by micro-organisms as they break down organic matter in a sample of water. The greater the quantity of oxygen consumed the more organic matter present. It can indicate the presence of sewage or other organic pollution.

Bog – a wetland formed where low oxygen levels and soil temperature cause incomplete decomposition, limited drainage and an accumulation of fibrous peat.

Brackish – water containing a salinity level between freshwater and salt water.

Capillary Fringe – the zone above the water table (top of the saturated zone) in which water is held by surface tension

Carcinogens – substances that stimulate the formation of cancer.

Condensation – the process in which a substance changes from a gas to a liquid usually by cooling.

Confined Aquifer – a water saturated layer of soil or rock that is bounded above and below by impermeable layers causing a pressurized water source.

Contaminated – made impure by contact or mixture with a pollutant.

Current – movement of water caused by tides, wind, temperature or water flowing in a stream
Deposition – the process of laying down sediment or accumulating layers of material carried in suspension.

Dissolved Oxygen – oxygen in solution in water; oxygen available to gill-breathing organisms.

Ecosystem – a functional system comprised of a community of organisms and their environment, including the energy transfers and nutrient cycling.

Effluent – any matter that enters the environment from a specific source; the term generally refers to waste water from a sewage treatment or industrial plant.

Epilimnion – the zone of a thermally stratified water body occupied by the upper layer or warmer water.

Erosion – the removal or wearing away of soil or rock by water, wind or other natural forces.

Eutrophication – The natural aging process of a body of water. This process may be accelerated by human activity, including industrial or agricultural runoff, sewage, or the introduction of exotic plants.

Evaporation – changing of a substance from a liquid to a gas.

Facultative Species – a species that doesn't require one specific habitat type for its survival, but will seek out a given habitat type if it is within its home range.

Fen – low, flat, marshy land with herbaceous vegetation.

Groundwater – water found at or beneath the water table, in saturated soil or bedrock.

Headwater – the highest reaches of a stream in a watershed or drainage basin.

Hydrology – the branch of science that studies the distribution of the earth's waters both above and below the ground, including the water cycle.

Hydrologist – scientist who studies the properties, distribution and effect of water in the environment.

Hydroxyl ions – an OH ion found in bases, certain acids and atmospheric compounds.

Hypolimnion – the zone of a thermally stratified water body occupied by the deeper, cooler water layer.

Inorganic – involving neither organic life nor products of organic life.

Infiltration – the process of water or other liquid soaking into soil.

Intrusion – an unwelcome addition of saltwater into a freshwater source.

Laminar Flow – smooth, unidirectional flow in a stream or river.

Leachate – substance dissolved or washed out by a percolating liquid.

Lentic – meaning still or calm. In ecology it refers to still water environments (ponds & lakes).

Limnetic Zone – the zone in a lake or pond occupied by deep water where light cannot penetrate to the bottom. This area does not allow rooted aquatic vegetation to grow.

Limnology – the scientific study of freshwater aquatic ecology.

Littoral Zone – that zone in a lake or pond occupied by shallow water or shoreline. Sometimes referred to as the rooted aquatic plant zone.

Lotic – meaning moving or flowing. In ecology it refers to flowing water environments (streams & rivers).

Macroinvertebrates – animals without backbones that are large enough to be observed without the aid of magnification.

Marsh – a low wetland covered with water part of the year, consisting of grasses, rushes and sedges.

Micro-organisms – small organisms that can only be seen with the aid of a microscope. They are important in the degradation and decomposition of organic material from nature or artificial mechanisms.

Morphometry – is the measurement of the shape of a body of water.

Non-point Pollution – pollution that enters water through run-off from land and is difficult to pinpoint rather than from a specific place such as an effluent pipe.

Nymph – larval phase of an some aquatic insects.

Obligate Species – a species requiring a certain type of habitat for its survival, for example a Spotted Salamander requires a vernal pool for reproduction.

Ontogeny – the course of development of a lake or pond from water body to land.

Order – name given to a group of related families.

Organic – of, related to, or derived from living organisms. Organic substances contain carbon.

Parameter – a typical element which is tested for and used as an indicator or water quality.

pH – a measure of hydrogen ion concentration or acidity. The pH scale ranges from 0 (most acidic) to 14 (most basic) with a pH of 7 being neutral.

Photic Zone – the zone in a body of water where light penetrates. The light supports photosynthesis of organic matter in this zone.

Phytoplankton – tiny drifting organisms in aquatic environments that are capable of photosynthesis.

Plankton – microscopic organisms that are suspended in an aquatic habitat. (character on Sponge Bob)

Precipitation – water falling, in a liquid or solid state, from the atmosphere.

Riparian – located or living along or near a stream, river or body of water.

Runoff – water that drains or flows off the surface of the land.

Salinity – the amount of salt present in a solution.

Saturated Zone – the subsurface zone in which all openings are filled with water

Spring – a natural point of groundwater discharge formed where an aquifer intersects the surface.

Stratification – development of different temperature layers of water in a lake or pond.

