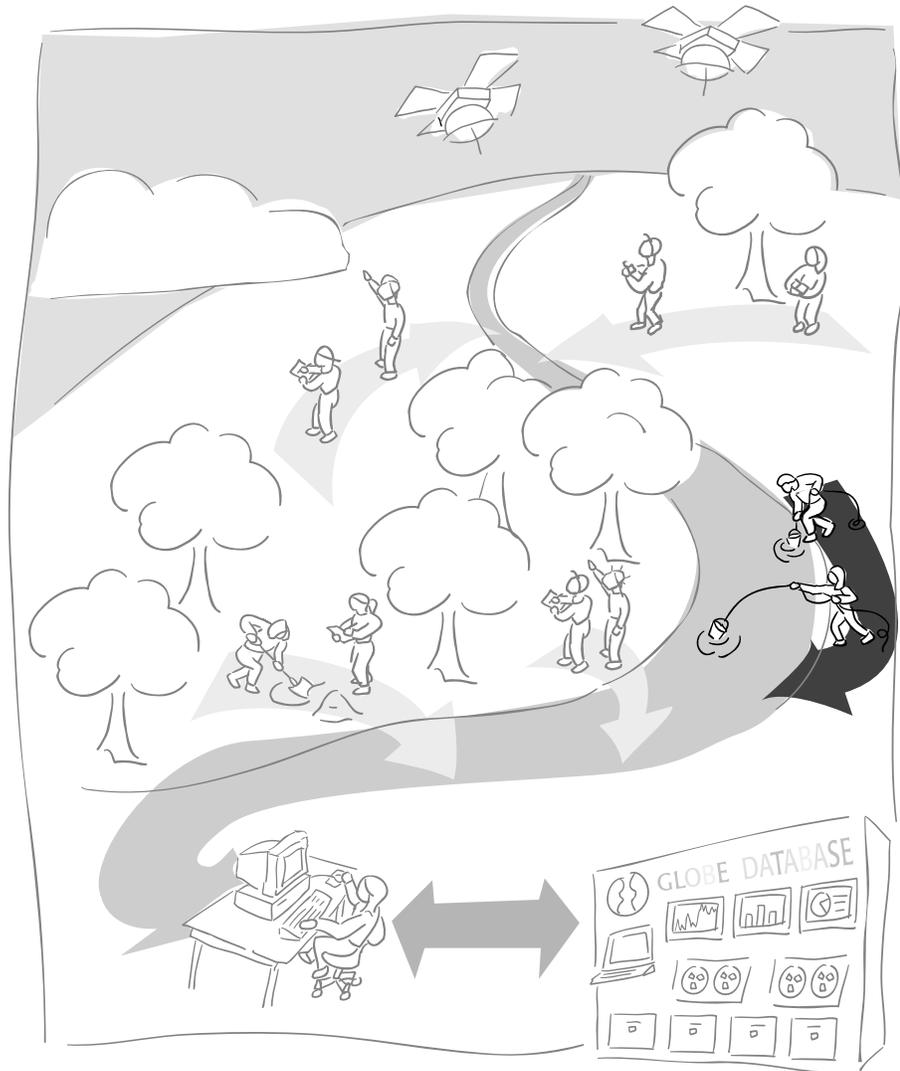


Hydrology Investigation



A GLOBE® Learning Investigation



Hydrology Investigation at a Glance



Protocols

Weekly Measurements

Basic
Transparency
Water Temperature
Dissolved Oxygen
Electrical Conductivity
Salinity
pH
Alkalinity
Nitrate

Optional Measurements

Salinity Titration (weekly)
Freshwater macroinvertebrates (twice a year)

Suggested Sequence of Activities

- Read the Introduction, especially the sections *What Measurements Are Taken* and *Getting Started*.
- The *Water Walk Learning Activity* sets the stage for developing a baseline knowledge and interest in your Hydrology Site.
- The *Model a Catchment Basin Learning Activity* provides the big picture view of the students' watershed and the water and study site in relation to this watershed.
- Map Your Hydrology Site. At the beginning of your study as part of defining your site, and once each year thereafter, create a map of the Hydrology Site and take photographs to send to GLOBE.
- The *Practicing Your Protocols Learning Activity* guides students through learning how to use the instruments and following the protocols so they collect reliable data.
- Begin Field Sampling. Go to the site and begin the weekly measurements for water.
- Use the *Looking at Data* section at the end of each protocol as a guide to examine your data, ask questions and interpret what you find. Start linking water data to other GLOBE measurements.
- Focus on Key Science Ideas by performing the following Learning Activities:
 - *Water Detectives* and *The pH Game* introduce students to key water chemistry variables and to the need using instruments to take certain measurements.
 - *Modeling Your Water Balance* lets students explore how to use their data for modeling.

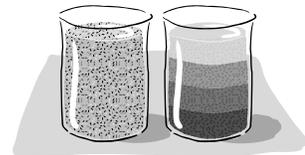




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Protocols

Instrument Construction, Site Selection, Site Documentation and Mapping, and Sampling Procedures

Water Transparency Protocol

Water Temperature Protocol

Dissolved Oxygen Protocol

Electrical Conductivity Protocol

Salinity Protocol

pH Protocol

Alkalinity Protocol

Nitrate Protocol

Optional Protocols

Freshwater Macroinvertebrates Protocol*

 Rocky Substrates in Running Water

 Multi-habitat (sampling a lake, pond, or stream with sandy or muddy bottom)

Marine Macroinvertebrates Protocol*

Salinity Titration Protocol*



Learning Activities

Water Walk*

Model a Catchment Basin

Practicing Your Protocols*

Water Detectives*

The pH Game

Modeling Your Water Balance



Appendix

Hydrology Site Definition Sheet Appendix 2

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Hydrology Investigation Data Sheet Appendix 5

Freshwater Macroinvertebrate Identification

Data Sheet Appendix 9

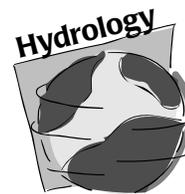
Hydrology Site Map Appendix 11

Glossary Appendix 12



* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.

Introduction



What is the condition of Earth's many surface waters – the streams, rivers, lakes, and coastal waters? How do these conditions vary over the year? Are these conditions changing from year to year?

Through the GLOBE *Hydrology Investigation*, you can help address these questions by monitoring the waters near your school. Our knowledge of global trends in water measurements is based on sampling at very few sites. This sampling has generally been done only a few times. For example, our information on many lakes is based on sampling done only once or twice more than ten years ago.

In order to evaluate water changes, we need access to reliable information on current and past conditions. If changes are already taking place, comparing multiple sites at different areas can help us understand what is happening.

Why Investigate the Surface Waters?

We do not just drink water; we are water. Water constitutes 50 to 90 percent of the weight of all living organisms. It is one of the most abundant and important substances on Earth. Water sustains plant and animal life, plays a key role in the formation of weather, helps to shape the surface of the planet through erosion and other processes, and approximately 70% of Earth's surface is covered in water.

Measures of dissolved oxygen and pH directly indicate how hospitable a body of water is to aquatic life. It is interesting to both follow the annual cycle of water parameters, such as dissolved oxygen, alkalinity and pH, and to make comparisons between different water bodies. We can ask such questions as: are dissolved oxygen levels always at the maximum allowed by the temperature of the water, or are they depressed during part of the year? If they are low, we want

to know the cause. We can see if pH becomes depressed right after a rain or when there is a lot of snowmelt running off into the lake or stream. If we do find a depression in pH, we would expect this water to have a low level of alkalinity. In fact, we would expect waters with a low alkalinity to have a depression in pH following rainfall or snowmelt. But we must take the measurement to confirm whether or not this really happens. Developing a database of water measurements will allow us to answer such questions.

Despite its abundance, we cannot use most of Earth's water. If we represent Earth's water as 100 liters, 97 of them would be seawater. Most of the remaining three would be ice. Only about 3 mL out of the whole 100 liters would be fresh water that we can consume; this potable water is pumped from the ground or taken from fresh water rivers and lakes.

In most countries current measurement programs cover only a few water bodies a few times during the year. We hope the GLOBE measurements you take will help fill this gap and improve our understanding of Earth's natural waters. This knowledge can help us make more intelligent decisions about how we use, manage and enjoy these resources.



The Big Picture

The Hydrologic Cycle

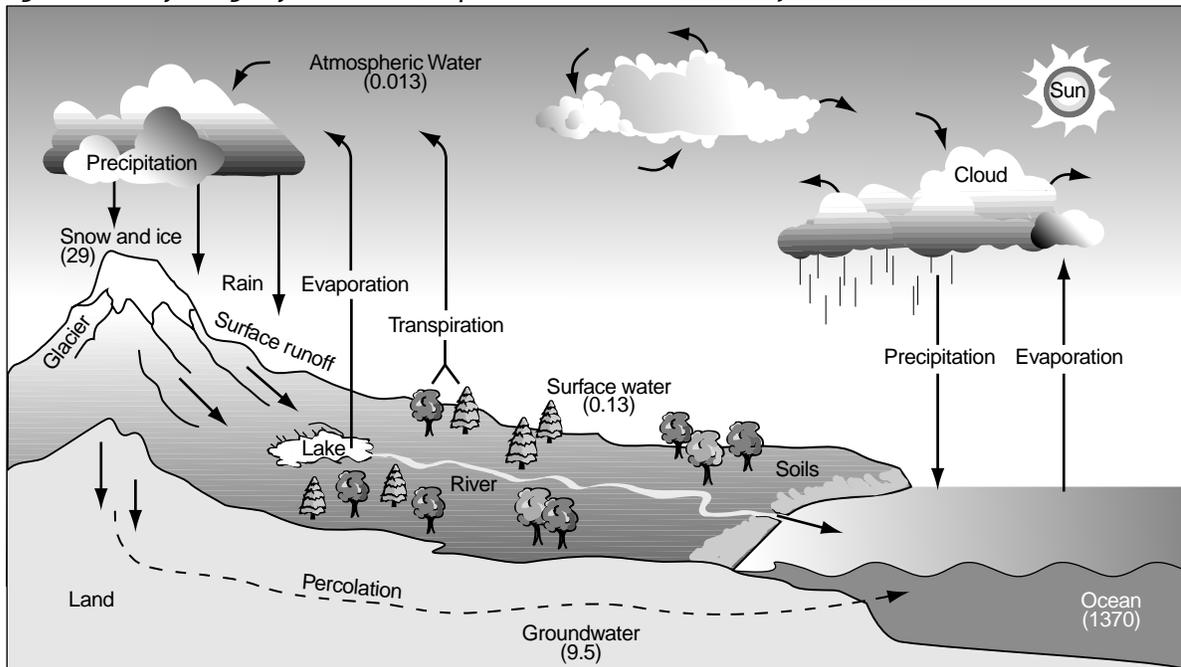
Water continually circulates between Earth's surface and atmosphere in what is called the hydrologic cycle. The hydrologic, or water, cycle is one of the basic processes in nature. Responding to heat from the sun and other influences, water from oceans, rivers, lakes, soils and vegetation evaporates into the air and becomes water vapor. Water vapor rises into the atmosphere, cools, and turns into liquid water or ice to become clouds. When water droplets or ice crystals get large enough, they fall back to the surface as rain or snow. Once on the ground water filters into the soil and is either absorbed by plants or percolates downward to groundwater reservoirs. If water does not filter into the soil, it runs off into streams and rivers and eventually into oceans, while some of it evaporates.



Waters in a lake, snow on a mountain, humid air or drops of morning dew are all part of the same system. Total annual water loss from the surface equals Earth's total annual precipitation. Changing any part of the system, such as the amount of vegetation in a region or land cover, affects the rest of the system.

Water participates in many important chemical reactions and is a good solvent. Completely pure water rarely occurs in nature because it carries impurities as it travels through the hydrologic cycle. Rain and snow capture aerosols from the air. Acidic water slowly dissolves rocks, placing dissolved solids in water. Small but visible pieces of rocks and soils also can become suspended in water and make some waters turbid. When water percolates into the ground, more minerals dissolve into water. Dissolved or suspended impurities determine water's chemical composition.

Figure HY-I-1: Hydrologic Cycle - Numbers in parentheses are the reservoirs of available water in 10^3 Km^3 .



After Mackenzie and Mackenzie 1995, and Graedel and Crutzen, 1993

GLOBE Measurements

What Measurements are Taken?

In this investigation students will measure the following water measurements:

- Transparency
- Water Temperature
- Dissolved Oxygen
- Electrical Conductivity
- Salinity
- pH
- Alkalinity

- Nitrate

Optional (Protocols on the GLOBE e-Guide):

- Salinity Titration
- Freshwater Macroinvertebrates

Individual Measurements

Transparency

Light, essential for growth of green plants, travels farther in clear water than in turbid water that contains suspended solids or colored water. Transparency is the degree to which light penetrates into water. Two methods commonly used to measure transparency are the Secchi disk and transparency tube. The Secchi disk was first used to measure transparency in 1865 by Father Pietro Angelo Secchi, the scientific advisor to the Pope. This simple and widely used measurement is the depth at which a 20-cm black and white disk lowered into water just disappears from view, and reappears again when raised. An alternate measure of transparency is obtained by pouring water into a tube with a pattern similar to that of a Secchi disk on the bottom and noting the depth of water in the tube when the pattern just disappears from view. The Secchi disk is used in deeper, still waters. The transparency tube can be used with either still or flowing waters and can be used to measure shallow water sites or the surface layer of deepwater sites.

Water Temperature

Water temperature is largely determined by the amount of solar energy absorbed by the water as well as the surrounding soil and air. More solar heating leads to higher water temperatures. Water

used in manufacturing and then discharged into a water body may also increase water temperature. Water evaporating from the surface of a water body can lower the temperature of water but only for a very thin layer at the surface.

Water temperature can be indicative of where the water originates. Water temperature near the source will be similar to the temperature of the source (e.g., snowmelt will be cool whereas some ground water is warm). Water temperature farther from the source is influenced largely by atmospheric temperature.

Other parameters, such as electrical conductivity and dissolved oxygen, are dependent on water temperature. It is also an important factor for what will live in a water body.

Dissolved Oxygen

Water is a molecule made of two hydrogen atoms and one oxygen atom – hence, H₂O. However, mixed in with the water molecules of any body of water are molecules of oxygen gas (O₂) that have dissolved in the water. Dissolved oxygen is a natural impurity in water. Aquatic animals, such as fish and the zooplankton they feed on, do not breathe the oxygen atom in water molecules. Rather, they breathe the oxygen molecules dissolved in the water. Without sufficient levels of dissolved oxygen in the water, aquatic life suffocates. Dissolved oxygen levels below 3 mg/L are stressful to most aquatic organisms.

pH

pH is a measure of the acid content of water. The pH of a water influences most of its chemical processes. Pure water with no impurities (and not in contact with air) has a pH of 7. Water with impurities will have a pH of 7 when its acid and base content are exactly equal and balance each other out. At pH values below 7 there is excess acid, and at pH levels above 7 there is excess base in the water.

Electrical Conductivity

Pure water is a poor conductor of electricity. It is the ionic (charged) impurities in water, such as dissolved salts, that enable water to conduct electricity. Since we lack the time or money to analyze water for each substance, we have found



a good indicator of the total level of impurities in fresh water to be its electrical conductivity. Electrical conductivity is the measurement of how well water passes an electrical current. The more dissolved salts there are in water, the greater its electrical conductivity.



Salinity

Water in seas and oceans is salty and has a much higher dissolved solids content than in freshwater lakes, streams and ponds. Salinity is a measure of that saltiness and is expressed in parts impurity per thousand parts water. The average salinity of Earth's oceans is 35 parts per thousand (35 ppt). Sodium and chloride, the components of common table salt (NaCl), contribute most to the salinity. In bays and estuaries we can find a wide range of salinity values since these are the regions where freshwaters and seawater mix. The salinity of these brackish waters is between that of freshwater, which averages 0.5 ppt, and seawater.



Every continent on Earth also has inland lakes that are saline. Some of the more prominent examples are the Caspian Sea in Central Asia, the Great Salt Lake in North America, and several lakes in the Great Rift Valley of East Africa. Some of these are even more saline than seawater. Waters acquire salinity because rivers carry salts that originated from the weathering or dissolving of continental rocks. When water evaporates the salts stay behind, resulting in a buildup of dissolved material. When water becomes saturated with salts, they precipitate out as solids. Whereas the ocean's salinity changes slowly, over many millennia, the salinity of inland waters can change more quickly, over hours to decades, when rainfall or snowmelt patterns change.



Alkalinity

Alkalinity is the measure of a water's resistance to the lowering of pH when acids are added to the water. Acid additions generally come from rain or snow, though soil sources are also important in some areas. Alkalinity is generated as water dissolves rocks containing calcium carbonate such



as calcite and limestone. When a lake or stream has low alkalinity, typically below about 100 mg/L as CaCO₃, a large influx of acids from a big rainfall or rapid snowmelt event could (at least temporarily) drop the pH of the water to levels harmful for amphibians, fish or zooplankton.

Nitrate

Plants in both fresh and saline waters require three major nutrients for growth: carbon, nitrogen and phosphorus. In fact, most plants tend to use these three nutrients in the same proportion, and cannot grow if one is in short supply. Carbon is relatively abundant in the air as carbon dioxide. Carbon dioxide dissolves in water and so a lack of either nitrogen or phosphorus generally limits the growth of aquatic plants. In some cases, trace nutrients such as iron can also be limiting. Sunlight can also limit growth. Nitrogen exists in water bodies in numerous forms: dissolved molecular nitrogen (N₂), organic compounds, ammonium (NH₄⁺), nitrite (NO₂⁻) and nitrate (NO₃⁻). Of these, nitrate is usually the most important for plant growth.

Freshwater Macroinvertebrates

Millions of small creatures inhabit fresh waters of lakes, streams, and wetlands. Macroinvertebrates, consisting of a variety of insects and insect larvae, crustaceans, mollusks, worms, and other small, spineless animals live in the mud, sand, or gravel of the substrate or on submersed plants and logs. They play a crucial role in the ecosystem. They provide an essential link in the food chain and are the source of food for many larger animals. Macroinvertebrates, such as freshwater mussels, help to filter water. Other types are scavengers and feed on decaying matter in the water, while certain macroinvertebrates prey on smaller organisms .

Macroinvertebrates can tell us a lot about the conditions within a water body. Many macroinvertebrates are sensitive to changes in pH, dissolved oxygen, temperature, salinity, transparency, and other changes in their habitat. Habitat is a place that includes everything that an animal needs to live and grow.

Macroinvertebrate samples allow us to estimate biodiversity, examine the ecology of the water body and explore relationships among water chemistry measurements and organisms at your Hydrology Site.

Where are the measurements taken?

All hydrology measurements are taken at the Hydrology Study Site. This may be any surface water site that can be safely visited and monitored regularly from your school, although natural waters are preferred.

Sites may include (in order of preference):

1. stream or river
2. lake, reservoir, bay or ocean
3. pond
4. an irrigation ditch or other water body if one of the above is not accessible or available

When are the measurements taken?

Collect all water measurements at roughly the same time each day, on a weekly basis. If your sampling site freezes over in winter or runs dry, be sure to enter this information each week until you again have free-flowing surface water to measure.

Note: Certain times of the year provide more exciting measurements. When runoff from a spring snowmelt is occurring on a river, the increased flow and sediment will dramatically change water measurements. One or more times a year, lakes can ‘turnover’ and the waters in the lake totally mix. This can occur in spring after the ice melts. Turnover can cause surprising changes to your measurement results. Be observant of seasonal and monthly changes. Use the *Comments* section of the GLOBE data entry pages to record observations that may help others interpret your water data.

Collect freshwater macroinvertebrate data twice a year, once in Spring and again in late Summer or early Autumn before the first freeze. If your seasons alternate between wet and dry, choose a date in the second half of the wet season and one date in the dry season, six months from the first sampling if possible. If you have no marked cyclic changes, ask local experts to find out when you should sample to find the peak abundance and diversity of macroinvertebrates in the water. Sample at that time and sample again six months later.

How many students should be involved?

Measurements should be taken by groups of 2-3 students. Tasks within a group include collecting samples, processing samples, and recording data. It is very useful to have multiple groups testing for each parameter (for example, three groups measure dissolved oxygen). This allows more students to get involved and builds in some quality control. Groups of students conducting the same test should look at each other’s results to determine if the data are similar. If there are different results for the same sample, students should check the procedures and redo the test to determine what caused the difference. Data quality control should be an important part of the science and the learning experience.

Table HY-I-1: Hydrology Measurement Levels and Approximate Time Required

Level	Measurements	Time (minutes)
<i>Beginning</i>	Transparency	10
	Temperature	10
	pH (paper)	10
	Conductivity	10
	Salinity	10
<i>Intermediate or Advanced</i>	Dissolved oxygen	20
	pH (meter)	10
	Alkalinity	15
<i>Optional</i>	Nitrate	20
	Salinity Titration	10
	Freshwater macro-invertebrates	3-6 hours



How long does it take to do the measurements?

The amount of time for doing the measurements will depend on the distance to your water site, the skill level of the students, and how your group is organized. If each student group performs all of the measurements it will take more time than if smaller groups are responsible for different sets of measurements each week.



Getting Started

For the weekly water protocols, students will take samples of water from a selected body of water, process the samples to determine their composition, and analyze the data to better understand the water and its impact on the environment. Each year, students are requested to map and photograph their site. One of the major factors that limit use of data is poor documentation of sites.

For the *Freshwater Macroinvertebrate Protocol*, students will sample their water sites twice a year to determine the relative number and types of invertebrates. Students will compare these data with the water chemistry data, historic data, and other indices to understand the patterns and trends of the water they are studying.

Educational Objectives

Students participating in the activities presented in this chapter should gain inquiry abilities and understanding of a number of concepts. These abilities include the use of a variety of specific instruments and techniques to take measurements and analyze the resulting data along with general approaches to inquiry. The *Scientific Inquiry Abilities* listed in the gray box are based on the assumption that the teacher has completed the protocol including the *Looking At The Data* section. If this section is not used, not all of the Inquiry Abilities will be covered. The *Science Concepts* included are outlined in the United States National Science Education Standards as recommended by the US National Research Council and include those for Earth and Space Science and Physical Science. The *Geography Concepts* are taken from the National Geography Standards prepared by the National Education Standards Project. Additional *Enrichment Concepts* specific to the hydrology measurements have been included as well. The gray box at the beginning of each protocol or learning activity gives the key concepts and scientific inquiry abilities covered. The following tables provide a summary indicating which concepts and abilities are covered in which protocols or learning activities.

References

T.E. Graedel and P.J. Crutzen (1993) *Atmospheric Change: An Earth System Perspective*. W.H. Freeman and Company, New York

ET. Mackenzie and J.A. Mackenzie (1995) *Our Changing Planet: An Introduction to Earth System Science and Global Environmental Change*. Prentice Hall, New Jersey.

National Science Education Standards	Protocols						
	Trans.	Temp.	Dis. Oxygen	pH	E. Cond.	Salinity	Sal. Titration
Earth and Space Sciences							
Properties of Earth Materials (K-4)							
Earth materials are solid rocks, soils, water and the atmosphere	■	■	■	■	■	■	■
Soils have properties of color, texture and composition; they support the growth of many kinds of plants							
Soils consist of weathered rocks and decomposed organic matter							
Changes in the Earth and Sky (K-4)							
The surface of the Earth changes (Erosion, weathering, etc.)							
Structure of the Earth System (5-8)							
Landforms are the result of destructive and constructive forces							
Soil consists of weathered rocks and decomposed organic matter							
Water circulates through the biosphere, lithosphere, atmosphere and hydrosphere (water cycle)							
Water is a solvent	■		■	■	■	■	■
Energy in the Earth System (9-12)							
The sun is the major source of energy at Earth's surface							
Solar insolation drives atmospheric and ocean circulation							
Geochemical Cycles (9-12)							
Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere)			■	■	■	■	■
Physical Sciences							
Properties of Materials (K-4)							
Objects have observable properties	■	■	■	■	■	■	■
Life Sciences							
The Characteristics of Organisms (K-4)							
Organisms have basic needs.							
Organisms can only survive in environments where their needs are met		■	■	■	■	■	■
Earth has many different environments that support different combinations of organisms		■	■	■	■	■	■
Organisms and their Environments (K-4)							
Organisms' functions relate to their environment							
Organisms change the environment in which they live	■		■	■			
Humans can change natural environments	■	■	■	■	■	■	■
Structure and Function of Living Systems (5-8)							
Ecosystems demonstrate the complementarily nature of structure and function							
Regulation and Behavior (5-8)							
All organisms must be able to obtain and use resources while living in a constantly changing environment	■	■	■	■	■	■	■

			Learning Activities					
Alkalinity	Fresh water macro-invertebrates	Nitrate	Water Walk	Model Watershed	Water Detective	pH Game	Practice Protocols	Model Balance
■		■						
	■		■	■				■
	■							
			■	■				
			■	■				■
			■	■				■
■		■	■	■	■	■	■	
■		■	■	■		■	■	
■		■	■	■				
■	■	■	■				■	
■	■	■	■				■	
	■							
■	■	■	■				■	

National Science Education Standards	Protocols						
	Trans.	Temp.	Dis. Oxygen	pH	E. Cond.	Salinity	Sal. Titration
Populations and Ecosystems (5-8)							
All populations living together and the physical factors with which they interact constitute an ecosystem							
Populations of organisms can be categorized by the function they serve in the ecosystem							
Sunlight is the major source of energy for ecosystems							
The Interdependence of Organisms (9-12)							
Atoms and molecules cycle among the living and non living components of the ecosystem							
Energy flows through ecosystems in one direction (photosynthesis-herbivores-carnivores-decomposers)							
Organisms both cooperate and compete in ecosystems							
The population of an ecosystem is limited by its resources							
Humans can change ecosystem balance							
Matter, Energy, and Organization in Living Systems (9-12)							
Energy for life derives mainly from the sun							
Living systems require a continuous input of energy to maintain their chemical and physical organizations							
The Behavior of Organisms (9-12)							
The interaction of organisms in an ecosystem have evolved together over time							

			Learning Activities					
Alkalinity	Fresh water macro-invertebrates	Nitrate	Water Walk	Model Watershed	Water Detective	pH Game	Practice Protocols	Model Balance
	■							
	■							
	■							
	■							

Protocols



Instrument Construction, Site Selection, Site Documentation and Mapping, and Sampling Procedures

Instructions to build some equipment are provided. Instructions are provided on how to select, describe and map a hydrology site. Students are shown how to take a water sample to test.

Water Transparency Protocol

Students will first measure water transparency at their undisturbed study site using a transparency tube or Secchi disk.

Water Temperature Protocol

Students will measure the temperature of water.

Dissolved Oxygen Protocol

Students will measure dissolved oxygen in the water at their site using a dissolved oxygen test kit.

Electrical Conductivity Protocol

Students will measure electrical conductivity of water at freshwater hydrology sites.

Salinity Protocol

Students will measure the salinity of a salty or brackish water sample using a hydrometer and thermometer.

pH Protocol

Students will measure the pH of water using either pH paper or a pH meter.

* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.

Alkalinity Protocol

Students will measure the alkalinity of water using an alkalinity test kit.

