

# Why Should We Be Concerned About Clean Water?

Adapted from: *A Brief History of the Clean Water Act*

Most forms of life on Earth require clean water and cannot survive without it. Though the supply used to be plentiful, the situation changed over time so that, by the 1970s, at least 65% of the water tested in U.S. waterways was unsafe for fishing or swimming because of pollution. The U.S. Congress was so concerned that it passed the Clean Water Act in 1972. The goal of the act was to provide all Americans with waterways safe enough for swimming and fishing. With the act, we rejected some old ideas and practices that led to the widespread water pollution, decided to clean up the pollution already present, and made a commitment to keep the waterways clean using good resource management practices.

Today, only about 33% of this nation's waters are considered unsafe for fishing and swimming. That's some improvement, but not enough, and many of those "safe" areas are now threatened by new sources of pollution. Most of the pollution we've been able to eliminate is from traceable sources like a factory or a sewage treatment plant. This type of pollution is called "point source pollution" because we can point to one place – one point – as the source of the problem. Unfortunately, most of the really damaging pollution is untraceable because it comes from multiple sources, reaching the waterways in runoff. When it rains, whatever is on the land washes into rivers, lakes, and oceans. Wetlands, stream corridors, and coastal areas are especially vulnerable to this type of pollution, called "nonpoint source pollution." It's a deadly combination of substances, including various pollutants from urban and suburban streets and parking lots, fertilizers and pesticides from lawns and farms, and other substances from forestry, ranching, and mining operations. All these runoff pollutants threaten environmental balance as well as human health. Every year, there are more warnings for people not to use certain beaches or eat certain fish or shellfish because of pollution. New threats to health such as the microorganism *Pfiesteria* arise as a consequence of new or continued pollution.

The United Nations recognized the connection between land use and clean water as an environmental crisis. In 1992, the General Assembly of the UN invited all countries on Earth to a conference in Brazil to discuss the problem. The leaders at this conference understood that all of us in the rapidly rising world population are trying to improve our standard of living. As we do so, we destroy the environment at an alarming rate. We clear land for new housing, transportation, growing food, and manufacturing, and we pollute. This disrupts many natural cycles like the water cycle, food chains, and O<sub>2</sub>/CO<sub>2</sub> cycles, and it reduces the supply of clean water for all organisms on Earth. The participants addressed the global question of how to allow for development while maintaining the natural ecosystems. They knew about the "interconnectedness" of all life on Earth and agreed that development must be balanced by environmental protection. They understood that if we fail to do this, there would soon be nothing left to develop. Humans cannot survive if the delicate balance of ecosystems on Earth is destroyed.

The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value.

—Theodore Roosevelt

# Stream Study

Aquatic ecosystems cannot be studied in isolation but must be viewed in relation to the surrounding area. The physical characteristics, or abiotic factors, of a stream are important in determining which organisms live there. One of the most important characteristics of any stream is its speed. A fast-moving stream is usually cold, has good light penetration, lower nutrient concentration, less organism diversity and lower overall productivity. Speed will vary in different portions of the stream such as rapids, riffles, pools, or on the inner or outer edges of a bend.

Overall biological characteristics of the stream are also significant because plants and animals living near the stream may alter the stream environment. The runoff from a nearby barnyard may increase the nutrients in a stream. Trees on the stream bank may shade the stream and lower the temperature during the day. Leaves and branches that fall from bank vegetation into the water may serve as food for aquatic organisms. These three examples illustrate just a few of the biological influences that may affect the stream you are studying.



As you begin your study, locate your stream on a topographical map. Determine the stream's source and where it joins with a larger body of water. Sketch the study site as it appears from overhead and make notes to describe the area. The sketch and description will help you understand how land around the stream is used and may include such things as evidence of runoff, the amount and variety of plant life present, types of animals present, human impact on the area, and any evidence of pollution.

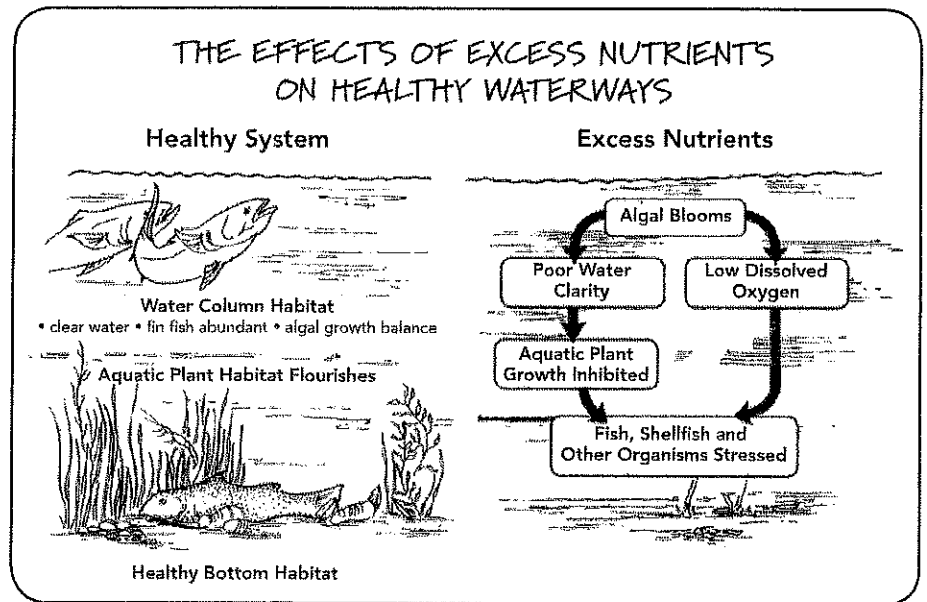


# Nitrates and Phosphates: The Effects of These Pollutants on Aquatic Ecosystems

**Nitrates** and **phosphates** are two nutrients essential for aquatic organisms. Both occur naturally in soil, water, and air. There are also many nitrates and phosphates in human sewage and farm animal manure. Plant fertilizers used on lawns and farm fields contain large amounts of these substances. High-temperature burning of fossil fuels also adds nitrogen to the atmosphere.

