Chapter 2: Surface Water

(Lakes, Ponds, Rivers, Streams)

Goals

Students will understand:

1. The concept of surface water
2. How surface water interacts with groundwater and the landscape
3. Major water quality issues in rivers and lakes
4. Characteristics of river and lake ecosystems

Background Information

Surface water refers to all the features that hold water on the Earth's surface including: oceans, streams, rivers, lakes, ponds, wetlands, etc. Watersheds are defined by these surface water features. When precipitation falls to the Earth as part of the water cycle, some of it flows along the land surface to streams and lakes, some of it is used by plants, some evaporates and returns to the atmosphere, and some sinks into the ground. The precipitation that flows along the land surface becomes runoff, flowing downhill and eventually collecting in surface water features. Runoff gathers in small streams that are joined by other streams to form larger streams. These larger streams serve as inlet water sources for lakes and ponds or combine with other streams to become wider and more substantial rivers heading toward the sea. Surface water is visible on the Earth's surface and supplies water for drinking, recreation, transportation, agriculture, and power generation. Consequently, most major cities developed near large surface water features for convenience. About three quarters of the Earth's surface is covered by water, but a majority of that water exists as salt water in oceans. Fresh surface water is limited to the land masses and makes up less than 1% of the planet's water. Although not as abundant a source of fresh water compared to groundwater, surface water is often a major source of drinking water. In this chapter, surface water will be limited to fresh water with a particular focus on streams, rivers, lakes, and ponds. Streams and rivers will be referred to as waterways and lakes and ponds will be referred to as waterbodies.

Surface Water in New Hampshire

Surface waters are an important part of the water cycle, contributing to groundwater recharge and ocean levels. Groundwater can also be a source of water for streams, rivers, lakes, and ponds. Whether groundwater is recharging surface water or whether surface water is recharging groundwater is dependent on both seasonal variations and precipitation patterns. **In New Hampshire, surface water tends to recharge groundwater in the fall, winter, and spring when precipitation is frequent. However in the summer months, groundwater contributes about 40% of the flow in rivers and streams.**

Surface water features and adjacent shorelines and stream banks are productive and diverse ecological systems, serving as critical feeding, spawning, and brood rearing habitat for many wildlife species. In addition, streams, rivers, lakes, and ponds provide many recreational (boating, fishing, swimming, wildlife observation), and economic (aesthetic appreciation, tourism, real estate values, agriculture) benefits. **Surface water also provides drinking water for 40% of New Hampshire residents.** Most of these benefits depend on high water quality in surface water. Consequently, it is important to understand these resources and develop strategies to monitor and protect them.

Waterways: Streams and Rivers

Streams and rivers are formed through the accumulation of enough water, surface runoff and groundwater, to create flow or water movement in a downhill direction. Small streams join other small streams to form a branching network across the watershed (Figure 1). When observed from the air, this network is often described like a tree where the topmost branches are the headwater streams and the trunk is the largest river that flows into the ocean or large lake. This network of flowing water from the headwater streams to the river mouth is called the river system. Water resource professionals have developed a simple method of categorizing streams in a river system. Headwater streams are, that have no tributaries flowing into them, are called first order streams. Streams that receive only first order streams are called second order streams. When two second order streams meet, the combined flow becomes a third order stream, and so on (Figure 1).

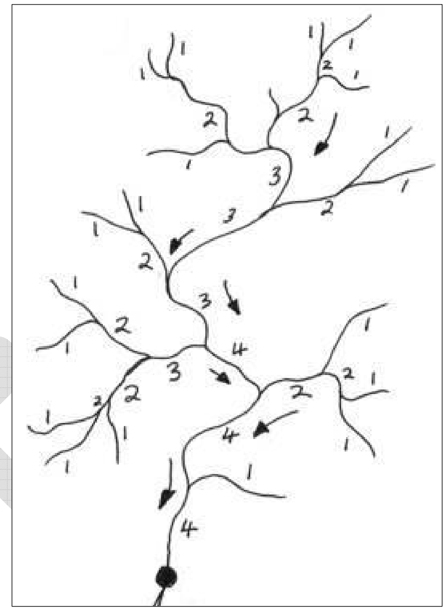


Figure 1. A river system with stream orders labeled (http://www.lifeinfreshwater.org.uk/Web%20pages/Rivers/Stream%20Order.htm).

The stream or **stream channel** is the land surface that is completely covered by flowing water. The fast moving water causes the mixing of water and air, which allows oxygen to be dissolved in the water. This process gives rivers and streams the oxygen levels needed to support aquatic life. If oxygen levels drop for some reason, either through natural processes or human disturbance, aquatic life will be limited to those organisms that can tolerate low oxygen conditions.

Within the stream channel there are three general habitat types important to aquatic life. Contributing a mixture of flows and depth, these habitats are called pools, riffles, and runs (Figure 2). A **pool** is deep with slow moving water and a stream bottom that consists of soft, fine sediments. A **riffle** is shallow with fast, turbulent water running over rocks. Riffles are often characterized by white caps, where water flowing quickly over rocks mixes the water with the air resulting in the highest dissolved oxygen concentrations in the stream. A **run** or glide is deep with gently and smooth flowing water and little or no turbulence. Making sure that a mix of pool, riffle, and run habitats are available within the stream system will help protect a diversity of aquatic life.

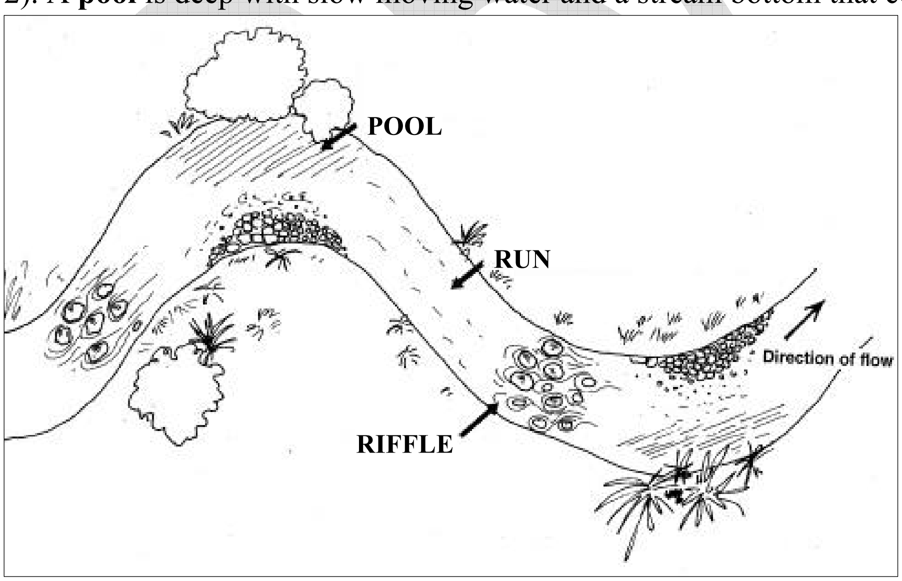


Figure 2. A drawing of pool, riffle, and run habitat types and their general location along a stream channel (http://share3.esd105.wednet.edu/rsandelin/ees/Resources/Flowing%20water%20concepts.htm).

Stream Substrate

One of the differences between pools, riffles, and runs is the substrate. **Substrate** is the material that makes up the bottom of the stream and can include: clay, silt, sand, gravel, cobble, boulder, or bedrock. These substrate types are differentiated by their size (Figure 3). The finer substrates, clay silt, and mud, tend to be more prevalent in pool habitats. Gravel, cobbles, and boulders are more common in runs and riffles. The spaces between these rocks provide habitat for fish, macroinvertebrates, and other aquatic life.

SMALL → LARGE

Substrate Type	Description
clay/silt/mud	Fine particles that have a sticky feeling. The spaces between the particles hold a lot of water, making the sediments feel like ooze.
sand	Tiny, gritty particles of rock that are smaller than gravel but coarser than silt. Up to 0.1 inch in size (smaller than marble).
gravel	Stones ranging from tiny quarter-inch pebbles to rocks of about 2 inches in size (marble to tennis ball).
cobble	Rocks between 2 and 10 inches in size (tennis ball to basketball).
boulder	Rocks greater than 10 inches in size (larger than basketball).
bedrock	Solid rock.

Figure 3. Table of substrate types and their relative sizes (EPA 2002).

Stream Channel Processes

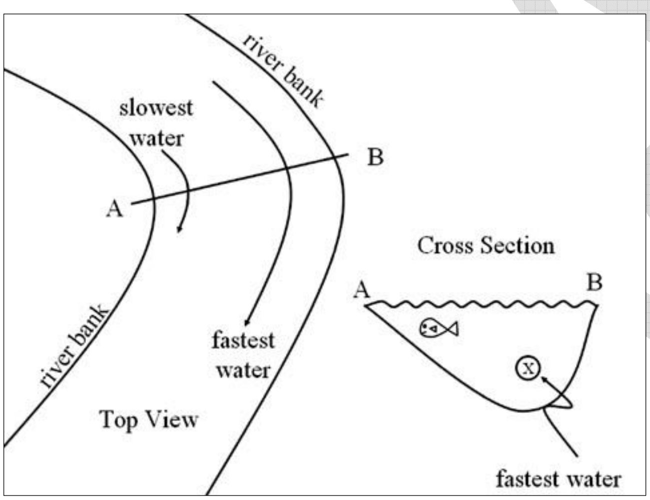


Figure 4. Water speed within a stream meander (http://www.mrsciguy.com/weathering.html).

Substrate types vary between pools, riffles, and runs because of differences in the speed of water flow along the stream channel. In a straight section of a stream, the fastest moving water is in the middle. More commonly, streams have curves or meanders that create interesting erosion and deposition patterns. Erosion and deposition are opposing processes. **Erosion** is the process of moving sediment from one location to another while **deposition** is the process of dropping material out of transportation. In a stream, the amount of erosion that occurs depends on the velocity and volume of water flow. Velocity increases when the slope and volume of water flow increases. As velocity increases, the stream will be able to transport larger and larger particles and the rate of erosion increases. The volume of water flow is influenced by precipitation and here in the northeast by snowmelt in the spring.

On a meander, the fastest moving water gets thrown to the outside of the curve and the slower moving water hugs the inside curve (Figure 4). Erosion tends to be greatest where the water is traveling the fastest (outside bend) and deposition tends to occur where water moves the slowest (inside bend) (Figure 5). The meander widens from erosion on the outside and deposition on the inside. Often the bank along outside bend will be undercut and along the inside bend the deposited substrate will create a point bar or sand bar (Figure 5). Consequently, the stream channel and substrate can change over time depending on erosion and deposition patterns within a stream system.