Stream Gradient – the steepness of the stream bed or ratio of vertical drop to horizontal distance.
Sublimation – the transition of a substance from the solid phase directly to the vapor phase, or vice versa, without passing through an intermediate liquid phase.

Suspended Load – the amount of substance carried by a stream or river that is in suspension, also referred to as suspended sediment.

Swamp – a wetland where the soil is saturated and often inundated with water with trees as the dominant vegetation.

Thermal Stratification – orientation of the water by temperature in a lake or pond where less dense, warmer water positions over the top of more dense, cooler water to form a layering affect.

Thermocline – the zone in a thermally stratified water body where you observe the maximum decrease of temperature with respect to depth. You observe the temperature decreasing rapidly as you descend through the water column.

Total Dissolved Solids – a measure of the amount of total dissolved minerals in water.

Total Coliform Bacteria – a measure of the amount of coliform bacteria found in a given water sample. Coliform bacteria reside in the intestines of vertebrate animals including humans.

Transpiration – the process of giving off water vapor through plant leaves.

Tributaries – small feeder streams that flow into larger streams and rivers.

Turbidity – a measure of the ability of light to penetrate water, indicating the amount of living and non-living suspended solids and dissolved substances. It's the measure of a water's cloudiness.

Turbulent Flow – water that moves erratically downstream, stirring up everything it contacts.

Turnover – thermal mixing within a water body. The temperature and wind conditions during certain times of the year contribute to the overall mixing of the water column eliminating thermal stratification.

Unconfined Aquifer – an aquifer in which the upper boundary is the top of the water table.

Vernal Pool – a temporary pond existing during the wet spring season and drying up in the summer.

Volatilize – dispersing chemicals into the air through the aeration process.

Water Cycle – the continuous circulation of water in systems throughout the planet, involving runoff, evaporation, condensation, precipitation, transpiration and sublimation.

Water Quality Index (WQI) – an index based on nine parameters (dissolved oxygen, pH, nitrates, total dissolved solids, turbidity, phosphates, BOD, fecal coliform and temperature) used to measure the quality of a body of water, compare changes over time and compare to other water bodies.

Water Table – the uppermost level of groundwater.

Watershed – the total land area draining to a particular body of water.

Wetland – any land that tends to be regularly wet or flooded.

Zooplankton – plankton that is composed of tiny, often microscopic, animal and animal matter.

Groundwater What is groundwater?

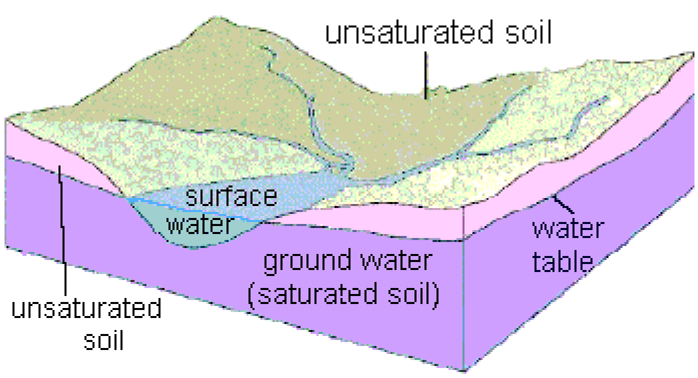
http://water.usgs.gov/edu/earthgw.html

These kids probably think there is some kind of magic happening here ... they pull down a lever and out of the ground below their feet comes clear, cool freshwater. They (and maybe you) may not realize that there is an immense amount of water in aquifers below the earth's surface. In fact, there is a hundred times more water in the ground than is in all the world's rivers and lakes.

Some water underlies the Earth's surface almost everywhere, beneath hills, mountains, plains, and deserts. It is not always accessible, or fresh enough for use without treatment, and it's sometimes difficult to locate or to measure and describe. This water may occur close to the land surface, as in a marsh, or it may lie many hundreds of feet below the surface, as in some arid areas of the West. Water at very shallow depths might be just a few hours old; at moderate depth, it may be 100 years old; and at great depth or after having flowed long distances from places of entry, water may be several thousands of years old.

Groundwater is a part of the water cycle. Some part of the precipitation that lands on the ground surface infiltrates into the subsurface. The part that continues downward through the soil until it reaches rock material that is saturated is groundwater recharge. Water in the saturated groundwater system moves slowly and may eventually discharge into streams, lakes, and oceans.

Here is a simplified diagram showing how the ground is saturated below the water table (the purple area). The ground above the water table (the pink area) may be wet to a certain degree, but it does not stay saturated. The dirt and rock in this unsaturated zone contain air and some water and support the vegetation on the Earth. The saturated zone below the water table has water that fills the tiny spaces (pores) between rock particles and the cracks (fractures) of the rocks.



Why is there groundwater?

A couple of important factors are responsible for the existence of groundwater:

(1) Gravity

Nothing surprising here - gravity pulls water toward the center of the Earth. That means that water on the surface will try to seep into the ground below it.