Nitrates and phosphates can be pollutants in a waterway. In fact, they are the two major pollutants in the waters of the Potomac watershed. An aquatic ecosystem quickly gets out of balance when an excess of either one is washed in, and then **eutrophication** may occur. The literal meaning of eutrophication is "well-nourished." Eutrophication used in the context of an ecosystem means that the water is over-enriched with nutrients like the nitrates and phosphates. This excess of nutrients causes accelerated growth of algae and higher forms of plant life. Thus, eutrophication describes an aquatic ecosystem that is out of balance due to natural aging or human influences.

A eutrophic body of water is rich in the nutrients that support abundant growth of aquatic plants at the surface. Microscopic producers, called algae, are an essential first link in the aquatic food web. When a waterway receives excess nutrients, an algal "bloom," or population explosion occurs. Because there are so many algae, the water turns a brownish or greenish color. This causes two major problems for other aquatic life. First, these algal blooms block sunlight from reaching beds of **submerged aquatic vegetation (SAV)**. These are benthic plants that grow entirely under water, providing habitat, food, and oxygen for many aquatic animals. SAVs can die when light is reduced. Secondly, when these large masses of algae die, they sink to the bottom, where bacteria break them down. The bacteria use up large amounts of oxygen in this process. With less oxygen in the water, fish, crabs, and other aquatic life forms are harmed or killed. Eutrophication can have both temporary and more permanent effects on aquatic ecosystems. Eutrophication reduces biodiversity by encouraging the growth of nutrient-tolerant plants and algal species that tend to displace more sensitive species. Any decrease in biodiversity makes a food web more vulnerable to collapse.



Nitrate and phosphate pollutants can come from two types of pollution based on the origin of the pollutants: **point source pollution** and **nonpoint source pollution**. Point source pollution can be traced to one certain point such as a pipe from a sewage treatment plant, a factory, or a power plant. Wastewater from these sources can contain toxic chemicals, phosphates, nitrates and other pollutants. Because of stricter regulations and better pollution-removal technology, point source pollution is much more easily controlled than nonpoint source pollution, which is pollution discharged over a wide land area that may be washed into a body of water.



Nonpoint source pollution originates from a source that is not easy to identify or from multiple sources, so these pollutants are very difficult to control. Nonpoint source pollution is sometimes called "**runoff**" because much of it is washed off the land by rain. Runoff includes fertilizers and toxic chemicals such as pesticides washing off lawns and farmland, oil, grease, litter from streets and parking lots, soil eroding off construction sites, and air pollutants washed into streams during rain events..

Most people fail to realize the great threat posed by nonpoint source pollution. Nonpoint source pollutants currently tend to have a much greater impact on life in streams and rivers than point source pollutants do.

# Nitrates

Both plants and animals need nitrogen to build protein and nucleic acids. In nature, nitrogen is much more abundant than phosphorus and is most commonly found in its molecular form ( $N^2$ ) in the atmosphere. In fact, it makes up about 79% of the air we breathe, but this form of nitrogen is useless to both plants and animals.

A certain amount of nitrogen gets into water by natural processes. Some types of bacteria and some algae are able to convert  $N^2$  into ammonia  $-1$  ( $NH^3$ ) and nitrate ( $NO^3$ ) that plants can use for growth. Animals get nitrogen by eating plants or other animals that feed on plants, both on land and in water. Waste from these animals decomposes, and the nitrates are recycled. When these organisms die, all the nitrogen in their bodies reenters the nitrogen cycle. Similarly the excrement from ducks and geese contribute a heavy load of nitrogen to areas where they are plentiful.

## OTHER SOURCES OF NITRATES

Though a certain amount of nitrogen is necessary in aquatic ecosystems, too much can cause problems. Humans are responsible for some of the excess nitrates in water. Runoff from the land can contain fertilizers, sewage from leaky cesspools or sewage treatment plants, manure from livestock, and nitrates from car exhaust. All these contain significant amounts of nitrogen. Increased levels of nitrogen are evident after a storm. The presence of nitrates in water during dry weather is an indication of direct drainage of sewage or manure into waterways.

## SIGNIFICANT LEVELS

Nitrates dissolve more readily in water than phosphates do. Thus, they tend to accumulate more quickly in bodies of water than do phosphates. Unpolluted water generally has a nitrate level below 4.4 mg/L. Nitrate levels above 4.4 mg/L indicate unsafe drinking water.

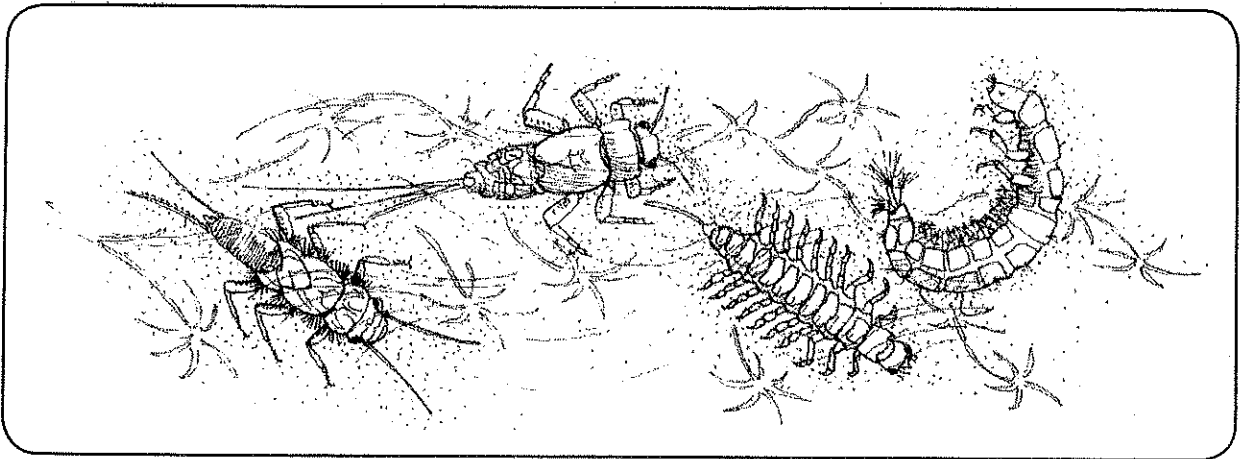
Nitrate contamination of groundwater is a major concern, especially in regions where large amounts of agricultural fertilizers are applied. Though nitrate itself does not cause any health problems, it is converted to nitrite when ingested, and nitrites may be quite harmful. Nitrate levels in the "unsafe" range convert to nitrites that are believed to cause hypoxia (low level of oxygen) in warm-blooded animals. Though the research is not conclusive, the ingestion of nitrite may be especially dangerous to unborn babies in the first three months of life, making the presence of nitrates in groundwater of special concern to pregnant women. Nitrites may be a cause of "blue baby syndrome" (methemoglobinemia), a potentially fatal condition.