Stream Vegetation

In addition to the physical condition of the stream channel, the living stream environment consists of several other important components starting from within the stream outward to the rest of the watershed (Figure 6). Vegetation within the stream and along the stream banks includes emergent, submergent (submerged), and floating plants. **Emergent plants** include plants with true stems, roots, and leaves with most of their vegetative parts above the water. **Submergent plants** also include some of the same types of plants, but they are completely immersed in water. **Floating plants** are detached from any substrate and are therefore drifting in the water. Vegetation within the stream channel filters polluted runoff from the surrounding watershed, provides food and habitat for aquatic life, settles out sediments and roots hold the soil in place, and uses nutrients within the stream thereby reducing the occurrence of algal blooms.

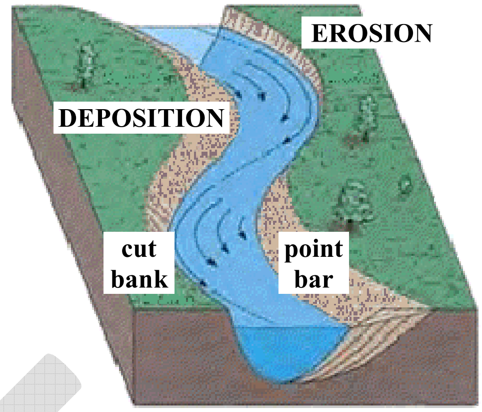


Figure 5. Erosion and deposition patterns along a stream channel. (http://www.chartiersgreenway.net/hydrology.htm).

Riparian Zone and Floodplain

Vegetation extending outward from the edge of the stream banks exists in the riparian zone (Figure 6). The **riparian zone** is the area adjacent to and along a stream that is often covered by vegetation. A healthy stream system, which has high water quality, requires a healthy riparian zone that has a diversity of plants, shrubs, and trees. This vegetation prevents erosion by holding soil in place, filters pollutants from runoff, provides habitat for animals that use the river, and adds nutrients to the river as leaves and other plant parts drop into the water. The riparian zone also provides shade through streamside or canopy cover. **Streamside cover** includes any overhanging vegetation that offers protection and shading for the stream and its aquatic inhabitants. Streamside cover keeps water temperatures cool, which in turn increases the capacity of water to hold oxygen, an environmental requirement for native brook trout and other organisms that require higher quality water (see Chapter 4 for more information about native brook trout). Changes to the riparian zone can occur when

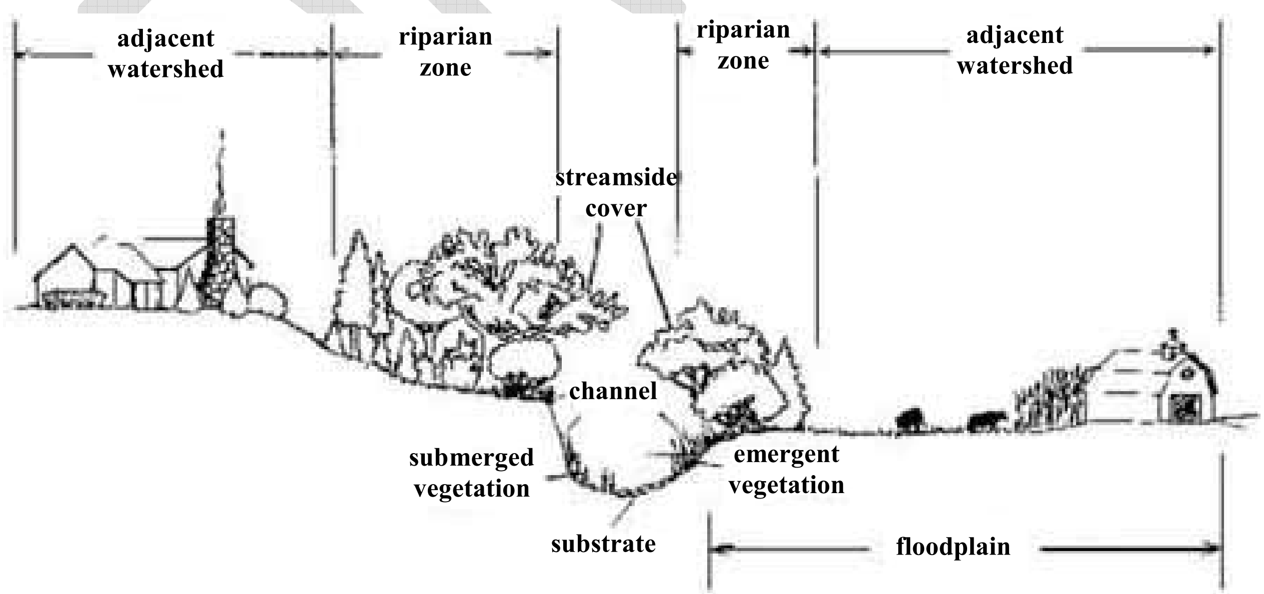


Figure 6. A diagram of the components of a living stream environment (EPA 2002).

roads, parking lots, fields, lawns, and other artificially cultivated areas, bare soil, rocks, or buildings are near the stream bank. These land use changes can degrade the stream's riparian zone and in turn negatively impact each of the stream components, and the aquatic insects, fish, and plants that inhabit them.

The riparian zone is often part of the stream's **floodplain**, the low area of land that surrounds a stream and holds the overflow of water during a flood. A healthy, densely vegetated riparian zone will help reduce the impacts of flooding. Beyond the riparian zone is the adjacent watershed. The **adjacent watershed** includes the higher ground that captures runoff and drains to the stream, often defined by the land extending from the riparian zone to about a quarter mile from the stream. Human activities within the floodplain and adjacent watershed also have considerable impact on stream water quality. Land use activities within these regions should be managed in a way to minimize the negative impacts to waterways (see Chapter 7 for more information about best management practices for water quality protection).

Waterbodies: Ponds and Lakes

Waterways are intricately connected to waterbodies. Waterways provide nutrients to fuel pond and lake productivity and also replenish water lost to evaporation, groundwater recharge, or outflows. Similar to waterways, waterbodies support a diversity of life that depends on variety of habitat conditions. In determining the health of a lake or pond, scientists look at: 1) the amount of dissolved oxygen in the water; 2) algal content; 3) the health of the fish; 4) the diversity of bottom-dwelling insect larvae; worms, shellfish, and other invertebrates; and 5) the amounts and types of pollution settled into the substrate (Figure 7).

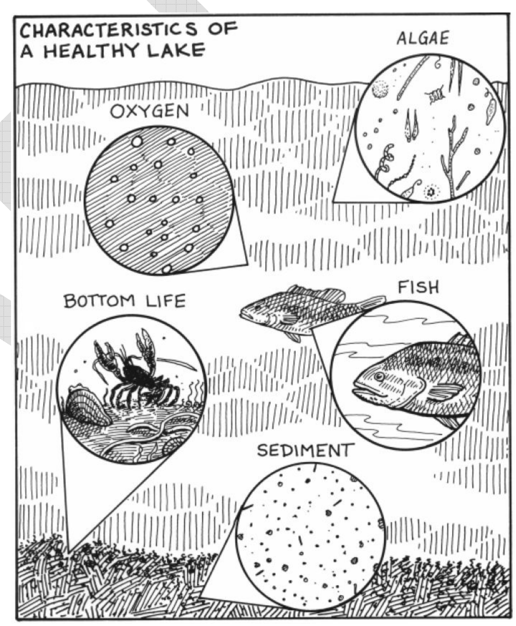


Figure 7. Components of a healthy lake ecosystem (EPA Region 4).

<u>Lake and Pond Classification</u>

These characteristics are further influenced by trophic states, which are used to describe a lake's natural aging process. **Trophic states** are based on the amount of available nutrients (nitrogen and phosphorus) for aquatic life and are a way to classify and refer to different types of lakes. The root of the word "trophy" means nutrients. Lakes that have more nutrients are considered more fertile and have more plants and algae. Often lakes age from a state called oligotrophic to mesotrophic and then finally eutrophic (Figure 8).

"Oligo" means very little. **Oligotrophic** lakes are low in nutrients and therefore tend to have little plant and algae growth; have deep, clear water; and support many fish species that require cold, well-oxygenated waters (Figure 8). Most of New Hampshire's glacial lakes are classified as oligotrophic and comprise approximately 30% of all the lakes in the state. (add local lakes for each trophic state?, ask Tara not sure which lakes fit into which category)

"Meso" means middle or mid. **Mestrophic** lakes have medium levels of nutrients and these waterbodies tend to be clear, have beds of submerged plants, and can have seasonal variations in oxygen level that limit high water quality fish from thriving. However, mesotrophic lakes are great fishing lakes and have the greatest diversity of fish species when compared to oligotrophic and eutrophic lakes. The majority of New Hampshire lakes, approximately 47%, are mesotrophic.

“Eu” means true and can be translated to mean true nutrients or truly nutrient rich. **Eutrophic** lakes are high in nutrients and support an abundance of life including a diversity of vegetation, frequent algae blooms, and large fish populations. Runoff from the surrounding watershed brings sediments, which hold nutrients and other materials that slowly build up on the lake bottom. Consequently, eutrophic lakes tend to be shallow, have cloudy water, and mucky, soft bottoms. The abundant aquatic life decomposes along the lake bottom using up oxygen. In the summer, this causes the bottom of eutrophic lakes to be void of oxygen. In shallow eutrophic lakes, the entire lake can become void of oxygen causing fish and other aquatic life to die. In New Hampshire 23% of the lakes fit into the eutrophic category and are the oldest.

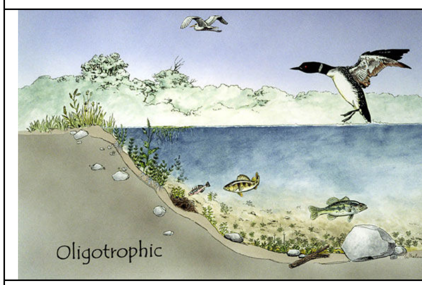
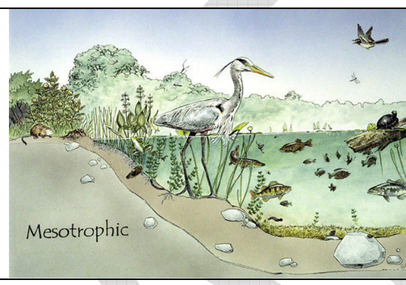
<table>
<tr><th>OLIGOTROPHIC</th><th>MESOTROPHIC</th><th>EUTROPHIC</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>• Sparse plants
• Low algae
• Clear water
• High oxygen throughout
• Rocky/sandy substrate</td><td></td><td>• Abundant plants
• High algae/blooms
• Cloudy water
• Low to no oxygen in lower water
• Mucky substrate</td></tr>
</table>

Figure 8. The three stages of lake aging (http://www.uwsp.edu/cnr/uwexlakes/ecology/classification/default.asp).