Nitrate Protocol

Students will measure the nitrate-nitrogen content of water using a nitrate test kit.

Freshwater Macroinvertebrate Protocol*

Students will collect, identify, and count macroinvertebrates at freshwater hydrology sites.

Marine Macroinvertebrate Protocol*

Students estimate the densities of certain animal species found in the intertidal zone at coastal sites.

Salinity Titration Protocol*

Students will measure the salinity of saltwater using a salinity titration kit.

* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.

Instrument Construction

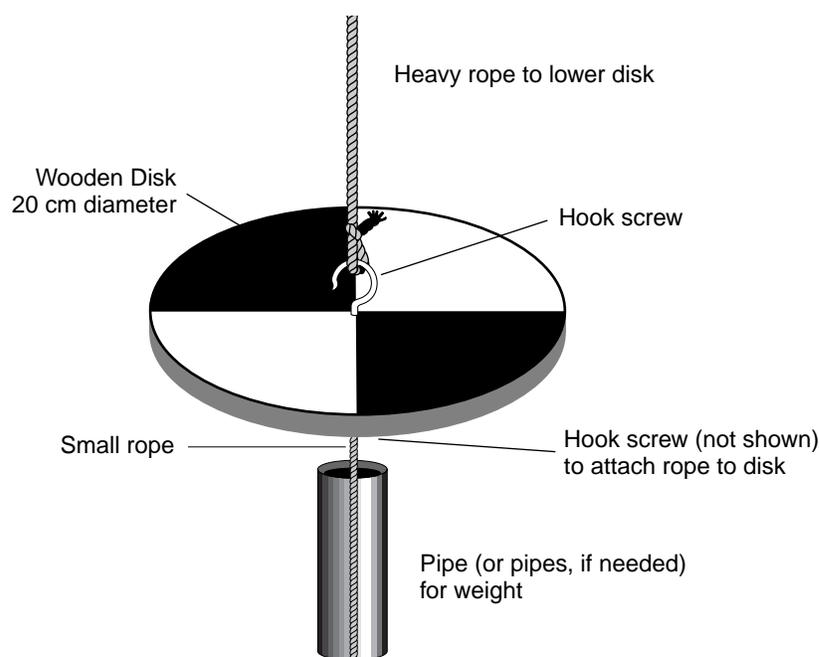
Instructions for Making a Secchi Disk to Measure Water Transparency

Materials

- Wooden disk (20 cm diameter)
- Paint (black and white)
- 2 hook screws (2-3 cm)
- Pipe(s) for weight
- 5 meters rope (or more, depending on depth of water)
- Meter stick
- Permanent, waterproof markers (black, red, blue)
- Short piece of rope (approximately 50 cm - 1 m)

Directions for Construction

1. Divide top of wooden disk into four equal quadrants. Draw lightly in pencil 2 lines crossing at a 90 degree angle to identify the quadrants.
2. Paint two opposite quadrants in black and the other two in white.
3. Screw a hook screw into the top center and bottom center of the disk. Tie the 5-m (or longer) rope through the screw in the top of the disk.
4. Tie the short piece of rope through the screw on the bottom of the disk. String the rope through the pipe. Tie a large knot at the bottom of the pipe so that it does not fall off when hanging vertically underneath the disk.
5. Measure and mark the rope above the top part of the disk with a black marker every 10 cm.
6. Measure and mark every 50 cm up from the disk with a blue marker and every meter with a red marker.





Instrument Construction

Instructions for Making a Transparency Tube to Measure Water Transparency



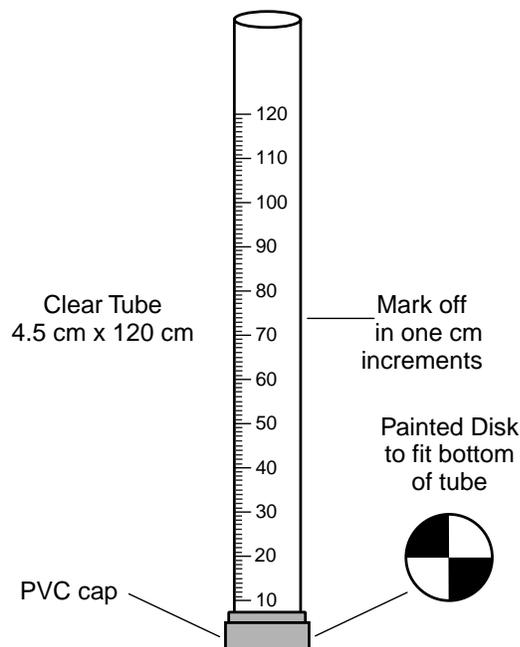
Materials

- Clear tube (approximately 4.5 cm x 120 cm)
- Permanent, waterproof black marker
- PVC cap (to fit snugly over one end of tube)
- Meter stick



Directions for Construction

1. On the bottom of the inside of the PVC cap, draw a Secchi disk pattern (alternating black and white quadrants) with the black marker.
2. Put the PVC cap over one end of the tube. Cap should fit tightly so water cannot leak out.
3. Use the marker and meter stick to draw a scale on the side of the tube. The bottom of the inside of the PVC cap where the Secchi disk pattern is drawn is 0 cm. Mark every cm up from that point.



Instrument Construction

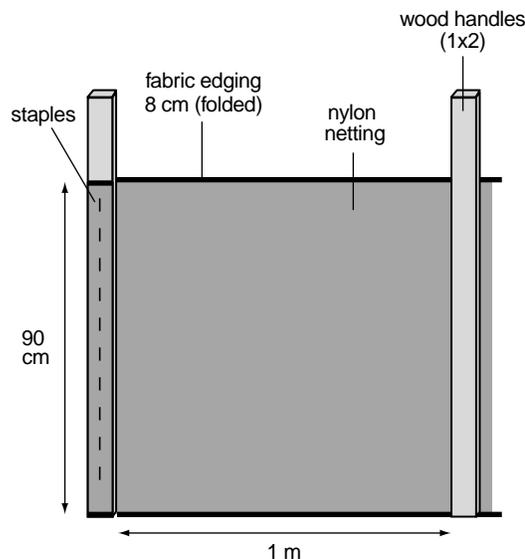
Instructions for Making a Kick-Net to Collect Freshwater Macroinvertebrates

Materials

- One piece of 95 cm x 132 cm nylon netting (0.5 mm mesh)
- Staples
- One piece of 120 cm x 150 cm (or larger) nylon netting (0.5 mm mesh) for a funnel (optional)
- 2 pieces of denim or other heavy fabric (8 cm x 132 cm each)
- 2 poles (132 cm long, 4 to 5 cm diameter)
- Needle and thread or heavy waterproof tape

Directions for Construction

1. Fold each of the 8 x 132 cm strips of heavy fabric over each of the long edges of the 95 cm x 132 cm nylon netting (0.5 mm mesh). Hold in place by sewing or using waterproof tape.
2. Attach the nylon netting and the fabric to the poles with staples. The poles should be even with the netting at the bottom and extend above the netting to form handles at the top.
3. Roll the poles so that the netting wraps around the poles until the width equals 1 m and staple again.
4. Optional: at the center, cut a 30 x 30 cm square to sew a funnel-shaped net. This is not necessary but can be very useful to concentrate organisms and transfer them into a bucket. If you have more 0.5 mm nylon netting, you could also make the whole net into a pouch or a funnel starting at the 90 cm by 100 cm edges and tapering back like a butterfly net.





Instrument Construction

Instructions for Making the D-net to Collect Freshwater Macroinvertebrates



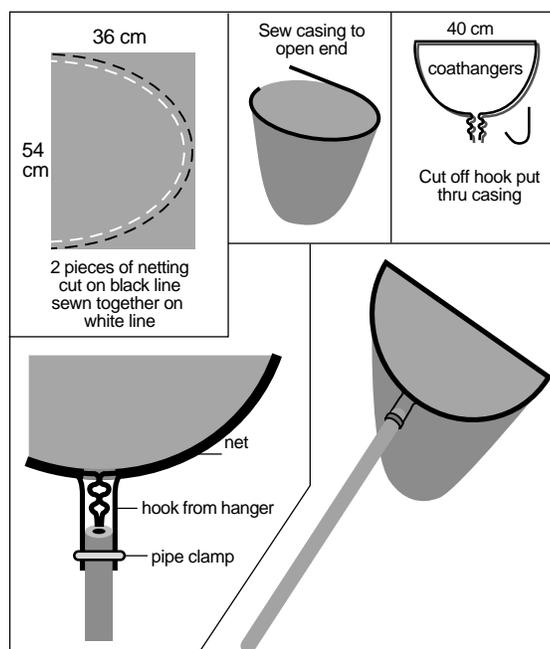
Materials

- 2 pieces of nylon netting (36 x 53 cm) (0.5 mm mesh)
- 1 meter of very stiff wire or 3 stiff coat hangers
- Heavy fabric (8 x 91 cm) (e.g. denim)
- Needle and thread or heavy waterproof tape
- 152 cm pole (e.g. broom or rake handle)
- 4 cm pipe clamp



Directions for Construction

1. Lay the 2 pieces of nylon netting on top of each other. Cut a net shape from the nylon netting pieces (see diagrams) and sew them together.
2. Open the net so that the seam is to the inside. Sew the strip of fabric (8 x 91 cm) on to the edge of the open end of the net, leaving an opening to insert the hangers.
3. Shape the heavy wire into a 'D' shape, with the straight side of the 'D' being about 40 cm long. If you are using hangers, cut the hooks from the hangers and untwist the wires, then shape them into a 'D'.
4. Insert the wire through the fabric casing and twist the ends together at the opening. Use heavy waterproof tape to tape the hangers together.
5. Drill a hole in the tip of the handle large enough to insert the ends of the wires.
6. Attach the net to the pole by inserting the ends of the wire into the hole drilled in the pole end. Loop a short piece of wire over the net frame and clamp the ends to the pole to secure the net to the pole.



Instrument Construction

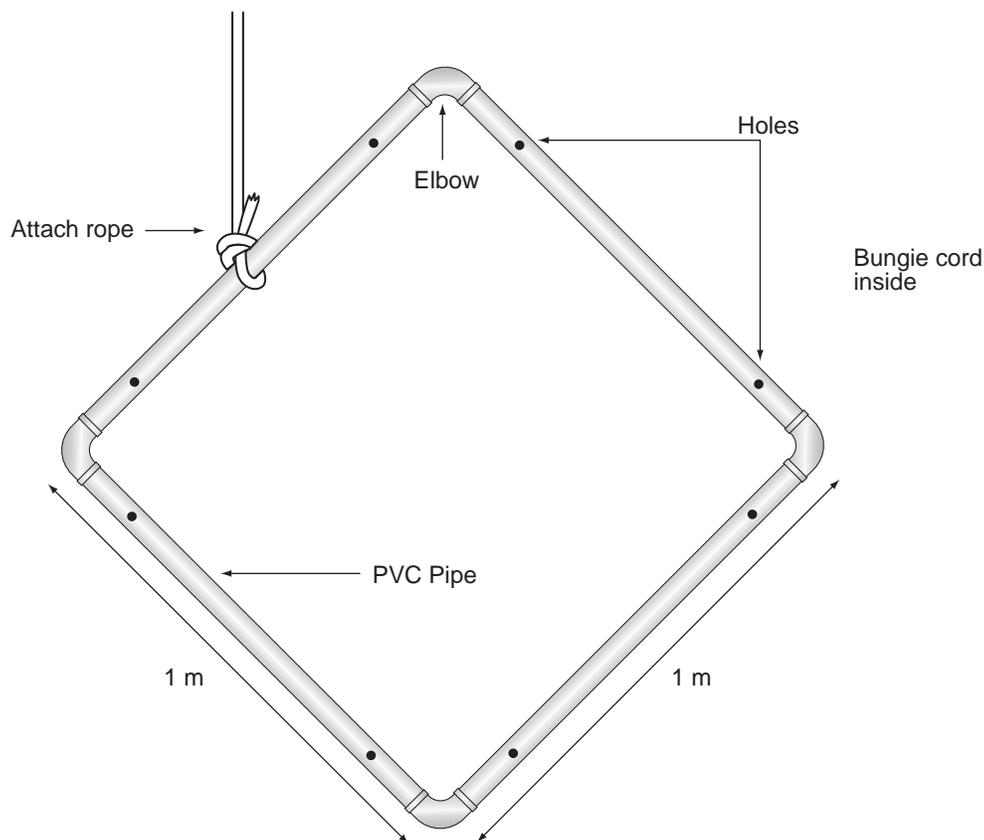
Instructions for Making the Quadrat to Use When Collecting Freshwater Macroinvertebrates

Materials

- ❑ Four poles of PVC pipe (100 cm long)
- ❑ 4 elbows of PVC pipe
- ❑ 3.5 meters of bungee cord
- ❑ 3 meters of rope (longer if needed)

Directions for Construction

1. Assemble the four poles with elbows and adjust to exactly 1 x 1 meter inside the frame.
2. Drill holes in the four poles to allow water to enter and the quadrat to sink.
3. Insert the bungee cord through the four poles and tie the two ends with a knot. The cord will hold the quadrat together in the water and will allow you to collapse the quadrat when not in use.
4. Attach a rope to the quadrat to use for lifting the quadrat out of the water after sampling.





Instrument Construction

Instructions for Making Sieves to Use When Collecting Freshwater Macroinvertebrates



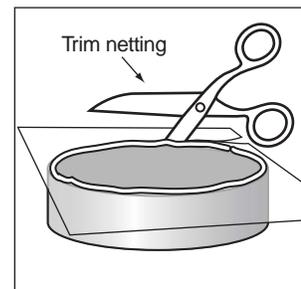
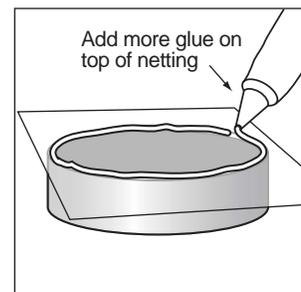
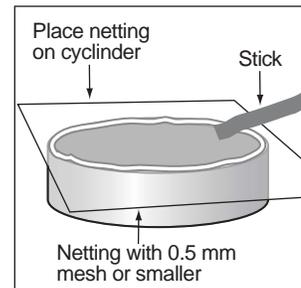
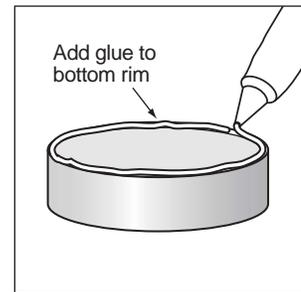
Materials

- One piece of 25 x 25 cm nylon, cotton, or metal netting (0.5 mm mesh or smaller)
- Waterproof glue
- One rigid plastic or metal cylinder (5 cm high and about 20 cm in diameter, but these dimensions can vary since the sieve is not used to quantify samples)
- Stick or spatula
- Scissors



Directions for Construction

1. The cylinders must be open at both ends. Add glue to the bottom rim of the cylinder.
2. Place the square of netting on top of the glue and use a stick or spatula to press the netting into the glue.
3. Add glue around the same rim but on top of the netting.
4. Allow the glue to dry completely (follow directions on glue package).
5. Once the glue is dry, cut the extra netting around the rim.



Instrument Construction

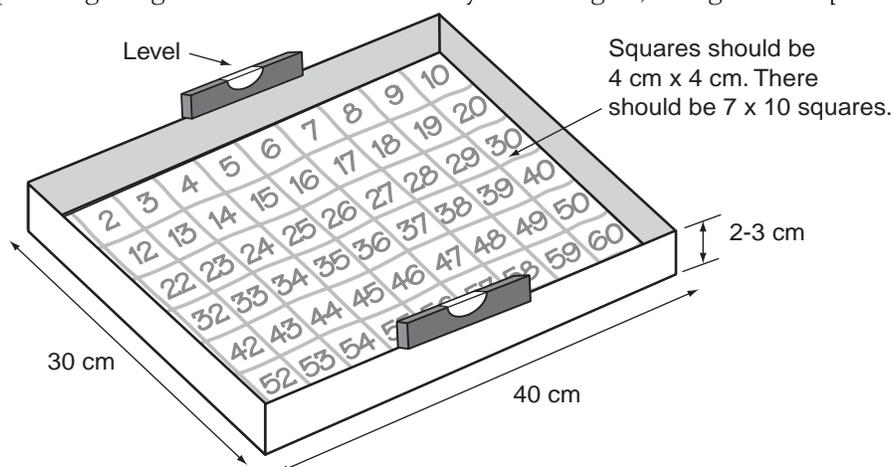
Instructions for Making the Sub-Sampling Grid to Use When Measuring Freshwater Macroinvertebrates

Materials

- Piece of stiff plastic, board or tray (30 x 40 cm) with at least 2-3 cm ridge around the outside OR shallow, white metal or plastic pan (30 x 40 cm) with flat bottom (a white plastic lid with flat bottom from storage boxes or sheet metal dampers can work)
- White waterproof, nontoxic paint (if your pan or grid sheet is not already white)
- Ruler
- Waterproof marker for drawing on sampling grid
- Graduated cylinder
- Tube of waterproof silicon caulking compound
- Two small levels

Directions for Construction

1. If using a flat sheet of plastic or board, cut to the correct size, then paint the sheet white with nontoxic, waterproof white paint. The ridge around the outside of the board should be tall enough to hold 2 – 3 cm of water on the board.
2. Draw a grid on your sheet or in the bottom of your pan. The squares of the grid should be 4 cm x 4 cm.
3. Use the caulking compound to outline each square, building the lines up to about 5 mm in height.
4. Number the squares consecutively.
5. Glue the two small levels onto opposite sides of the grid.
6. Measure the volume of water necessary to cover the whole grid with water so that each square is wet almost all the way up to the 5 mm line. This will contain the live macroinvertebrates in their sub-sampling squares.
7. Record this grid volume and the number of squares onto the *Freshwater Macroinvertebrate Identification Data Sheet*.
8. Practice spreading the grid volume of water evenly over the grid, filling all the squares.





Frequently Asked Questions

1. How much weight do I need on my Secchi disk?

Use enough weight so that the disk will be pulled vertically down under the water.



2. How long should the rope be on the Secchi disk?

The length of the rope will depend on how clear your water is and from where you are measuring. If you are measuring from a dock or bridge, for instance, extra rope may be needed to reach the water surface. If your water tends to be murky and you are measuring from near the surface, you may not need more than a couple of meters of rope.



3. Where do I find a long, clear tube for my transparency tube?

Many hardware stores carry long tubes for protecting fluorescent light bulbs. These are inexpensive and make excellent transparency tubes. If these are not available, any long, clear plastic tube of the appropriate size can be used. Length of tube is more important than diameter.



4. What do I do if my tube leaks around the cap?

If your tube leaks, use waterproof silicone caulk to seal around the cap.



5. Is it acceptable to make a small hole in the transparency tube near the bottom, fill the tube with water, then slowly release water until the disk at the bottom appears?

This method is acceptable as long as the measurement is made very quickly. Particles settle quickly, especially if they are being pulled down by water being released at the bottom. The reading must be made before particles settle and obscure the disk. These tubes should be emptied and rinsed between readings to be sure no particles remain on the bottom to affect the next reading.

6. Can a transparency tube be longer or shorter than 120 cm?

The tube should be within a few centimeters of the 120 cm standard. Some schools might test waters that never have a transparency greater than 20 centimeters, and for them there is no need for the longer tube. Others might have waters that are always >120 cm and need a longer tube to indicate the greater transparency. The standard distance of the eye to the disk (120 cm), however, should be maintained to standardize the measurement.

Site Selection

Ideally, the *Hydrology Study Site* is located within the 15 km x 15 km GLOBE Study Site. Within this area, select a specific site where the hydrology measurements (water temperature, transparency, pH, dissolved oxygen, alkalinity, electrical conductivity or salinity, nitrate, or freshwater macroinvertebrates) can be taken. You may also choose a water body of special interest to you within your GLOBE Study Site. The water bodies that scientists are most interested in are (in order of preference):

1. Stream or river
2. Lake, reservoir, bay, or ocean
3. Pond
4. An irrigation ditch or other water body used because one of the above is not accessible or available within your GLOBE Study Site.

You should collect all water samples from the same place at the *Hydrology Site* each time. This is called the *Sampling Site*.

If the site is a moving body of water, like a stream or a river (*lotic*), locate your *Sampling Site* at a riffle area (a place where the water is turbulent and moving but not too fast) as opposed to still water or rapids. If the site is a still body of water, like a lake or reservoir (*lentic*), find a *Sampling Site* near the outlet area or along the middle of the water body, but avoid taking samples near an inlet. A bridge or a pier are good choices.

If your brackish or salt water body is affected by tides, you will need to know the times of high and low tide at a location as close as possible to your *Hydrology Site*.

Freshwater macroinvertebrate sampling is done at locations near your water quality *Sampling Site*. Since different creatures live in different habitats, sampling sites will depend on the habitat type or types represented near your site. The protocols will direct you in selecting and sampling different habitats.

If others are doing research at your Hydrology Study Site, contact them before your students take measurements to avoid your students potentially interfering with other research. Your students may be able to contribute to ongoing research by taking measurements.

Documenting Your Hydrology Study Site



Information about your GLOBE Hydrology Site is essential for students and scientists to interpret the water data of your school. Students need to keep current and accurate Science Logs, report unusual findings, and attempt to understand the data they are collecting both spatially and temporally. This means understanding what is in their entire watershed and how their area changes over time. Students will find seasonal patterns and they may also find longer-term changes or trends.

You will be asked to provide information on your site in three ways: through written comments, photographs, and a field map.

Written Comments

Students are asked to provide specific information when they define their site, by filling out the *Hydrology Site Definition Sheet*.

In addition to supplying this information, you must also carefully observe and report other things that may affect the water at your site. For example, you may observe migratory waterfowl in the pond, a large storm may have caused trees to fall into the stream or a new bridge is being built slightly up the stream from where you are sampling. You may be collecting other GLOBE data such as precipitation, soil pH, or land cover that might affect the water. Teachers can support these efforts by helping students find other resources to use such as maps, reports from other monitoring groups or government agencies, local experts, and other people who may have special insight into the history of the community.

As requested on the *Hydrology Site Definition Sheet*, please provide the manufacturer and model name for the test kits. If you change the type of kit, please update the site definition information.

All observations should be documented in Science Logs. They should also be reported in the *Hydrology Site Definition Sheet*, under *Comments*, and reported to GLOBE.

Photographs

Once each year, take photographs of your Hydrology Study Site and send them to GLOBE. Take four photographs, one in each cardinal direction (north, south, east, and west) while standing where you normally stand to collect your water sample. Have two sets of pictures printed, one for your records and one for GLOBE. Label each photograph with your school's name and address, the Hydrology Study Site name, and cardinal direction. Submit labeled copies of the photographs to GLOBE by mailing them to the address given in the *Implementation Guide*.

Field Map

Draw and submit a field map of your Hydrology Site each year following the guidelines in the *Mapping Your Hydrology Site Field Guide*. The field map will help you become familiar with your site and identify micro habitats as well as surrounding land cover that may affect the water.

Teacher Support

Each time you establish a new Hydrology Study Site, your students should fill out a new *Hydrology Site Definition Sheet*, take photographs of the site, and make a map following the *Documenting Your Hydrology Study Site* and *Mapping Your Hydrology Study Site Field Guides*. After the initial site description, you should update your site definition information, as well as take new pictures, create a new map, and submit them to GLOBE once a year. Ideally, this should be done at the beginning of the school year. If you are using a new group of students to take Hydrology measurements, use this opportunity to introduce them to your existing Hydrology Study Site. If you are using the same group of students, use this opportunity to explore and document any changes that may have occurred since the previous year. Maintaining your site definition information, providing current photographs and site maps of your Hydrology Study Site once a year, are essential for the interpretation of your Hydrology data by your students, other GLOBE students, and scientists alike.

When you create the map of your Hydrology Study Site select a stretch of at least 50 meters along the bank that contains the site where you collect your Hydrology measurements as well a variety of habitats. The *Mapping Your Hydrology Study Site Field Guide* asks students to walk along the 50-m stretch they are mapping. Students should do this only if it is safe for them to do so. If your site is a river or stream, the likely habitats you may find are,

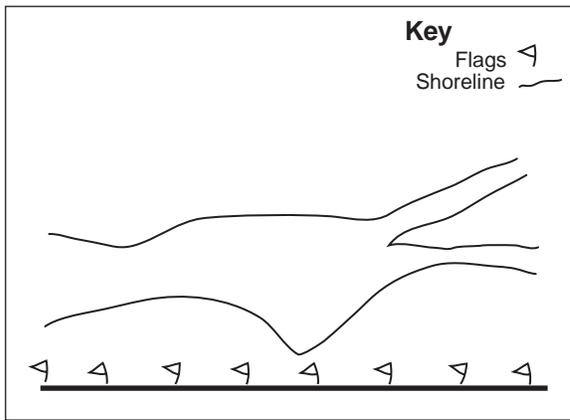
- run areas - where water flows freely and there is no turbulence;
- pool areas - where water is standing or still; finest sediments will deposit here;
- riffle areas - where there are rocky obstructions in the river bed resulting in turbulence; rocks deposit here;
- gravel bars – deposits of gravel within the stream, above the normal level of the water; and

- sand bars - deposits of sand within stream, above the normal level of the water.

If your study site is a lake, pond, reservoir, bay, ocean or other, likely habitats you will find are,

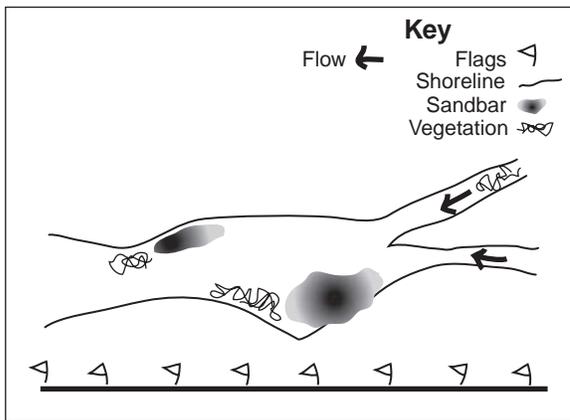
- vegetated banks: areas where vegetation grows into or hangs into the water;
- logs or snags: areas where partly or wholly submerged logs, branches, or other vegetation form habitat areas;
- aquatic vegetation: areas where submersed plants grow; and
- gravel, sand or silt: areas with no plants or debris.

The following is an illustrated example of creating a field map of a Hydrology Study Site.



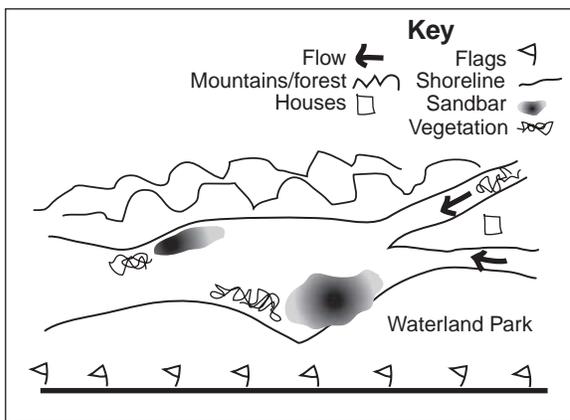
Begin by laying out a transect and marking it every 3 meters with flags. Each square on your paper will represent the area between two flags.