# Benthic Macroinvertebrates

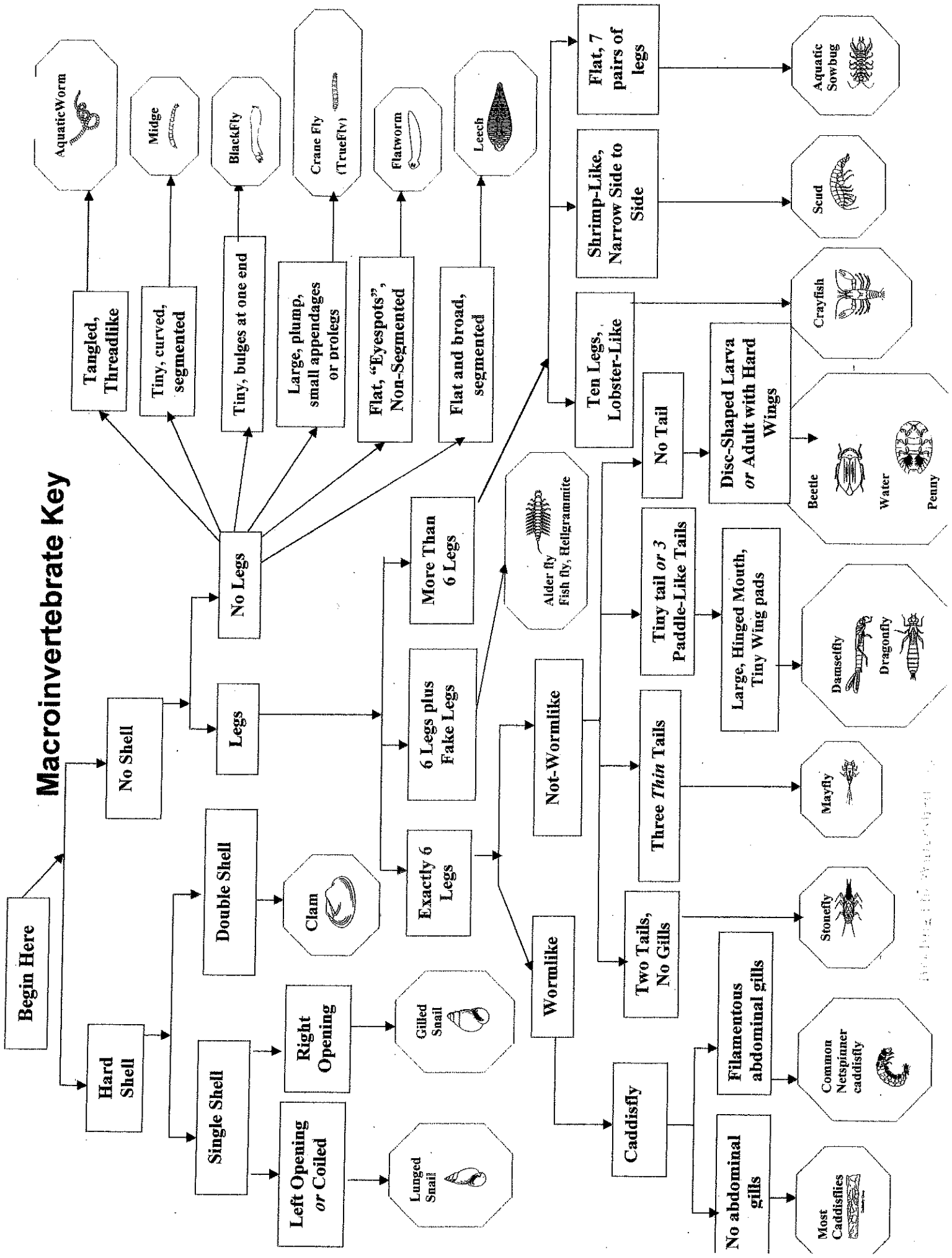
Living things interact with their physical environment. When the physical environment changes, organisms must adapt or die. Therefore, the variety of organisms living in a stream provides the best indicator of a stream's overall ecological health. Organisms in the benthic zone, the area at the bottom of a body of water, filter plankton and organic particles from the water. Benthic Macroinvertebrates are excellent indicator species because many are sensitive to pollution and low dissolved oxygen levels. A low level of dissolved oxygen, often caused by excess nutrients such as nitrates and phosphates, is the primary cause of benthic degradation, or loss of populations.

The benthic community includes a wide variety of organisms with diverse body shapes and adaptations for survival. Flowing water places great demands on the organisms living in it and the faster the water moves, the more difficult the living conditions. In fast streams, organisms must keep from being swept away by the current. Adaptations to help them hold on include having very flattened bodies (mayflies), having claws or hooks to hold on to the substrate (riffle beetles, sow bugs), or being able to build nests to anchor them to the substrate (caddisflies). Slower streams have more sediment, so organisms must be able to move to keep from being buried. These organisms often have the ability to burrow into the silt or mud (nematodes, annelids, and some species of mayfly and dragonfly larvae). The slower water also makes for easier swimming, so such creatures as freshwater shrimp and daphnia are able to swim freely.