Some lakes may be naturally eutrophic for hundreds of years, however other lakes have gradually increased in nutrients as a result of human activities and have changed from mesotrophic to eutrophic relatively rapidly. The trophic state of a lake is a useful distinction, but should be considered as a general definition of lake condition. Each lake is different and the trophic state is dependent on many different aspects of the lake itself, its surrounding watershed, and climate. There is definite overlap between the three trophic states and no concrete dividing lines.

<u>Lake Turnover</u>

Over time lakes age according to the process described above, however there are also seasonal fluctuations in the lake ecosystem. Many lakes in New Hampshire mix freely twice a year (once in the spring and once in the fall), are thermally stratified in the summer, and have stable temperatures in the winter. These seasonal fluctuations occur because of the relationships between water density and temperature. Water is most dense at 39°F (4°C) and gets less dense when temperatures increase or decrease. Within a lake profile, the denser water will be heavier and sink to the bottom while the less dense water is lighter and will be at the top of the lake.

In the winter, most of the water under the ice is 39°F. However, there is a thin layer of water under the ice that is colder than 39°F and therefore less dense. This thin layer of water floats on top of the lake, under the ice, throughout the winter. Called winter or inverse thermal stratification, the water column does not mix under the ice (Figure 9).

In the spring, the ice melts and the top layer of water on the lake gets warmed by the sun to 39°F, which matches the temperature of the rest of the lake. Then the wind begins to mix the water and as a result, oxygen and nutrients get distributed evenly throughout the water column (from the surface waters to the bottom waters). This process is referred to as spring turnover (Figure 9). The timing and duration of spring turnover depends on the size and depth of the lake.

As spring continues, the sun warms the upper surface water while the water on the bottom remains cool. As a result, the water at the surface becomes less dense than the cooler underlying bottom waters. The density difference between the surface water and the underlying bottom water prohibits the mixing of the water column and the diffusion of dissolved oxygen to the bottom waters. This is the beginning of summer stratification. By mid-June many of the deeper lakes in New Hampshire have thermal stratification. **Thermal stratification** is a process by which a deep lake becomes layered by temperature in the summer months (Figure 9). The layers will separate because colder water sinks to the bottom, leaving warmer water at the surface. In deeper lakes, there are usually three layers: hypoliminion, metalimnion, and epiliminion. The **hypolimnion** is the deep, cold, relatively undisturbed bottom waters of a thermally stratified lake. Water temperature changes quickly through the metalimnion or thermocline. The **metalimnion (thermocline)** is the middle layer in a thermally stratified lake where the decrease in temperature with depth is at its greatest. The upper, well-circulated, warm layer of a thermally stratified lake is the **epilimnion**.

In the fall, the winds and cooler air begin to mix the lake again. The surface waters cool and are mixed with the bottom waters, similar to what happens in the spring. This is referred to as fall turnover.

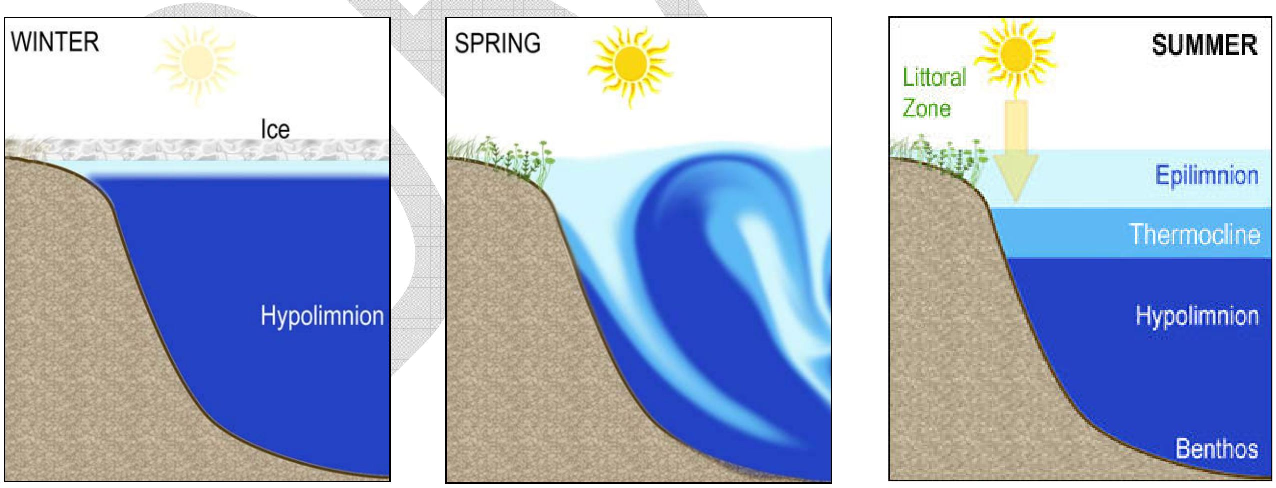


Figure 9. How lake systems change throughout the season based on water temperature fluctuations (http://www.rmbel.info/Reports/Static/LL_springturnover.aspx).

Surface Water Pollution

As runoff flows through the watershed to recharge surface water it can pick up substances that are on the land surface. Water's ability to act as a universal solvent can be both beneficial and harmful to surface water features. Water collects and transports important nutrients needed by plants and animals, however water also accumulates harmful pollutants that are discharged in streams, rivers, lakes, and ponds. There are two general categories of water pollution: point source and non-point source. **Point source pollution** refers to sources of pollution that are easily traced back to a specific discharge point, such as sewage treatment plant and industrial effluent pipes. In contrast, **non-point source pollution** includes sources of pollution that are distributed throughout the landscape and find their way into surface water as runoff flows over land surfaces (Figure 10).

Most point sources are currently monitored by the Environmental Protection Agency through permitting programs and are no longer a major source of water pollution. However, non-point source pollution continues to increase with population growth and development. In addition, managing non-point sources is complicated because it is difficult to determine their origin or there are so many sources that the task is overwhelming. Each and every one of us contributes to non-point source pollution whether we are aware of it or not. Some examples of non-point sources of pollution and their causes include:

- sand and salt, which may come from winter road maintenance
- oil and gas, which may come from spills at home or leaks on the road
- nutrients, which may come from uncovered manure piles, leaky septic systems, or excessive use of fertilizers
- sediment, which may come from natural or manmade erosion, construction sites, clear-cuts, or cropland
- fertilizers, pesticides, insecticides, and herbicides, which may come from agricultural lands or residential areas
- heavy metals such as mercury and lead, which can come from industrial waste or parking lot and road runoff
- increased acidity from precipitation/atmospheric fallout
- bacteria such as *E. coli* from leaking septic systems, excessive concentrations of waterfowl

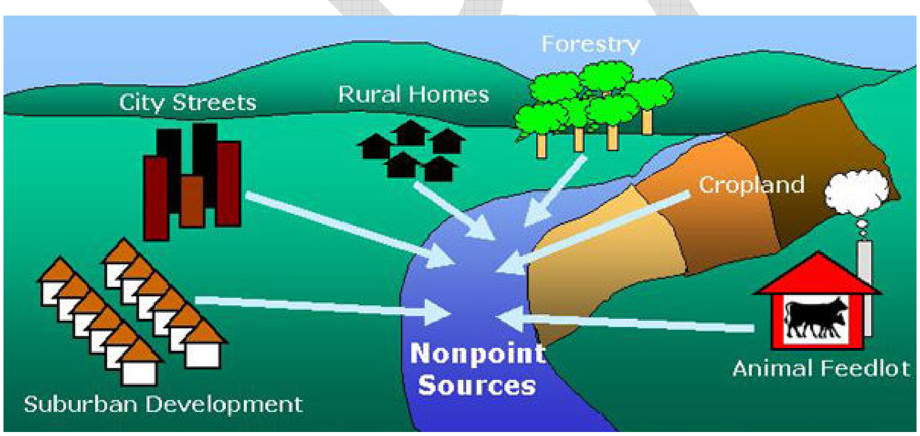


Figure 10. Examples of non-point source pollution in a watershed (http://www.magazine.noaa.gov/stories/mag112.htm).

Reducing non-point sources of pollution is important, especially in watersheds where surface water features are impaired because they no longer provide the benefits they used to. Although an incredibly complex issue, this can be achieved through watershed planning and use of best management practices (see Chapter 6 for more information). **Best management practices (BMPs)** are methods that have been determined to be the most effective, practical means of preventing or reducing pollution. Watershed planning is a general term that can involve many different strategies to reduce water pollution, such as BMPs, water quality monitoring, citizen involvement, properly locating land use activities within the watershed so that they are the least likely to impact surface water.

Water Quality Monitoring

Water quality is the ability of a waterbody to support all appropriate beneficial uses. Beneficial uses refer to the ways water is used by humans and wildlife, such as for drinking water and fish habitat. If water supports a beneficial use, water quality is said to be “good” or “unimpaired”. If water does not support a beneficial use, water quality is said to be “poor” or “impaired”. Good water quality implies that harmful substances (pollutants) are absent from the water, and needed substances (oxygen, nutrients) are present. Surface waters in New Hampshire are classified according to their uses. Class A is the highest quality designation. Class A surface waters have the potential to be acceptable drinking water supply sources after adequate treatment. Class B is the second highest quality, considered acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies. The New Hampshire Department of Environmental Services (NH DES) sets water quality criteria for different biological, chemical and physical attributes that each class of water must meet in order to support these uses.

Water quality data provides an understanding of how land use and underlying geology affects the water in lakes, ponds, rivers, streams, and groundwater supplies. Water quality monitoring is required to create an understanding of baseline (or background level) conditions of aquatic systems and detect water quality changes over time. The parameters that are monitored depend on land uses and activities in the area and can vary from watershed to watershed. Common parameters to monitor in rivers and streams are temperature, dissolved oxygen, turbidity, conductivity, and pH (see Appendix A for more information on these parameters). In lakes and ponds, the focus tends to be on preserving water clarity for recreational and aesthetic purposes. Common parameters to monitor in waterbodies include Secchi disk transparency, chlorophyll a, and phosphorus (see Appendix A for more information about these parameters). Many pollutants are invisible, so measuring and monitoring as many parameters as possible helps to paint a more complete picture of water health. With regular testing, changes in water quality can be detected before the pond, lake or stream is seriously impacted. Water quality information also empowers communities to make informed planning and resource-protection decisions.