Draw the bank or coastline by measuring from the transect to the shore. If the far shore is too far away to fit on your map, indicate this with an arrow and the approximate distance.

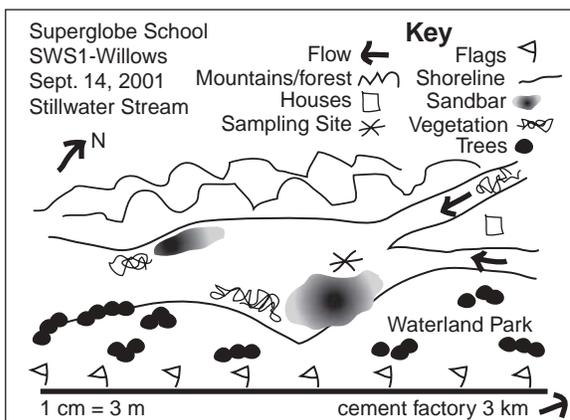


Add features to your water site. Show areas of different habitats, snags, dams or bridges, sand bars, etc. Use a different symbol in the Key to represent each feature.

Indicate the direction of water flow or inlet and outlets if known.



Add features from the surrounding area such as residential areas, trees, forests or grasslands, agricultural or recreational areas, parking lots, etc.



Add other features along the water site that might help identify your site or interpret your data such as cliffs, big trees, docks, limestone outcrops, clay deposits, etc.

Important features not shown on the map, such as industry or dams upstream, can be indicated with an arrow and approximate distance.

Add your school and site name, name of the water body, scale, north arrow, and date.

Documenting Your Hydrology Study Site

Field Guide

Task

Describe and locate your Hydrology Study Site.

What You Need

- Hydrology Site Definition Sheet
- GPS Protocol Field Guide
- Pencil or pen
- Compass
- GPS Receiver
- Camera
- GLOBE Science Log

In the Field

1. Fill in the information on the top of your *Hydrology Site Definition Sheet*.
2. Name your site by creating a unique name that describes the location of your site.
3. Locate your Hydrology Study Site following the *GPS Protocol Field Guide*.
4. Record the name of the water body you are sampling, using the name commonly used in maps. If your water body does not have a common name, then provide the name of the water body your water site comes from or flows into or both. For example, Unnamed Stream, Tributary to Green River; Unnamed Stream, Outlet from Whiterock Lake; Unnamed Stream, Outlet from Bear Lake, Tributary to Black Creek.
5. Record whether the water is salt water or fresh water.
6. If your water site is moving water, record whether it is a stream, river, or other and its approximate width in meters.
7. If your water site is standing water, record whether it is a pond, lake, reservoir, bay, ditch, ocean or other and whether it is smaller than, larger than, or about equal to a 50 m x 100 m area. If known, indicate the approximate area (km²) and depth (meters).
8. Record whether your sample location is an outlet, bank, bridge, boat, inlet or pier.
9. Record whether you can see the bottom.
10. Record the material from which the bank or channel is made.
11. Record the type of bedrock, if known.
12. Record the manufacturer and model number for each chemical test kit you are using, if any.

13. Record in the *Comments* section any information that may be important for understanding the water at your site. Some possible observations might be:
 - a. Any upstream discharge into your body of water
 - b. Whether the flow (streams) or water level (lakes) is regulated or is natural (for example, flow is regulated downstream of dams).
 - c. Types of plants and animals observed
 - d. Amount of vegetation in the stream
 - e. Human uses of the water: fishing, swimming, boating, drinking water, irrigation, etc.
 - f. Other information about why this specific site was selected.
14. Standing where you will be collecting your water sample, take four photographs of your sampling area, one in each cardinal direction (N, S, E, W). Use a compass to determine the direction.
15. Print two sets of photographs and label each photo with your school's name and address, your Hydrology Study Site name, and cardinal direction. Keep one set for your records.
16. Submit the other set to GLOBE by mailing them to the address given in the *Implementation Guide*.

Mapping Your Hydrology Study Site

Field Guide

Task

Make a scaled field map of your Hydrology Site.

Materials

- Hydrology Site Mapping Sheet (1 cm grid paper)
- Measuring tape (50 m)
- Compass
- Flags (18)
- Pencil/eraser

In the Field

1. Select a section of the bank at least 50 meters long as your study area, if possible. You may consider the entire water body as your study area if it is small enough. The area should contain the sampling site where you collect your water measurements as well as a variety of habitats.
2. Use the measuring tape to measure a straight transect, at least 50 meters long, parallel to the shoreline, and within 10 meters of the bank. The transect will be varying distances from the water if the bank is not straight.
3. Place flags at the two ends and at every 2 meters along the transect.
4. Start drawing your map using the flags to help keep it to scale.

Note: Using the *Mapping Field Sheet* or graph paper with 1 cm squares, each square should represent 2 meters. Put the scale on your graph.
5. Mark the transect and flag positions on the map.
6. Draw the waterline or bank by measuring from each flag directly to the water, placing a small dot on the map to show the waterline, then connect the dots with a dotted line to indicate the bank.
7. Put in the opposite bank or indicate the approximate distance to the opposite bank if known.
8. Use an arrow to indicate the direction of water flow or the inlet and outlet of your water body.
9. Create a key with symbols for special features found at your site. Use these symbols to indicate where special features are located on the map. Suggested features to include:
 - Within the sampling area: riffle areas, pools, vegetated areas, logs, rocky areas, gravel bars, sand bars, bridges, docks, jetties, dams, etc.

- Around the sampling area: land cover (or MUC codes), geological features such as cliffs or rocky outcrops, man-made features such as houses, parks, parking lots, factories, roads, dumps or debris, etc.
10. Show the location of your Hydrology Sampling Site.
 11. Include the following information on the map:
 - Name of site
 - Name of water body
 - North arrow
 - Date
 - Scale (e.g., 1 cm = 3 m)
 - Key to all symbols used on the map
 12. Photocopy your map and keep the original for your records.
 13. Submit a copy to GLOBE by mailing it to the address given in the *Implementation Guide*.

Note: Make sure to include your school's name and address, as well as the name of your Hydrology Study Site.

Frequently Asked Questions

1. Is it acceptable to use a man-made site, e.g. a pond built near the school?

Although natural sites are first in the order of preference, man-made sites may be used. Many lakes and ponds are man-made

2. My coastline curves. Is this an appropriate site?

You will seldom find a perfectly straight coastline. Try to pick as straight a stretch of coast as possible or an area of coast representative of the water body.

3. There are agricultural fields to the north of my site. How should I indicate them?

In the *Comments* section, note anything within your watershed that you think might affect the water. On the field map, note direction and approximate distance to major land cover features of the surrounding area.

4. My beach has both rocky and sandy shores. Should I choose a mix or try to find a site with just one type of habitat?

Try and find a site with just one type of habitat. The sampling procedures for different types of coast are different.

5. We live fairly near to a river, but my class can't go that far for sampling every week. Should we choose a less preferable, but closer site?



Try to sample water bodies that are significant to your area, even if you have to use a less frequent sampling strategy. Sites closer to the school, that can be sampled weekly, can also be chosen as a second sampling site. This often makes for interesting comparisons between the sites.

6. Can I choose a site that is sometimes dry?

Water sites may sometimes dry up, be frozen, or become flooded so that data cannot be collected. If one of these situations occurs, check 'dry', 'frozen' or 'flooded' on the data entry page for each week that you cannot collect a water sample. This will indicate to researchers that the site is still being monitored even though water data cannot be collected.

7. Can I have more than one site on a river or lake?

Multiple sites along a watershed are desirable. Significant differences might be found at sites with different depths, near different land cover, or in tributaries of a larger river or body of water.



Sampling Procedures



Quality Assurance and Quality Control

A quality assurance and quality control (QA/QC) plan is necessary to ensure that test results are as accurate and precise as possible. Accuracy refers to how close a measurement is to its true value. Precision means the ability to obtain consistent results. Accurate and precise measurements are achieved by,

- 
- practicing the measurement techniques of the protocols;
 - collecting the water sample or invertebrate sample as directed;
 - performing tests immediately after collecting the water sample;
 - carefully calibrating, using and maintaining testing equipment;
 - following the directions of a protocol exactly as described;
 - repeating measurements to check their accuracy and to determine any sources of error;
 - minimizing contamination of stock chemicals and testing equipment ;
 - checking to be sure the numbers submitted to the GLOBE Student Data Server are the same as those recorded on the *Hydrology Data Sheets*; and
 - examining your data for reasonableness and anomalies.



Calibration

Calibration is a procedure to check the accuracy of testing equipment. For example, to ensure that the pH instruments are functioning properly, a solution of known value is tested. Calibration procedures vary among the measurements and are detailed in each protocol. Certain calibrations must be done in the field just before the measurement is taken. Other calibration procedures are done in the classroom.



Collecting the Water Sample

If students are able to SAFELY reach the water body (within arms' reach), then water temperature, pH, dissolved oxygen, and electrical conductivity measurements can be taken on site (*in situ*) directly at the water's edge. However, the measurements of alkalinity, salinity, and nitrate require a sample to be taken with a bucket using the bucket sampling procedure. For electrical conductivity, if the temperature of the water sample is outside the range of 20-30°C, then allow the sample to adjust to the temperature within that range before conducting the measurement.

Important: The sequence in which the measurements are performed is critical to their accuracy and precision. Transparency measurements should be taken first, followed immediately by the water temperature measurements, the dissolved oxygen test, then electrical conductivity or salinity, pH, alkalinity, and finally nitrate.

If taking water measurements when students are collecting freshwater macroinvertebrates, collect water quality measurements first.

Testing for transparency, temperature, and dissolved oxygen must be done on site (*in situ*) immediately after collecting the water sample. Do not let the bucket of water sit for more than 10 minutes (preferably less) before taking the measurements and keep the water sample out of the sun. Take a new sample after 10 minutes.

A sample of surface water can be used with the transparency tube. The Secchi disk measurement is only appropriate for deeper water and measurements are generally taken from a bridge or pier, away from the water's edge.

The dissolved oxygen test may be started in the field and completed within 2 hours in the classroom. To do this, the sample is first fixed in the field (see the directions in your dissolved oxygen kit for fixing the sample).

Important: Dissolved oxygen measurements have limited value unless the temperature of the water is known. Measure dissolved oxygen only if you are able to measure water temperature. If your site has salty or brackish water you must also measure salinity in order to interpret the dissolved oxygen measurements.

Samples may be bottled (see *Bottling a Water Sample for Classroom Testing Field Guide*) and tested for pH, alkalinity, nitrate, and salinity or electrical conductivity after returning to the classroom. Measurement of pH and nitrate should be completed within two hours of collecting the sample. Alkalinity, electrical conductivity or salinity may be conducted within 24 hours. However, it is necessary to measure electrical conductivity before measuring pH to make sure the electrical conductivity is high enough to measure pH accurately. See *pH Protocol*.

Safety

Consult the Material Safety Data Sheets (MSDS) that come with test kits and buffer solutions. Also consult your local school district's safety procedure guidelines. If you are testing potentially contaminated water or using kits with chemicals, latex gloves and safety goggles are strongly recommended.

Disposal of Liquid Waste

After tests have been conducted, all resulting solutions or liquids (except for the ones produced by the nitrate analysis and salinity titration) should be collected in a wide-mouthed screw top plastic waste container and disposed of in a school sink or utility sink while flushing with excess water. Or, they should be disposed of according to your local school district's safety procedure guidelines. The wastes from the nitrate analysis and the salinity titration (which typically contain cadmium and chromate) should be collected in separate containers and disposed of according to your local school district's safety procedure guidelines.

Measurements (in the order to be taken)	Maximum time allowed between collecting the water sample and taking the measurements
Transparency (Secchi disk)	Testing always made <i>in situ</i>
Transparency (tube)	10 minutes
Water Temperature	10 minutes
Dissolved Oxygen	10 minutes at site or within 2 hours after sample is fixed
pH (using paper)	10 minutes on site or 2 hours after sample is bottled
pH (using meter)	10 minutes on site or 2 hours after sample is bottled
Conductivity	10 minutes on site or 24 hours after sample is bottled
Salinity (hydrometer)	10 minutes on site or 24 hours after sample is bottled
Salinity (titration kit)	10 minutes on site or 24 hours after sample is bottled
Alkalinity	10 minutes on site or 24 hours after sample is bottled
Nitrate	10 minutes on site or 2 hours after sample is bottled

Collecting a Water Sample in a Bucket

Field Guide

Task

Collect a water sample in a bucket for testing.

What You Need

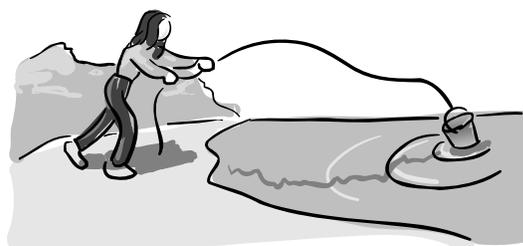
- Bucket with rope tied securely to handle
- Latex gloves (recommended)

In the Field

1. Rinse the bucket with sample water from the site. To avoid contamination, do not pour the rinse water back into the sampling area. Be careful not to disturb the bottom sediment. Do not use distilled water to rinse the bucket or use the bucket for any other purpose.
2. Hold tightly onto the rope. If your sampling site is a stream, throw the bucket out to a well-mixed area (a riffle), a little distance from the shore. Ideally, the water should be flowing at least slightly. If you are sampling from a lake, bay, or the ocean, stand on the shore and throw the bucket as far out as possible to collect your sample.
3. If the bucket floats, jostle the rope until some water enters the bucket. You should always take a sample from the top surface water. Be careful not to let the bucket sink to the bottom or stir up bottom sediment.
4. Allow the bucket to fill about $\frac{2}{3}$ to $\frac{3}{4}$ full and pull it back in with the rope.
5. Immediately begin testing procedures or bottle the sample (see *Bottling a Water Sample for Classroom Testing Field Guide*).



Rinsing the water bucket.



Casting the bucket.

Bottling a Water Sample for Classroom Testing

Field Guide

Task

Bottle a water sample to take back to the classroom for testing pH, conductivity or salinity, alkalinity, and nitrate.

What You Need

- 500-mL polyethylene bottle with lid
- Permanent marker
- Masking tape

In the Field

1. Label a 500-mL polyethylene bottle with your school's name, the teacher's name, the site name, the date and time of collection.
2. Rinse the bottle and cap with sample water 3 times.
3. Fill the bottle with sample water until the water forms a dome shape at the top of the bottle so that, when the cap is put on, no air is trapped inside.
4. Put on the cap and seal the cap of the bottle with masking tape.

Note: Tape serves as a label, and an indicator of whether the bottle has been opened. Tape should NOT be in contact with the water sample itself.

5. Store these samples in a refrigerator at about 4° C until they can be tested (within 2 hours for pH and nitrate and within 24 hours for alkalinity and salinity or electrical conductivity).
6. Once the seal is broken, first do the test for salinity or electrical conductivity, then pH, then nitrate test, and then alkalinity. The sample will need to reach 20° - 27° C before testing for electrical conductivity. Ideally, all the measurements should be performed during the same lab session.

Water Transparency Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Purpose

To determine the transparency of water using a Secchi disk (still, deep water) or transparency tube (flowing or shallow waters)

Overview

In still, deep water, students will lower a Secchi disk until it cannot be seen and then pull up the disk until it just reappears. In flowing or shallow waters, students will collect a sample of water in a bucket and then pour water into a transparency tube just until the bottom of the tube cannot be seen. Students will record the depth of water in the tube. The depth of water for both the Secchi disk and transparency tube depends on the amount of suspended and colored material in the water.

Student Outcomes

Students will learn to,

- use the Secchi disk or transparency tube;
- examine reasons for changes in the transparency of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries);
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Sciences

Water is a solvent.

Earth materials are solid rocks, soils, water and the atmosphere.

Physical Sciences

Objects have observable properties.

Life Science

Organisms change the environment in which they live.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a transparency tube or Secchi disk to measure water transparency.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes

Level

All

Frequency

Weekly

Materials and Tools

Hydrology Investigation Data Sheet

Cloud Cover Protocol Field Guide

Latex gloves

Secchi Disk Measurement

- *Secchi Disk Transparency Protocol Field Guide*
- Secchi disk (with rope)
- Meter stick
- Clothespins (optional)

Transparency Tube Measurement

- *Transparency Tube Transparency Protocol Field Guide*
- *Collecting a Water Sample in a Bucket Field Guide*
- Transparency tube
- Cup for pouring water into the tube

Preparation

If a Secchi disk or transparency tube is not purchased, one must be made.

Prerequisites

A brief discussion of how the Secchi disk or transparency tube is used to measure water transparency is necessary before students make their first measurement.

Practice protocol before taking measurements.



Water Transparency Protocol – Introduction

How clear is the water? This is an important question for those of us who drink water. It is an even more important question for the plants and animals that live in the water. Suspended particles in our water behave similarly to dust in the atmosphere. They reduce the depth to which light can penetrate. Sunlight provides the energy for photosynthesis (the process by which plants grow by taking up carbon, nitrogen, phosphorus and other nutrients, and releasing oxygen). How deeply light penetrates into a water body determines the depth to which aquatic plants can grow.

Transparency decreases with the presence of molecules and particles that can absorb or scatter light. Dark or black material absorb most wavelengths of light, whereas white or light materials reflect most wavelengths of light. The size of a particle is important as well. Small particles (diameters less than 1 μm) can scatter light.



The fate of light entering a water body depends on the amount, composition and size of the dissolved and suspended material. “Hard” water lakes with lots of suspended CaCO_3 particles preferentially scatter blue-green light, whereas lakes with organic materials appear more green or yellow. Rivers with high loads of sediments are often the color of the sediments (e.g. brown).

Sediments can come from natural and human sources. Land with little vegetative cover (such as agricultural land and deforested land) can be major sources of sediments. Colored organic material can come from *in situ* productions such as detritus and biota or from inputs into the water body.

GLOBE offers two techniques to measure transparency. If your hydrology site is at a water body that is deep and still (not flowing as a stream), use the Secchi disk. If your site is at a water body that is shallow or flowing, then you need to use the transparency tube. These two measurements are related but slightly different. Both measure transparency; however, you cannot directly compare Secchi disk and transparency tube measurements between sites.

Figure HY-TR-1: Measuring Transparency in Shallow or Running Water

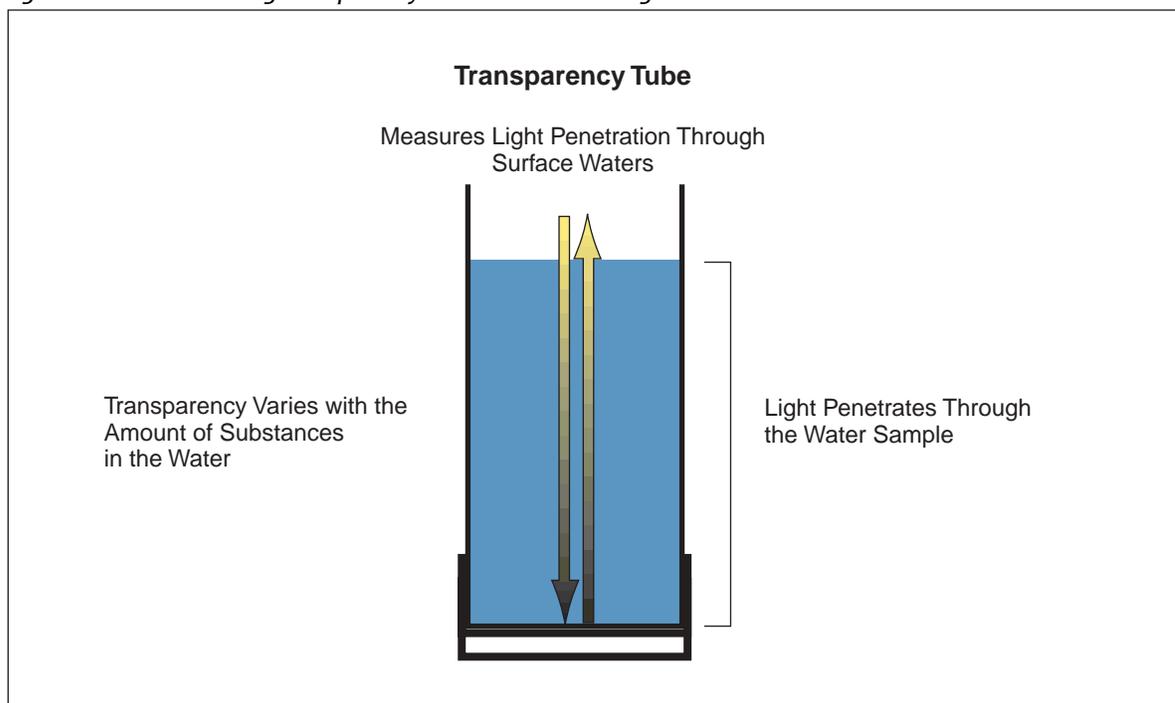
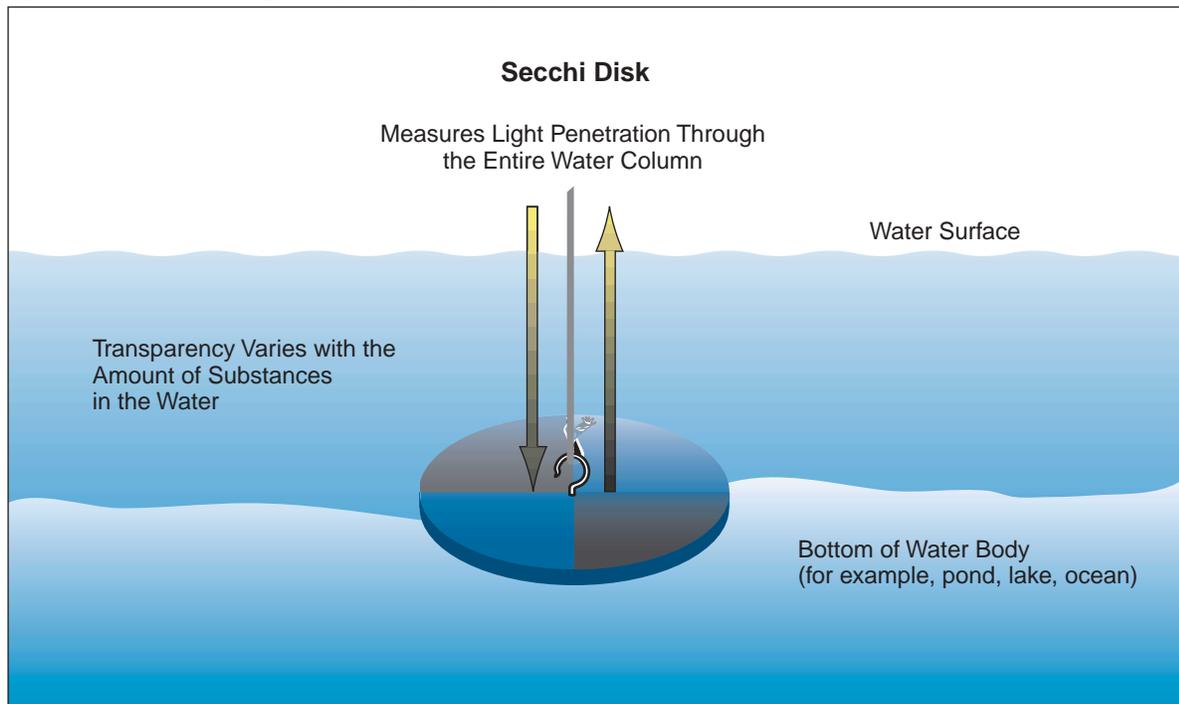


Figure HY-TR-2: Measuring Transparency in Deep and Still Water



The Secchi disk measures a column of water. Light penetration may vary with depth in that column of water. All light being reflected from the Secchi disk is passing through the water from the surface. The transparency tube, on the other hand, measures the transparency of a sample of water taken from just below the surface. Light may enter the transparency tube from the sides as well as the top. Because the water sampling is different (a column vs. a surface sample) and the instrument used does not allow equivalent penetration of light, the two measurements are not directly comparable. Figures HY-TR-1 and HY-TR-2 illustrate these differences.

Teacher Support

Supporting Protocols

Atmosphere: Atmospheric data, such as precipitation and temperature, can be important to the interpretation of transparency data. Transparency may change rapidly in response to inputs of water, such as precipitation or runoff from snowmelt. Snowmelt will occur when the air temperature warms enough to melt the snow.

Land Cover: Seasonal changes in land cover may affect transparency. For instance, runoff from agricultural fields during plowing may cause transparency changes. Land cover changes may increase erosion rate by exposing the soil. It is helpful to know the land cover upstream of your Hydrology study site in order to interpret your transparency data.

Supporting Activities

The *Transparency Protocol* may be used to illustrate how different variables may affect a measurement (*Practicing Your Protocols: Transparency*). Students can graph variations in their data resulting from taking the measurement in the sun, shade, wearing



sunglasses, waiting different amounts of time before taking the reading, etc. These experiments help students to understand the importance of following the protocols, as well as help them identify the variables that affect transparency.



Measurement Procedures

The *Transparency Protocol* asks for cloud cover measurements. See the *Cloud Protocol* in the *Atmosphere Investigation*.



Transparency measurements are made in the shade. Glare on the water from sunlight or differences in visibility between measurements on cloudy days or sunny days may affect the measurements. To standardize the data, all measurements are made in the shade.

Secchi Disk Protocol

The *Secchi Disk Transparency Protocol* asks for three measurements: 1) the distance between the water surface and where the disk disappears, 2) the distance between the water surface and where the disk reappears, and 3) the distance between the observer and the water surface. If you are taking measurements at the water surface, then record “0” for the last measurement. Knowing the distance between the observer and the water surface helps scientists better interpret and compare data among sites.



If the Secchi disk reaches the bottom of your water body before it disappears, record the depth of the water with a greater sign (e.g., >30 m).

Do not mark the rope for the Secchi disk with distance measurements so that you can read the depths directly on the rope. Often ropes stretch when they are wet. It is better to use the meter stick than to mark the rope.



Instrument Maintenance

1. Rinse the transparency tube or Secchi disk with clean water after use, then let it drain and dry completely.
2. Store the tube with an extra PVC cap over the open end to protect it from damage.
3. Do not store meter sticks inside the tube – dampness may warp the stick or cause the varnish to peel off.

Questions for Further Investigation

Does the transparency of the water change with other parameters, such as precipitation, water temperature, wind speed and direction, seasons, and land cover?

How would major changes in land cover around your Hydrology Site (e.g., forest fire or clear cutting) affect water transparency at your site?

Secchi Disk Transparency Protocol

(for deep, still waters)

Field Guide

Task

Measure the transparency of your water sample.