(2) The Rocks Below Our Feet

The rock below the Earth's surface is the bedrock. If all bedrock consisted of a dense material like solid granite, then even gravity would have a hard time pulling water downward. But Earth's bedrock consists of many types of rock, such as sandstone, granite, and limestone. Bedrocks have varying amounts of void spaces in them where groundwater accumulates. Bedrock can also become broken and fractured, creating spaces that can fill with water. And some bedrock, such as limestone, are dissolved by water -- which results in large cavities that fill with water.

In many places, if you looked at a vertical cross-section of the earth you would see that rock is laid down in layers, especially in areas of sedimentary rocks. Some layers have rocks that are more porous than others, and here water moves more freely (in a horizontal manner) through the earth. Sometimes when building a road, the layers are revealed by road cuts, and water can be seen seeping out through the exposed layers.

Try as it might, gravity doesn't pull water all the way to the center of the Earth. Deep in the bedrock there are rock layers made of dense material, such as granite, or material that water has a hard time penetrating, such as clay. These layers may be underneath the porous rock layers and, thus, act as a confining layer to retard the vertical movement of water. Since it is more difficult for the water to go any deeper, it tends to pool in the porous layers and flow in a more horizontal direction across the aquifer toward an exposed surface-water body, like a river.

Visualize it this way: get two sponges and lay one on top of the other. Pour water (precipitation) on top and it will seep through the top sponge downward into the bottom sponge. If you stopped adding water, the top sponge would dry up and, as the water dripped out of the bottom sponge, it would dry up too. Now, put a piece of plastic wrap between the sponges, creating your "confining layer" (making the bottom sponge an impermeable rock layer that is too dense to allow water to flow through it). Now when you pour water on the top sponge, the water will seep downward until it hits the plastic wrap. The top sponge will become saturated, and when the water hits the plastic wrap it won't be able to seep into the second sponge. Instead, it will start flowing sideways and come out at the edges of the sponge (horizontal flow of groundwater). This happens in the earth all the time -- and it is an important part of the water cycle.

Information on this page is from Waller, Roger M., Ground Water and the Rural Homeowner, Pamphlet, U.S. Geological Survey, 1982

WATER QUALITY PARAMETERS

Temperature:

Affects DO. Cold water holds more Oxygen than warm water

Raise in temp: more photosynthesis & plant growth: more oxygen needed by aquatic organisms

Animal survival: if temp changes too much, many organisms cannot survive

Pollution and wastes: can raise temperature

pH:

Range most organisms prefer: 6.5 - 8.0

Turbidity:

Values vary. Increases sharply during and after rainfall

Rise in turbidity; Rise in temperature; Decrease in DO

Conductivity:

Significant increases may be an indicator that pollutants have entered the water.

Every water will have a baseline

Ideal: 150 – 500 µS/cm to support aquatic life

Reality in fresh water: 50 – 1500 µS/cm

Nitrate:

Natural levels < 1 mg/L

+10 mg/L significant effect on freshwater environment

DO:

Consistent high levels best for healthy ecosystem

Levels vary depending on:

Time of day, Water temp, Season, Depth, Altitude, Rate of flow

0 – 2 mg/L = not enough to support life

2 – 4 mg/L = only a few fish and aquatic insects can survive

4 – 7 mg/L = good for many aquatic animals, low for cold water fish

7 – 11 mg/L = very good for most stream fish

Phosphate:

Concentrations over .05 mg/L will likely have impacts on ecosystem

Concentrations over .1 mg/L definitely have impacts on ecosystem

BOD:

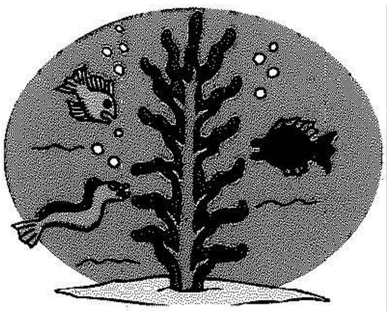
Amount of oxygen consumed by microorganisms in the process of decomposing organic matter in the stream water.

The harder the microorganisms work; more oxygen they use; higher measure of BOD (and less for other life)

AFFECTS DO. High BOD measure harms stream health the same ways low DO does

PHOSPHORUS CYCLE: (Nutrient)

- Enters the water
- Plants take up Phosphorus and grow too much
- Plants (algae) die and sink to the bottom
- Bacteria at the bottom decompose dead plants, using up Oxygen in the process
- Oxygen levels drop, killing fish and other aquatic insects
- Phosphorus continues to enter water
- Cycle continues



Organic Waste:

Comes from something living or was once living, raw or poorly treated sewage, runoff from farms and feedlots, decaying aquatic plants and animals, leaves in the water

NITROGEN CYCLE: (Nutrient)

- Enters the water
- Plants take up Nitrogen and grow and grow
- Plants (algae) die and sink to the bottom
- Bacteria at the bottom decompose dead plants, using up Oxygen in the process
- Oxygen levels drop, killing fish and other aquatic insects
- Nitrogen continues to enter water
- Cycle continues