Ossipee Watershed

<u>Waterways: Streams and Rivers</u>
The Ossipee Watershed is fortunate to include many streams and rivers, including the major ones listed in Figure 11.

<u>Waterbodies: Ponds and Lakes</u>
In addition to Ossipee Lake (~4,000 acres) and Silver Lake (995 acres), 80 lakes and ponds are included within the Ossipee watershed (for a combined acreage of 4,995, representing 2% of the watershed (Figure 12).

In many ways, the Ossipee Lake System is the heart of the Ossipee Watershed. Comprised of approximately 4,000 acres of water, the lake consists of a main body of water known as Ossipee Lake and four large connecting bodies of water (Figure 13). Water flows from Silver Lake, Bearcamp Pond and Dan Hole Pond to Ossipee Lake via the West Branch, Bearcamp and Pine Rivers, then into Broad Bay; from Broad Bay to Leavitt Bay, from Leavitt Bay to Berry Bay, and from Berry Bay to the Ossipee River. Figure 14 identifies these waterbodies and provides characteristics of each.

Town	Major Streams & Rivers
Effingham	Flanders Brook, Hodgedon Brook, Leavitt Brook, Mastin Brook, Phillips Brook, Pine River, Red Brook (#2), Wilkinson Brook, South River, Ossipee River
Freedom	Bennett Brook, Blaisdell Brook, Cold Brook, Lovering Brook, Moulton Brook, Nason Brook, Ossipee River, Shawtown Brook, Square Brook, Stony Brook, West Branch River
Madison	Blaisdell Brook, Cook's Brook, Deer River, Ferrin Brook, Forrest Brook, Frost Brook, Ham Brook, Salter Brook, West Branch
Ossipee	Badge Brook, Bearcamp River, Beech River, Canaan Brook, Chocorua River, Dan Hole River, Folsom Brook, Frenchman Brook, Gile Brook, Lovell River, Peavey Brook, Pike Brook, Pine Brook, Pine River, Poland Brook, Red Brook (#1), Stony Brook (#2), Sumner Brook, West Branch, White Brook, Youngs Brook
Sandwich	Arwood Brook, Captain Neal Brook, Cold River, Heath Brook, Pond Brook, Tewksberry Brook, Tilton Brook, White Brook, Whiteface River
Tamworth	Bearcamp River, Blasde Brook, Bryant Brook, Chocorua River, Claybank Brook, Cold Brook (#2), Deer Brook, Durrell Brook, Hoag Brook, Lord Brook, Meadown Brook, Meadow Brook (#2), Mill Brook, Paugus Brook, Sanborn Brook, Sanger Brook, Stony Brook, Swift River (#2), Tewksberry Brook, Whitin Brook, Wonalancet River

Figure 11. Major streams and rivers in the Ossipee Watershed (Green Mountain Conservation Group 2007).

Town	Major Ponds & Lakes
Eaton	Hatch Pond, Long Pond, Purity Lake (partial)
Effingham	Berry Bay (partial), Chalk Pond, Hutchins Pond, Leavitt Bay (partial), Province Lake (partial).
Freedom	Danforth Ponds, Duck Pond, Huckins Pond, Loon Lake (to the Ossipee River), Lake Ossipee (partial), Shaw Pond, Trout Pond
Madison	Blue Pond, Cooks Pond, Cranberry Bog, Davis Pond, Drew Pond, Durgin Pond, Lily Pond, Loud Pond, Mack Pond, Mailly Pond, Moores Pond (partial), Purity Pond (partial), Silver Lake, Whitton Pond (partial)
Ossipee	Archers Pond, Bean Pond, Black Pond, Conner Pond, Dan Hole Pond (partial), Duncan Lake, Garland Pond, Heath Pond, Lily Pond, Little Dan Hole Pond, Lost Pond, Moody Pond, Lake Ossipee (partial), Pine River Pond, Snake Pond, Upper & Lower Beech Ponds, White Pond
Sandwich	Bearcamp Pond, Beaver Pond (partial), Miles Pond
Tamworth	Beaver Pond (partial), Chocorua Lake, Great Hill Pond, Jackson Pond, James Pond, Little Lake, Lonely Lake, Moores Pond (partial), White Lake
Tuftonboro	Dan Hole Pond (partial)
Waterville Valley	Flat Mountain Pond

Figure 12. Major ponds and lakes in the Ossipee Watershed (Green Mountain Conservation Group 2007).

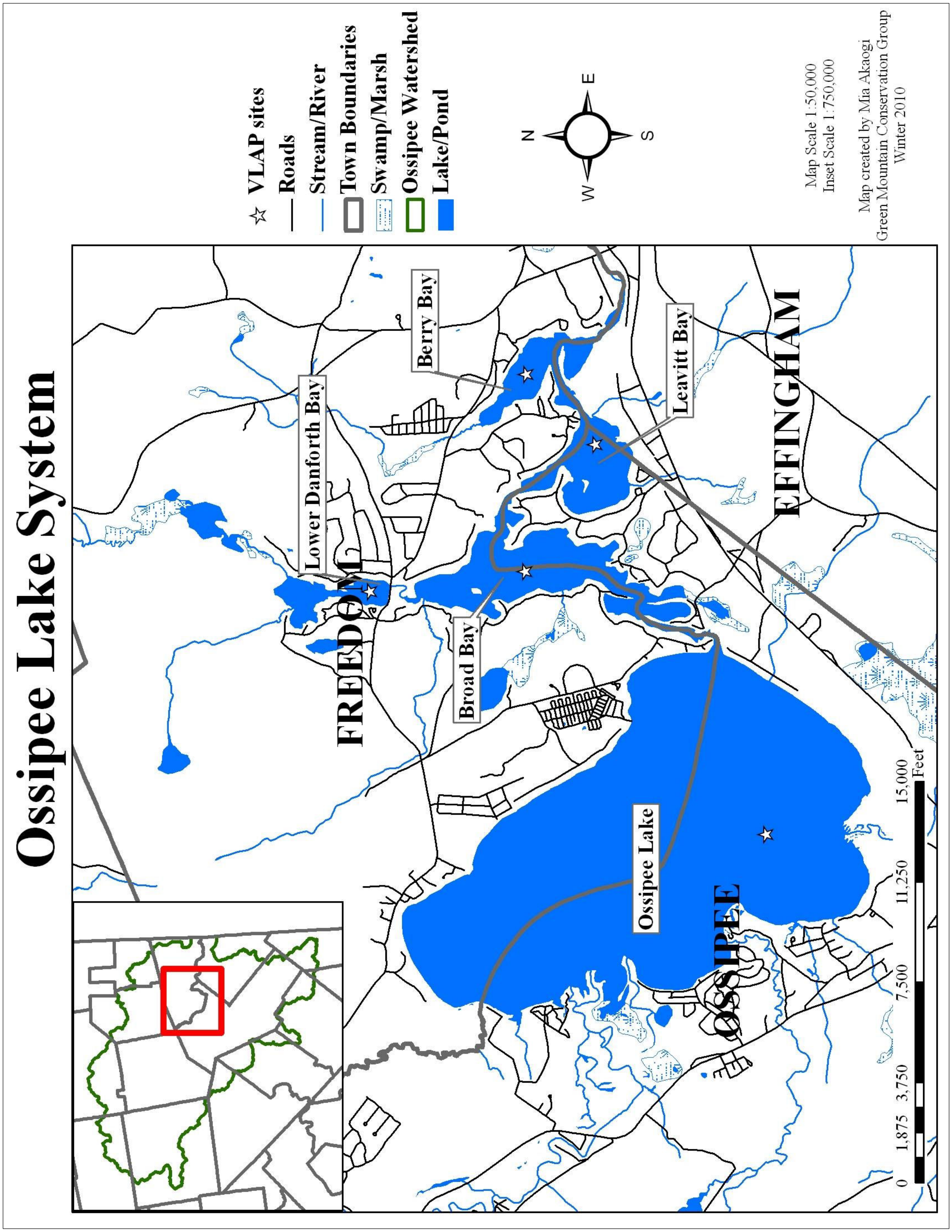


Figure 13. Ossipee Lake System with VLAP sampling sites indicated with stars (Akaogi 2010).

Lake	Town	Max. Depth (ft)	Volume (m^3)	Area (acres)
Broad Bay	Ossipee	73	15,573,500	463
Leavitt Bay	Ossipee	42	2,429,000	176
Berry Bay	Freedom	38	2,147,000	145
Danforth Pond Lower	Freedom	55	918,500	31
Lake Ossipee	Ossipee	60	108,421,500	3,091
Total Ossipee Lake System	Ossipee & Freedom	73	12,989,500	3,909

Figure 14. Ossipee Lake System waterbodies and characteristics (Green Mountain Conservation Group 2007).

Surface Water Monitoring Programs

In 2002, the Green Mountain Conservation Group (GMCG) established a three-part, long-term monitoring program to track surface water quality across the Ossipee Watershed. This water quality monitoring program includes: the Regional Interstate Volunteers for the Ecosystems and Rivers of the Saco (RIVERS) program, the Volunteer Lake Assessment Program (VLAP), and the Ossipee Lake Tributary (OLT) program. In 2006, the Volunteer Biological Assessment Program (VBAP) was added to get a more complete picture of stream and river water quality (see Chapter 4 for more information about VBAP). Currently, 19 river sites, 11 major tributaries of Ossipee Lake, and 10 macroinvertebrate sampling sites are monitored within the watershed (Figure 15). The RIVERS program is managed in conjunction with the University of New Hampshire (UNH) and the Saco River Corridor Commission (SRCC) in Maine. The RIVERS program tests the 19 river sites bi-weekly April through October and has been extended to include year-round sampling at 9 sites (Figure 16). OLT sites are monitored bi-weekly just in the summer months (mid-June to August). A total of nineteen parameters are monitored for RIVERS and OLT sites. Five parameters are tested in the field, including pH, temperature, dissolved oxygen, conductivity and turbidity. For some of the sites, fourteen additional chemical parameters are also measured, including total phosphorus, sodium, chloride, calcium, magnesium, total dissolved nitrogen, nitrate, sulfate, potassium, phosphate, dissolved organic carbon, silica, dissolved organic nitrogen, and ammonium.