What You Need

- | | |
|---|---|
| <input type="checkbox"/> Hydrology Investigation Data Sheet | <input type="checkbox"/> Meter stick |
| <input type="checkbox"/> Cloud Cover Protocol Field Guide | <input type="checkbox"/> Pen or pencil |
| <input type="checkbox"/> Secchi disk with rope attached | <input type="checkbox"/> Clothespins (optional) |

In the Field

1. Fill in the top portion of the *Hydrology Investigation Data Sheet*.
2. Record the cloud cover (see *Cloud Cover Protocol Field Guide* in the *Atmosphere Investigation*).
3. Stand so that the Secchi disk will be shaded or use an umbrella or piece of cardboard to shade the area where the measurement will be made.
4. If you cannot reach the water surface, establish a reference height. This can be a railing, a person's hip, or the edge of a dock. All measurements should be taken from this point.
5. Lower the disk slowly into the water until it just disappears.
6. Mark the rope with a clothespin at the water surface or, if you cannot easily reach the water surface (for example, if you are standing on a dock or bridge), mark the rope at your reference height.
7. Lower the disk another 10 cm into the water, then raise the disk until it reappears.
8. Mark the rope with a clothespin at the water surface or at your reference height.
9. There should now be two points marked on the rope. Record the length of the rope between each mark and the Secchi disk on your *Hydrology Investigation Data Sheet* to the nearest cm. If the depths differ by more than 10 cm, repeat the measurement and record the new measurements on your *Data Sheet*.
10. If you marked the rope at the water surface, record "0" as the distance between the observer and the water surface.
11. If you marked the rope at a reference point, lower the disk until it reaches the surface of the water and mark the rope at the reference point. Record the length of the rope between the mark and the Secchi disk as the distance between the observer and the water surface.
12. Repeat steps 5-11 two more times with different students observing.



Frequently Asked Questions

1. When comparing data between sites, do you need to make an adjustment for data taken at the water surface compared to data taken from a bridge or dock?

This distance is not used to adjust the Secchi disk data. However, reporting the distance between the observer and the water helps in data interpretation.



2. My students are using a pond for our hydrology measurements.



They go out in a boat and use a Secchi disk for the transparency. We are not sure of the two measurements we are asked to give. They measure the line at the surface of the water to the top of the disk when it disappears and reappears. What is the other measurement?

For the other measurement, distance from where you read the line to the water surface, you should enter zero. Some schools will make Secchi disk readings from a bridge or pier, and report the depth measured using a reference level that is not the water surface, but some distance above the water surface. So they need to also enter the distance from the pier to the water. That way we have all of the raw data in the database.

Transparency Tube Transparency Protocol

(for shallow or flowing waters)

Field Guide

Task

Measure the transparency of your water sample.

What You Need

- Hydrology Investigation Data Sheet*
- Collecting Your Water Sample in a Bucket Field Guide*
- Cloud Cover Protocol Field Guide*
- Transparency tube
- Cup for pouring water into the tube
- Latex gloves
- Pen or pencil

In the Field

1. Fill in the top portion of the *Hydrology Investigation Data Sheet*.
2. Record the cloud cover. See *Cloud Cover Protocol Field Guide* from *Atmosphere Investigation*.
3. Put on gloves. Collect a surface water sample. See *Collecting Your Water Sample in a Bucket Field Guide*.
4. Stand with your back to the sun so that the transparency tube is shaded.
5. Pour sample water slowly into the tube using the cup. Look straight down into the tube with your eye close to the tube opening. Stop adding water when you cannot see the pattern at the bottom of the tube.
6. Rotate the tube slowly as you look to make sure you cannot see any of the pattern.
7. Record the depth of water in the tube on your *Hydrology Investigation Data Sheet* to the nearest cm. **Note:** If you can still see the disk on the bottom of the tube after the tube is filled, record the depth as >120 cm.
8. Pour the water from the tube back into the sample bucket or mix up the remaining sample.
9. Repeat the measurement two more times with different observers using the same sample water.



Frequently Asked Questions



1. Is it all right to make a small hole in the transparency tube near the bottom, fill the tube with water, then slowly release water until the pattern at the bottom appears?

This method is acceptable as long as the measurement is made very quickly. Particles settle quickly, especially if they are being pulled down by water being released at the bottom. The reading must be made before particles settle and obscure the pattern.



Water Transparency Protocol – Looking at the Data

Are the data reasonable?

As always the first thing a researcher should ask when looking at data is: Does the data seem reasonable and make sense? However, when dealing with transparency data, this might not be an easy question to answer. As some general guidelines, most natural waters have transparency values ranging from 1 meter to a few meters. A low value, less than 1 meter, would be expected in a highly productive (i.e., lots of microscopic algae) body of water. A low value can be due also to a high concentration of suspended solids. Extremely clear lakes, coastal waters and areas around coral reefs can have transparency values of up to 30-40 m.

Transparency values, however, can be highly variable, even within a single body of water. Suspended particulates of varying nature effect how transparent a water body is. Some of these substances include soil, algae and other planktonic organisms, decaying leaves, and various pollutants. Transparency can also change with respect to time. For example, a large rainstorm could drastically reduce the transparency in a stream, river or pond over the course of minutes by the introduction of turbid runoff. A sudden warming during spring can produce a large influx of snowmelt that could increase the transparency. Since transparency is very site specific, the best way to see if the data are reasonable is to keep collecting samples over several years or longer. The data in Figure HY-TR-3 seem reasonable because the points in this data show a temporal trend. The large number of consistent data points makes this trend apparent. When looking at Figure HY-TR-4 the erratic nature of these data points makes it unclear if these data are reasonable. A more consistent data record could show that a trend is indeed present. However, these data could be perfectly reasonable without the presence of a trend because its erratic nature could be caused by any combination of the above-mentioned factors.

What do scientists look for in these data?

Transparency data can give a good indication of the biological productivity of a water body. Typically a productive lake will have low transparency due to an abundance of biota (particularly algae). If the Secchi depth is less than 1 m, small changes in nutrient inputs can cause major changes in productivity and therefore in transparency. During warm weather in highly productive lakes, oxygen depletion can occur, causing massive fish kills. The depth to which light penetrates determines the depth at which rooted plants can grow.

Yearly trends in transparency data can be used to investigate annual cycles within a water body. A good example of this is the data in Figure HY-TR-3 that was taken from the inlet of a reservoir in Czech Republic. There is an apparent increase in transparency during winter months and a decrease in transparency for the summer months. One possible explanation is that algae are a major factor affecting the transparency of this water body. In the summer months, the algae are in greater abundance causing the transparency to decrease. Winter months, decreased sunlight, and cold temperatures are usually associated with low algal production leading to an increase in transparency. Seasonal trends in precipitation might be seen in the transparency data as well.

Transparency is not a good indicator of water quality. It provides information on how many particulates are in a water sample, but does not reveal the nature of these particulates. Therefore, a clear water sample with a high transparency could contain harmful substances while a more turbid sample with lower transparency could be harmless.

Example of a Student Research Investigation.

Forming a Hypothesis

A student decides to look for seasonal variations in GLOBE transparency measurements. He first looks for GLOBE schools that have taken transparency data. In order to have enough data points to draw some conclusions, he looks only at schools that have taken 30 or more transparency measurements.



He finds an interesting trend in the data from Crescent Elk School, California. The measurement site, Elk Creek, shows higher transparency values in the summer months and lower values in the winter months. This student realizes that this trend is the opposite of what one would expect if algal growth was the primary factor controlling transparency. The student remembers learning somewhere that the winter months are the rainy season for the West Coast of the United States.

Since quite often increased rainfall is associated with increased runoff, he hypothesizes that in Elk Creek transparency levels will be lower during the raining season and higher during the dry season.

Collecting and Analyzing Data

Using the GLOBE Web site, the student plots both the transparency tube measurements and the precipitation data for Elk Creek from July 1998 to July 2001. From this graph there appears to be a correlation between the two data sets. See Figure HY-TR-5.

He then downloads the monthly averages for precipitation and transparency tube measurements for this site (Table HY-TR-1). He then plots the data on two different axes in a plotting program. It is now apparent from this plot that there is indeed a correlation between precipitation and transparency in the Crescent Elk data (Figure HY-TR-6). The correlation is best seen in the data from the summer months of 1998 to the winter months of 1999. The transparency plot is inversely proportional to the precipitation for this time. In other words, the transparency decreases as the amount of precipitation increases. There are some extraneous peaks in the transparency data, but this can be expected. Transparency is influenced by many additional factors other than precipitation.

The precipitation for 2000 was more sporadic for this site. It does not show as strong a seasonal trend as the other years examined. This is also reflected in the transparency data for this time period.

Based on these results he concludes that the initial hypothesis was partially supported by the data. It appears that the transparency for the Elk Creek site is influenced by precipitation events, however there are other factors also affecting transparency.

Future Work

He now wants to contact the Elk Creek School and discuss his hypothesis with them. The school might be able to provide clues as to what other factors may be influencing the transparency in the creek.

He is curious to look at other school data to see if the pattern for transparency is similar or different.

Table HY-TR-1

Month	Ave. Rain (mm)	Ave. Turb. Tube (cm)
7/1998	0	125
8/1998	0	125
9/1998	0	125
10/1998	88.3	101
11/1998	431.4	
12/1998	265.0	101
1/1999	188.4	96
2/1999	390.1	102
3/1999	103.6	90
4/1999	62.3	119
5/1999	72.5	104
6/1999	4.5	113
7/1999	1.0	110
8/1999	11.5	115
9/1999	4.0	77
10/1999	43.0	115
11/1999	137.0	99
12/1999	143.4	86
1/2000	470.5	92
2/2000	316.7	83
3/2000	306.3	94
4/2000	452.0	105
5/2000	451.2	85
6/2001		125

Figure HY-TR-3

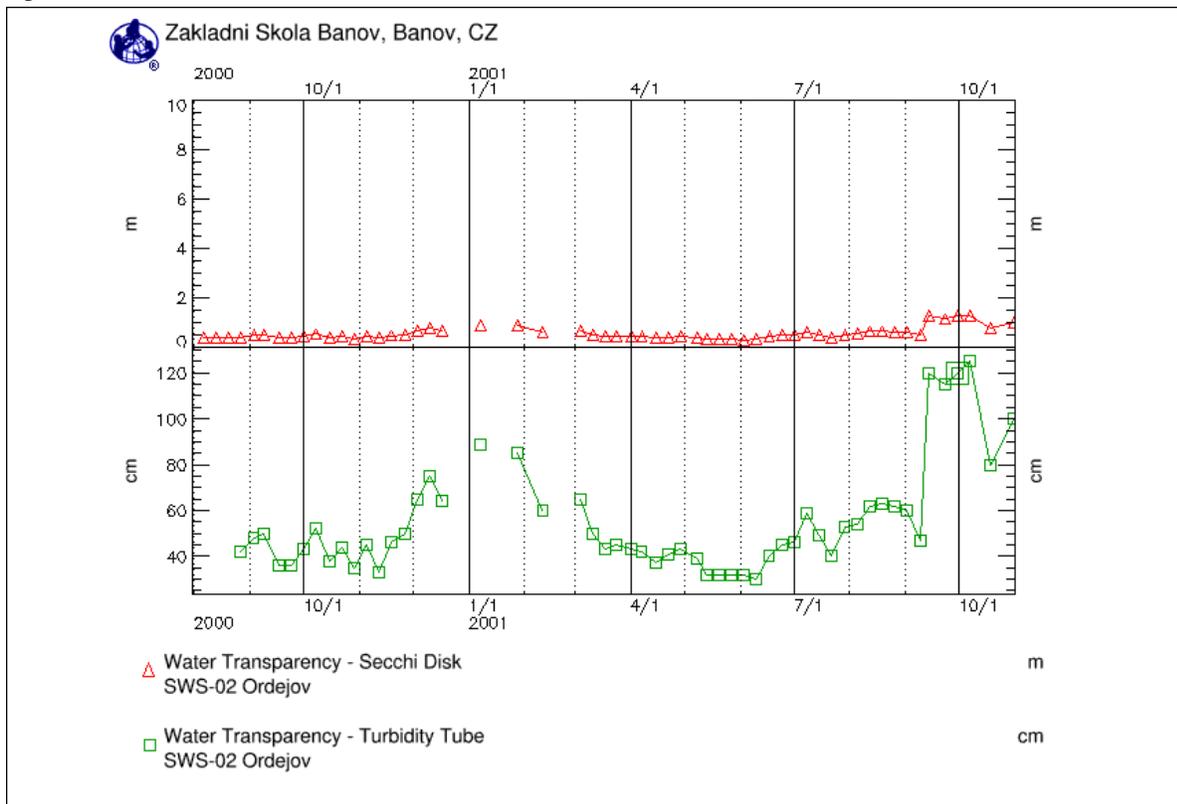


Figure HY-TR-4

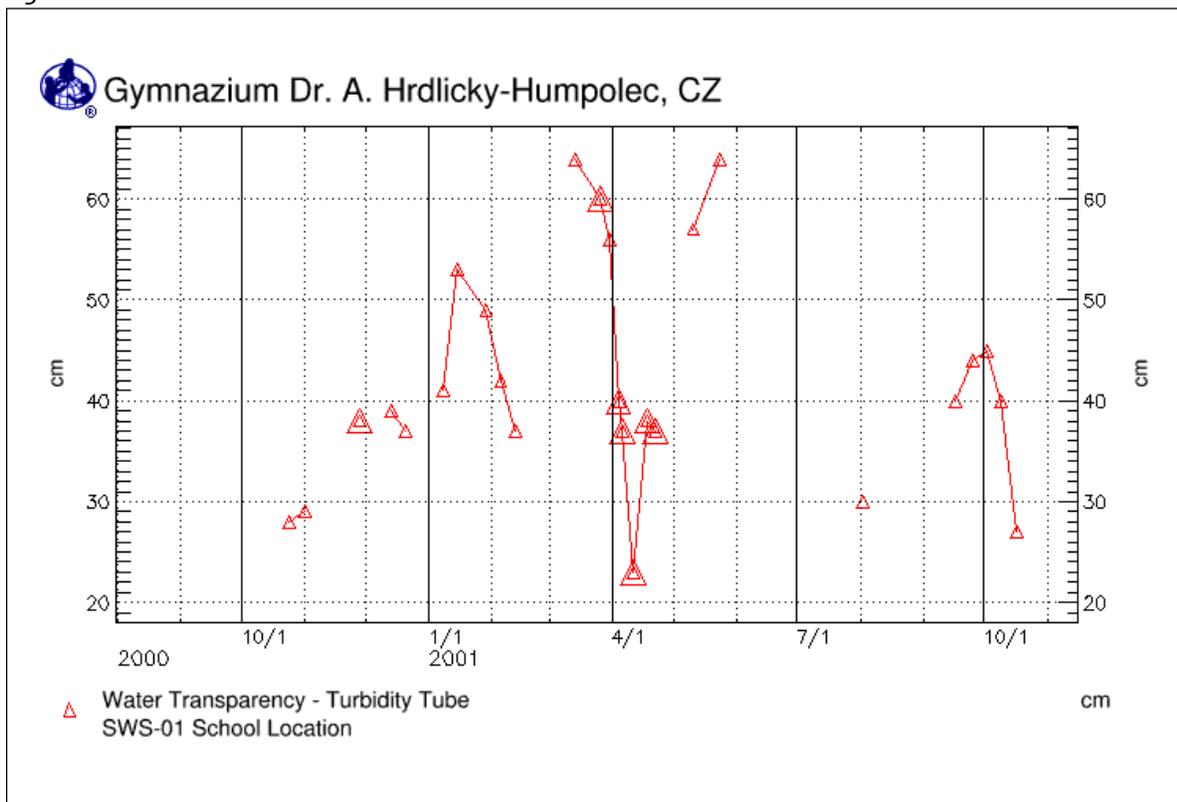


Figure HY-TR-5

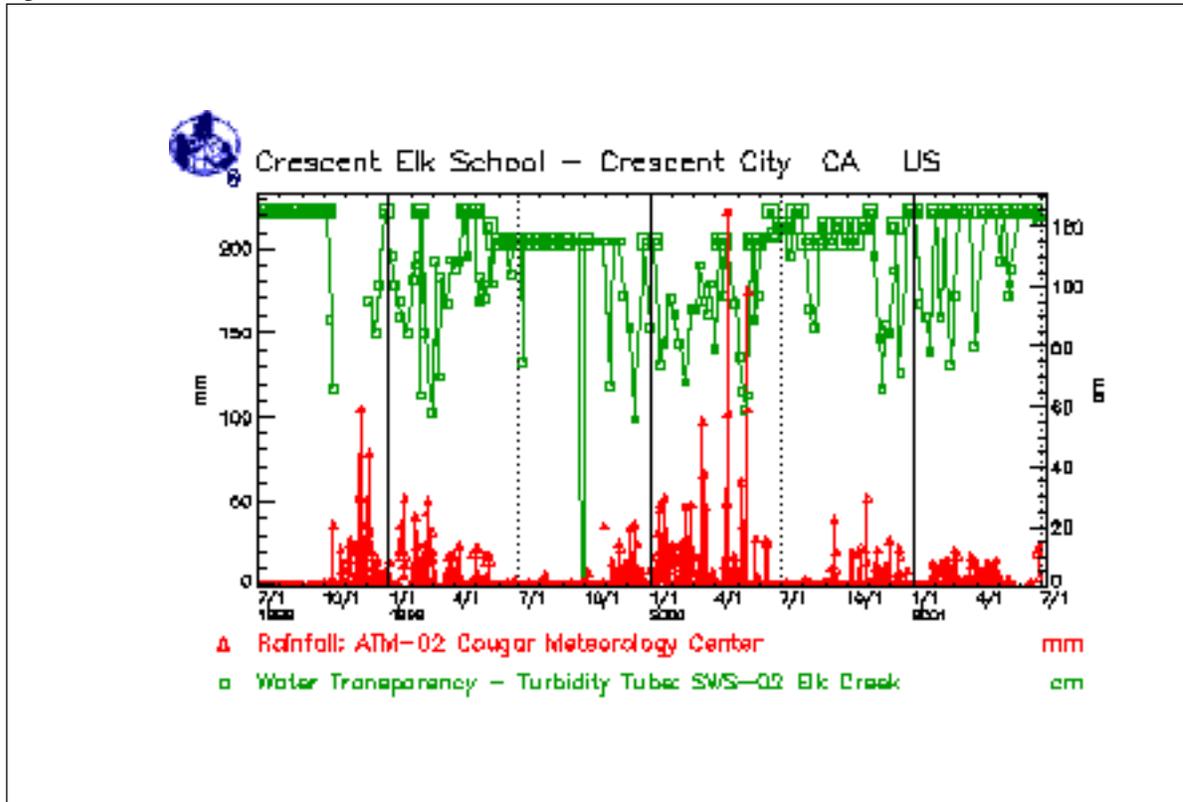
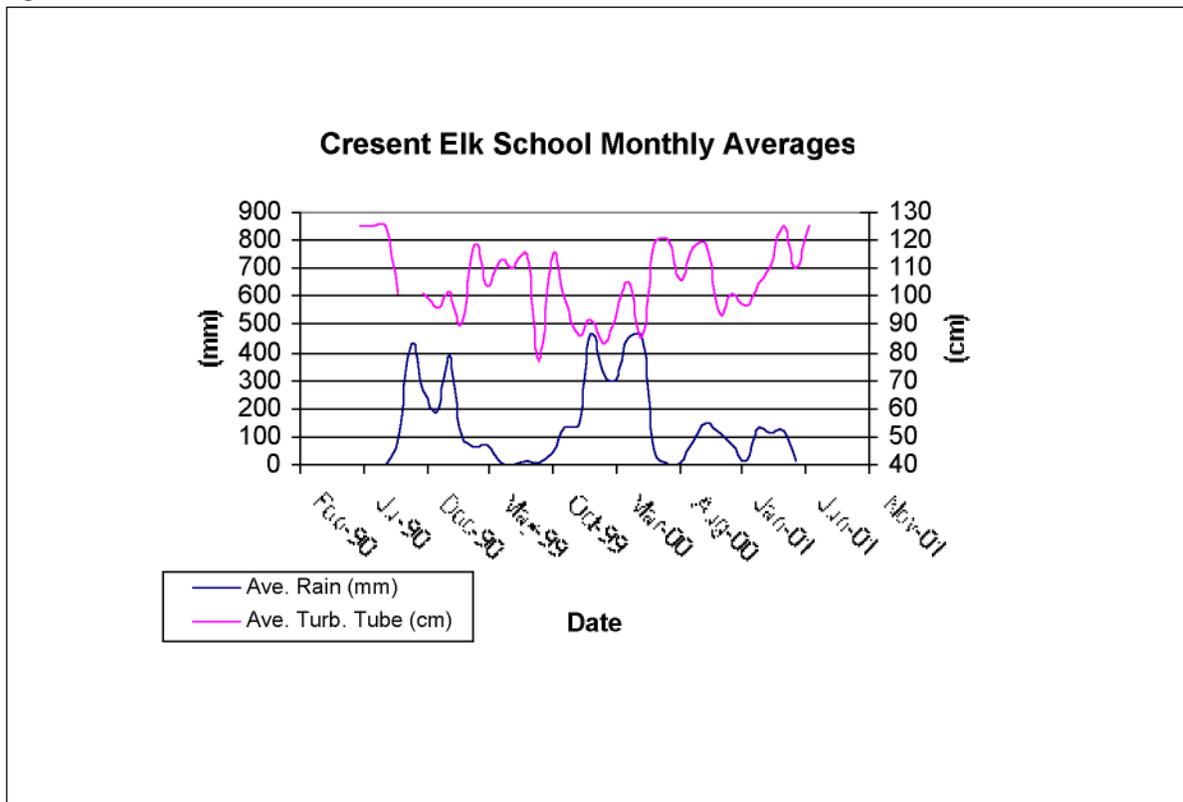


Figure HY-TR-6



Water Temperature Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Purpose

To measure the temperature of a water sample

Overview

Students use an alcohol-filled thermometer to measure the temperature of water.

Student Outcomes

Students will learn,

- how to use a thermometer;
- examine reasons for changes in the temperature of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Sciences

Earth materials are solid rocks, soils, water and the atmosphere.

Physical Sciences

Objects have observable properties.

Life Science

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a thermometer to measure water temperature.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes; Calibration: 5 minutes

Level

All

Frequency

Weekly

Calibration every 3 months

Materials and Tools

Hydrology Investigation Data Sheet

Water Temperature Protocol Field Guide

Alcohol-filled thermometer

Latex gloves

Clock or watch

Enough string to lower the thermometer into the water

Rubber band

For Calibration:

- *Calibrating the Hydrology Thermometer Lab Guide*
- Thermometer
- 400 mL ice
- Distilled water
- 500 mL beaker

Preparation

None

Prerequisites

None



Water Temperature Protocol – Introduction

Temperature is an easy measurement to make. It is, however, very important because it allows scientists to better understand other hydrology measurements such as dissolved oxygen, pH and conductivity.



Temperature influences the amount and diversity of aquatic life. Lakes that are cold and have little plant life in winter, bloom in spring and summer when water temperatures rise and the nutrient-rich bottom waters mix with the upper waters. Because of this mixing and the warmer water temperatures, the spring overturn is followed by a period of rapid growth of microscopic aquatic plants and animals. Many fish and other aquatic animals also spawn at this time of year when the temperatures rise and food is abundant. Shallow lakes are an exception to this cycle, as they mix throughout the year.



Water temperature is also important because warm water can be fatal for sensitive species, such as trout or salmon, which require cold, oxygen-rich conditions. Warmer water tends to have lower levels of dissolved oxygen.



Finally, water temperature is important for understanding local and global weather patterns. Water temperatures change differently than air temperatures because water has a higher heat capacity than air. Water also helps to change air temperature through the processes of evaporation and condensation.



Teacher Support

Advance Preparation

Use the *Practicing Your Protocols: Water Temperature Learning Activity* to help students explore sources of error in their temperature collection procedure.

Make sure that the thermometer has been calibrated within 3 months.

Supporting Protocols

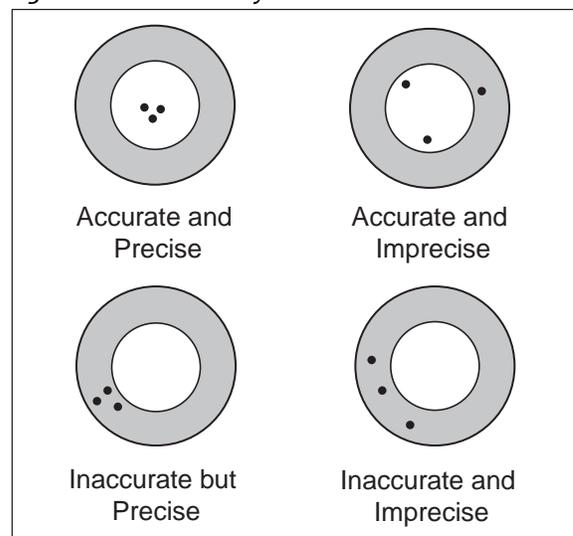
Air and Soil Temperature Protocols: Integration of the water temperature with atmosphere and soil temperatures provides an excellent example of how different substances transfer and retain heat differently, resulting in a better understanding of how energy is transferred and stored in the Earth's system.

Supporting Activities

The measurement of water temperature provides a good opportunity for teachers to introduce basic concepts of data accuracy and precision.

Data are accurate when the sample average (average of student observations) is equal to the true average. Data are precise when the student observations fall within a narrow range. Results may be accurate, though imprecise, when students have a wide scatter in their observations.

Figure HY-TE-1: Accuracy vs. Precision



Results may be precise, though inaccurate, when student measurements are within a narrow range, but when the mean does not equal the true mean.

The GLOBE Hydrology *Temperature Protocol* is designed so that the data students' report are both accurate and precise. Students are required to take at least three measurements and then calculate the mean. If any of the observations fall more than 1.0° C away from the mean, the measurement is done again to improve the precision of the data.

Measurement Procedures

Because water temperature is an easy measurement to take, students sometimes become careless about following the protocol. Sources of error include not leaving the instrument in the water long enough to stabilize, removing the thermometer from the water so that the measurement changes before it can be read, and not reading the thermometer at eye level.

Except for transparency, water temperature is taken before the other water measurements. Take the water temperature measurement as soon as possible after the water sample is taken because temperature tends to change very rapidly after a sample is collected.

Read the temperature value on the thermometer while the bulb of the thermometer is in the water. The temperature reading can change quickly once the thermometer is out of the water, especially if the air temperature is very different from the water temperature or if it is windy. Wind can cause evaporation to occur rapidly, lowering the temperature

It is important that the water temperature be taken at the same place every week. There may be several degrees of difference in water temperature over a small area in your water body: sunny areas vs. shady areas, or shallow and deeper areas.

Attach a string, long enough to reach the water, to the top of the thermometer. Tie a rubber band to the other end of the string. Have students slip the rubber band over their wrist when taking the temperature to avoid dropping or losing the instrument.

The alcohol column in the thermometer may become separated, especially if the thermometer is not stored in an upright position. Students are asked to examine their instrument and report this problem to the teacher. The column may be rejoined by holding tightly to the top of the thermometer and shaking it down or swinging it.