THINK OF IT THIS WAY

PARTS PER MILLION, PARTS PER BILLION, PARTS PER TRILLION...HOW MUCH IS THAT? TRY THINKING ABOUT THEM IN A NEW WAY:

Think of one part per million as:

- 1 inch in 16 miles
- 1 minute in 2 years
- 1 cent in $10,000
- 1 ounce of salt in 31 tons of potato chips
- 1 bad apple in 2,000 barrels

One part per billion compares with:

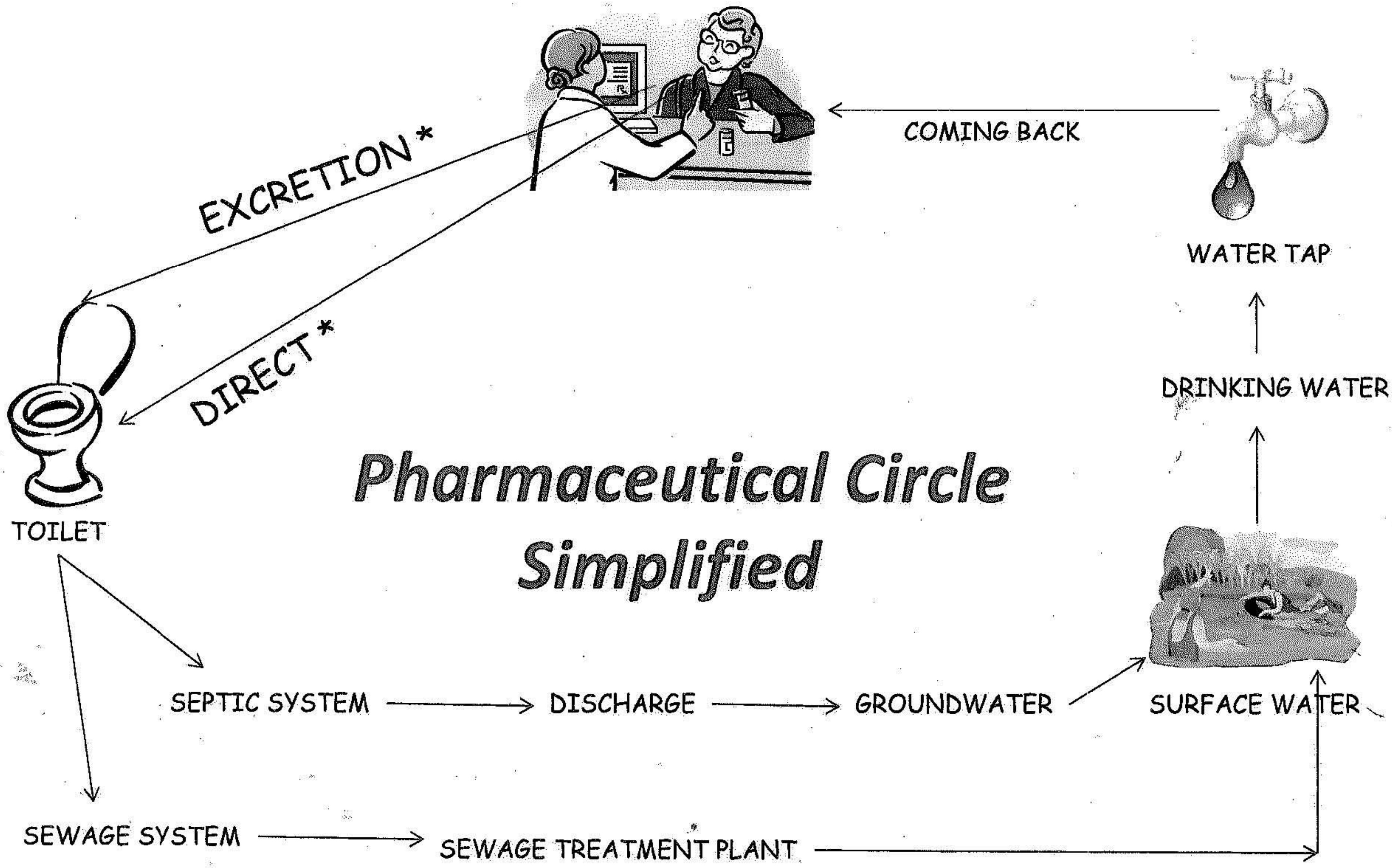
- 1 inch in 16,000 miles
- 1 second in 32 years
- 1 cent in $10 million
- 1 pinch of salt in 10 tons of potato chips
- 1 bad apple in 2 million barrels

One part per trillion compares with:

- 1 inch in 16 million miles (more than 600 times around the earth)
- 1 second in 320 centuries
- 1 grain of sugar in an Olympic-sized pool
- 1 bad apple in 2 billion barrels
- 1 postage stamp in an area the size of Dallas
- 1 flea on 360 million elephants

Taken from www.groundwater.org

Pharmaceutical Circle Simplified



* Pharmaceuticals can also enter our waters from animals (i.e veterinary, animal feed lots, farms)

Kf 2012

Lesson 1- Introductory Lesson-Determination of Overall Water Quality Using a Quantitative Macroinvertebrate Survey

Objectives:

Students will be able to:

-identify various types of macroinvertebrates found in water ecosystems.