The Ossipee Lake System has been tested since 1990 by the NH Lakes Lay Monitoring Program and NH DES Volunteer Lakes Assessment Program (VLAP), with assistance from local volunteers, GMCG, and Ossipee Lake Alliance (OLA). Deep spots in each of the five main waterbodies are tested each summer (usually in July and August) for biological, chemical and physical water quality parameters (Figure 17). Parameters include: chlorophyll-a, transparency, total phosphorus, chloride, conductivity, pH, dissolved oxygen, turbidity, acid neutralizing capacity, nitrogen, bacteria and phytoplankton. These programs have continued to add data to the historical database to determine year to year conditions of the lakes and to identify any short or long-term changes in water quality. While the Broad and Leavitt Bays have been monitored since 1990, Ossipee Lake, Berry Bay and Danforth Pond have only been monitored since 2003.

Water quality monitoring results from RIVERS, OLT, VLAP, and VBAP over the last nine years have shown that surface waters across the Ossipee Watershed generally have high water quality. The majority of sites have low nutrient levels with total phosphorus concentrations below 50 µg/L and nitrate and ammonium levels below 1mg N/L. Physical parameters were within a healthy range to support aquatic life with dissolved oxygen concentrations above 5 mg/L and 75% saturation, conductivity levels below 100 µS/cm2 and low turbidity levels. Annual macroinvertebrate sampling

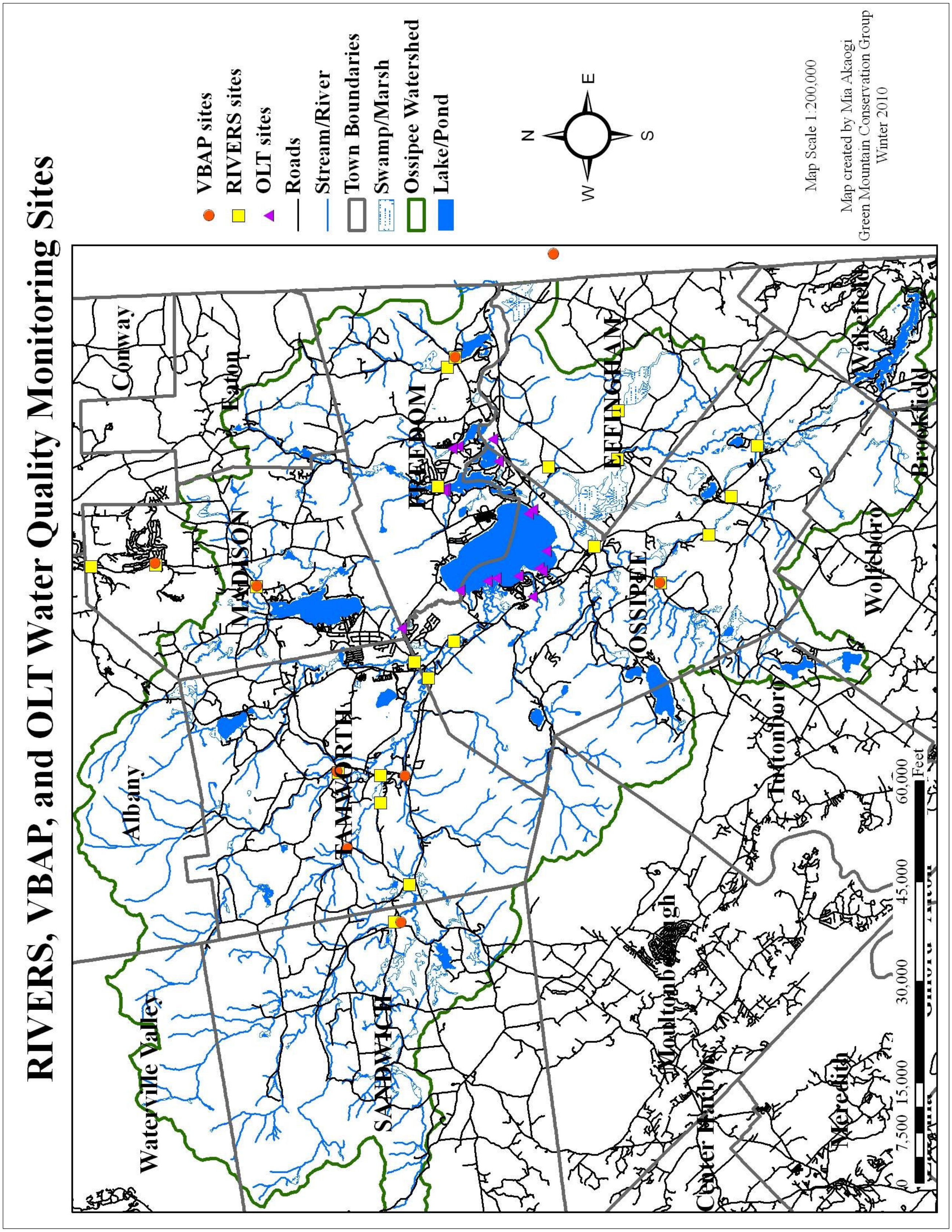


Figure 15. RIVERS, OLT, and VBAP water quality monitoring sites in the Ossipee Watershed (Akaogi 2010).

through VBAP indicates that the majority of the ten river sites sampled were in “excellent” to “good” condition.


Figure 16. Mother and son pair collect water quality data as a part of RIVERS (GMCG).

Lake monitoring data for Ossipee Lake, Berry Bay, Broad Bay, Leavitt Bay and Danforth Pond show that average yearly concentrations of most parameters (chlorophyll-a, transparency, total phosphorus, and conductivity) remain in a low (good) to average range for New Hampshire lakes. However, analyses of phosphorus levels show areas of concern in the Ossipee Lake system. Based on initial calculations of each of the bays’ average phosphorus levels from 2002-2010, two out of the five bays show phosphorus levels that are at or above the threshold for oligotrophic waterbodies (8 µg/L). Both Berry Bay and Danforth Pond exhibit levels of phosphorus that indicate they are impaired (Berry Bay 8 µg/L; Danforth Pond 10 µg/L). The other three sites have average phosphorus levels that are close to the threshold for oligotrophic lakes (Broad Bay 7.9 µg/L; Leavitt Bay 7.3 µg/L; Ossipee Lake 7.7 µg/L), meaning they are not far from being considered impaired waterbodies according to the state’s criteria. NH DES reports that in 2010, Ossipee Lake had the highest mean annual phosphorus levels since monitoring began in 2002.


Figure 17. Campers help collect lake water quality data as a part of VLAP (GMCG).

Another growing water quality concern is increasing cloudiness in the Ossipee Lake System. In 2008, statistical analyses performed by NH DES staff showed decreasing transparency trends in Leavitt and Broad bays over the past eighteen years. A significant decline in transparency from 1990-2009 of 3.128% per year was shown for Broad Bay (Figure 18) and a 2.33% per year was shown for Leavitt Bay. In fact, four of the five bays show decreasing transparency trends. These trends are cause for concern and point to the need for additional monitoring, analyses, and best management practices to reduce stormwater runoff to the lake and its tributaries.

According to NH DES, New Hampshire’s surface waters traditionally have low conductivity levels but levels are increasing at a statistically significant rate. Some sites in the Ossipee Watershed are showing elevated sodium, chloride and conductivity levels, at times three to four times higher than the typical background levels for New Hampshire surface waters. Road salt application is the dominant source of these elevated levels. Road salt applied in the winter can enter streams directly through culverts and roadside ditches or accumulate in roadside soils, enter the groundwater and make its way to surface waters.

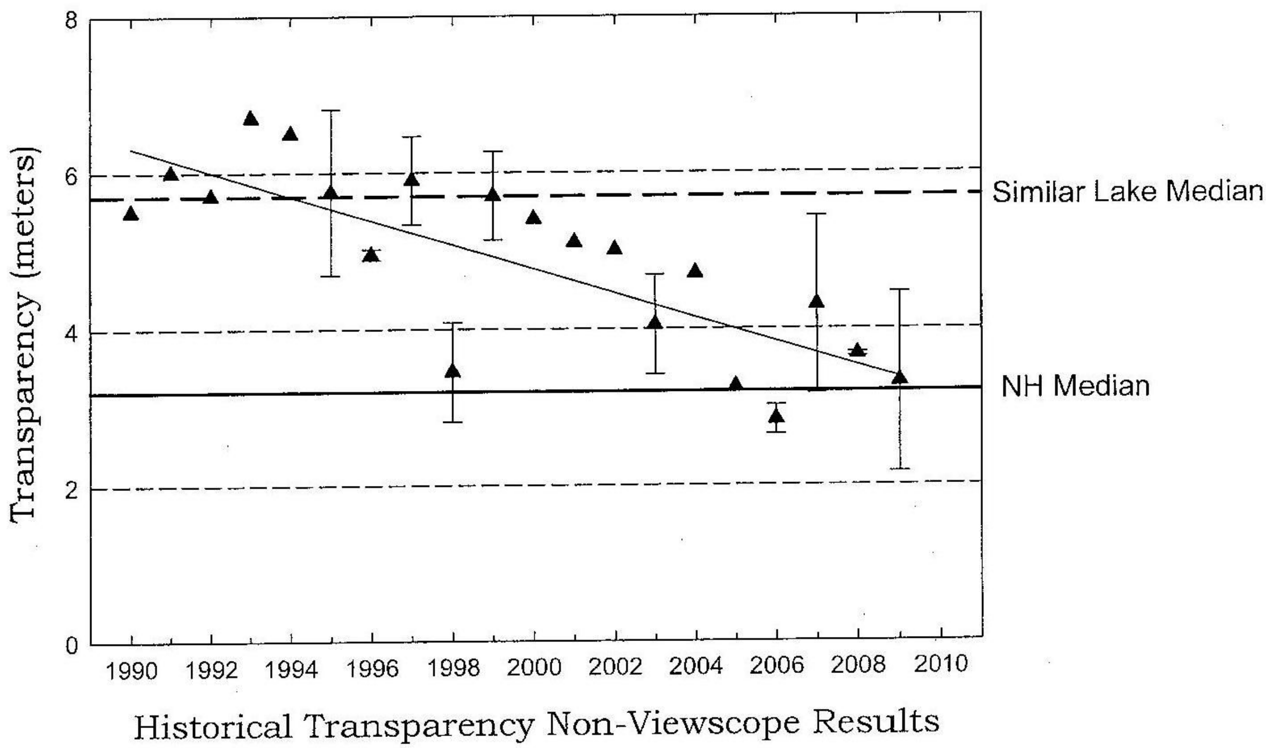


Figure 18. Historical transparency results for Broad Bay (NH DES 2009).