Instrument Maintenance

1. Make sure that the string and rubber band attached to the thermometer are not frayed before each use.
2. Store the thermometer upright in a beaker or other holder. Storing the thermometer on its end prevents the alcohol column from separating.
3. Make sure that the alcohol column is continuous and has not become separated.

Helpful Hints

Use the *Calibrating the Hydrology Thermometer Lab Guide* to check the accuracy of a new thermometer. If the new thermometer is not reading correctly, contact the manufacturer.

Questions for Further Investigation

How does a sudden change in air temperature affect water temperature?

Is the range of air temperature different in areas next to large water bodies as compared to areas away from water bodies?

How do water temperatures compare to air temperatures in the winter? In the summer?

Calibrating the Hydrology Thermometer

Lab Guide

Task

Calibrate the alcohol-filled thermometer.

What You Need

- Alcohol-filled thermometer
- 100-mL distilled water
- 500 mL beaker
- 400-mL crushed ice

What to Do

1. Stir together 100 mL of water and 400 mL of crushed ice in the beaker to make an ice-water bath.
2. Let the ice-water bath sit for 10 to 15 minutes so that it reaches its lowest temperature.
3. Put the bulb of the thermometer into the bath. Gently move the thermometer around in the ice-water bath.
4. Leave the thermometer in the water for three minutes.
5. Read the temperature without removing the bulb of the thermometer from the water.
6. Let the thermometer stay in the water sample for one more minute.
7. Read the temperature again. If the temperature has not changed, go to Step 8. If the temperature has changed since the last reading, repeat Step 6 until the temperature stays the same.
8. The thermometer should read between -0.5° and 0.5° C.
9. If the thermometer does not read the proper temperature, notify your teacher. These thermometers do not have an adjustment and must be replaced if they do not read temperature with the expected accuracy ($\pm 0.5^{\circ}$ C).

Water Temperature Protocol

Field Guide

Task

Measure the temperature of your water.

What You Need

- Hydrology Investigation Data Sheet
- Alcohol-filled thermometer
(with string and rubber band attached)
- Clock or watch
- Latex gloves
- Pen or pencil

In the Field

1. Fill out the top portion of your *Hydrology Investigation Data Sheet*.
2. Put on the gloves.
3. Slip the rubber band around your wrist so that the thermometer is not accidentally lost or dropped into the water.
4. Check the alcohol column on your thermometer to make sure there are no air bubbles trapped in the liquid. If the liquid line is separated, notify your teacher.
5. Put the bulb end of the thermometer into the sample water to a depth of 10 cm.
6. Leave the thermometer in the water for three minutes.
7. Read the temperature without removing the bulb of the thermometer from the water.
8. Let the thermometer stay in the water sample for one more minute.
9. Read the temperature again. If the temperature has not changed, go to Step 10. If the temperature has changed since the last reading, repeat Step 8 until the temperature stays the same.
10. Record the temperature on the *Hydrology Investigation Data Sheet*.
11. Have two other students repeat the measurement with new water samples.
12. Calculate the average of the three measurements.
13. All temperatures should be within 1.0° C of the average. If they are not, repeat the measurement.



Frequently Asked Questions

1. I noticed on the GLOBE Web site that some schools were reporting water temperatures below 0.0° C. Is this possible?

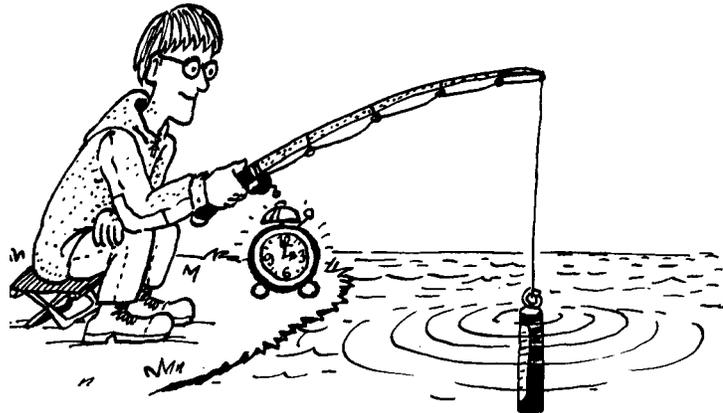
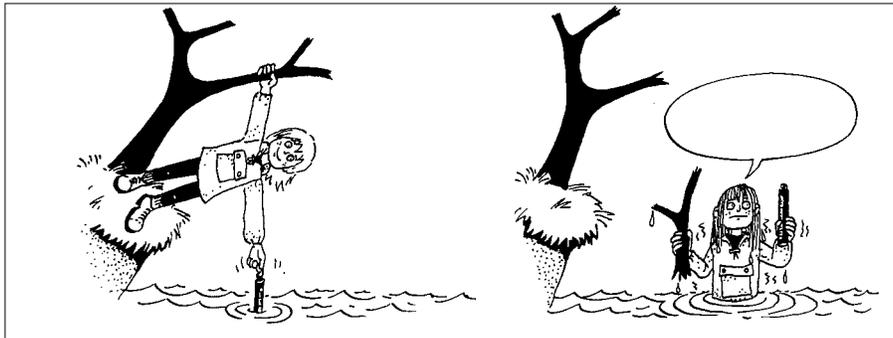
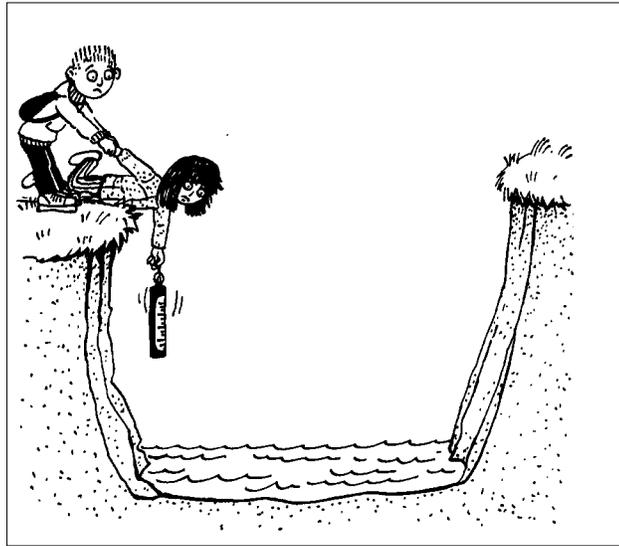
Yes. Distilled water will freeze at 0.0° C, but adding dissolved particles in the water may lower the freezing point.

2. Why is the water temperature sometimes colder and sometimes warmer than the air temperature?



Water has a higher *specific heat* than air.

This means it takes water longer to heat up and longer to cool down than it does air. As a result, air responds much more quickly than water to changes in temperature.



Source: Jan Smolik, 1996, TEREZA, Association for Environmental Education, Czech Republic



Water Temperature Protocol – Looking at the Data

Are the data reasonable?

Water temperature generally shows strong seasonal patterns. Graph the water temperature over time to create a picture of these patterns. Extreme outliers should be easy to recognize. An outlier is a measurement that has a value very different from the values of other data taken on days shortly before or after the extreme value. Also, graph the water temperature with the air temperature. Since water temperature generally changes more slowly than air temperature, there will be a delay (days to weeks) in changes of water temperature compared to air temperature. The range of water temperatures will also be narrower.

Can the water temperature be below zero? Many students believe they have found an error if the water temperature is a negative number. However, 0.0° C is the freezing point for distilled water. Water that has dissolved salts has a lower freezing point.

What do scientists look for in these data?

Water temperature is sometimes called a master variable because almost all properties of water, as well as chemical reactions taking place in it, are affected by it. Dissolved oxygen is strongly correlated with temperature. A graph of the water temperature and dissolved oxygen shows that oxygen solubility increases for colder temperatures.

Sudden increases or decreases of water temperature are unusual. Water has a higher heat capacity (specific heat) than air, thus it heats and cools more slowly. Unusual swings in water temperature of the expected seasonal patterns should be investigated. Identify the watershed for your site. Possible sources of sudden temperature changes might be due to release of water from upstream dams, factories, or snowmelt.

Example of a Student Research Project

Project 1

Forming a Hypothesis

Students in Czech Republic are examining plots of water temperature. They are plotting the average monthly water temperatures for several surface water sites in Czech Republic. They notice an interesting trend in the data for SWS-01, collected by Zakladni Skola Bystrice Nad Perstejnem. Site metadata indicates that this water body is the Bystrice River. According to their plot (Figure HY-TE-2), average monthly water temperature in the summer months (June, July, August) seems to be increasing each year from 1997 through 2001.

The students hypothesize that: *increases in water temperature are a result of increase in air temperature.*

Collecting and Analyzing Data

The students create a plot combining monthly mean air temperature and surface water temperature on the same plot (Figure HY-TE-3). Air temperature is clearly increasing in the summers over this same time period, except in July 2000, when air temperature and water temperature are *both* lower. Therefore, the students conclude the rising summer air temperature is responsible for the rising stream temperature. Their hypothesis is correct.

Note: In Figure HY-TE-3, the scale for the water temperature is on the left side of the graph, and the scale for the water temperature is on the right side of the graph. The scales are not the same. Downloading and plotting the data on the same scale – see Figure HY-TE-4, for an example – can also be useful, and allow you to more easily compare the actual values, and not just the trends.

Communicating Results

The students present this result to their class and use it as the starting point for a discussion. Next ask the question: Is this trend seen at all nearby sites?



Project 2

Forming a Hypothesis

The students who worked on the previous project are interested in continuing their research. They now want to know if the trends they observed for the surface water in the Bystrice River appears in other areas nearby. In other words, is this local occurrence or is it fairly widespread?

They hypothesize that: *other sites nearby should show the same increase in water temperature and air temperature.*

Collecting and Analyzing Data

They look at the surface water data for their country on the GLOBE server and see that the four schools with the most surface water data are: Zakladni Skola - Ekolog. Praktikum in Jicin; Zakladni Skola, Bystrice Nad Perstejnem in Bystrice; Zakladni Skola Banov in Banov; and Zakladni Skola, Postoloprty in Postoloprty.

They have already looked at the data for the Bystrice River. The other three surface water sites are the Cidlina River in Jicin, the Ordejov Reservoir in Banov, and the Ohre River in Postoloprty. (**Note:** To see the names and descriptions of some of the water bodies, it is useful to check the site information/metadata on the sites!)

First they make combined plots of the water temperature at all the schools and plot them. The three new sites are shown in Figures HY-TE-5 through Figure HY-TE-7.

At two of the schools, Zakladni Skola Banov and Zakladni Skola Jicin, the site number changed from SWS-01 School Location to a new site number with the proper name of the water body (Cidlini River and Ordejov Reservoir), which is why data from more than one surface water site is plotted.

The students do not see any apparent trends in summer stream temperature on the Cidlini River or the Ohre River). There appears to be a slight increase in summer air temperature at Banov, but it is not as large as the increase at Bystrice Nad Perstejnem. A water temperature change is not as obvious either. There are no water temperature

data from summer 1999, so trends in water temperature across the five-year period are hard to judge.

The students conclude that the increase in air and water temperature that occurred at Bystrice Nad Perstejnem did not occur in at least two of the other three sites. They conclude that their hypothesis is not valid.

Communicating Results

The students combine the result of this project with the previous project and write a report for their class. They submit their report to the GLOBE site under *Student Investigations*.

Future Research Questions

What happens to water temperature at these four sites after 2001?

Do any other sites show increasing (or decreasing) trends in temperature?

How much can water temperature increase before dissolved oxygen levels begin to get dangerously low? Are any of these water bodies at risk?



Figure HY-TE-2

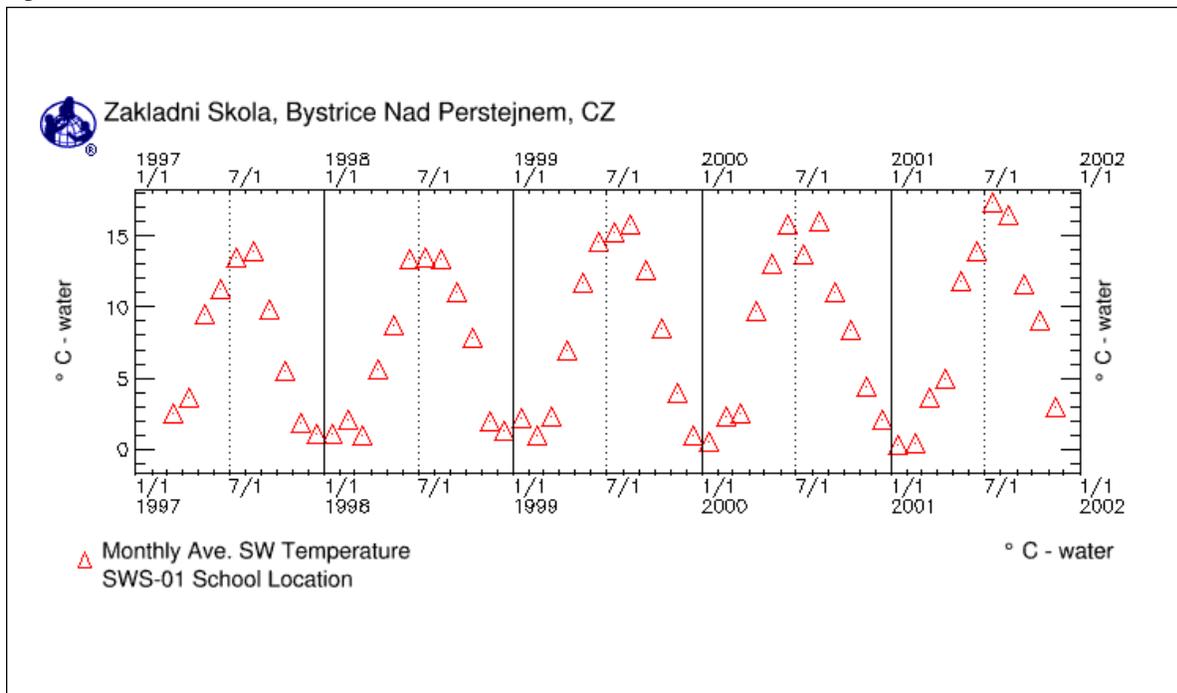


Figure HY-TE-3

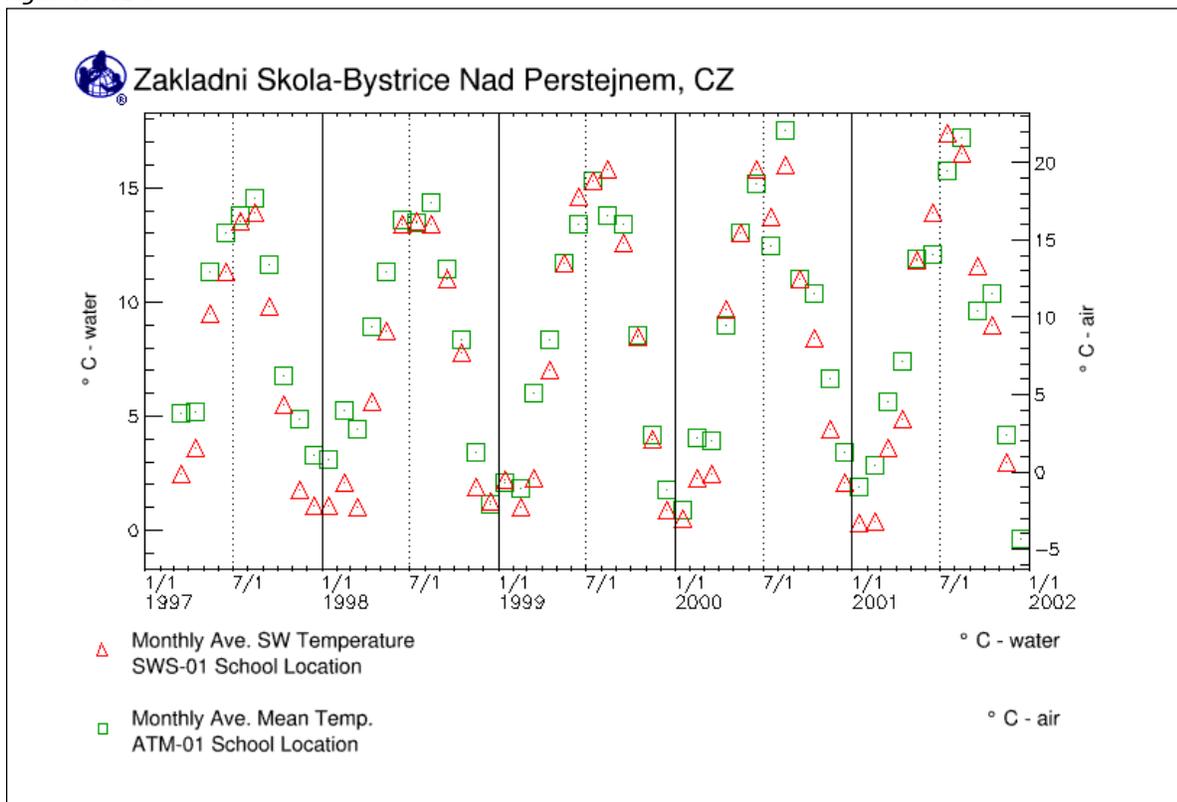


Figure HY-TE-4

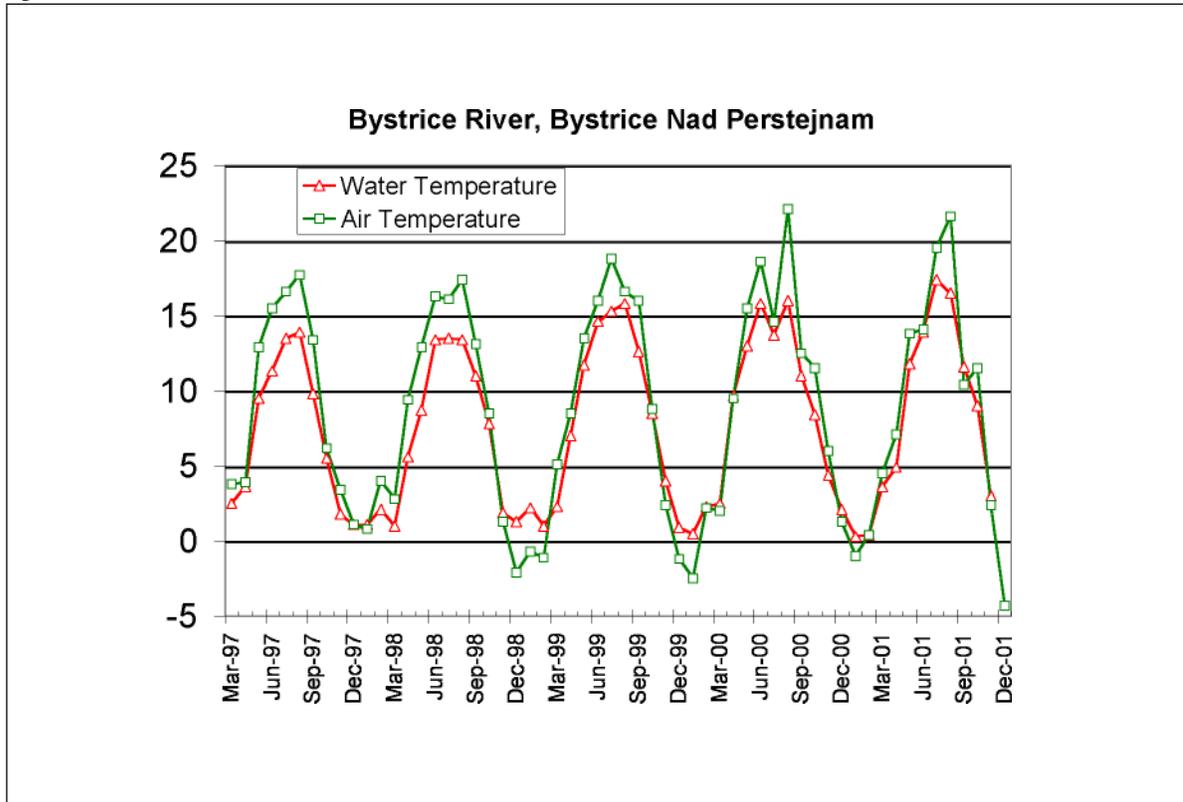


Figure HY-TE-5

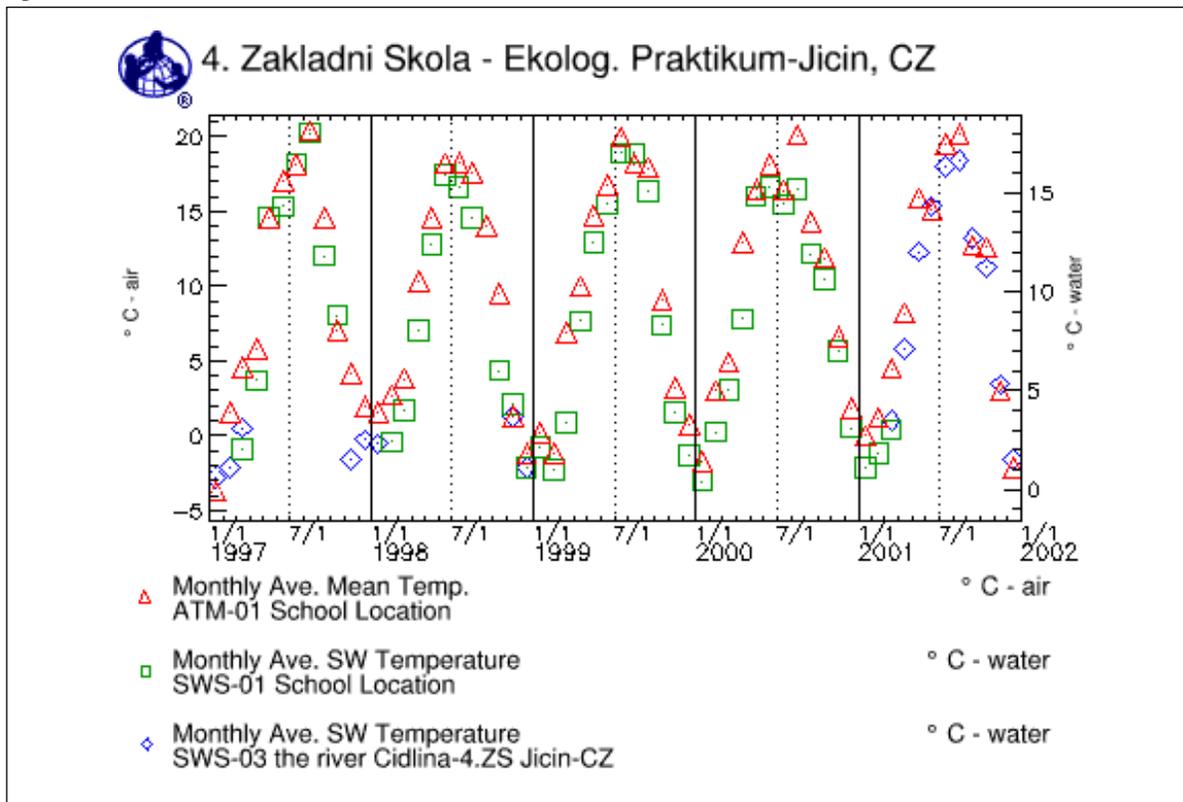


Figure HY-TE-6

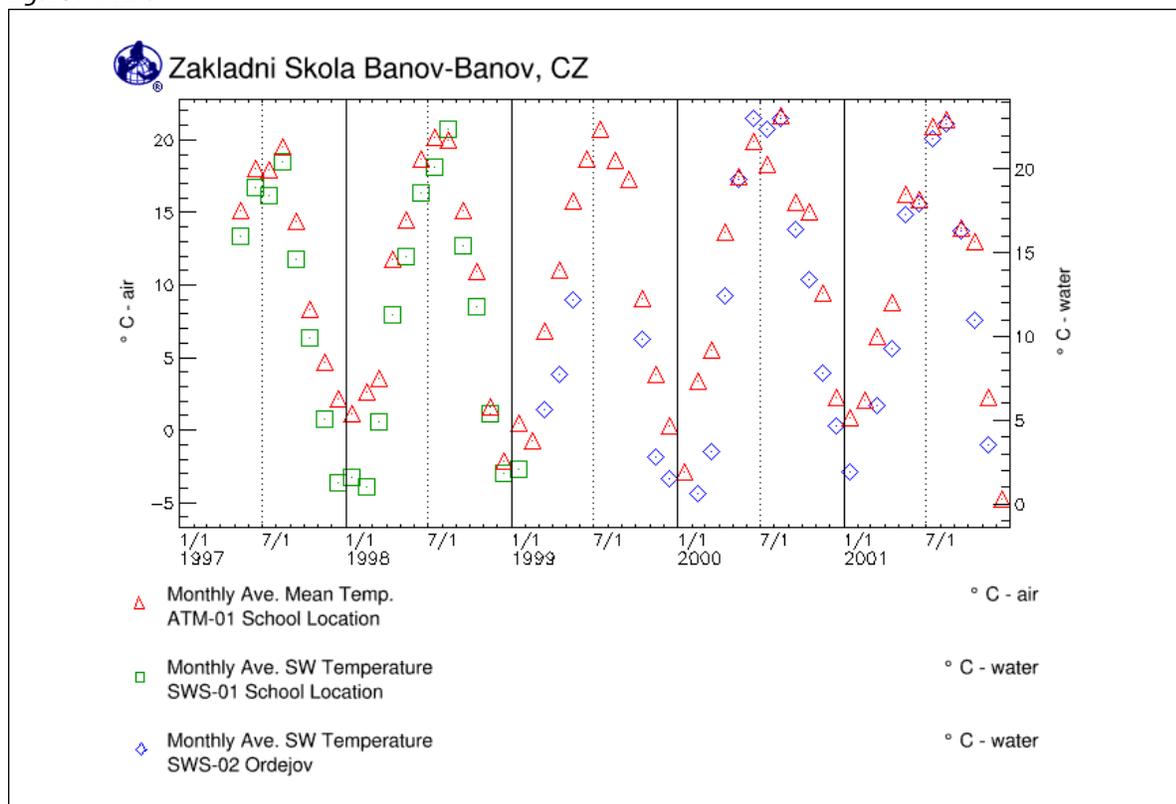
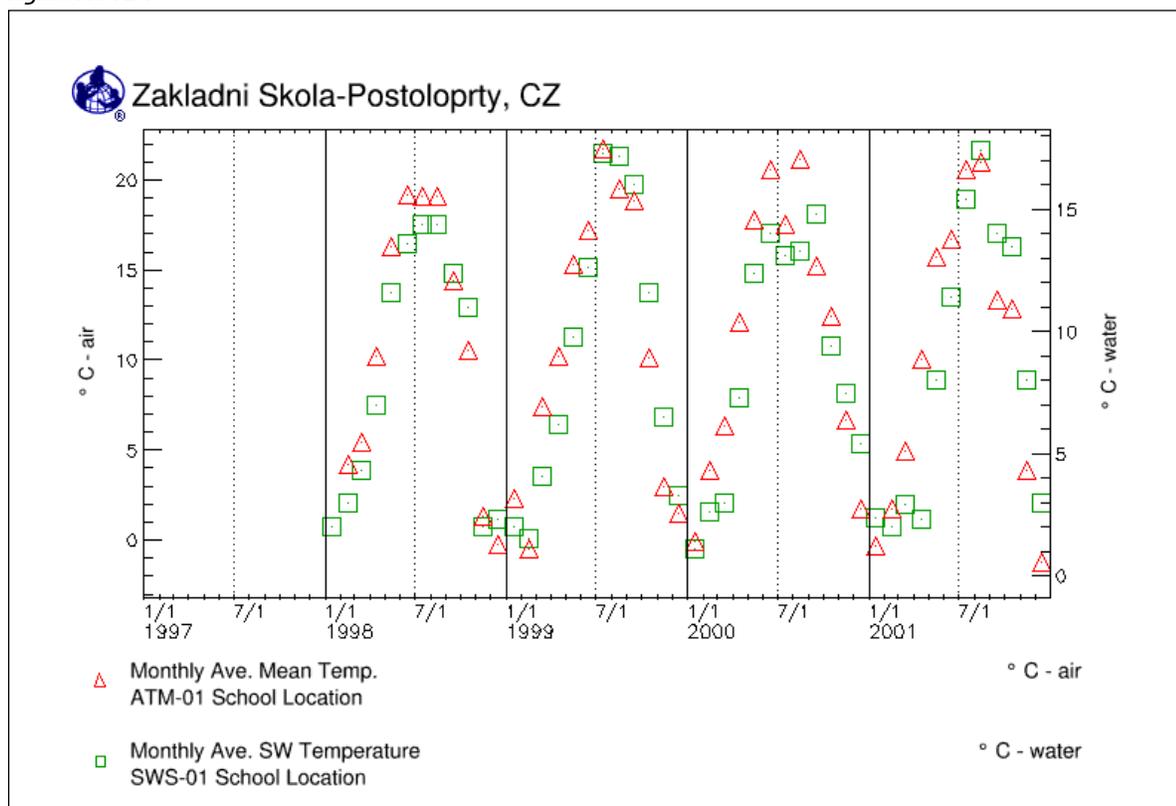


Figure HY-TE-7



Dissolved Oxygen Protocol



Purpose

To measure the amount of oxygen dissolved in water

Overview

Students will use a dissolved oxygen kit to measure the dissolved oxygen in the water at their hydrology site. The exact procedure depends on the instructions in the dissolved oxygen kit used.