-perform a quantitative macroinvertebrate survey to determine the overall water quality of a water ecosystem.

Materials:

Water sample from a local stream or pond (sample must be fresh and contain debris from the bottom and edges of the water)

Macroinvertebrate Identification charts

Assorted trays and petri dishes for separation of sample

Dissecting microscope and hand lenses

Small paintbrushes

Pipets

Procedure:

1. Working with a partner, take an approximate 500 ml sample of the water including the debris.

2. Pour a portion of the sample into a petri dish and examine it under low power on the microscope.

3. Using the identification charts, count and identify 100 macroinvertebrates. Try not to

hunt for only the large ones or your sample will be biased. If you can not find 100 macroinvertebrates in your sample, take an additional 500 ml sample. Continue this procedure until you and your partner have counted and identified 100 macroinvertebrates.

4. Identify and count the numbers of each type of organism listed below.

5. Multiply the number of each type by its biotic value.

6. Add up all the numbers and divide by 10. This gives the Biotic Index Value. Check the Biotic Value chart at the bottom of the page to determine the quality of your water sample.

7. Compare your group value with the class values. Do they agree? Why or why not?

Class I Pollution intolerant: These organisms are highly sensitive to pollution.

Class II Somewhat pollution tolerant: These organisms will be found in clean and slightly polluted waterways.

Class III Pollution tolerant: These organisms will be found in polluted, as well as clean aquatic ecosystems.

Class I	Biotic Value	Number Found	Class II	Biotic Value	Number Found	Class III	Biotic Value	Number Found
Stonefly nymph	10		Beetle larva	8		Midge fly larva	5	
Mayfly nymph	10		Sowbug	8		Snails	4	
Dobsonfly larva	10		Scud	6		Leech	2	
Caddisfly larva	10		Clams, Mussels	6		Aquatic worms	0	
Riffle beetle	10		Crayfish	6				
Water penny	10		Cranefly larva	6				
			Dragonfly nymph	6				
			Damselfly nymph	6				
			Black fly larva	6				
Total			Total			Total		

For example if you find:

25 mayflies	25 x 10 = 250
15 caddisflies	15 x 10 = 150
20 stoneflies	20 x 10 = 200
20 scuds	20 x 6 = 120
20 midge larva	20 x 5 = 100
Total	= 820 / 10 = 82

Based on the Biotic Index value the water quality is excellent.

Biotic Index

Excellent	>70
Good	60-79
Fair	40-59
Poor	<40

Reading Topographic Maps

This site is an excerpt from Appendix E of the Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire, 1991. Alan Ammann, PhD and Amanda Lindley Stone. This document and method is commonly called �The New Hampshire Method.�

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nh/technical/dma/?cid=nrcs144p2_015706

How to Read a Topographic Map and Delineate a Watershed (300 Kb)

In order to successfully delineate a watershed boundary, the evaluator will need to visualize the landscape as represented by a topographic map. This is not difficult once the following basic concepts of the topographic maps are understood.

Each contour line on a topographic map represents a ground elevation or vertical distance above a reference point such as sea level. A contour line is level with respect to the earth's surface just like the top of a building foundation. All points along any one contour line are at the same elevation.

The difference in elevation between two adjacent contours is called the contour interval. This is typically given in the map legend. It represents the vertical distance you would need to climb or descend from one contour elevation to the next.

The horizontal distance between contours, on the other hand, is determined by the steepness of the landscape and can vary greatly on a given map. On relatively flat ground, two 20 foot contours can be far apart horizontally.

On a steep cliff face two 20 foot contours might be directly above and below each other. In each case the vertical distance between the contour lines would still be twenty feet.

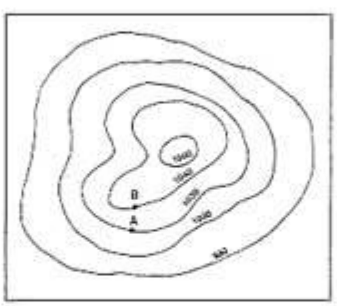


Figure E-1: Isolated Hill

One of the easiest landscapes to visualize on a topographic map is an isolated hill. If this hill is more or less circular the map will show it as a series of more or less concentric circles (Figure E-1, left. Click here or on the figure for a higher-quality, larger image). Imagine that a surveyor actually marks these contour lines onto the ground. If two people start walking in opposite directions on the same contour line, beginning at point A, they will eventually meet face to face.