Indoor Activities

Activity 1: Stream Table

NH State Science Standards

- To be completed

Source: Adapted from "Erosion: Nature or Unnatural" developed by Friends of the Chicago River in their Chicago River Science Lessons which are available online at: http://www.chicagoriver.org/education/curricula/lesson_plans/.
Summary: This activity explores how water erodes the land within a stream system.
Objectives: Students will be able to define erosion.
Estimated Time: 1 hour
Materials:
For each group of 5 students

- Student directions and worksheet
- Aluminum turkey pan
- Bucket
- 2 large, color plastic cups
- 2 clear, plastic cups
- 1 large plastic spoon
- Book or block to prop up stream table
- Soil (3 part sand, 1 part humus, 1 part gravel) to fill all stream tables half full

Directions:
Before Class

1. Prepare the stream table. Cut a hole in the bottom of each turkey pan near one of the shorter sides.
2. Mix up the soil mixture to be used in the stream tables. The mix should contain 3 parts sand, 1 part humus, and 1 part gravel. Add soil mixture to each of the stream tables, on the side opposite the hole.
3. Prepare the cups. Pierce a small hole in the bottom of half of the colored plastic cups and a large hole in the bottom of the other half of cups. Mark a line on the inside of the cup near the top of the cup that represents an even amount of water (such as 1, 1 ½, or 2 cups). This will ensure that students always use the same amount of water.

During Class

1. At the beginning of class tell students that people have been noticing that the land seems to be disappearing, particularly the land around our rivers. Where is it going? Who or what is taking it away? They will be figuring that out.
2. Divide students into groups of five. Each member of the group gets a role:
    a. **Recorder:** records the group's predictions and results.
    b. **Bucket holder:** places the bucket on the floor under the hole in the stream table and makes sure the bucket does not overflow.
    c. **Water collector:** collects runoff water in the clear plastic cup (for the turbidity test) from under the hole in the stream table.
    d. **Soil spreader:** moves the soil around to create the landscape and stream.
    e. **Water maker:** drips water on the stream table.

3. Pass out student directions and worksheets (Student Workbook). Depending on your students, you may want to model the activity for your students before having them carry out the experiment.
4. Give students time to conduct their investigations.
5. After students conduct the experiment, discuss the following as a class:
    a. What happened to the banks and bottom of the stream?
    b. What happened to the rocks and small pebbles?
    c. What were the differences between the two trials?
    d. What could explain these differences?
    e. At the end of the day, have students share their ideas for what would cause there to be more water flowing in the river.

Associated Student Workbook Activities

- What do you know about the Ossipee Watershed? (Chapter 2, page 1)
- Stream Table Activity Directions (Chapter 2, page 2-3)
- Stream Table Activity Worksheet (Chapter 2, page 4-6)

Activity 2: Topsy Turvy Lake Turnover

Source: Adapted from "Studying Thermal Stratification" developed by Water on the Web and available online at http://www.waterontheweb.org/curricula/bs/student/thermal/study.html.
Summary: This experiment investigates how thermal stratification occurs in lakes.
Objectives: Students will be able to understand visually how cold water sinks and warm water floats.
Estimated Time: 30 minutes to 1 hour
Materials:

For each student or group of students

- 2 clear cups or glasses
- 1 colored ice cube (add food coloring to the water before freezing)
- 1 gallon of cold (the colder the better) colored water (use food coloring in the water)
- Warm water

Directions:

Part 1. Fill a glass halfway with cold water. Carefully pour a ¼ cup of warm, clear water into the glass (It is best if the warm water is poured slowly in from the side of a tilted glass to avoid mixing). Try to create a glass of water that has two distinctly separate layers.

Part 2. Fill the second glass with warm water. Place a colored ice cube in the glass. Observe and record what happens for 5 minutes.

Discussion Questions:

1. In the first experiment, why did the warm water stay on top of the cold, colored water?
2. In the second experiment, why did the colored water that melted from the ice cube sink?
3. Do these things happen anywhere in nature?

Associated Student Workbook Activities

- Topsy Turvy Lake Turnover Worksheet (Chapter 2, page 7)

Field component/Service project

River Monitoring (RIVERS)

- Youth are encouraged to volunteer for the RIVERS water quality monitoring program under the supervision of an adult. Green Mountain Conservation Group trains new volunteers every April. Sampling occurs bi-weekly May through October and involves testing a stream or river site before 9am.
- Contact GMCG at (603)539-1859 or gmcgnh@roadrunner.com for more information and training date.

Lake Monitoring (VLAP)

- Many summer camps and programs currently volunteer in the VLAP lake monitoring program. Youth are encouraged to participate and should contact Green Mountain Conservation Group in the spring if they are interested. Sampling occurs in July and August and involves taking a boat out to one of the 5 deep spots in the Ossipee Lake System.

Analysis

Graphing

- Ask GMCG for water quality data for a local lake, river, or stream. Graph the data by parameter over time and make observations about water quality changes.

Mapping

- Map all surface waters within the Ossipee Watershed. Identify the school's location and determine which subwatershed it is a part of.
- Map streams and rivers within a subwatershed of the Ossipee Watershed. Show direction of water flow and label stream orders.
- Map non-point sources of pollution around a local lake, pond, or stream.

Extensions

- Follow Activity 1: Stream Table with "Sum of the Parts" in Chapter 6 to connect stream processes with pollution sources and impacts.
- Build a Secchi Disk and monitor a pond or lake near school over the course of a season. This data can be analyzed and graphed as a class activity. Instructions can be found at http://www.anr.state.vt.us/env03/activities/Water%20Activity.pdf.
- Participate in the annual Secchi Dip-In event by collecting transparency readings for a local lake or pond during the summer. More information about this national event can be found at http://dipin.kent.edu/index.html.

Assessment Tools

- Draw a diagram of a stream and explain where erosion and deposition might occur and why. Also label riffle, run, and pool habitats.
- Student quiz (Appendix B)

Glossary

Adjacent watershed: The higher ground that captures runoff and drains to the stream, often defined by the land extending from the riparian zone to about a quarter mile from the stream.

Algae: Simple single-celled (phytoplankton), colonial, or multi-celled, mostly aquatic plants, containing chlorophyll and lacking roots, stems and leaves.

Algal Bloom: A heavy growth of algae in and on a body of water. This is usually a result of high nitrates and phosphate concentrations entering waterbodies.

Best management practices (BMPs): Methods that have been determined to be the most effective, practical means of preventing or reducing pollution.

Deposition: The process of dropping material that is being transported by water or wind.

Emergent plants: Plants with true stems, roots, and leaves with most of their vegetative parts above the water.

Epilimnion: The upper, well-circulated, warm layer of a thermally stratified lake.

Erosion: The gradual wearing away of land surface materials, especially rocks, sediments, and soils, by the action of water, wind, or a glacier. Usually erosion also involves the transport of eroded material from one place to another.

Eutrophic lake: “Eu” means true and can be translated to mean true nutrients or truly nutrient rich. Eutrophic lakes are high in nutrients and support an abundance of life including a diversity of vegetation, frequent algae blooms, and large fish populations.

Floodplain: The low area of land that surrounds a stream and holds the overflow of water during a flood.

Floating plants: Plants that are detached from any substrate and are therefore drifting in the water.

Headwaters: The origins of a stream.

Hypolimnion: The deep, cold, relatively undisturbed bottom waters of a thermally stratified lake.

Impervious surface: A paved or other hard surface that does not allow water to penetrate.

Impaired waterbody: A waterbody with chronic or recurring violations of water quality standards or beneficial uses identified by state and national environmental agencies.

Macroinvertebrate: Organism that lacks a backbone and is large enough to be seen with the naked eye. Examples include crayfish, mussels, aquatic snails, aquatic worms, and the larvae of insects.

Mesotrophic lake: “Meso” means middle or mid. Mestrophic lakes have medium levels of nutrients and these waterbodies tend to be clear, have beds of submerged plants, and can have seasonal variations in oxygen level that limit high water quality fish from thriving.

Metalimnion (thermocline): The middle layer in a thermally stratified lake where the decrease in temperature with depth is at its greatest.

Nitrogen: The most abundant atmospheric gas, nitrogen comprises approximately 78% of the Earth's atmosphere. This element is especially important for plant growth and is used by both plants and animals to carry out many of the functions of life.

Non-point source pollution: Sources of pollution that are distributed throughout the landscape and find their way into surface water as runoff flows over land surfaces.

Nutrients: Inorganic substances (most commonly nitrogen and phosphorus) required by plants to manufacture food through photosynthesis.

Oligotrophic lake: "Oligo" means very little. Oligotrophic lakes are low in nutrients and therefore tend to have little plant and algae growth; have deep, clear water; and support many fish species that require cold, well-oxygenated waters.

Point source pollution: Sources of pollution that are easily traced back to a specific discharge point, such as sewage treatment plant and industrial effluent pipes.

Pool: A pool is deep with slow moving water and a stream bottom that consists of soft, fine sediments.

Riffle: A riffle is shallow with fast, turbulent water running over rocks. Riffles are often characterized by white caps, where water flowing quickly over rocks mixes the water with the air resulting in the highest dissolved oxygen concentrations in the stream.

Riparian zone: The riparian zone is the area adjacent to and along a stream that is often covered by vegetation.

Run: A run or glide is deep with gently and smooth flowing water and little or no turbulence. Making sure that a mix of pool, riffle, and run habitats are available within the stream system will help protect a diversity of aquatic life.

Runoff: Water from rain, snowmelt, or irrigation that flows over the ground and returns to streams. It can collect pollutants from air or land and carry them to streams and other surface waters.

Sediment: Soil, sand or minerals washed from land into surface waters.

Septic system: A system that treats and disposes of household wastewater under the ground.

Stream channel: The land surface that is completely covered by flowing water.

Streamside cover: Any overhanging vegetation that offers protection and shading for the stream and its aquatic inhabitants.

Submergent (submerged) plants: Plants that are completely immersed in water.

Substrate: The material that makes up the bottom of a stream and can include: clay, silt, sand, gravel, cobble, boulder, or bedrock. These substrate types are differentiated by their size.

Surface water: Surface water refers to all the features that hold water on the Earth's surface including: oceans, streams, rivers, lakes, ponds, wetlands, etc.

Thermal stratification: A process by which a deep lake becomes layered by temperature in the summer months.

Trophic states: A way to classify and refer to different types of lakes based on the amount of available nutrients (nitrogen and phosphorus) for aquatic life. The root of the word "trophy" means nutrients.

Water quality: The ability of a waterbody to support all appropriate beneficial uses. Beneficial uses refer to the ways water is used by humans and wildlife, such as for drinking water and fish habitat. If water supports a beneficial use, water quality is said to be "good" or "unimpaired". If water does not support a beneficial use, water quality is said to be "poor" or "impaired".