## Resources



# Macroinvertebrate Key



# Riffles, Pools, and Bends



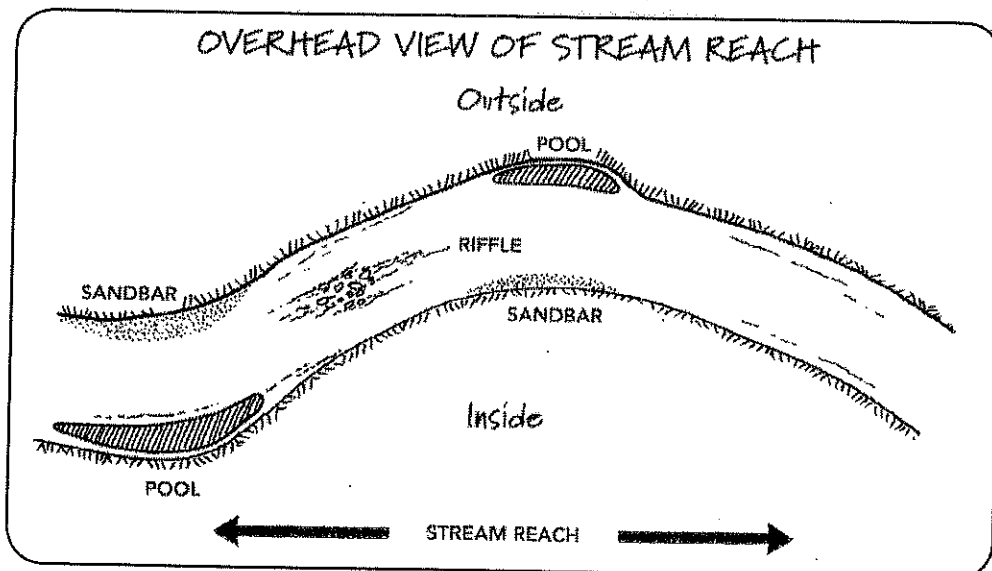
Rocks and debris in a stream may create shallow areas. Water rushes over these shallow areas to form an area of rapids with turbulent flow called a **riffle**. Riffles aerate (add oxygen to) the water and provide habitat for many invertebrates.



A **pool** is a deeper area of water that is quiet and often has no visible flow. Pools provide deeper areas for fish and other larger aquatic organisms. Streams that have many pools and riffles are able to support more life and a greater variety of species than streams that do not.



A **bend** is a change in the direction of the stream channel and the flow of water. Larger, slow-flowing rivers usually have more bends that can provide different habitats. The cutting action of the water at bends provides regions of varying depth and water velocity. Frequently, there is erosion of the bank on the outside of a bend and sediment deposition on the inside of the bend.



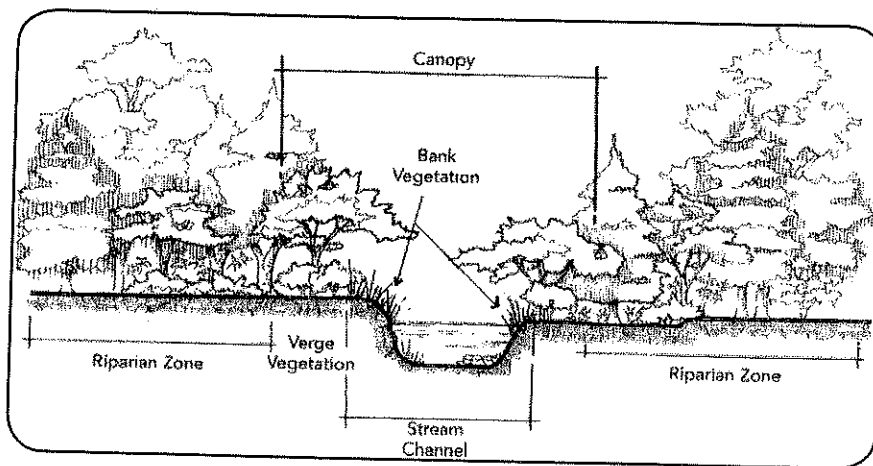
# Land Vegetation

The condition and composition of **vegetation** (e.g., trees, shrubs, grasses) around a stream is a good indication of the health of the aquatic environment. Vegetation provides a natural buffer against erosion and prevents transport of sediments into streams. When vegetation around a stream is degraded or absent, there is less protection for the stream. Deterioration of water quality and habitat for aquatic plants and animals may occur.

A **riparian** area refers to land adjacent to streams, rivers, or water bodies that directly affects and is affected by the water. Trees, shrubs, and other types of vegetation make up the riparian area along waterways. These plants prefer moist to very wet soil and can withstand the disturbance of water flowing over and around them. Riparian vegetation along riverbanks provides a unique habitat in mutual balance with the river channel.

The riparian area includes bank vegetation and verge vegetation. **Bank vegetation** refers to trees, shrubs, grasses, and other vegetation actually growing on the stream bank (sides of the stream channel). The trees from

this area overhanging the stream form the stream **canopy**. Bank vegetation provides food and shelter for aquatic organisms in the form of fallen twigs, leaves, fruits, flowers, and branches.



**Verge vegetation** starts at the top of the bank and extends to the next major line of vegetation or to the point of a change in land use. Excellent verge vegetation is a wide corridor of undisturbed native vegetation. As verge vegetation deteriorates the corridor of vegetation narrows and exotic (non-native)

plants replace native vegetation. In areas of very poor verge vegetation, there is no native tree or shrub layer, resulting in patchy growth or bare soil.