Student Outcomes

Students will learn to,

- use a dissolved oxygen kit;
- examine reasons for changes in the dissolved oxygen of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Organisms change the environment in which they live.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a chemical test kit to measure dissolved oxygen.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

20 minutes

Quality Control Procedure: 20 minutes

Level

Middle and Secondary

Frequency

Weekly

Quality Control Procedure every 6 months

Materials and Tools

Hydrology Investigation Data Sheet

Dissolved Oxygen Protocol Field Guide

Dissolved oxygen kit

Latex gloves

Safety goggles

Waste bottle with cap

Distilled water

For Quality Control Procedure:

- 100-mL graduated cylinder

- 250-mL polyethylene bottle with lid

- Clock or watch

- Thermometer

- *Solubility of Oxygen Table*

- *Correction for Elevation Table*

- *Hydrology Investigation Quality Control Procedure Data Sheet*

- *Quality Control Procedure for Dissolved Oxygen Lab Guide*



Preparation

Suggested activity: *Practicing Your Protocols: Dissolved Oxygen*

Find out what the elevation is at your school.

Prerequisites

Discussion of safety procedures when using chemical test kits

Dissolved Oxygen Protocol – Introduction

The GLOBE *Dissolved Oxygen Protocol* measures the amount of molecular oxygen (O_2) dissolved in water. It does not measure the amount of oxygen in the water molecule (H_2O). Students often confuse the oxygen that is part of the water molecule (the O in H_2O) with dissolved oxygen (O_2).

Just like animals that live on land, animals that live in water need molecular oxygen to breathe. However, there is much more oxygen available in the atmosphere for animal respiration than in water. Roughly, two out of ten air molecules are molecular oxygen. In water, however, there are only five or six oxygen molecules for every million water molecules. The amount of dissolved oxygen in the water determines what can live there. Some animals, like salmon or mayfly larvae, require higher oxygen levels than other animals like catfish or leeches.

We call the amount of dissolved oxygen the water will hold (under specific conditions) the solubility of dissolved oxygen. Factors affecting the solubility of dissolved oxygen include water temperature, atmospheric pressure, and salinity.

Cold water can dissolve more oxygen than warm water. For example, at 25° C, dissolved oxygen solubility is 8.3 mg/L, whereas at 4° C the solubility is 13.1 mg/L. As temperature goes up, water releases some of its oxygen into the air. Water can hold less dissolved oxygen at higher elevations because there is less pressure. Solubility of dissolved oxygen also decreases as salinity increases.

Dissolved oxygen can be added to water by plants during photosynthesis, through diffusion from the atmosphere, or by aeration. Aeration occurs when water is mixed with air. Such mixing occurs in waves, riffles, and waterfalls.

The amount of dissolved oxygen also is affected by what lives in the water. Just as photosynthesis by terrestrial plants adds oxygen to the air we breathe, photosynthesis by aquatic plants contributes dissolved oxygen to the water. Water may become supersaturated, meaning that the dissolved oxygen levels are greater than its solubility. The extra dissolved oxygen would then eventually be released back into the air or be removed through respiration.

The living biota of water systems makes up only a very small portion of the total organic matter of the system. Most organic matter in aquatic ecosystems is non-living and it is collectively referred to as detritus. The organic matter can be produced *in situ* or enter water bodies from the surrounding land (from both natural and human sources). The cycling of organic carbon between living and nonliving components is known as the carbon cycle. Organic matter is produced during photosynthesis and is consumed during respiration. During respiration, biota (fish, bacteria, etc.) consume dissolved oxygen.

Teacher Support

Supporting Protocols

Water Temperature: Oxygen solubility is dependent on temperature. It is therefore important to collect water temperature data along with dissolved oxygen data.

Atmosphere Protocols: Atmosphere measurements such as cloud cover, precipitation, and air temperature may also be useful in interpreting dissolved oxygen data. Increased cloud cover, for instance, may result in a decrease in photosynthesis during the day.

Land Cover: It is also useful for hydrology measurements to know about the land cover in your watershed. The land cover in a watershed can influence the amount of organic matter in the aquatic environment.

Advance Preparation

Students should do the quality control procedure as described in the *Quality Control Procedure for Dissolved Oxygen Lab Guide* to test both the accuracy of their procedure and the precision of the kits. Doing the quality control will give students, teachers, and scientists confidence that the tests are being done properly.

Determine the elevation at the location (e.g., school) where the quality control procedure will be performed.

Measurement Procedure

Dissolved oxygen test kits involve two parts – sample preservation (stabilization or fixing) and sample testing. Preservation involves the addition of a chemical to the sample that precipitates in the presence of dissolved oxygen, followed by the addition of a chemical that produces a colored solution. Testing involves adding drops of a titrant solution until the color disappears. The dissolved oxygen value is calculated from the volume of titrant added.

The amount of dissolved oxygen in the water can change rapidly after the sample has been collected. It is therefore important to do this test soon after the sample is collected. The water sample for the

dissolved oxygen test should be ‘fixed’ at the water site (see instructions in your dissolved oxygen kit). After the sample is fixed, the sample may be taken back to the school to finish the test.

In following the instructions in the test kit, the following techniques should be followed.

Make sure there is no air in the bottle that contains the water you will test. To check for air bubbles in the sample bottle, turn the bottle upside down while it is capped and look for bubbles.

- Hold bottles and droppers vertically when adding drops of reagent to your water sample so that all of the drops of reagents are the same size.
- If students are asked to ‘mix’, they should cap the bottle and do a ‘windshield wiper motion’ to gently mix the chemicals.
- The precipitate is settled when there is a distinct line between the clear liquid at the top and the settled material at the bottom (fresh water). It takes a long time (greater than 15 minutes) for the precipitate to settle in salty and brackish water. Wait until there is a distinct line between clear liquid and settled material in the lower half of the bottle.
- Make sure you have no air bubbles in your titrator when you fill it.
- If your kit asks you to titrate to a “pale yellow”, hold a sheet of white paper behind the bottle and continue titration until the liquid is almost clear before adding the starch solution.

There is no elevation compensation required when measuring the actual amount of dissolved oxygen in a water sample from your Hydrology Site. This is only done on the quality control procedure.

Quality Control Procedure

For the quality control procedure, students compare the measured dissolved oxygen in their standard solution with the saturated value from the table in order to determine if their kit and procedures are correct.

To make a saturated standard, students saturate distilled water by shaking a partially filled bottle



of distilled water for 5 minutes. Since the solubility decreases with increasing temperature, increasing salinity, and decreasing air pressure, we control these variables in our dissolved oxygen standard by using distilled water, and correcting for the water temperature and elevation (an indirect measure of air pressure). You need to know the elevation (e.g., your school) where the procedure will be done. Table HY-DO-2 contains the correction values for various atmospheric pressures and elevations.

The shaken standard can be poured directly into the sample bottle until the bottle is completely filled. You will not add oxygen to the sample by pouring it since the water sample is already saturated with oxygen. After the sample bottle is filled, follow the instructions for the kit to measure the amount of dissolved oxygen.

Safety Precautions

- Students should wear gloves and goggles when handling chemicals and water that may contain potentially harmful substances such as bacteria or industrial waste.
- Local authorities should be consulted on the proper disposal of used chemicals.

Helpful Hints

Mark each item in the kit with a dot of paint or nail polish of the same color. Mark other kits with different colors to avoid having chemicals or titrators exchanged between kits.

Managing Students

If there is not enough time to have students measure the dissolved oxygen of three different samples at the hydrology site, have one or more students perform the whole measurement. Then have the other students use the same fixed sample for sample testing later in the classroom or lab.

Instrument Maintenance

1. Chemicals should be tightly capped immediately after they are used.
2. Rinse the sample bottle and titration tube with distilled water after use.
3. Discard chemicals from the dropper or titrator. They should not be put back into the original containers because they may be contaminated.
4. Do not rinse the titrator with distilled water as long as it has not been contaminated. Rinsing with distilled water often leaves a drop of water in the titrator that is difficult to remove.
5. Store the titrator with the plunger removed to avoid the rubber end sticking in the tube.

Questions for Further Investigation

How would a change in the amount of dissolved oxygen affect what lives in a water body?

How could warming or cooling of the atmosphere affect the amount of dissolved oxygen in your water?

How could changes in the land cover around your water site affect the amount of dissolved oxygen in your water?

Quality Control Procedure for Dissolved Oxygen

Lab Guide

Task

Check the accuracy of your dissolved oxygen kit. Practice using your dissolved oxygen kit properly.

What You Need

- | | |
|--|--|
| <input type="checkbox"/> Hydrology Investigation Quality Control Data Sheet | <input type="checkbox"/> Dissolved oxygen test kit |
| <input type="checkbox"/> Distilled water | <input type="checkbox"/> Latex gloves |
| <input type="checkbox"/> 100-mL graduated cylinder | <input type="checkbox"/> Goggles |
| <input type="checkbox"/> 250-mL polyethylene bottle with lid | <input type="checkbox"/> Pen or pencil |
| <input type="checkbox"/> Thermometer | <input type="checkbox"/> Clock or watch |
| <input type="checkbox"/> Waste bottle with cap for discarding used chemicals | |

What To Do

1. Rinse the 250-mL bottle twice with distilled water.
2. Pour 100 mL of distilled water into the 250-mL bottle.
3. Put the lid on the bottle. Shake the bottle vigorously for 5 minutes. This is the standard you will use to test your kit.
4. Uncap the bottle and take the temperature of the water (see *Water Temperature Protocol Field Guide*). Be sure the tip of the thermometer does not touch the bottom or sides of the bottle.
5. Record the temperature of the distilled water standard on the *Hydrology Investigation Quality Control Data Sheet*.
6. Pour the standard into the sample bottle in your dissolved oxygen kit. Fill the sample bottle completely to the top. Put the lid on the sample bottle. Turn the bottle upside down while it is capped. There should not be any air bubbles.

Note: It is not necessary to immerse the sample bottle in the water to collect your sample when you are doing the quality control procedure.

7. Put on your gloves and protective goggles.
8. Follow the directions in your dissolved oxygen kit to measure the dissolved oxygen of your standard.
9. Record the amount of dissolved oxygen (mg/L) in your standard on your *Hydrology Investigation Quality Control Data Sheet*.
10. Look up the temperature you recorded earlier on the *Solubility of Oxygen Table*. See Table HY-DO-1.
11. Record the solubility for your water temperature.
12. Find the elevation closest to yours on the *Correction for Elevation/Pressure Table*. See Table HY-DO-2.
13. Record the correction value for your elevation.
14. Multiply the solubility of your standard times the correction value. This is the expected amount of dissolved oxygen in your standard.
15. Compare the amount of dissolved oxygen you measured with the kit to the expected amount for your standard.
16. If the measurement is within ± 1 mg/L, record the dissolved oxygen value on the *Hydrology Investigation Quality Control Procedure Data Sheet*. If the measurement is not within this range, repeat the entire quality control procedure.
17. If your measurements are still not in range, record the value you got and report to your teacher that the kit is not working properly.
18. Pour all used chemicals into the waste bottle. Clean your kit with distilled water.

Table HY-DO-1: Solubility of Oxygen in Fresh Water Exposed to Air at 760 mm Hg Pressure

Temp °C	Solubility mg/L	Temp °C	Solubility mg/L	Temp °C	Solubility mg/L
0	14.6	16	9.9	32	7.3
1	14.2	17	9.7	33	7.2
2	13.8	18	9.5	34	7.1
3	13.5	19	9.3	35	7.0
4	13.1	20	9.1	36	6.8
5	12.8	21	8.9	37	6.7
6	12.5	22	8.7	38	6.6
7	12.1	23	8.6	39	6.5
8	11.9	24	8.4	40	6.4
9	11.6	25	8.3	41	6.3
10	11.3	26	8.1	42	6.2
11	11.0	27	8.0	43	6.1
12	10.8	28	7.8	44	6.0
13	10.5	29	7.7	45	5.9
14	10.3	30	7.6	46	5.8
15	10.1	31	7.4	47	5.7

Table HY-DO-2: Correction Values For Various Atmospheric Pressures and Elevations

Pressure millibars	elev m	Correction value %	Pressure millibars	elev m	Correction value %
1023	-84	1.01	841	1544	0.83
1013	0	1.00	831	1643	0.82
1003	85	0.99	821	1743	0.81
993	170	0.98	811	1843	0.80
988	256	0.97	800	1945	0.79
973	343	0.96	790	2047	0.78
963	431	0.95	780	2151	0.77
952	519	0.94	770	2256	0.76
942	608	0.93	760	2362	0.75
932	698	0.92	750	2469	0.74
922	789	0.91	740	2577	0.73
912	880	0.90	730	2687	0.72
902	972	0.89	719	2797	0.71
892	1066	0.88	709	2909	0.70
882	1160	0.87	699	3203	0.69
871	1254	0.86	689	3137	0.68
861	1350	0.85	679	3253	0.67
851	1447	0.84	669	3371	0.66



Frequently Asked Questions

1. Why does the amount of dissolved oxygen I measured not agree with the amount I calculated?

There are two reasons why these numbers may not match. First, you may not have followed the instructions on your kit exactly or you may have made small errors in the procedure you used. Here are some trouble-shooting tips:

1. Make sure you do not have any air bubbles in your sample bottle or your titrator (for kits that use a titrator). To check for air bubbles in the sample bottle, turn the bottle upside down while it is capped and look for bubbles.
2. Measure accurately. If you are adding drops from a bottle, hold the bottle vertically so that all of the drops are the same size.
3. Allow all of the precipitate to settle. If you shake the bottle too hard before the precipitate settles, it may take 10 minutes or more for the settling to happen.
4. Record accurately. If your kit asks you to count drops, have two people count to insure accuracy. If your kit asks you to read a titrator, make sure to read the instructions for accurately reading the titrator that come with your kit.



The second reason your measured value may not be the same as your calculated value is that there may be something wrong with the chemicals in your kit. In this case, you will need to get new chemicals.



Dissolved Oxygen Protocol

Field Guide

Task

Measure the dissolved oxygen of your water sample.

What You Need

- Hydrology Investigation Data Sheet
- Latex gloves
- Goggles
- Dissolved oxygen kit
- Distilled water
- Waste bottle with cap for used chemicals
- Pen or pencil

In the Field

1. Fill in the top of the *Hydrology Investigation Data Sheet*.
2. Put on the gloves and goggles.
3. Rinse the sample bottle and your hands with sample water three times.
4. Place the cap on the empty sample bottle.
5. Submerge the sample bottle in the sample water.
6. Remove the cap and let the bottle fill with water. Move the bottle gently or tap it to get rid of air bubbles.
7. Put the cap on the bottle while it is still under the water.
8. Remove the sample bottle from the water. Turn the bottle upside down to check for air bubbles. If you see air bubbles, discard this sample. Collect another sample.
9. Follow the directions in your Dissolved Oxygen Kit to test your water sample.
10. Record the dissolved oxygen in your water sample on the *Data Sheet* as *Observer 1*.
11. Have two other students repeat the measurement using a new water sample each time.
12. Record their data on the *Data Sheet* as *Observers 2* and *3*.
13. Calculate the average of the three measurements.
14. Each of the three measurements should be within 1 mg/L of the average. If one of the measurements is not within 1 mg/L of the average, find the average of the other two measurements. If both of these measurements are within 1 mg/L of the new average, record this average.
15. Discard all used chemicals into the waste container. Clean your dissolved oxygen kit with distilled water.



Frequently Asked Questions

1. Why do we have to do the measurements at the same time of day?

The amount of dissolved oxygen may change during the day as the water begins to warm up. More light penetrating the water causes more photosynthesis to occur. This can also increase the amount of dissolved oxygen. For this reason it is important to do your Hydrology measurements at the same time of day each week.



2. What will make my dissolved oxygen levels change over the year?



Besides seasonal differences in temperature, seasonal changes in the flow of your stream, changes in transparency, or changes in productivity (amount of growth of plants and animals in the water) will cause changes in dissolved oxygen levels.

Dissolved Oxygen Protocol – Looking at the Data

Are the data reasonable?

The amount of dissolved oxygen you measure depends on your water site. Dissolved oxygen is added to water through aeration (water running or splashing), diffusion, and by photosynthesis of aquatic plants. It is used up by respiration. The maximum amount of dissolved oxygen your water can hold (saturated solution) depends on elevation (atmospheric pressure) at your site, water temperature, and salinity of your sample. Dissolved oxygen in natural waters may vary from 0.0 mg/L to around 16.0 mg/L. Distilled water at 0.0 C has a solubility of 14.6 mg/L at sea level. Warm, still waters might have dissolved oxygen levels of about 4 or 5 mg/L. Cold, running waters might have oxygen levels at 13 or 14 mg/L. Higher levels are possible due to photosynthesis by plants and lower levels are possible due to respiration.

Since dissolved oxygen levels are dependent on water temperature as well as other variables such as photosynthesis and respiration in the water, it is helpful to look for seasonal trends. Graph the dissolved oxygen and water temperature data over a year. Look for similarities in the seasonal patterns. Dissolved oxygen data should be collected at the same time of day each week since oxygen levels at a site will change throughout the day as the water warms up and photosynthesis increases during the afternoon. Data collected at different times of day make seasonal patterns much more difficult to interpret. In addition to finding seasonal patterns, graphing your data will help you to check for other potential errors, such as misplaced decimal points.

In Figure HY-DO-1 the dissolved oxygen of 3.0 on February 7, 1999 is extremely low. This is not a normal value for this water body at this time of year. We would expect the observed value of dissolved oxygen to be around 11-13 mg/L. If you come across such values, contact the school and ask them to double check their *Data Sheets* and make sure that this is the value that is on the sheet.

After you have collected a few samples, you should know approximately what your value should be. If you get an unexpected measurement (higher or lower than you would expect based on the air temperature and values from previous weeks, do it again with a new water sample and clean sample bottles. If you get the same result, make a note in the metadata that you are aware of the unusual values for that date, and that they are indeed correct.

What do people look for in the data?

Most organisms will not exist at dissolved oxygen levels less than 3.0 mg/L. Some sensitive organisms will not live in oxygen levels less than 7.5 mg/L. Dissolved oxygen levels that drop at low levels (i.e., less than 5 mg/L) are a reason for concern. Excess nutrients (e.g., fertilizer, organic-rich waste water) added to the water body can cause an overgrowth of vegetation and algae, causing increased decay in the water. The bacteria that decompose the organic matter respire and use oxygen.

In addition to looking at the amount of dissolved oxygen in the water, it is also interesting to compare the amount of measured dissolved oxygen with a calculated value for saturation. This can tell us about the productivity of the water body. In a productive water body, plants will be producing oxygen through photosynthesis. Dissolved oxygen values will vary throughout the day, with maximum value occurring in the early afternoon and lowest levels occurring during the night (when respiration is not balanced by photosynthesis). At certain times of the day (typically early afternoon), some water bodies may actually have a dissolved oxygen measurement above the saturation level, indicating that more oxygen is being produced by photosynthesis that is being consumed by respiration. Water bodies that are highly turbid have low light penetration and low productivity. They are typically characterized by low dissolved oxygen levels.

The GLOBE visualizations page on the Web site displays values of saturated dissolved oxygen for your site that you can compare graphically with your actual measurements.



An Example of a Student Research Investigation

Forming a Hypothesis

A student interested in dissolved oxygen is looking at the time plot of dissolved oxygen at Reynolds Jr Sr High School SWS-02 site, called “Covered Bridge” (Figure HY-DO-2). She notices that the values of dissolved oxygen in late December 2000 through January 2001 were much lower than values in previous winters. During that time period the values ranged from 7 to 10 mg/L for about a month. During the previous three winters, dissolved oxygen consistently ranged from 11 to 15 mg/L. The low values are similar to those found during the warmer periods.



Knowing that the *saturated* dissolved oxygen levels are usually related to temperature, she hypothesizes that the *water temperature during this time period is higher than normal and the warmer water is responsible for the lower dissolved oxygen values.*



She contacts the school and learns that this water body is the Shenango River.



Collecting and Analyzing Data

She begins by plotting the monthly mean values of dissolved oxygen and temperature. See Figure HY-DO-3.

The unusually low January 2001 dissolved oxygen is even more apparent when looking at the monthly averages. However, there does not appear to be a corresponding increase in water temperature, which is about 3° C.



If temperature is normal, then the values of saturated dissolved oxygen should be high as well. This would mean that the *dissolved oxygen deficit*, which is the difference between the saturated and observed values, is unusually high for some reason.

The GLOBE visualizations page will calculate monthly averages for water temperature and measured dissolved oxygen, but not for saturated dissolved oxygen, so the student decides to calculate the monthly averages for saturated dissolved oxygen herself. She generates a plot with dissolved oxygen, saturated dissolved oxygen, and



Table HY-DO-3

	Water Temp. degrees C	Dissolved oxygen mg/L	Saturated DO mg/L	DO use mg/L
Date				
1/2/1998	5	11.2	12.8	1.6
1/10/1998	5.5	10.5	12.6	2.1
1/17/1998	2	12.1	13.8	1.7
1/24/1998	1.5	12.6	14	1.4
1/31/1998	2	11.7	13.8	2.1
Average	3.2	11.6	13.4	1.8
Date				
1/9/1999	0	12.3	14.6	2.3
1/16/1999	0	12.3	14.6	2.3
1/23/1999	1	10.8	14.2	3.4
1/30/1999	0.5	11.6	14.4	2.8
Average	0.4	11.8	14.5	2.7
Date				
1/6/2000	3	13.6	13.5	-0.1
1/13/2000	1.2	13	14.1	1.1
1/20/2000	0	13	14.6	1.6
1/27/2000	0	13.3	14.6	1.3
Average	1.1	13.2	14.2	1.0
Date				
1/5/2001	6	9.8	12.4	2.6
1/12/2001	1	9.8	14.2	4.4
1/19/2001	2	8.5	13.8	5.3
1/26/2001	1	7.4	14.2	6.8
Average	2.5	8.9	13.7	4.8

water temperatures, and then creates a data table. She transfers this information into a spreadsheet.

She extracts all the January values for each of the years (Table HY-DO-3). She then calculates the dissolved oxygen deficit (saturated dissolved oxygen – measured dissolved oxygen). Then for each year, she calculates the average for each of the four terms.

The average dissolved oxygen in 2001 was 8.9 mg/L. In 1998-2000, it was 11.6, 11.8 and 13.2, respectively.

However, the water temperature was about the same for all four Januarys: 3.2°, 0.4°, 1.1° and 2.5° C. The temperature was actually warmer in January of 1998 than 2001, and the measured DO was higher. Therefore, the decrease in dissolved oxygen does not seem to be related to temperature

The average dissolved oxygen deficit ranged from 1.0 to 2.7 mg/L the first three years, and was 4.8 in 2001. The dissolved oxygen deficit is almost twice as high in January 2001 as it was in the next highest year (January 1999) when it was 2.7.

She concludes that: *Measured dissolved oxygen values are lower in January 2001 than in January 1998-2000. Water temperature and saturated dissolved oxygen values are about the same, so the decrease in dissolved oxygen is not related to a change in water temperature.*

Therefore her hypothesis that warmer water was causing the lower dissolved oxygen value was rejected. It is all right to disprove your hypothesis. Scientist do this all the time. Often in finding out that our hypothesis is not correct, we come up with alternatives that lead to a better understanding of the problem at hand.

Future Research

There is nothing in this data to suggest WHY the dissolved oxygen is so much lower in winter 2001 than during the 3 previous years. The student does notice that the 2000-2001 winter seems longer in duration than the other winters but cannot think of why that might affect dissolved oxygen levels later in the winter. She also notices that the summer dissolved oxygen data in 2000 appear more variable than in previous years. Perhaps something else has changed in the river to cause a higher demand for dissolved oxygen. One reason might be that more bacteria, such as those associated with decaying organic matter from sewage, might be present in the water. A student might investigate whether there have been external changes in the watershed.