References

Environmental Protection Agency. (2002). *Volunteer Lake Monitoring: A Methods Manual*. Retrieved from http://water.epa.gov/type/watersheds/monitoring/lakevm.cfm

Environmental Protection Agency. (2002). *Volunteer Stream Monitoring: A Methods Manual*. Retrieved from http://water.epa.gov/type/rsl/monitoring/stream_index.cfm

Environmental Protection Agency Region 4, Alabama Department of Environmental Regulation, & LEGACY – Partners in Environmental Education. (n.d.). *The Water Sourcebooks*. Retrieved from http://www.epa.gov/safewater/kids/wsb/

Green Mountain Conservation Group. (2007). *Ossipee Watershed Natural Resource Guide*. Retrieved from http://www.gmcg.org/gmcg.php?id=160

New Hampshire Department of Environmental Services. (2009). *New Hampshire Lake Assessment Program: Ossipee Lake System (Berry Bay, Broad Bay, Lake Ossipee, Leavitt Bay, Lower Danforth Pond) Ossipee 2009 Biennial Report*. Concord, NH; New Hampshire Department of Environmental Services.

New Hampshire Department of Environmental Services. (n.d.) *Lake Biology Fact Sheets*. Retrieved from http://des.nh.gov/organization/commissioner/pip/factsheets/bb/index.htm

New Hampshire Department of Environmental Services. (n.d.) *New Hampshire's Basic Lake Ecology*. Retrieved from http://des.nh.gov/organization/divisions/water/wmb/vlap/ecology.htm

New Hampshire Department of Environmental Services. (n.d.) *Volunteer Lake Assessment Program*. Retrieved from http://des.nh.gov/organization/divisions/water/wmb/vlap/index.htm

New Hampshire Department of Environmental Services. (n.d.) *Volunteer River Assessment Program*. Retrieved from http://des.nh.gov/organization/divisions/water/wmb/vrap/index.htm

New Hampshire Lakes Association. (n.d.) *A Brief History of Lakes*. Retrieved from http://www.nhlakes.org/

Rufer, Moriya. (2007). *Lakes Learning News Column*. Retrieved from http://www.rmbel.info/Reports/Static/Publications.aspx

The Asia Foundation. (2008). *Teachers Manual for Water Quality Monitoring in Rivers*. Retrieved from http://www.mongolianriverresources.mn/index.php?option=com_content&task=view&id=138&pid=146

Water on the Web. (2007). *Curricula*. Retrieved from http://www.waterontheweb.org/

Appendix A: Explanation of Surface Water Quality Parameters

Chlorophyll-a

Chlorophyll-a is the green photosynthetic pigment found in the cells of plants. In surface waters, microscopic plant life is limited primarily to algae. Collecting a water sample from a lake or pond and extracting the chlorophyll-a from the algae cells contained in that sample can give a good indication of the concentration of algae. However, the chlorophyll-a concentration cannot be considered a precise measurement of algal density because the amount of chlorophyll-a found in living cells varies among algal species. Two lakes can have identical densities of algae, but have significantly different concentrations of chlorophyll-a because they are dominated by different species. In addition, the amount of chlorophyll that is produced varies based on how much sunlight the algae are receiving. Healthy algae try to maintain chlorophyll concentrations that maximize photosynthetic efficiency. Chlorophyll levels in a plant cell usually decrease when light is abundant and increase during the night or under low light conditions. Despite these considerations, monitoring chlorophyll-a concentrations continues to be a good method for determining algae density in surface waters.

The amount of algae in a lake depends on many factors including: water temperature, water transparency (this determines how far down in the water sunlight can reach for photosynthesis), amount of zooplankton and fish that are eating algae, and the amount of nutrients (such as nitrogen and phosphorus). One of the major concerns for any lake or pond is cultural eutrophication. Eutrophication is the process of increased productivity of a lake as it ages and becomes a eutrophic lake. Nutrient inputs increase the biological productivity of the waterbody, including the amount of algal and plant growth. Often this process is greatly accelerated by human influence and is termed cultural eutrophication. Any activity in the watershed that increases nutrient input causes eutrophication. Land use changes can result in significant changes in the amount of nutrients found in runoff. Studies in New Hampshire have shown that phosphorus export from agricultural lands is 5 times greater than from forested lands, and urban areas may be more than 10 times greater. Stormwater runoff from these developed land areas is the major source of nutrients for most lakes. Other activities that contribute to eutrophication are lawn and garden fertilizers, faulty septic systems, washing with soap in or near the lake, erosion into the lake, dumping or burning leaves in or near a lake, and feeding ducks.

Some algae in surface waters is normal, however in high concentrations this may be an indication of excess nutrient input from human activities and is not aesthetically pleasing. In general, concentrations of chlorophyll-a below 5mg/m3 is considered good. A concentration of chlorophyll-a that is 5.1-15mg/m3 is more than desirable and a concentration greater than 15mg/m3 is considered a nuisance amount. These are general categories determined by NH DES that are applicable to lakes in New Hampshire.

Water Clarity (Secchi Disk Transparency)

The Secchi disk originated with Father Pietro Angelo Secchi, an astrophysicist, who was requested to measure transparency in the Mediterranean Sea by Commander Cialdi, head of the Papal Navy. Secchi was the scientific advisor to the Pope. Secchi used some white disks to measure the clarity of water in the Mediterranean in April of l865. Since then, the Secchi disk has become a standard piece of equipment for lake scientists. It is a weighted circular disk 20 centimeters (about eight inches) in diameter with alternating black and white quadrants painted on the surface. The disk is attached to a measured line that is marked off either in meters or feet. The Secchi disk is used to measure how deep a person can see into the water, which is also known as water clarity. It is lowered into the lake by the measured line until the observer loses sight of it. Then it is raised until it reappears. The depth at which the disk vanishes and reappears is known as the Secchi disk transparency.

There are many factors that can influence Secchi disk transparency. Water transparency can be reduced by microscopic organisms (algae, zooplankton, and phytoplankton), natural or unnatural dissolved materials that color or stain the water, and suspended sediments. Other factors, unrelated to lake conditions, can also affect a Secchi disk reading. These outside factors can include: the observer's eyesight and other sources of human error, the angle of the sun (time of day, latitude, season of the year), weather conditions (cloud cover, rain), and water surface conditions (waves, sun glare, surface scum).

In general, for surface water quality the deeper the Secchi disk reading the better. However, transparency values may vary depending on the maximum depth of the lake or pond. In shallow surface waters the Secchi disk may touch the bottom of the lake or pond before vanishing from sight. In this case, the true Secchi disk reading is greater than the depth of the lake. NH DES has set guidelines for Secchi disk transparency. A reading that is less than 2 meters is considered poor, between 2-4.5 meters is good, and greater than 4.5 meters is exceptional. In very clear lakes, readings greater than 10 meters are common.

Phosphorus

Phosphorous is an essential nutrient for plant growth and is the main limiting nutrient to plant growth in freshwater systems. Monitoring the concentration of phosphorus in surface waters provides information about water fertility. Phosphorus is one of several essential nutrients that algae need to grow and reproduce. In many lakes, phosphorus is in short supply and is a limiting factor for algal growth. However, in watersheds where human activities increase the amount of phosphorus available, the excess phosphorus fertilizes the water and can stimulate increased algal growth. A high concentration of algae in a lake often decreases water clarity, which is a common aesthetic concern for lake residents and users.

Sources of phosphorus in surface waters include: septic systems, animal waste, fertilizer, road and construction erosion, industrial waste, wetlands, and atmospheric deposition. In nature, phosphorus is usually present in low concentrations and comes from only a few natural sources. As a result, lakes located in pristine watersheds rarely have problems with algal blooms. Found in fertilizers, foods, and various detergents and cleaning products, phosphorus is common in many products that humans use or dispose of on a regular basis. Consequently, phosphorus is primarily associated with human activities within the watershed. Phosphorus tends to attach itself to soil particles. When the soil is disturbed, through construction or heavy rain events, phosphorus can be washed into waterways. In addition, phosphorus tends to accumulate in slow moving stream reaches and impoundments (i.e. upstream of a dam, in lakes and in wetlands) where phosphorus that is attached to soil particles settles out of the water column. When a region becomes rich in phosphorus, it can result in localized algal blooms and related water quality problems, including cultural eutrophication.

Class A and Class B surface waters do not have any numeric standards and are allowed naturally occurring phosphorus. However, Class B waters should not contain nitrogen or phosphorus in concentrations that would impair any existing or designated uses. In New Hampshire, ranges of total phosphorus in lakes and ponds are: 1-10µg/L is low (good), 11-20µg/L is average, 21-40µg/L is high, and greater than 40µg/L is excessive. Due to variability in naturally occurring phosphorus levels and difficulty identifying an exact source, NH DES has not identified a standard for surface waters. However, the state does pay attention to readings above 0.05mg/L or 50µg/L.

Turbidity

Turbidity is a measure of the amount of suspended particles in the water, such as clay, silt, algae, and decaying plant material. It is measured in nephelometeric turbidity units (NTUs), the measure of light refraction through a vial of water. In a water sample that is turbid, the light is scattered and absorbed, rather than transmitted in straight lines through the water. The more suspended material in the water, the more light is refracted. Turbidity is related to water clarity and transparency. High turbidity tends to reduce water clarity and decrease Secchi disk transparency.

Turbidity levels are influenced by any activities that increase the amount of suspended material in the water. Sources of increased turbidity include soil erosion, waste discharge, stormwater runoff, and excessive algal growth. High turbidity readings are often found in water adjacent to construction sites. Also, improper sampling techniques (such as hitting the bottom sediments or sampling streams with little flow) may also cause high turbidity readings. Rain events often contribute to surface water turbidity by flushing sediment, organic matter and other materials from the surrounding landscape. These suspended materials can clog fish gills, reduce disease resistance in fish, lower growth rates, and affect egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates. Higher turbidity increases water temperature because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of dissolved oxygen.

For Class A surface waters there is no standard other than what naturally occurs. Class B surface waters should not exceed naturally occurring turbidity levels by more than 10 NTUs. In New Hampshire, turbidity values for lakes and ponds range from less than 0.1 NTUs (minimum) to 22.0 NTUs (maximum) with an average of 1.0 NTUs.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current and is an indication of the number of ions in a water sample. It is influenced by the presence of ions that have a negative charge such as chloride (Cl^-), nitrate (NO_3^-), sulfate(SO_4^-), and phosphate (PO_4^{3-}) and ions that have a positive charge such as sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), iron (Fe^{2+}, Fe^{3+}), and aluminum (Al^{3+}). Organic compounds like oil, various automotive liquids, alcohol, and sugar do not conduct an electrical current well and therefore have low conductivity when in water. Conductivity does not differentiate between ions and only gives a reading of how much is there. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported at 25°C, which is also referred to as specific conductivity.