If these same two people start out in opposite directions on different contours, beginning at points A and B respectively, they will pass each other somewhere on the hill and their vertical distance apart would remain 20 feet. Their horizontal distance apart could be great or small depending on the steepness of the hillside where they pass.

A rather more complicated situation is where two hills are connected by a saddle (Figure E-2, left. Click here or on the figure for a higher-quality, larger image). Here each hill is circled by contours but at some point toward the base of the hills, contours begin to circle both hills.

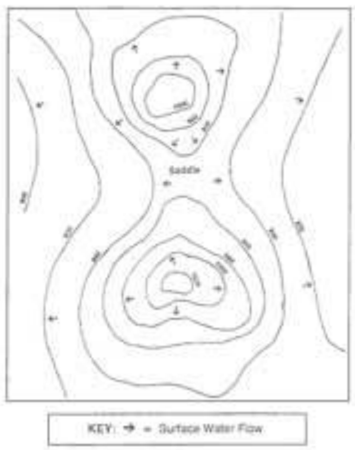


Figure E-2: Saddle

How do contours relate to water flow? A general rule of thumb is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. Water flows from the top of the saddle or ridge, down each side in the same way water flows down each side of a garden wall (See arrow on Figure E-2).

As the water continues downhill it flows into progressively larger watercourses and ultimately into the ocean. Any point on a watercourse can be used to define a watershed. That is, the entire drainage area of a major river like the Merrimack can be considered a watershed, but the drainage areas of each of its tributaries are also watersheds.

Each tributary in turn has tributaries, and each one of these tributaries has a watershed. This process of subdivision can continue until very small, local watersheds are defined which might only drain a few acres, and might not contain a defined watercourse.

Figure E-3 (right, click here or on the figure for a higher-quality, larger image) shows an idealized watershed of a small stream. Water always flows downhill perpendicular to the contour lines. As one proceeds upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Like-wise the valley slopes upward on each side of the stream. A general rule of thumb is that topographic lines always point upstream. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape even when there is no stream depicted on the map. In Figure E-3, for example, the direction of streamflow is from point A to point B.

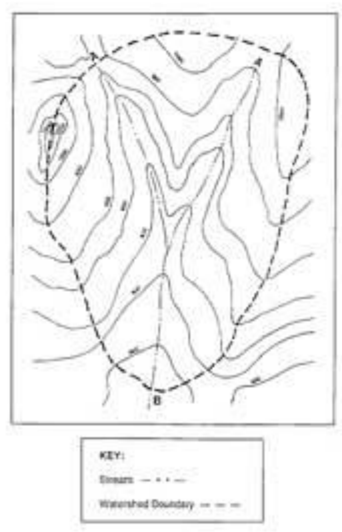


Figure E-3: Idealized Watershed Boundary

Ultimately, you must reach the highest point upstream. This is the head of the watershed, beyond which the land slopes away into another watershed. At each point on the stream the land slopes up on each side to some high point then down into another watershed. If you were to join all of these high points around the stream you would have the watershed boundary. (High points are generally hill tops, ridge lines, or saddles).

How to Delineate a Watershed

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The following procedure and example will help you locate and connect all of the high points around a watershed on a topographic map shown in Figure F-4 below (for a higher quality and larger image, click on the figure). Visualizing the landscape represented by the topographic map will make the process much easier than simply trying to follow a method by rote (first visit How to Read a Topographic Map).

1. Draw a circle at the outlet or downstream point of the wetland in question (the wetland is the hatched area shown in Figure E-4 to the right)
2. Put small "X's" at the high points along both sides of the watercourse, working your way upstream towards the headwaters of the watershed.
3. Starting at the circle that was made in step one, draw a line connecting the "X's" along one side of the watercourse (Figure E-5, below left). This line should always cross the contours at right angles (i.e. it should be perpendicular to each contour line it crosses).
4. Continue the line until it passes around the head of the watershed and down the opposite side of the watercourse. Eventually it will connect with the circle from which you started. At this point you have delineated the watershed of the wetland being evaluated.

Figure E-4: Delineating a Watershed Boundary - Step 1

Figure E-5: Delineating a Watershed Boundary - Step 2

The delineation appears as a solid line around the watercourse. Click here or on the figure for a higher quality, larger image. Generally, surface water runoff from rain falling anywhere in this area flows into and out of the wetland being evaluated. This means that the wetland has the potential to modify and attenuate sediment and nutrient loads from this watershed as well as to store runoff which might otherwise result in downstream flooding.

Measuring Watershed Areas

There are two widely available methods for measuring the area of a watershed: a) Dot Grid Method, and b) Planimeter. These methods can also be used to measure the area of the wetland itself as required by The New Hampshire Methods.

a) The dot grid method is a simple technique which does not require any expensive equipment. In this method the user places a sheet of acetate or mylar, which has a series of dots about the size of the period at the end of this sentence printed on it, over the map area to be measured. The user counts the dots which fall within the area to be measured and multiplies by a factor to determine the area. A hand held, mechanical counting device is available to speed up this procedure.

b) The second of these methods involves using a planimeter, which is a small device having a hinged mechanical arm. One end of the arm is fixed to a weighted base while the other end has an attached magnifying lens with a cross hair or other pointer. The user spreads the map with the delineated area on a flat surface. After placing the base of the planimeter in a convenient location the user traces around the area to be measured with the pointer. A dial or other readout registers the area being measured.