Figure HY-DO-1

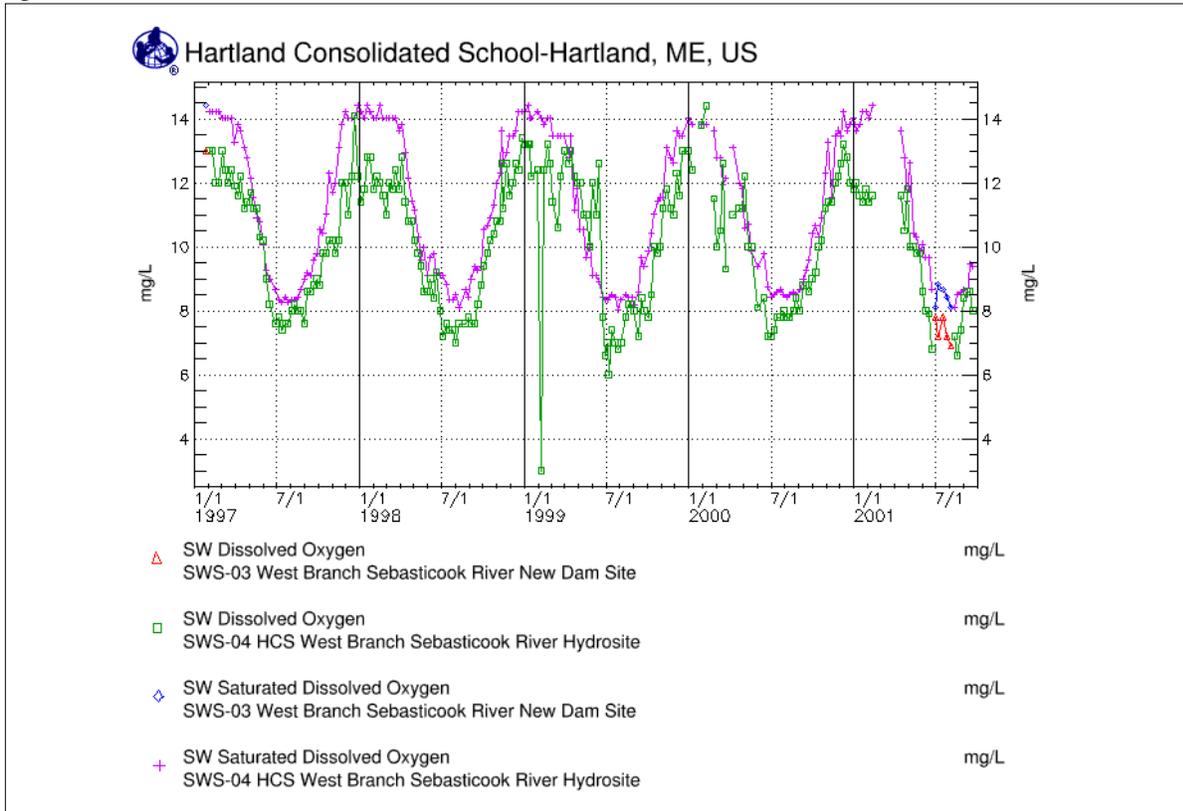


Figure HY-DO-2

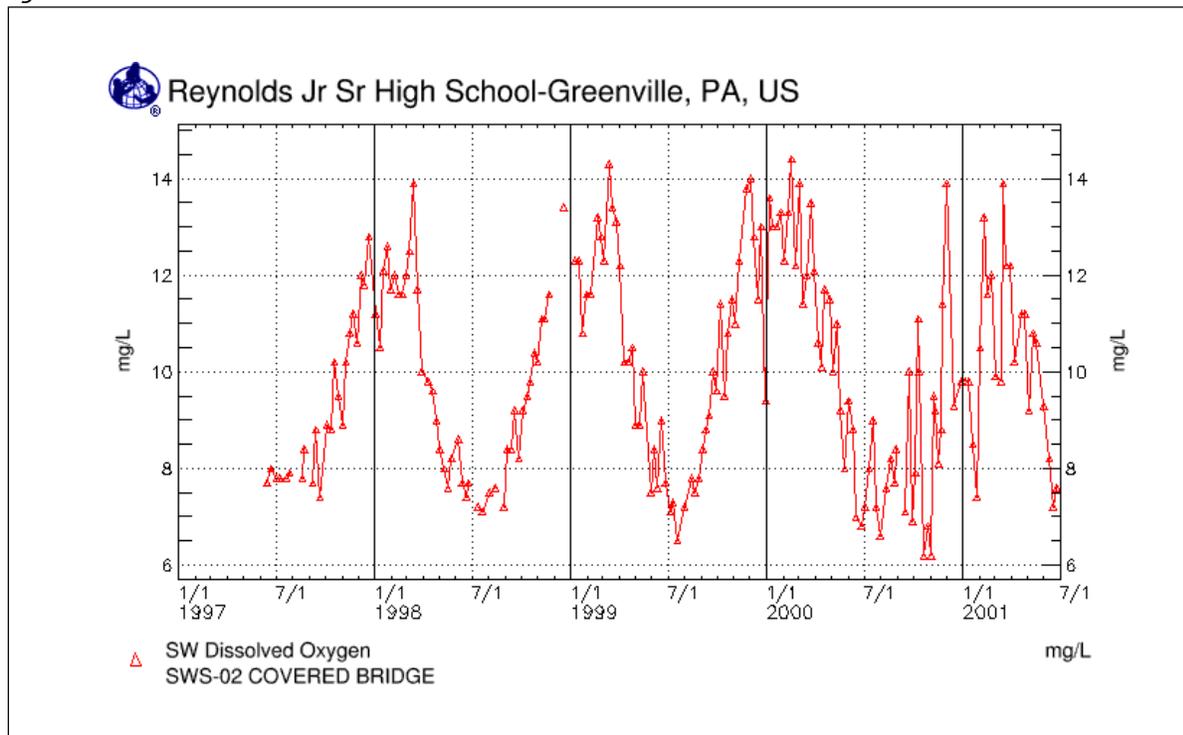
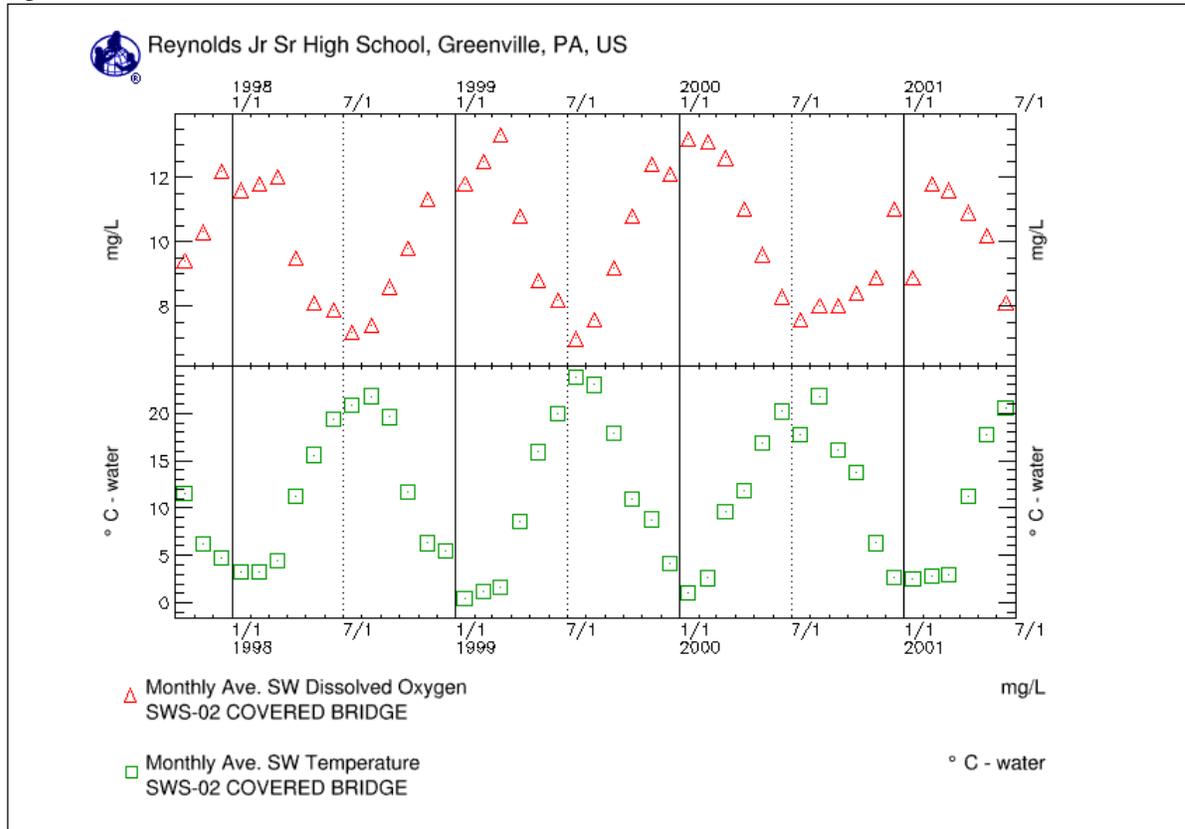


Figure HY-DO-3



Electrical Conductivity Protocol



Purpose

To measure the conductivity of the water at a freshwater hydrology site

Overview

Students will calibrate and take electrical conductivity measurements using an electrical conductivity meter.

Students will estimate the total dissolved solids from the electrical conductivity measurements.

Student Outcomes

Students will learn to,

- use an electrical conductivity meter;
- examine reasons for changes in the electrical conductivity of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a conductivity meter to measure conductivity of water.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes

Level

All

Frequency

Weekly

Materials and Tools

Hydrology Investigation Data Sheet

Electrical Conductivity Protocol Field Guide

Total Dissolved Solids tester (or conductivity tester)

Thermometer

Distilled water in wash bottle

Soft tissue

Two 100-mL beakers

Latex gloves

650-ml plastic water bottle

For Calibration, the above plus:

- Standard solution

- Small screwdriver

- *Electrical Conductivity Calibration Protocol Lab Guide*

Preparation

Suggested Learning Activities:

Practicing Your Protocols: Electrical Conductivity Water Detectives (e-guide only)

Prerequisites

None



Electrical Conductivity Protocol – Introduction

Have you ever left water to evaporate from a dish? What was left after the water evaporated?



Fresh water has many natural impurities – including salts or minerals dissolved in the water that we cannot always see or smell. As water comes in contact with rocks and soil, some minerals dissolve in the water. Other impurities can enter a water body through runoff or wastewater releases. If water contains high amounts of dissolved salts, it may be harmful to use for watering crops.



We call the amount of mineral and salt impurities in the water the total dissolved solids (abbreviated TDS). We measure TDS as parts per million (ppm). This tells us how many units of impurities there are for one million units of water, by mass. For water we use at home, we prefer a TDS of less than 500 ppm, although water with higher TDS can still be quite safe. Water used for agriculture should have TDS below 1200 ppm so sensitive crops are not harmed. Manufacturing, especially of electronics, requires impurity-free water.



We use an indirect measure to find the TDS of water. One way to measure impurities in water is to find out if it conducts electricity. Pure water is a poor conductor of electricity. When certain solids (typically salts) are dissolved in water, they dissociate and form ions. Ions carry an electrical charge (either positive or negative). More ions in water mean the water will conduct electricity better.



The electrical conductivity meter measures how much electricity is being conducted through a centimeter of water. If you look at the meter you will see that the electrodes are 1 cm apart. Conductivity is measured as microSiemens per cm (mS/cm). This is the same unit as a micromho, mho.



To convert the electrical conductivity of a water sample (mS/cm) into the approximate concentration of the total dissolved solids (ppm)

in the sample, you must multiply the conductivity (mS/cm) by a conversion factor. The conversion factor depends on the chemical composition of the dissolved solids and can vary between 0.54 - 0.96. For instance, sugars do not affect conductivity because they do not form ions when they dissolve. The value 0.67 is commonly used as an approximation, if the actual conversion factor is not known.

$$\text{TDS (ppm)} = \text{Conductivity (mS/cm)} \times 0.67$$

Drinking water with a conductivity of 750 mS/cm will have an approximate concentration of total dissolved solids of 500 ppm. Pure alpine snow from remote areas has a conductivity of about 5 - 30 mS/cm.

Table HY-EC-1: Estimated Conversion from Conductivity (mS/cm) to Total Dissolved Solids (ppm) based on Average Conversion Factor of 0.67

Conductivity (mS/cm)	TDS (ppm)	Conductivity (mS/cm)	TDS (ppm)
0	0	1050	704
50	34	1100	737
100	67	1150	771
150	101	1200	804
200	134	1250	838
250	168	1300	871
300	201	1350	905
350	235	1400	938
400	268	1450	972
450	302	1500	1005
500	335	1550	1039
550	369	1600	1072
600	402	1650	1106
650	436	1700	1139
700	469	1750	1173
750	503	1800	1206
800	536	1850	1240
850	570	1900	1273
900	603	1950	1307
950	637	2000	1340
1000	670	>2000	>1340



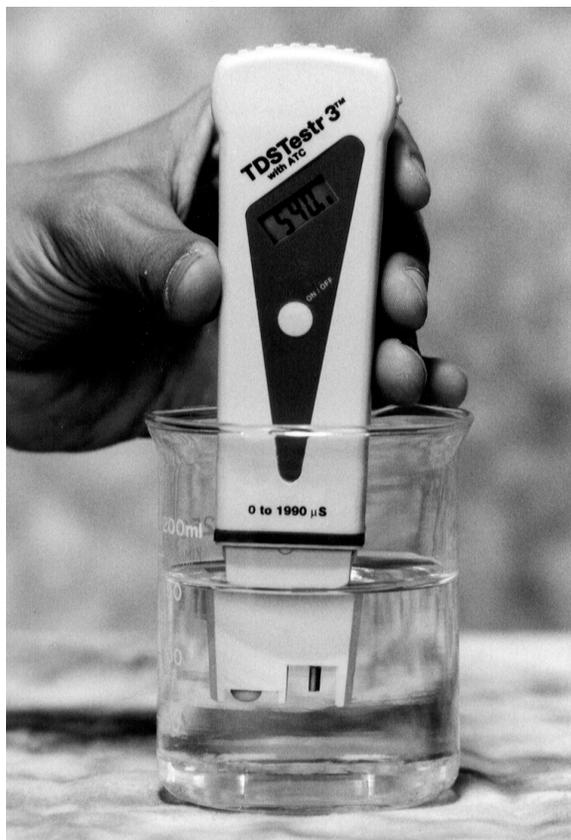
Teacher Support

Measurement Procedure

There are several manufacturers and models of conductivity meters. Some models may measure conductivity in increments of 10 mS/cm; others in increments of 1.0 mS/cm. If your model measures in increments of 10 mS/cm, you will have to calibrate it as closely as you can to the standard solution. The meters need to be calibrated before testing the water sample. This can be done in the classroom shortly before going to the hydrology site or at the hydrology site.

Some conductivity meters may indicate that they have an automatic temperature compensation (ATC). Testing by the GLOBE Hydrology team has indicated that the temperature compensation on conductivity meters is generally not reliable. For this reason, all water should be brought to room temperature (20° - 30° C) for testing, even if the manufacturer claims that the meter is temperature compensated. It is very important to take the

Figure HY-EC-1: Using the Conductivity Meter



temperature of the water when doing the conductivity measurement. The temperature of the solution when the conductivity measurement is taken will help to identify errors resulting from meter error instead of actual changes in total dissolved solids.

If the water at your Hydrology Site is not between 20° - 30° C, you need to either 1.) let the water warm in the sample bucket or separate container while students take other hydrology measurements at the hydrology site, or 2.) collect a sample in a water bottle and take back to the classroom. After the water reaches 20° - 30° C, students can take the conductivity measurement.

Never immerse the meter totally in water. Only the part indicated in the instructions for the meter should be immersed in water.

Quality Control Procedure

Calibrating the conductivity meter should be done in the classroom or lab before going to the Hydrology Site. The temperature of the conductivity standard should be about 25° C.

Supporting Protocols

Water Temperature: It is important to take the temperature of water at the hydrology site following the *Water Temperature Protocol*. If the temperature at the site is not between 20° - 30° C, it is important to let a sample of water reach this temperature range.

Soil Characteristics and Land Cover: Soil Characteristics and Land Cover data provide information on the possible source of the materials dissolved in the water.

Atmosphere: Atmosphere data, especially precipitation, may also affect the concentration of total dissolved solids in your water.

Supporting Activities

A discussion of good conductors and poor conductors may help students understand the measurement better. To illustrate the conductivity of water, have students measure distilled water with the conductivity meter. They will find a



reading near zero. Stir a small amount of salt into the water and watch the reading go up!



Students may also benefit from a discussion of indirect measures. Some things are difficult to measure directly. For instance, it would take a long time to count the fingers of everyone in the school! But we could estimate the number of fingers indirectly by counting the students and multiplying by 10. What other indirect measures can students think of?

Safety Precautions

Students should wear gloves when handling water that may contain potentially harmful substances such as bacteria or industrial waste.



Helpful Hints

It is a good idea to keep an extra set of batteries on hand for the conductivity tester. Many use small, flat 'watch' type batteries.



Instrument Maintenance

Electrical Conductivity Meter

1. The meter should be stored with the cap on. Never store the meter in distilled water.
2. The electrodes should be well rinsed with distilled water after use to avoid mineral deposit accumulation.
3. The electrodes should periodically be cleaned with alcohol.

Standard Solution

1. The standard should be stored in a tightly capped container in the refrigerator. Making a seal with masking tape will reduce evaporation.
2. Write the date that the standard was purchased on the bottle. Standards should be discarded after one year.
3. Never pour used standard back into the bottle.



Questions for Further Investigation

Would you predict the conductivity of the water at your site to go up or down after a heavy rain? Why?

Would you expect the conductivity to be greater in a high mountain stream that receives fresh snowmelt or in a lake at lower elevations?

Why do you think water with high levels of TDS is harmful to plants?

Electrical Conductivity Calibration Protocol

Lab Guide

Task

Calibrate your electrical conductivity tester.

What You Need

- | | |
|---|---|
| <input type="checkbox"/> Electrical conductivity tester | <input type="checkbox"/> Soft tissue |
| <input type="checkbox"/> Standard solution | <input type="checkbox"/> Two 100-mL beakers or two plastic cups |
| <input type="checkbox"/> Thermometer | <input type="checkbox"/> Latex gloves |
| <input type="checkbox"/> Distilled water in wash bottle | <input type="checkbox"/> Small screwdriver |

In the Lab

1. Bring the standard solution to room temperature (about 25° C).
2. Pour standard solution into each of the two clean 100-mL beakers or cups to a depth of about 2 cm.
3. Remove the cap from the electrical conductivity tester and press the On/Off button to turn it on.
4. Rinse the electrode at the bottom of the tester with distilled water in the wash bottle.
5. Gently blot dry with a tissue. **Note:** Do not rub or stroke the electrode while drying.
6. Put the probe of the meter into the first beaker of standard. Stir gently for 2 seconds to rinse off any distilled water.
7. Take the meter out of the first beaker. Do NOT rinse with distilled water.
8. Put it into the second beaker.
9. Stir gently, and then wait for the numbers to stop changing.
10. If the display does not read the value of your standard solution, you must adjust the instrument to read this number. (For most meters, you can use a small screwdriver to adjust the calibration screw on the meter until the display reads the standard value.
11. Rinse the electrode with distilled water and blot it dry. Turn off the meter and put the cap on to protect the electrode.
12. Pour the standard from the beakers into a waste container. Rinse and dry the beakers

Electrical Conductivity Protocol

Field Guide

Task

Measure the electrical conductivity of your water sample.

What You Need

- | | |
|---|--|
| <input type="checkbox"/> Hydrology Investigation Data Sheet | <input type="checkbox"/> Paper towel or soft tissue |
| <input type="checkbox"/> Electrical conductivity tester | <input type="checkbox"/> 2 100-mL beakers |
| <input type="checkbox"/> Thermometer | <input type="checkbox"/> Latex gloves |
| <input type="checkbox"/> Distilled water in wash bottle | <input type="checkbox"/> One clean 600-700 ml plastic water bottle with cap (for sample water) |

In the Field

1. Fill out the top portion of the *Hydrology Investigation Data Sheet*
2. Put on latex gloves.
3. Record the temperature of the water to be tested. If water is between 20° – 30° C, go to step 5.
4. If your water is below 20° C or above 30° C, fill a clean sample bottle (600-700 mL) with the water to be tested. Cap and bring back to the classroom. Allow the water to reach 20° – 30° C, record the temperature and then proceed to step 5.
5. Rinse two 100-mL beakers two times with sample water.
6. Pour about 50 mL of water to be tested into two 100-mL beakers.
7. Remove the cap from the meter. Press the On/Off button to turn it on.
8. Rinse the electrode with distilled water. Blot it dry. Do not rub or stroke the electrode while drying.
9. Put the electrode in the water sample in the first beaker. Stir gently for a few seconds. Do not let the meter rest on the bottom of the beaker or touch the sides.
10. Take the meter out of the first beaker. Shake gently to remove excess water, then put it into the second beaker *without* rinsing with distilled water.
11. Leave the electrodes submerged for at least one minute. When the numbers stop changing, record the value on the *Hydrology Investigation Data Sheet* by *Observer 1*.
12. Have two other students repeat the measurement using fresh beakers of water each time. The meter does not need to be calibrated for each student. Record these measurements as *Observers 2 and 3*.
13. Calculate the average of the three observations.
14. Each of the observations should be within 40 mS/cm of the average. If one or more of the values is not within 40 mS/cm, pour a fresh sample and repeat the measurements and calculate a new average. If all observations still are not within 40.0 of the average, discuss possible problems with your teacher.
15. Rinse the electrode with distilled water, blot dry, and put the cap on the meter. Rinse and dry the beakers and sample bottle.

Frequently Asked Questions

1. Why does my conductivity reading slowly change?

If your conductivity meter is not temperature equilibrated with the sample, the reading will slowly drift until the meter and the sample reach the same temperature. Also if your sample temperature is very different from the surrounding air temperature, the conductivity reading can drift as the sample warms or cools to equilibrate with the air.

2. What happens if my water is really salty or brackish?

Most meters will only measure up to 1990.0 uS/cm. If your water has higher conductivity than this, the meter will not give a reading. You should use the *Salinity Protocol* to measure the dissolved solids in your water.

3. Will the meter give me an electrical shock?



No, however, you should not touch the electrode to avoid contaminating it. The tester should be handled carefully. If it is dropped into the water it may be ruined.



Electrical Conductivity Protocol – Looking at Your Data



Are the data reasonable?

The conductivity tester measures conductivity from 0 to 1990.0 mS/cm. Waters with conductivity values greater than 1990.0 mS/cm must be tested for total dissolved solids by using the *Salinity Protocol*. As a general trend for fresh water, conductivity increases the farther the sample site is from the source. Most conductivity testers increase in units of 10.0 and have a range of error of ± 40.0 mS/cm.



Conductivity may vary significantly with the type of water body and the site. It is therefore important to look at the conductivity of your own site over time. Graph your data and examine them for upward or downward trends. Pay close attention to values that may seem questionable. Check your metadata or other protocol data such as precipitation to see if your values can be explained by other environmental factors.



What do scientists look for in these data?

Scientists use conductivity data as a measure of water quality. High values can mean water that tastes bad or is too salty for watering crops. Most municipal water quality reports use conductivity or TDS measurements to show that their drinking water is within the locally established limits. Scientists also look for trends in the conductivity data. Seasonal trends are often observed for water bodies that receive a portion of their water directly from snowmelt in the spring, water bodies that are affected by land cover, or water bodies that are located in areas with definite rainy seasons. Scientists can use the seasonal data they obtain to forecast water quality issues for years to come.

Example of a Student Research Project.

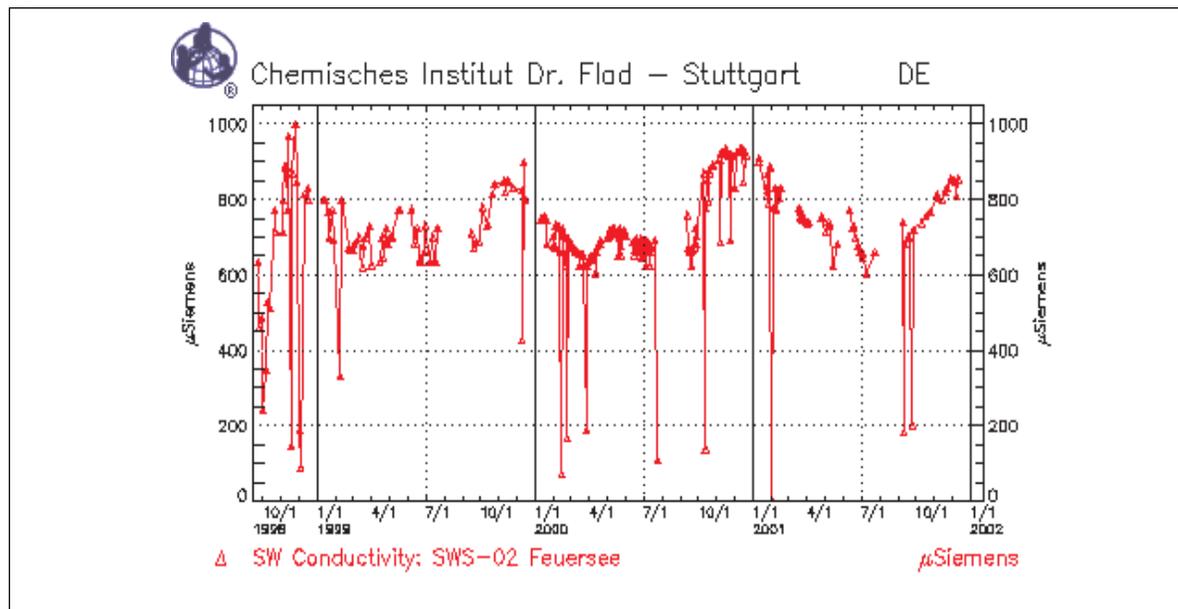
Forming a Hypothesis

A student researcher wants to investigate conductivity. She hypothesizes that annual or seasonal fluctuations in conductivity data should be apparent in GLOBE measurements.

Collecting and Analyzing Data

She starts by searching the GLOBE database for schools that have taken conductivity measurements. She then eliminates schools that

Figure HY-EC-2



have not taken measurements consistently over the course of at least one full year. After plotting the data for several schools using the GLOBE server, the student finds an interesting trend for the data from Chemisches Institut Dr. Flad in Stuttgart, Germany. This graph is shown in Figure HY-EC-2.

The water body where this school takes its measurements is Feuersee, a freshwater lake.

Table HY-EC-2

Date	Cond.
9/1998	527
10/1998	519
11/1998	789
12/1998	545
1/1999	754
2/1999	617
3/1999	675
4/1999	677
5/1999	737
6/1999	692
7/1999	665
9/1999	689
10/1999	790
11/1999	840
12/1999	760
1/2000	730
2/2000	639
3/2000	624
4/2000	654
5/2000	706
6/2000	669
7/2000	613
9/2000	681
10/2000	785
11/2000	878
12/2000	907
1/2001	859
2/2001	701
3/2001	755
4/2001	746
5/2001	697
6/2001	712
7/2001	640
9/2001	560
10/2001	752
11/2001	820
12/2001	842

From this plot the student noted that the conductivity measurements tend to be higher in the winter months and lower in the summer months. She then investigates further by downloading the monthly averages for conductivity values of Chemisches Institut Dr. Flad from the GLOBE Web site. These data are shown below in Table HY-EC-2.

The student then imports these data into a spreadsheet program, and she plots the data as shown in Figure HY-EC-3.

From this plot, the same overall trend can be seen, however it is not as apparent as in Figure HY-EC-1.

The student then decides to look at the trends on a seasonal rather than monthly basis. She divides the year into the four seasons and assigns the months December – February as winter, March – May as spring, June – August as summer and September – November as autumn. She calculates an average conductivity for each season. These data are shown in Table HY-EC-3.