The vegetation in the riparian area affects many features of the waterway ecology such as light, temperature, and bank stability. It acts as a physical buffer to reduce runoff, and is especially effective as a sediment trap. It forms habitats for birds and small mammals, provides overhanging shelter for fish, serves as a place for emergent insects to rest, feed, and lay eggs, improves water quality by filtering runoff before it reaches the water, and promotes sediment deposition on the land. Riparian vegetation slows floodwaters and reduces the total volume of water entering the stream through root absorption. It provides opportunities for recreational activities such as fishing, hiking, bird watching, picnicking, and camping. Riparian vegetation is vulnerable to destruction by natural change and careless human management. It is as important to protect as the river channel itself.

# Stream Speed

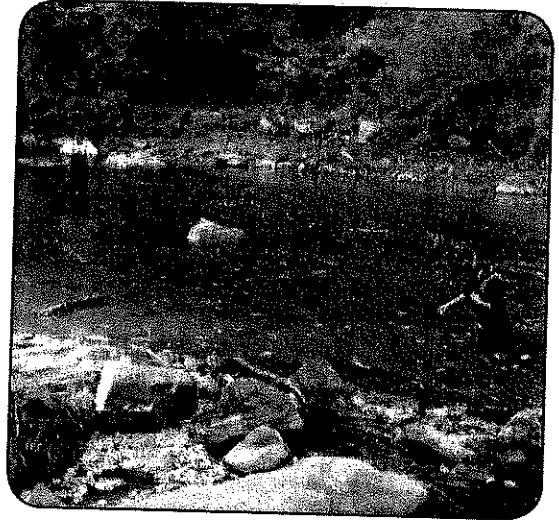
The physical characteristics, or abiotic factors, of a stream are most important in determining which organisms live there. Stream speed is one of the most important characteristics of any stream. A fast-moving stream is usually cold, has good light penetration, lower nutrient concentration, less organism diversity, and lower overall productivity than slow moving streams. A slow-moving stream is warmer, has less light penetration, a higher nutrient concentration, and more organism diversity. Speed will vary in different portions of the stream moving faster over riffles and the outer edges of a bend, and slower through pools and the inner edges of a bend. During the following investigation, you will determine the overall speed of the stream.

## MATERIALS LIST FOR EACH GROUP:

- Orange, rubber ducky or ping pong ball
- Watch with a second hand
- Flash tape
- 10-meter length of rope

## PROCEDURE:

1. Measure a 10-meter section of stream. String flashing tape across the stream at each end of the 10-meter segment.
2. Drop the orange into the middle of the stream above the beginning of your 10-meter segment.
3. Start timing when the orange crosses the "start" line of your 10-meter segment.
4. Record the time in seconds that it takes the orange to travel the length of your stream segment.
5. Repeat Step 2 for a total of 3 trials. Average your results.
6. Divide 10 meters by your average time to get the midstream speed in meters/sec. Overall stream speed is approximately 0.8 (m/s) of the midstream speed. (Water in the middle of the stream channel moves more quickly than water on the sides and bottom.) Use the following formula to calculate overall stream speed.  
$$\text{Overall stream speed (meters/sec)} = \text{midstream speed (meters/sec)} \times 0.8$$
7. Record the overall stream speed on your data sheet



# Dissolved Oxygen (DO)

For a body of water to be considered "healthy," it must have enough dissolved oxygen (DO) to support organisms such as fish, invertebrates, plants and aerobic bacteria. They all require oxygen for cellular respiration, just as humans do. People have noticed that aquatic animals often suffer from lowered DO levels in the late nights and early mornings during a summer heat wave. Read the information below and find out why.

## SOURCES OF DISSOLVED OXYGEN

Much of the DO in water comes from the atmosphere because gaseous oxygen dissolves at the surface where air and water meet. Disturbance of the surface by rainfall, wind, or movement over rocks (such as rapids and riffles) causes more oxygen to dissolve. The more the water churns and bubbles, the more oxygen gets mixed with the water and dissolves in it. Another source of DO is the oxygen that aquatic plants and phytoplankton (including algae) produce during photosynthesis.

## PHYSICAL INFLUENCES ON DISSOLVED OXYGEN

DO levels rise and fall with the season as well as with the time of day. The general rule is that warm water holds less oxygen than cold water, so the same body of water has a lower DO level when it's warm than when it's cooler. Water also holds less oxygen at higher altitudes, so on a given day, a lake at the top of a mountain would contain less oxygen than an otherwise similar lake at the bottom of the same mountain.

Aquatic plants need light to produce oxygen, so DO levels are usually low whenever light is low. This includes nights, cloudy days, and whenever dense algal growth blocks sunlight. People decrease DO whenever we do anything that causes water to be warmer than normal. Sometimes we use water to cool machinery in a factory or power plant and then return the water to a waterway. The water that is returned is warm because of the heat it absorbed from the hot machinery, so it can't hold much oxygen. This produces "thermal pollution," a problem causing major changes in aquatic ecosystems worldwide.

## UNITS OF MEASUREMENT FOR DISSOLVED OXYGEN

We measure DO either in milligrams of oxygen per liter of water (mg/L) or in parts per million (ppm). We can also convert those amounts to percent (%) saturation.

## HOW MUCH DISSOLVED OXYGEN IS ENOUGH?

Different aquatic species require different amounts of oxygen for healthy survival. Some species require different amounts at different life stages (such as tadpole versus adult frog). However, in most cases, bodies of water with consistently high levels of DO (90 % saturation or higher) are considered healthy. That means they are stable and capable of supporting many different kinds of aquatic life.

### Dissolved Oxygen levels of:

- 5 – 6 mg/L are sufficient for most species.
- < 3 mg/L are stressful to most aquatic species.
- < 2 mg/L are fatal to most species.

If DO levels fall, organisms that can move (like fish and some types of invertebrates) leave the low DO areas and congregate in areas with higher levels of oxygen. This temporary increase in population may deplete the food or oxygen in the new area, compounding the problem. Organisms that can't move (like oysters), move too slowly (like clams), or are trapped (like crabs in a crab trap) usually die when DO levels decrease below their oxygen requirements.