Planimeters cost from several hundred dollars up to a thousand dollars or more depending on the degree sophistication. For the purposes of The New Hampshire Method, a basic model would be sufficient. Dot counting grids are more affordable, and are in the 10 to 20 dollar range. Both planimeters and dot grids are available from engineering and forestry supply companies. Users of either of these methods should refer to the instructions packaged with the equipment they purchase.

Fanwort infestation at West Boylston, MA

Caution

- Once an invasive species is established, it is almost impossible to eradicate and expensive to control.
- Just one plant fragment is capable of infesting an entire lake.
- The dense mats formed by invasive plants may prevent fishing.
- Invasive mussels and zooplankton displace native species, disrupt the ecosystem, and reduce biodiversity.
- Invasive plants can cause unsightly masses of plants and unpleasant odors.

Your actions can make a difference!

How can you help?

- Remove all plant parts from your fishing gear. Dispose of plant matter far above waterline on dry land or in a trash can.
- Dispose of bait water away from the shore. Do not release unused bait fish into any water body.
- Check, clean, and dry your nets, waders, boots, and fishing equipment between trips.
- Help spread the word and inform others about invasive plants.
- Familiarize yourself with invasive species with this and other guides.
- Contact DCR if you find any of the plants or animals in this brochure in the reservoir or watershed.

Department of Conservation and Recreation
180 Beaman Street
West Boylston, MA 01583
508-792-7423 ext. 241
www.mass.gov/dcr

dcr
Massachusetts

STOP AQUATIC INVASIVES

It's the Law

Department of Conservation and Recreation
Wachusett Reservoir

Hydrilla infestation at Clinton, MA

What are invasive species?

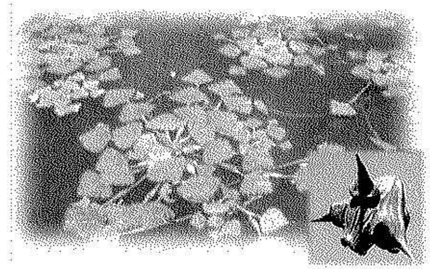
Wachusett Reservoir contains a wide variety of plants and animals that are essential to its ecosystem. Many species are native and are well adapted to our climate. Some species were brought here from other parts of the country and the world. When introduced into our region, these species are called "exotic," "non-native," or "invasive."

When a native or non-native species is able to significantly alter an area's ecology, it is considered an "invasive species."

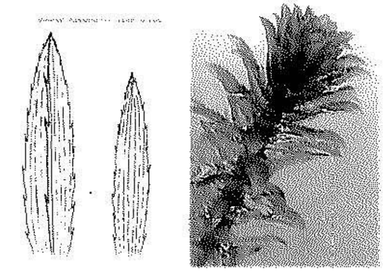
- Many invasive plants grow rapidly in the reservoir and excessive growth negatively impacts water quality.
- The spread of invasive species causes native species to decline, and the animals that depend on them must either relocate or perish. This reduces the biodiversity of the area and disrupts the environment.
- The aesthetic appeal, recreational value and surrounding property values of water bodies decline as invasive species take over.
- Once exotic plants are established, they are difficult to eradicate. DCR has invested hundreds of thousands of dollars to manage invasive plants and repair the damage they cause.