The ions that influence conductivity readings can be from natural sources, such as bedrock, or introduced by human activity. In unpolluted surface waters, geology and groundwater are the primary influences on conductivity levels. Due to the predominance of granite, which does not easily dissolve into ions in water, New Hampshire surface waters have traditionally had low conductivity values. Specific conductivity readings can help locate potential pollution sources because polluted water usually has higher conductivity than unpolluted waters. High conductivity may indicate pollution from such sources as road salting, septic systems, wastewater treatment plants, urban stormwater runoff, or agricultural runoff.

While there is no numeric standard for surface waters in the state because variations in watershed geology can result in natural fluctuations in conductivity levels, values exceeding 100µS/cm generally indicate human disturbance. In general, a specific conductivity value of 0-100µS/cm is considered normal, 101-200µS/cm indicates low impact, 201-500µS/cm shows moderate impact, and greater than 501µS/cm is high impact. Conductivity levels can often be correlated with sodium and chloride concentrations because they tend to be the dominant ions in water. Sodium chloride is the chemical name for salt. In New Hampshire, conductivity in surface waters has been increasing at a statistically significant rate, largely due to the influence of road salting.

Temperature

Temperature is a measurement of the average kinetic energy of moving molecules within a substance. When water is cold, it has a low temperature and water molecules move slowly. When water is warm or hot, it has a high temperature and water molecules move fast. Temperature is often measured with a thermometer and can be reported in degrees Fahrenheit (°F), degrees Celsius (°C) or Kelvin (K). Most scientific research uses metric units. Consequently, water quality monitoring programs measure temperature in degrees Celsius (°C). Water temperature is a critical parameter for aquatic life and has an impact on other water quality parameters such as dissolved oxygen concentrations and bacterial activity. Water temperature controls the metabolic and reproductive processes of aquatic organisms and can determine which fish and macroinvertebrate species can survive in a given river or stream.

Many factors can influence surface water temperature including air temperature, sunlight, shading, water source, and the width, depth, and water movement within the river, stream, lake, or pond. Human activities that can impact temperature include: industrial discharge of water used as coolant (thermal pollution), percent impervious surface in the watershed that contributes stormwater runoff, the cutting of trees which once shaded the water, dams or other impoundments, and soil erosion (which increases turbidity and heat absorbed from the sun). The metabolic rates of organisms increase with increasing water temperature, which in turn increases the need for oxygen. More plants grow in warmer waters, which also results in more plants dying and more oxygen being used as bacteria decomposes the organic matter. Gases dissolve more easily in cooler water and so water temperature also plays a large role in the amount of dissolved oxygen found in surface waters. Organisms such as trout and mayfly nymphs thrive in cooler, more oxygen-rich waters (13ºC and below) while bass and most plant life prefer warmer waters (20ºC and above). The middle temperature range supports salmon, trout, water beetles, and limited plant life.

There are currently no temperature standards for either Class A or B surface waters in New Hampshire. However, NH DES is in the process of collecting biological and water temperature data that will contribute to the development of a procedure for assessing surface waters based on water temperature and its corresponding impact to the biological integrity of the water resource.

pH

pH is a measure of how acidic or basic water is. Specifically, pH is a measure of the concentration of hydrogen ions (H+) and hydroxide ions (OH -) in the water. Acidic solutions have greater numbers of H+ and basic solutions have greater numbers of OH-. Pure water has equal amounts of H+ and OH- in it. The pH scale ranges from 0 to 14, with 7 indicating a neutral pH (neither acidic nor basic).

For example, distilled water has a pH of 7. Basic or alkaline solutions (e.g. bleach and ammonia) have pH values greater than 7 and acidic solutions (e.g. battery acid, lemon juice, vinegar) have pH values less than 7.

pH is influenced by naturally occurring factors such as the geology, soils, or organic acids (decaying leaves and other matter). Wetlands, in particular, can lower pH because the tannic and humic acids released by decaying plants cause water to become more acidic. Human activities can also influence pH levels in surface waters. Wastewater discharge and atmospheric deposition of nitric and sulfuric acids in acid rain can also decrease pH levels. Under normal conditions, rain and snow have pH values near 5.6. However, in New England rainfall tends to have a lower pH because of pollution emissions from sources such as coal-fired power plants and car exhaust leading to "acid rain". Consequently, the typical pH of rain in the Northeast is closer to 4. In contrast to watersheds where limestone is the dominant bedrock and the acid buffering capacity is high, New Hampshire surface waters are particularly vulnerable to acid rain because granite (the dominant rock type) has little buffering capacity.

In surface waters, pH affects many chemical and biological processes. This is important to the survival and reproduction of fish, macroinvertebrates, and other aquatic life. Different organisms flourish within different ranges of pH and pH levels outside of an organism's preferred range can limit growth, limit reproduction, and lead to physiological stress. Low pH can also allow toxic elements and compounds such as heavy metals to become more "available" for uptake by aquatic plants and animals. This can cause deformities in fish and produce conditions that are toxic to aquatic life.

The Class A and Class B surface water standard for pH is 6.5-8.0, unless natural conditions influence pH otherwise. Lower pH values, between 6.0 and 8.0, are often observed in New Hampshire streams due to the impact of acid rain and low buffering capacity of the underlying geology. Consequently, there has been some thought about reducing the minimum pH to 6.0 but for the present the standard remains as it is. The majority of aquatic life prefers a range of 6.5-8.0 and their ability to complete a life cycle greatly diminishes as pH falls below 5.0 or exceeds 9.0. pH levels below 5.5 can severely limit growth and reproduction in fish, as is the case with brook trout in some streams in New England.

Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen in the water. It is expressed as a concentration in terms of milligram per liter (mg/L) or as a percent saturation (%). The concentration is a measure of the amount of oxygen in a volume of water, while the percent saturation is a measure of the amount of oxygen in the water divided by the amount of oxygen that water can hold at maximum saturation. The amount of dissolved oxygen that water can hold is dependent upon temperature and atmospheric pressure as gases dissolve more easily in cooler water under higher pressure. Both of these measurements are necessary to accurately determine whether New Hampshire surface water quality standards are met. Aquatic animals, including fish, amphibians, and macroinvertebrates, require sufficient concentrations of dissolved oxygen to survive. Aquatic plants and algae produce oxygen in the water during the day and consume oxygen during the night. Bacteria utilize oxygen both day and night when they process organic matter into smaller and smaller particles.

Oxygen is dissolved into the water from the atmosphere, aided by wind and wave action, or by rocky, steep, or uneven stream beds and from aquatic plants as a product of photosynthesis. The concentration of dissolved oxygen is dependent on many factors including: temperature, water flow, water depth, the amount of organic matter, and sunlight. Dissolved oxygen levels also tend to fluctuate throughout the day, rising throughout the day as a result of photosynthesis and reaching a peak in late afternoon. Overnight, as photosynthesis stops and organisms continue to use oxygen, levels fall, reaching a low point just before dawn. In some instances, water can become saturated with more than 100 percent dissolved oxygen. Depletions in dissolved oxygen can cause major changes in the kinds of aquatic organisms that inhabit surface waters.

The dissolved oxygen standard for Class A surface waters is 6mg/L (at any place or time) or 75% (minimum daily average). For Class B surface waters the standard is 5mg/L (at any place or time) or 75% (minimum daily average). Both of these standards are subject to unusual natural conditions that would otherwise change dissolved oxygen levels. When dissolved oxygen falls below 5mg/L or a 75% minimum daily average, inputs of nutrients, wastes, or other organic material may be occurring. Levels are also considered critical for aquatic organisms when they fall below 5 mg/L.

Appendix B: Student Quiz

Chapter 2: Surface Water

Student Quiz

Define the following word.

1. Surface water: ____

   ____

   ____

   ____

Fill in the blank.

2. Number the following types of substrate in order from smallest (1) to largest (6).

   a. _____ cobble

   b. _____ clay/silt/mud

   c. _____ bedrock

   d. _____ gravel

   e. _____ sand

   f. _____ boulder

3. What are three types of stream habitat?

   g. ____________________

   h. ____________________

   i. ____________________

4. What are five things that can be monitored in a stream or lake to understand its water quality?

   j. ____________________

   k. ____________________

l. ____________________

m. ____________________

n. ____________________

True/False

5. _____ In a stream, water travels the fastest on the outside of a curve.

6. _____ Deposition is the opposite of erosion.

7. _____ When water moves slowly, it can pick up big rocks and move them.

8. _____ In a lake, warm water usually rises.

9. _____ Oxygen is not very important for fish, plants, and other aquatic life.

10. _____ Trees growing along a river or stream help shade and protect the banks from erosion.

11. _____ If a stream looks clear, the water quality is always excellent.

12. _____ A eutrophic lake has very little plant and algae growth and almost no nutrients.

13. _____ A healthy riparian zone along a stream or river should have a diversity of plants (trees, shrubs, flowers, grasses, etc.)

Draw a diagram of a stream in the box below:

Make sure to label the stream channel, riparian zone, riffle, run, pool, and the direction of water flow. Explain where erosion and deposition are most likely to occur and why.

Chapter 2: Surface Water

Student Quiz Answer Sheet

Define the following word.

1. Surface water:

   Surface water refers to all the features that hold water on the Earth's surface including: oceans, streams, rivers, lakes, ponds, wetlands, etc.

Fill in the blank.

2. Number the following types of substrate in order from smallest (1) to largest (6).

   a. __4__ cobble

   b. __1__ clay/silt/mud

   c. __6__ bedrock

   d. __3__ gravel

   e. __2__ sand

   f. __5__ boulder

3. What are three types of stream habitat?

   a. __pool______________

   b. __riffle______________

   c. __run________________

4. What are five things that can be monitored in a stream or lake to understand its water quality?

   a. __dissolved oxygen____

   b. __pH_________________

   c. __temperature________

d. __turbidity_________

e. __phosphorus_______

True/False

5. __T__ In a stream, water travels the fastest on the outside of a curve.

6. __T__ Deposition is the opposite of erosion.

7. __F__ When water moves slowly, it can pick up big rocks and move them.

8. __T__ In a lake, warm water usually rises.

9. __F__ Oxygen is not very important for fish, plants, and other aquatic life.

10. __T__ Trees growing along a river or stream help provide shade and protect the banks from erosion.

11. __F__ If a stream looks clear, the water quality is always excellent.

12. __F__ A eutrophic lake has very little plant and algae growth and almost no nutrients.

13. __T__ A healthy riparian zone along a stream or river should have a diversity of plants (trees, shrubs, flowers, grasses, etc.)