# Fecal Coliform

In June 1998, thirteen toddlers developed a serious *Escherichia coli* infection after a day of fun in a local swimming pool. It was later determined that a child had defecated in the pool. Though none of the children died, five were hospitalized, two in critical condition. This mode of infection was unusual for *E. coli*, since it is usually passed when people eat contaminated meat that has been undercooked or eat contaminated fruits and vegetables that have been inadequately washed.

Fecal coliform bacteria (most commonly *Escherichia coli*, abbreviated *E. coli*) are found naturally in the lower intestine of many vertebrates, including humans. They aren't found in water unless intestinal wastes (feces) have contaminated the water, so their presence in water is a reliable indicator of fecal contamination. Fecal coliform bacteria don't usually cause disease, but many other types of organisms present in sewage can do so. It's much easier to test for *E. coli* than for all the other possible types of fecal coliform. Therefore, *E. coli* can be used to warn us about the possible presence of those other pathogenic (disease causing) organisms.

## HOW FECAL COLIFORM RESULTS ARE EXPRESSED

The results of tests for coliform bacteria in water are expressed as the number of bacterial colonies per 100 milliliters (mL) of water.

## SIGNIFICANT LEVELS

Because of nonpoint source pollution, most untreated water contains low levels of coliform bacteria. Water treatment facilities monitor these levels. Factors such as water temperature, DO levels, and speed of stream flow can all affect bacterial levels, making it difficult to maintain one steady water quality. For this reason certain levels of coliform bacteria are "allowable" in water. Though we might prefer that all our water be 100 % free of bacteria, some of the things we use water for, like flushing toilets, need not be the same quality as the water we use for drinking. There are three levels of water usage: drinking water, primary contact (such as swimming), and secondary contact (such as washing vegetables intended for human consumption). Refer to the chart below. High levels of bacteria indicate water that is unsafe for human contact of any kind.

Water usage	Desirable numbers of bacteria colonies per 100 mL of H <sub>2</sub> O	Acceptable numbers of bacteria colonies per 100 mL of H <sub>2</sub> O
Drinking water	0	0
Primary contact	< 200	< 1,000
Secondary contact	< 1,000	< 5,000

# pH

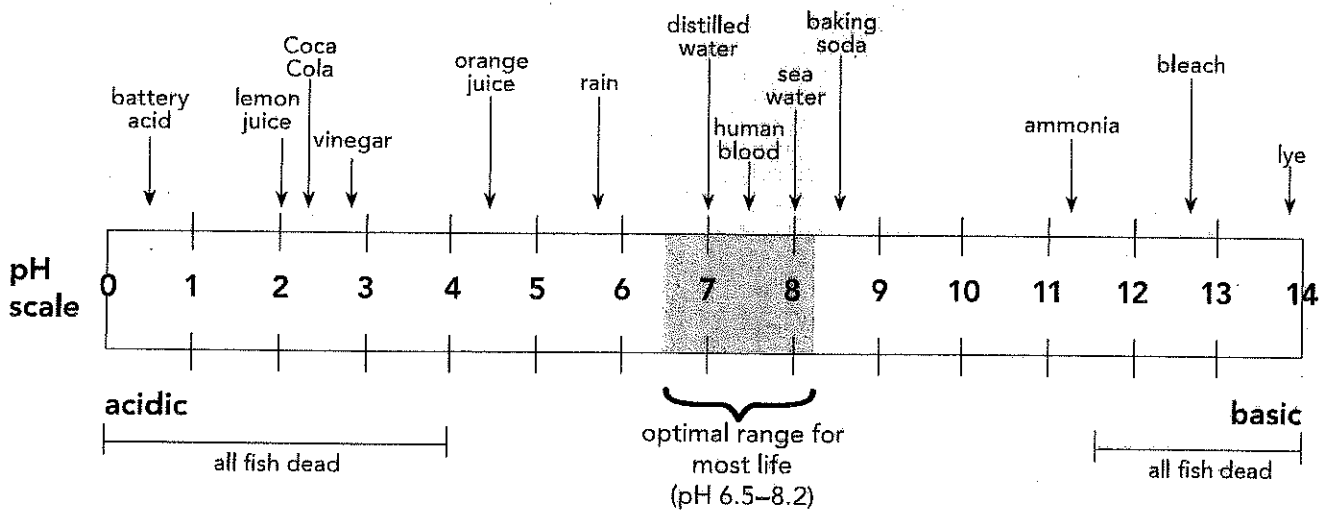
The pH test is one of the most common analyses used in water testing. What we call acidity is really a measure of the hydrogen ion ( $H^+$ ) concentration in the sample. pH ranges from 0 - 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids, and those with a pH above 7.0 are considered bases. Most rainwater has a pH of about 5.6. The chart below shows the pH of common substances and pH limits for aquatic organisms.

## SIGNIFICANT LEVELS

Though different aquatic organisms have a different optimal pH, most can tolerate anything between 6.5 and 8.5. Many chemical and biological processes are affected by pH. A pH level outside this range can reduce the diversity in the stream because it stresses the body systems of most organisms and can reduce their reproductive success. Many factors can affect the acidity of aquatic ecosystems. Some of these are acid rain, minerals that dissolve out of rocks, melting snow, heavy precipitation, accidental spills, agricultural runoff, and sewer overflow. Organisms themselves may also affect the pH. The more dissolved  $CO_2$  there is present in water, the more acidic the pH becomes (pH decreases). Photosynthesis by aquatic plants removes dissolved  $CO_2$ , so waterways with growing plants often show an increase in pH during the growing season and a decrease when the plants die. This is especially true if the water is still or slow-moving. Organisms living in these areas must be able to either adapt to the fluctuations or move in order to survive. Low pH (acidity) can also make toxic substances more mobile and easier for aquatic plants and animals to absorb. Some species like rainbow trout are more sensitive than other species to this toxic condition.