Invasive Species to Look Out For

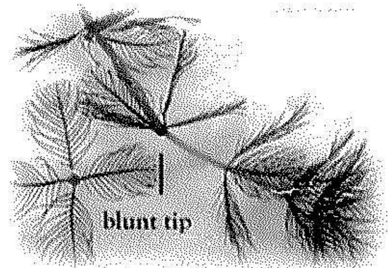
European Niaid



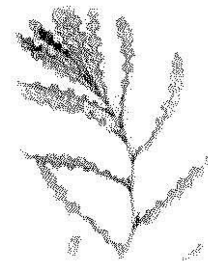
Water Chestnut and Seed



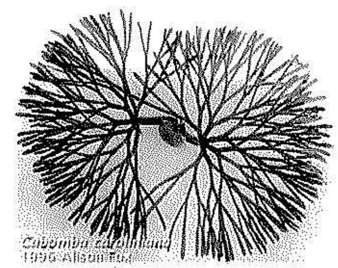
Hydrilla



Eurasian Milfoil



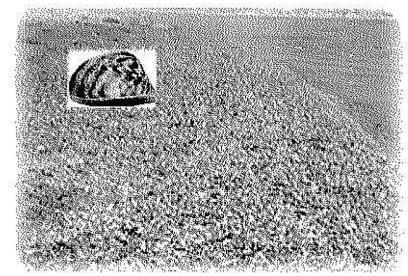
Curly-leaf Pondweed



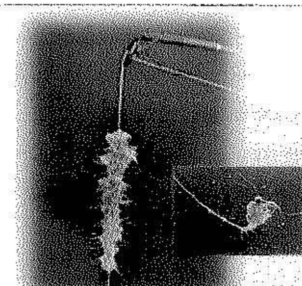
Fanwort

Asian Clam

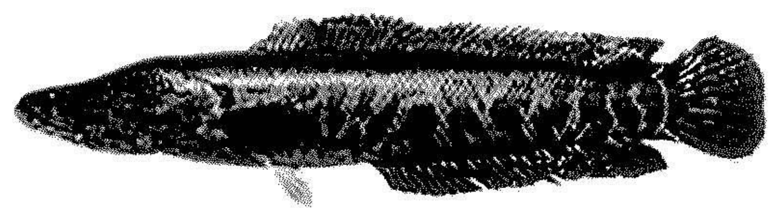
Didymo



Zebra Mussel

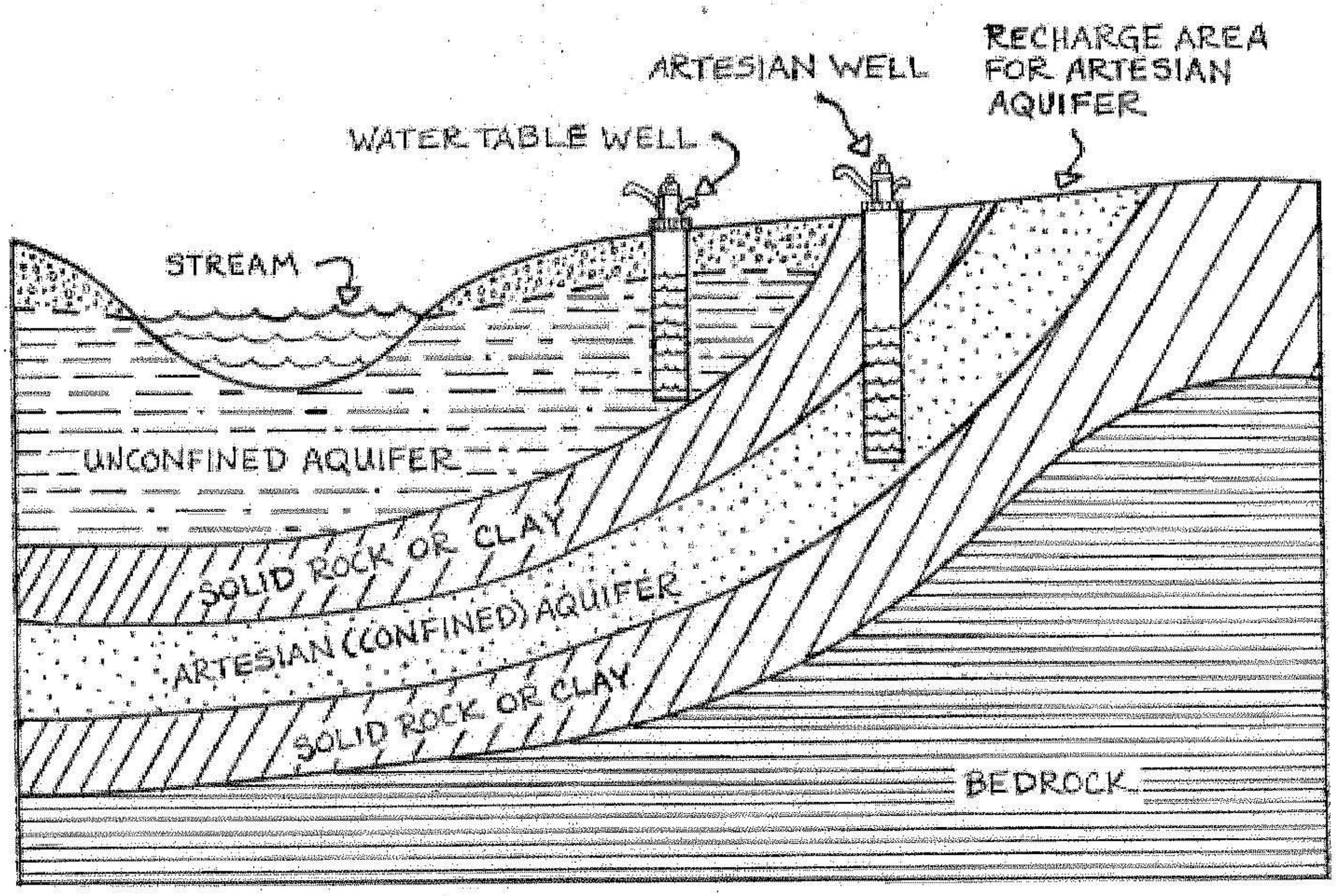


Spiny Water Flea



Snakehead Fish

AQUIFER DIAGRAM



Generalized Wachusett Food Web