## MEASURING pH

Simple test kits are used to measure pH. Test the pH of a sample immediately because pH may quickly change due to biological and chemical activity in the sample container. The pH is expressed as a number from 1 to 14, including tenths (e.g., 6.7).



# Biochemical Oxygen Demand (BOD)

Most organisms require oxygen, including the bacteria that decompose organic matter. When aerobic bacteria decompose organic material, they break it down by oxidation (combining with oxygen). BOD is an abbreviation for biochemical oxygen demand, a measure of how much oxygen these bacteria use in the aerobic oxidation of organic matter. Some pollutants such as inadequately treated sewage are organic, and bacteria use oxygen dissolved in the water to decompose them. For more information about dissolved oxygen, refer to page 27 of the Teacher Resources.

## MEASURING BIOCHEMICAL OXYGEN DEMAND

We measure BOD by comparing the amount of dissolved oxygen present in a freshly collected water sample with the amount of dissolved oxygen in a second sample collected at the same time and place but allowed to "sit" for five days under special conditions so that the bacteria in the sample have time to work. The difference between the dissolved oxygen in the two samples is how much oxygen the decomposing bacteria used to oxidize the organic material in the water during the 5-day incubation period. The amount of dissolved oxygen used over 5 days is the BOD.

## SIGNIFICANT LEVELS

The BOD of unpolluted, natural waters is 5 mg/L or less. Since very little oxygen is being used, there is plenty available for a variety of aquatic organisms. If a lot of organic material is added to the water, the BOD increases, that means there is a high demand for oxygen, specifically by bacteria that are decomposing organic matter. Raw sewage may have a BOD level of 150 to 300 mg/L. When aerobic bacteria use up a lot of the dissolved oxygen, little is left for other aquatic organisms. Wastewater treatment plants must reduce BOD to levels specified in their discharge permits. These levels vary according to area, but they are usually between 8 and 150 mg/L, with most permits specifying about 30 mg/L BOD so that aquatic life isn't threatened with suffocation.

# Water Temperature

## HOW IS TEMPERATURE IMPORTANT TO THE HEALTH OF A RIVER?

Temperature affects many of the chemical properties of water itself, as well as many biological and physical processes within the aquatic ecosystem. Among other things, temperature affects the

- 1) oxygen content of the water (oxygen levels become lower as temperature increases).
- 2) rate of photosynthesis by aquatic plants.
- 3) metabolic rates of aquatic organisms.
- 4) sensitivity of organisms to toxic wastes, parasites, and diseases.

Acceptable temperatures vary from site to site and season to season. In general, however, temperatures above 27° C (80.6° F) are unhealthy.

## HOW IS WATER TEMPERATURE IMPORTANT TO AQUATIC ORGANISMS?

Water temperature is one of the key factors determining what species are best suited to certain regions. Different species of fish and other aquatic organisms have different optimal temperatures, some surviving best in colder water, others in warmer water. Refer to the following chart for temperature ranges.

If temperatures are outside a species' optimal range for a long period of time, organisms become stressed and often die. More sensitive species can be weakened by even a short "temperature shock" and become more subject to disease or parasitism as a result. Water temperature affects metabolism in aquatic animals as well as many behaviors, including general activity, feeding, and reproduction. A week or two of high temperatures each year may make a stream unsuitable for sensitive organisms, even though temperatures are within tolerable levels throughout the rest of the year.

Range description	Celsius	Fahrenheit
Warm	20° - 25°	68° - 77°
Cool	13° - 19°	55° - 67°
Cold	5° - 12°	41° - 54°

## WHAT CAUSES CHANGES IN WATER TEMPERATURE?

Obviously, natural processes such as changing weather and groundwater flowing into waterways can cause temperature changes, but many things that people do can also cause it. We cause temperature change when we do things such as:

- 1) removing stream bank vegetation that shades the water.
- 2) impounding water (when we confine it, like with a dam).
- 3) discharging water we heated by using it to cool something.
- 4) channeling water from impervious urban surfaces which heats water going into storm drains that flow into rivers.

## WHAT ARE ACCEPTABLE CHANGES IN WATER TEMPERATURE IN A ONE MILE REACH?

A change of more than 4 or 5 degrees Celsius in less than a one-mile length of the stream indicates a source of thermal pollution or a significant change in the tree canopy shading a stream. Both causes will degrade the quality of the aquatic habitat.

## IMPACTS OF CULTURAL EUTROPHICATION

Eutrophication is a natural cycle that is supposed to take thousands of years. Cultural eutrophication, what we cause, is so accelerated that it can occur in years or months, quite possibly resulting in the death of an entire ecosystem. The first sign of cultural eutrophication is usually an algal bloom that makes the water pea soup green. Aquatic plants that normally grow in shallow waters become very dense. Swimming and boating may become impossible. While the nutrients last, rapid reproduction of algae and macroscopic plants continues. When the nutrients are used up, many of the excess plants and algae die.

This "kill" provides a great deal of organic material for bacteria to decompose. Since the bacteria use oxygen in this process, dissolved oxygen in the water decreases, and aquatic animals must either move out of the area or die. These conditions usually occur near the bottom of a lake or impounded river stretch, and produce gases like hydrogen sulfide, unmistakable for its "rotten egg" smell.

## SIGNIFICANT LEVELS

In natural bodies of water, an orthophosphate level of 1.0 mg/L is considered excellent. Levels of 2-3 mg/L contribute to increased plant growth and algal blooms, and levels of 4.0 mg/L and higher may temporarily stimulate plant growth enough to surpass natural eutrophication rates.

# Turbidity

Turbidity is cloudiness. Cloudy or turbid water contains suspended solids such as soil particles (clay, silt, and sand), plankton, including algae, and various microbes. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand), large enough to block some of the light rays and reduce the amount of light that can pass through. The higher the turbidity, the less light passes through to the plants living under water. Dissolved substances don't generally contribute to turbidity. (For a discussion of total dissolved solids, refer to page 35.)

## HOW TURBIDITY AFFECTS THE ENVIRONMENT

Turbidity causes higher water temperatures because the suspended particles absorb heat. This reduces the amount of dissolved oxygen (DO) in the water because warm water holds less oxygen than cold water does. Because higher turbidity reduces the amount of light passing through the water to aquatic plants, photosynthetic activity is reduced, and less oxygen is produced. This further reduces the DO. Suspended materials can also clog the gills of fish and other animals.

Since the animals get less oxygen, their body systems are stressed, their resistance to disease is lowered, and their growth rates are reduced. The sediments can also interfere with the development of their eggs and young. Particles of sediment may even smother fish eggs and benthic macroinvertebrates.

## Resources

### WHAT ARE THE SOURCES OF SEDIMENTS THAT CAUSE TURBIDITY?

- **EROSION.** Soil particles are the most common cause of high turbidity. Normally, plant roots hold soil in place and absorb rainwater. Many human activities remove the soil's protective plant cover, and the soil washes or blows away. Construction companies often leave large areas of exposed soil. Farmers may leave fields unplanted after a harvest. Timber companies cut down trees to make lumber or paper, and new trees take years to grow. Rain on any of these areas picks up soil and carries it into streams or rivers. The fewer plants there are, the less water gets absorbed and the faster the water flows off the land. The larger volume of water causes streams to flow faster. Faster flowing streams erode their own banks, increasing the sediments in the water. This causes a sharp rise in the turbidity of the stream. Dry weather causes a different kind of erosion problem: wind carries the dry dirt into streams.
- **WASTE MATERIALS.** Waste materials from factories, towns, and cities may get into the water by accident, or deliberately if the waterway is used as a convenient "dump." Even natural materials such as leaves and grass can increase turbidity if they are dumped into these waterways and begin to decay.
- **IMBALANCE IN THE ECOSYSTEM.** Various types of imbalance can increase turbidity. If disturbance of the ecosystem has eliminated all but the most pollution-tolerant species of fish (such as carp), their numbers will increase. Large numbers of bottom feeders like carp stir up sediments. Nutrient imbalance may cause eutrophication, encouraging the overgrowth of algae populations. In this case, the cloudiness in the water looks green.

### SIGNIFICANT LEVELS

Drinking water should have a turbidity less than 0.5 Jackson Turbidity Units (JTU). Typical groundwater is considered acceptable with a turbidity of anything less than 1.0 JTU. In a stream, turbidity higher than 40 JTU can damage gills and interfere with the ability of fish to find food.

# Total Dissolved Solids (TDS)

Each body of water contains a unique mixture of dissolved materials. Total dissolved solids (TDS) is the amount of material dissolved. The composition depends mainly on the solubility of the substances in contact with the water, including soils and rocks along the waterway. We can measure TDS by filtering the water (to take out suspended solids) and evaporating the water from the filtrate. What was dissolved in the water sample will be left behind. We can also measure the electrical conductivity of the water because many dissolved solids increase conductivity.

## SOURCES OF TDS

Human activity increases TDS in natural waterways. Runoff from urban areas carries salt from the streets, fertilizers from lawns, and many other materials. Wastewater treatment plants can add phosphorus, nitrogen, and dissolved organic matter.

## SIGNIFICANT LEVELS

Rainwater has very little dissolved in it, so it has a low TDS level of  $< 10$  mg/L. Rivers typically contain between 100 and 2,000 mg/L dissolved material. Municipal water systems try to achieve  $< 500$  mg/L TDS for drinking water. Higher TDS levels give water a mineral taste and can cause the water to have a laxative effect.

## CHANGES IN AQUATIC LIFE

Aquatic life depends upon a constant TDS level for a variety of reasons. For example, dissolved calcium affects how easily water can flow into and out of an organism's cells. High TDS can cause water balance problems for organisms. Low TDS concentrations may limit growth of aquatic life. Phytoplankton and floating aquatic plants, for example, absolutely require the nitrates and phosphates dissolved in the water because they have no roots to take up those nutrients.

# Apparent Color and Odor

## APPARENT COLOR

The apparent color of water is the result of both dissolved substances and suspended materials, so color can provide useful information about the water's source and content. Pure water absorbs various wavelengths of light at different rates. Blue light and blue-green light are the wavelengths best transmitted through water, so a white surface under pure water appears blue. Natural metallic ions, plankton, including algae, industrial pollution, and plant pigments from humus and peat may all produce different colors in water.

Determine the apparent color of water by lowering a white disk far enough below the water surface to produce a distinct color. Use the table of colors below to hypothesize the source of the water color.

Color	Source
Blue	Low accumulation of dissolved materials and particulate matter (indicating low productivity)
Yellow or brown	Organic materials: humus, peat, decaying plants
Reddish or deep yellow	Algae or dinoflagellates
Green	Phytoplankton or algae
Yellow, red, brown, or gray	Soil runoff

## ODOR

The odor (smell or scent) of water can indicate what's in it. Odor can be caused by the natural presence of algae and dissolved minerals. Municipal or industrial wastes, decomposing plants, or microbial activity can also cause odor. Odor affects how acceptable we find drinking water, how willing we are to use a waterway for recreational purposes, and how fish and other aquatic foods taste to us.

**Odor Test:** Your nose is an excellent odor-detecting device. Collect a water sample in a wide-mouthed jar. Waft the air above the water sample toward you with your hand. Use the table of odors below to describe what you smell.

Odor	Nature of Odor
Aromatic (spicy)	Cloves, lavender, lemon
Flowery	Geranium, violet, vanilla
Chemical	Industrial wastes, chlorine, oil refinery wastes, medicinal, sulfur (rotten eggs)
Disagreeable/unpleasant	Fishy, pigpen, septic (stale sewage)
Earthy	Damp earth
Grassy	Crushed grass
Musty	Decomposing straw, mold