Table HY-EC-3

Season	Cond.
autumn-1998	612
winter-1999	639
spring-1999	696
summer-1999	679
autumn-1999	773
winter-2000	710
spring-2000	661
summer-2000	641
autumn-2000	781
winter-2001	822
spring-2001	733
summer-2001	637
autumn-2001	711



The student then graphs the data as shown in Figure HY-EC-5.



From this plot she is able to see the annual trend more clearly. The student makes a note that the data for August were not available for any of the years in this data set and therefore the summer season is the average of only June and July. The student then decides to plot the data a final way. This time she calculates the average conductivity values of each month for the four-year period, as shown in Table HY-EC-4.

She plots these data as shown in Figure HY-EC-5.



Here again an annual trend can be seen. The student notes that the averages for November, December and January were much higher than the other months in the year. She realizes she

might not have picked the best months to represent each season. Perhaps, November – January should have been chosen for winter. This would most likely have produced a more noticeable trend. However, the student is confident that she has indeed discovered a site that shows an annual trend.

Future Research

For further investigation, the student could contact the school and ask them if they have any ideas of what could be causing this cycle.

She could also look at the seasonal patterns of other measurements, such as precipitation, to see if they might also be related.

She could also repeat this studying by looking at seasonal and monthly patterns in conductivity at other sites.



Table HY-EC-4

	1998	1999	2000	2001	Ave.
January		754	730	859	781
February		617	639	701	652
March		675	624	755	685
April		677	654	746	692
May		737	706	697	713
June		692	669	712	691
July		665	613	640	639
August					
September	527	689	681	560	614
October	519	790	785	752	712
November	789	840	878	820	832
December	545	760	907	842	764



Figure HY-EC-3

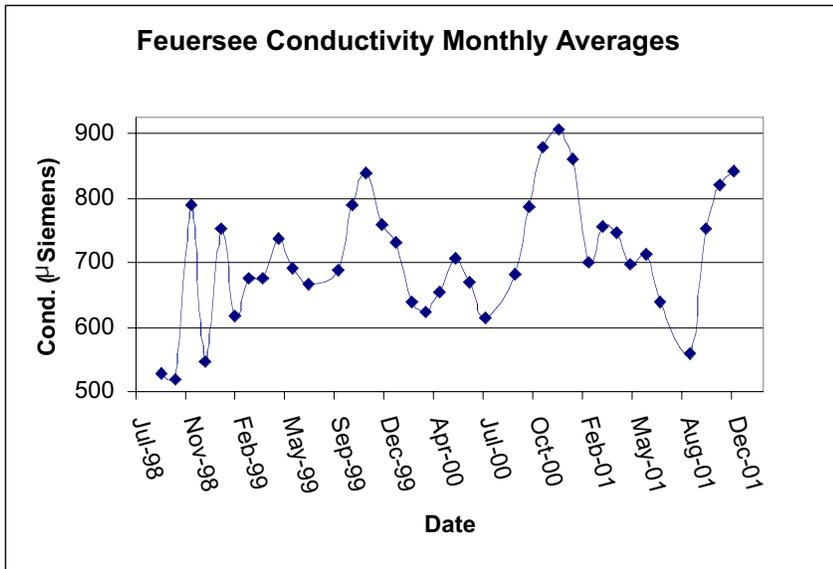


Figure HY-EC-4

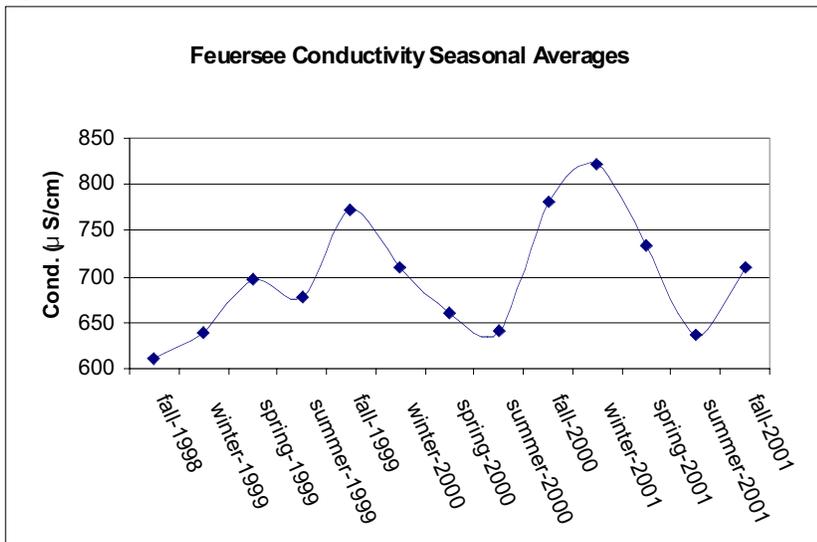
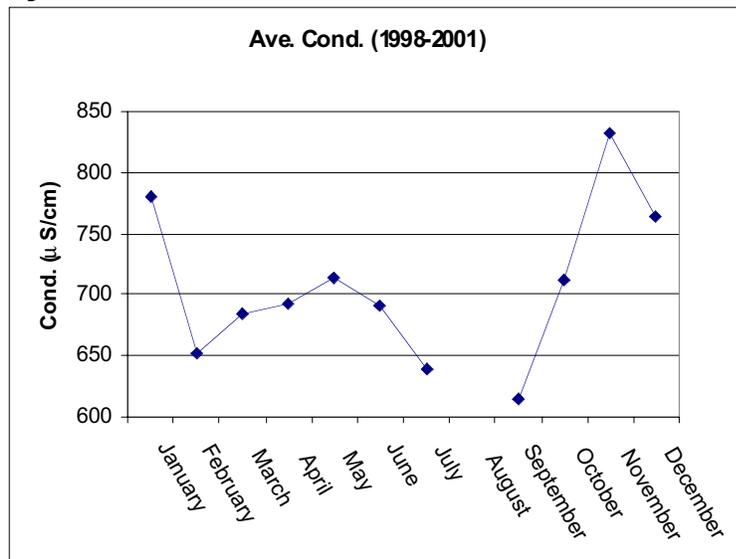


Figure HY-EC-5



Salinity Protocol



Purpose

To measure the salinity of the water at your hydrology site

Overview

Students will use a hydrometer to measure the specific gravity of the water sample, and use a thermometer to measure the temperature. With these two values, students will use tables to determine the salinity.

Student Outcomes

Students will learn to,

- use a hydrometer;
- apply concepts of density and specific gravity to salinity (advanced);
- use tables of specific gravity and temperature values to determine salinity;
- examine reasons for changes in salinity;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Science

Objects have observable properties.

Life Science

Organisms can survive only in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a hydrometer to measure salinity.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes

Quality control – 10 minutes

Level

All

Frequency

Weekly

Quality control check every 6 months

Materials and Tools

Hydrology Investigation Data Sheet

Salinity Protocol Field Guide

Water Temperature Protocol Field Guide

Tide table for region closest to your hydrology site

Hydrometer

Conversion table in *Teacher's Guide*

500-mL clear graduated cylinder

Alcohol-filled thermometer

Latex gloves

For Quality Control Procedure, the above plus:

- *Hydrology Investigation Quality Control Procedure Data Sheet*



- *Quality Control Procedure for Salinity Protocol Lab Guide*
- Salt (NaCl)
- Distilled water
- Balance
- Two 1-liter bottles with caps and labels for storing standards

Preparation

Suggested Learning Activities:
Practicing Your Protocols: Salinity (e-guide only)
Water Detectives (e-guide only)

Prerequisites

Instruction on reading a tide table

Salinity Protocol – Introduction

Why do some types of plants and animals live in brackish estuaries while others live in the ocean and still others live in freshwater lakes and streams? One of the main reasons is the difference in salinities among these environments. Salinity is the measurement of the amount of dissolved solids in water. There are many different types of solids dissolved in water, but the most common dissolved solid is sodium chloride (NaCl). Dissolved solids are often called salts.

All animals and plants have salts inside the cells of their bodies. The concentration of those salts is about one third that of seawater. Plants and animals in both fresh and salt water have special mechanisms to maintain a proper salt balance between their cells and their environment. Freshwater organisms are saltier than the water they live in. Fresh water tends to enter their cells and must be pumped out to keep the cells from swelling and even exploding. Animals such as fish in salt water are less salty than the seawater they live in. Many saltwater fish excrete salts from their gills and produce little urine so that they minimize the loss of liquids from their bodies. Sharks solve the problem by storing extra salts in their cells so that they are in balance with the salt content of the surrounding seawater. As well, animals that feed on organisms that live in brackish or salt water have developed ways to manage the salt content. For instance, seabirds and sea turtles have special salt glands to excrete the salt they take in with food and water. Organisms adapted to one type of environment cannot be moved into another without serious injury or death.

The Earth's oceans average 35 parts per thousand (ppt) salinity. Fresh water measures 0.5 ppt or less. Coastal waters and surface waters of the ocean far from shore can be less salty than 35 ppt due to fresh water input from land or rain, or more salty due to high rates of evaporation in hot climates. Some seas and lakes are also salt water. Some examples include the Caspian Sea in central Asia, the Great Salt Lake in North America, and several lakes in the Great Rift Valley of East Africa. These water bodies are salty because water flows into them, and then evaporates, leaving the salts in the inland sea or lake behind. Freshwater bodies have outlets so the salts move through them instead of accumulating.

Brackish water is water that is saltier than fresh water, but not as salty as seawater. It is found in estuaries and bays where salt water and fresh water mix. Estuaries are bodies of water that are partly enclosed from the open ocean and usually have a freshwater river source. Tides may affect the salinity in these water bodies. When the tide is high, the salinity may be higher than when the tide is low. Salinity may decrease when large amounts of fresh water are added during rain or snowmelt. Plants and animals living in these waters must be able to adapt to rapid and large changes in salinity. The young of many sea animals, such as baby shrimp and fish, live in brackish estuaries. Often these young animals have the ability to survive in a wider range of saltiness than as adults.



Teacher Support

Electrical Conductivity vs. Salinity

The salinity measurement is used to find the total dissolved solids (or salinity) of brackish or salt water. This may be a site along an ocean, estuary, or salt lake. Fresh water has too little dissolved solids to accurately determine the total dissolved solids using the hydrometer. GLOBE schools with freshwater sites use the *Electrical Conductivity Protocol* to find the total dissolved solids in their water. The *Electrical Conductivity Protocol* for fresh water will only measure up to 2000 microSiemens/cm. If your water goes beyond this range you will have to use the *Salinity Protocol*.

Supporting Concepts

Density and Specific Gravity

Density is the ‘lightness’ or ‘heaviness’ of materials of the same size. Density indicates the size of the molecules and how tightly packed the molecules are in a particular substance. The larger and more tightly packed the molecules, the denser the substance is. Density is measured by how heavy something is compared to its volume. We say that a metal spoon is denser than a wooden spoon of the same size because the metal spoon is heavier. Which is denser – a baseball or a solid iron ball of the same size?

Specific gravity is also a measure of density. When we measure specific gravity, we are comparing the density of a material to the density of pure water at 4° C. We use water as a standard because it is a common substance. We use 4° C because that is the temperature at which water is most dense. The specific gravity of pure water at 4° C is by definition 1.0. A substance denser than pure water at 4° C has a specific gravity greater than 1.0.

$$\text{Specific gravity} = \frac{\text{mass of an object of a certain volume}}{\text{mass of an equal volume of pure water.}}$$

If we want to know the specific gravity of an object such as a rock, we need to know the:

1. mass of the rock
2. volume of the rock
3. mass of an equal volume of pure water

The first piece of information is easy. We determine the mass of the rock by weighing it on a balance.

To find the second piece of information, we need to talk about displacement and have a short history lesson.

Archimedes lived in ancient Greece. He discovered two important things while sitting in his bathtub (or so the story goes). The first was that when he stepped into the water, the water level went up. When he sat down, the water level went up even more. He found that when a body is placed in water, it displaces (or moves out of the way) a volume of water equal to the volume of the body.

So, to find the volume of our rock, pour some water into a graduated cylinder. Put the rock in the water. Note how much the water volume increases. The increase in water volume is equal to the volume of the rock. We now have our second piece of information.

Archimedes’ second important discovery was that when a body is placed in the water, it seems to lose mass. This *mass loss* is equal to the mass of the water displaced. So, we can determine the mass of the water that was displaced to get the third piece of information we need. (Or we can calculate the mass of the water since we know that the mass of 1.0 mL of water is 1.0 gram.)

Now, divide the mass of the rock by the mass of the water displaced, and you have the specific gravity of the rock.

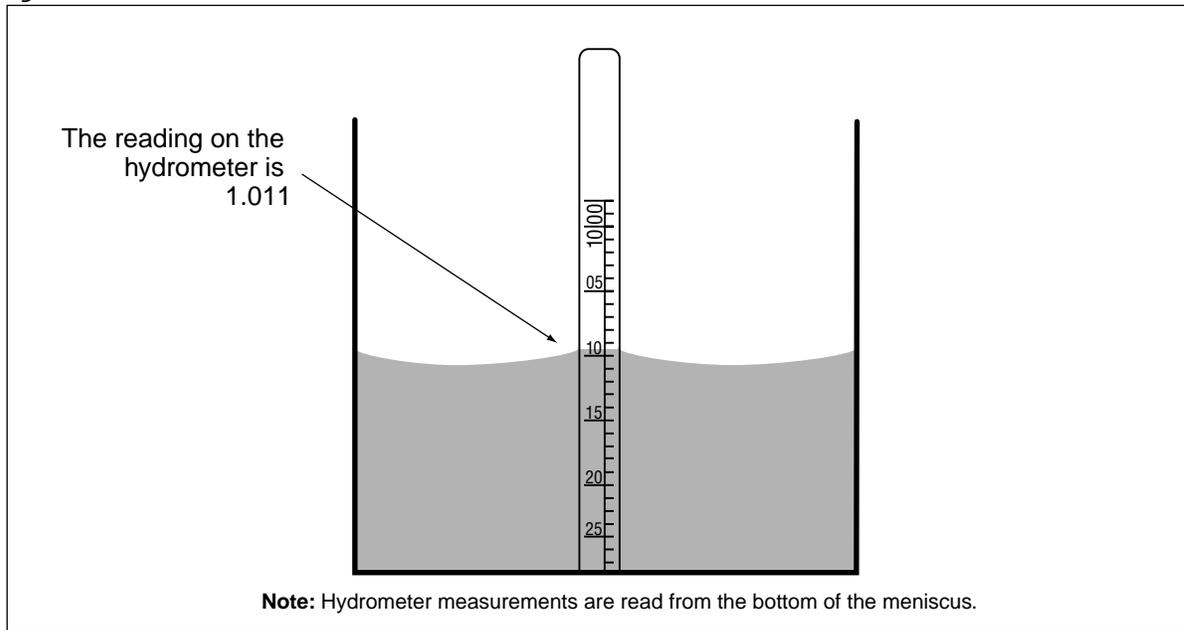
$$\text{Specific gravity} = \frac{\text{mass of rock}}{\text{mass of displaced water}}$$

Each mineral has a characteristic specific gravity. Specific gravity can thus be used to help to identify minerals. Many common rocks are made of a mineral, silica, and have a specific gravity of 2.65. For the *Salinity Protocol*, we are trying to determine the amount of dissolved mineral. This may be a little more difficult for students to understand since they cannot see the ‘rock’. But the principle is the same. We are using the hydrometer to calculate the displacement caused by the addition of dissolved minerals (solids).

Tides

Tides are caused by the gravitational pull of the moon and the sun on Earth. Because the moon is so much closer to Earth than the sun, the moon

Figure HY-SA-1



exerts the greater pull on Earth. The most extreme tides, called spring tides, occur during full and new moons when Earth, moon, and sun are in a line. During quarter and three quarter moons, the moon, Earth and sun form a right angle and the tidal range (the difference between high and low tides) is the smallest. These tides are called neap tides.

Most areas have two low and two high waters per day with one set of high and low more extreme than the others. This is called a mixed semidiurnal tide (mixed because the two tide cycles are uneven and semidiurnal because there are two sets per day). The two high and low water levels occur over approximately 24 hours with each high and low approximately six hours apart. Tide cycles actually occur over a lunar day, which is 24 hours and 50 minutes long. The two low tides in a day occur on average every 12 hours 25 minutes. The time of the first low tide each day occurs on average approximately 50 minutes later than the day before. Local topographic features may cause these times to vary.

Zero tide datum (also expressed as + 0, or "plus 0") is a measure of the average low tide level. There are two different definitions used worldwide for the zero tide datum: mean lower low water and mean low water. Mean lower low water is *the mean of the lowest tides* for that area. Mean low water is *the mean of all of the low tides* for that area. The zero tide datum will be found in the legend of the

tide table. Students will need to check off on the data sheet which definition of zero tide datum is used on their tide table.

Measurement Procedure

Using the Hydrometer

The hydrometer is an instrument that allows us to measure the specific gravity of a fluid. Remember that specific gravity is a comparison of the density of the fluid you are measuring to the density of pure water at 4° C.

A hydrometer is a small float with a scale on its stem. If you put the hydrometer in pure water at the same temperature, it will float at the same depth. As salts are added to the water, it begins to float higher. As the water gets denser, more of the hydrometer is exposed. Marks along the hydrometer allow you to read the specific gravity directly from the hydrometer without having to calculate the mass of the water displaced.

With most substances, "cooler is denser". Water changes densities as it cools and warms. Remember that specific gravity is measured according to water at 4° C. Your hydrometer may take specific gravity readings at a different temperature. Look on your instrument to find the temperature for which it is calibrated. If the temperature of your water is different from the temperature for which the hydrometer is calibrated, you have to make an adjustment for temperature using a conversion table.

Table HY-SA-1: Tide Table for Aberdeen, Washington

Tide Predictions (High and Low Waters) August, 2002								
Source: NOAA, National Ocean Service								
Daylight Saving Time								
Day	Time	Ht.	Time	Ht.	Time	Ht.	Time	Ht.
1	Th	131am L 0.6	730am H 2.0	106pm L 0.8	740pm H 2.6			
2	F	233am L 0.5	841am H 1.9	206pm L 1.0	832pm H 2.7			
3	Sa	335am L 0.3	956am H 1.9	313pm L 1.1	928pm H 2.7			
4	Su	432am L 0.1	1105am H 2.0	417pm L 1.1	1024pm H 2.8			
5	M	526am L -0.2	1204pm H 2.2	516pm L 1.0	1118pm H 2.9			
6	Tu	616am L -0.4	1256pm H 2.3	611pm L 0.9				
7	W	1209am H 3.0	703am L -0.6	143pm H 2.5	702pm L 0.8			
8	Th	1258am H 3.2	747am L -0.7	228pm H 2.6	751pm L 0.6			
9	F	147am H 3.2	831am L -0.8	309pm H 2.7	839pm L 0.5			
10	Sa	237am H 3.2	913am L -0.7	349pm H 2.8	927pm L 0.3			
11	Su	327am H 3.2	955am L -0.6	428pm H 2.9	1017pm L 0.2			
12	M	419am H 3.0	1037am L -0.4	508pm H 3.0	1109pm L 0.1			
13	Tu	514am H 2.8	1121am L -0.1	549pm H 3.0				
14	W	1206am L 0.1	614am H 2.5	1209pm L 0.2	634pm H 3.0			
15	Th	108am L 0.1	721am H 2.3	104pm L 0.5	725pm H 3.0			
16	F	215am L 0.0	837am H 2.1	206pm L 0.8	824pm H 2.9			
17	Sa	323am L 0.0	956am H 2.1	313pm L 0.9	928pm H 2.9			
18	Su	428am L -0.1	1110am H 2.2	419pm L 1.0	1032pm H 2.9			
19	M	527am L -0.2	1211pm H 2.3	521pm L 0.9	1130pm H 2.9			
20	Tu	618am L -0.3	101pm H 2.5	616pm L 0.8				
21	W	1221am H 2.9	703am L -0.3	142pm H 2.6	705pm L 0.7			
22	Th	106am H 2.9	744am L -0.3	220pm H 2.7	750pm L 0.6			
23	F	148am H 2.9	821am L -0.3	254pm H 2.7	831pm L 0.5			
24	Sa	228am H 2.8	856am L -0.2	326pm H 2.7	910pm L 0.5			
25	Su	307am H 2.8	928am L 0.0	355pm H 2.7	949pm L 0.4			
26	M	346am H 2.7	1000am L 0.2	423pm H 2.7	1027pm L 0.4			
27	Tu	426am H 2.5	1029am L 0.3	450pm H 2.7	1107pm L 0.4			
28	W	510am H 2.3	1058am L 0.5	519pm H 2.7	1152pm L 0.4			
29	Th	600am H 2.2	1129am L 0.8	551pm H 2.7				
30	F	1244am L 0.4	659am H 2.0	1208pm L 1.0	633pm H 2.6			
31	Sa	146am L 0.4	810am H 2.0	113pm L 1.2	730pm H 2.6			

Note: Heights in this table are in meters. Many tide tables in the United States and in Canada are in feet. To convert feet to meters, divide the data by 3.28 ft/m.
All tide tables (including this one) are in local time. You will need to convert to UT.



Reading a Tide Table

You need a tide table calculated for the local area to determine the tides in your area. The tide table will give you the dates, times and water levels for high and low water. These are available from government agencies, private fisheries and tourist agencies. They can also be found on the web, in newspapers, or published as booklets. Because tides vary each year with the lunar cycle, it is necessary to use a tide table calculated for the current year. Tides also vary with each locality, so try to get a tide table for the exact area you are observing, or for the closest area for which tide tables are available. You may need to consult two tide tables - a primary tide table based on a tide station in the general region of your site and an auxiliary tide table with corrections for time and tidal height for your particular site.



To determine the tidal height at a particular time and date, read on the tide table the times of high and low water for the date you sampled that bracket the time you sampled. Determine whether the tide was coming in or going out when you sampled by assuming that the tide turned (changed direction) at the times of low and high tides. For instance if you sampled at 4 PM on August 1, 2002 (Table HY-SA-1), the tide was coming in because it was low at 1:06 PM and high at a later time, 7:40 PM.



To determine the time and date of the lowest tide for a particular month, use your tide table to find the heights of the tides over the entire month. Which number is lowest (including negative numbers)? This is the lowest tide of the month when the water recedes the farthest from the shore.



Which number is the highest? This number is likely to fall just after the lowest tide. Look at the illustration for the tide table for Aberdeen, Washington for August 2002 to determine the times and dates of highest and lowest tides for that month. The most extreme low tide of -0.8 meters occurred on Aug 9th at 08:31 local time. A high tide of 3.2 meters occurred 6 hours 44 minutes earlier at 01:47 local time.



It is important to know for interpreting your data which zero tide datum is used on your tide table.



The negative numbers refer to water levels below the zero tide datum for your area. For example, a tide level of - 0.5 is read as “minus one half meter below the zero tide level”.

Supporting Activities

Hydrometers are used to compare the densities of many liquids. For example, the amount of sugar in fruit juice, the amount of fat in milk, and the amount of salt in water. You can create your own practice hydrometer with a weight (e.g. clay or putty) on a stick suspended in water. Take three different clear liquids: freshwater, saltwater, and distilled water. Identify each liquid using a hydrometer. You can calibrate the practice hydrometer by comparing it to a calibrated hydrometer.

Helpful Hints

- The glass hydrometer is easily broken. Always lay it down gently. Do not lay it where it could roll off of a table. Gently place the hydrometer into the 500-mL cylinder – do not drop it in!
- The 35 ppt standard may be kept up to one year in a tightly closed bottle and can be used many times.
- After you receive a new hydrometer, use standards to check its accuracy. It is not reading correctly, contact the manufacturer.

Questions for Further Investigation

Would brackish water be good to use for irrigation? Why or why not?

Why do all of Earth's oceans have approximately the same salinity (35 ppt)?

How might a rise in ocean level affect estuary and bay areas?

How does salinity at your site compare to salinity at other sites at the same and different latitudes?

How does outflow of freshwater from nearby rivers influence salinity at your site?

Are there seasonal patterns of river water use in your area?

Would you expect to find seasonal changes in salinity levels at your site?

How does salinity vary with average monthly air temperature at your site?

Quality Control Procedure for Salinity Protocol

Lab Guide

Task

Check the accuracy of your hydrometer.

What You Need

- Water Temperature Field Guide*
- Hydrometer
- Salinity Conversion table in *Teacher's Guide*
- 500-mL clear graduated cylinder
- Alcohol-filled thermometer (calibrated)
- Hydrology Investigation Quality Control Procedure Data Sheet*
- Distilled water
- Salt (NaCl)
- Balance

In the Lab

Make the 35 ppt Standard

1. Measure 17.5 g of table salt (NaCl) with the balance.
2. Pour the salt into the 500-mL cylinder.
3. Fill the cylinder to the 500-mL line with distilled water.
4. Gently mix the salt and water until all of the salt is dissolved. This is your 35-ppt standard.

Check your Hydrometer Using Distilled Water

1. Pour 500 mL of distilled water into the 500-mL cylinder.
2. Put the thermometer in the distilled water. Use the *Water Temperature Field Guide* to measure the water temperature. Record on the *Hydrology Investigation Quality Control Procedure Data Sheet*.
3. Place the hydrometer gently into the water. After it stops bobbing, read the specific gravity at the bottom of the meniscus. It should not touch the sides of the cylinder. Read to three places and record on the *Hydrology Investigation Quality Control Procedure Data Sheet*.
4. Look up the specific gravity and temperature on the conversion table. The salinity should be between 0.0 and 1.0 ppt.
5. If the salinity is not between 0.0 and 1.0 ppt, recheck your measurements. If the salinity is still not between 0.0 and 1.0 ppt, your hydrometer is not reading correctly.

Check your Hydrometer Using the Standard

1. Put the standard in a 500-mL cylinder.
2. Put the thermometer in the distilled water. Use the *Water Temperature Field Guide* to measure the water temperature. Record on the *Hydrology Investigation Quality Control Procedure data Sheet*.
3. Gently place the hydrometer into the cylinder. When it stops bobbing, read the specific gravity at the bottom of the meniscus. It should not touch the sides of the cylinder. Read to three places and record on the *Hydrology Investigation Quality Control Procedure Data Sheet*.
4. Look up the specific gravity and water temperature on the conversion table to find the salinity of the water. Record the salinity on the *Hydrology Investigation Quality Control Procedure Data Sheet*.
5. If the salinity standard is off by more than 1 ppt, mix a new standard and repeat the procedure. If it is still off by more than 1 ppt, talk to your teacher about possible problems.
6. Discard the 35-ppt standard or pour it into a clean and dry 1-L bottle, cap, and label. Rinse equipment with distilled water, dry, and store.

Salinity Protocol

Field Guide

Task

Measure the salinity of your water sample.

What You Need

- Tide Table for your area
- Thermometer
- Hydrology Investigation Data Sheet*
- Conversion Table
- Water Temperature Protocol Field Guide*
- Pen or pencil
- Hydrometer
- Latex gloves
- 500-mL clear, graduated cylinder

In the Field

1. Fill out the top portion of your *Hydrology Investigation Data Sheet*.
2. In the Salinity section of the *Hydrology Investigation Data Sheet*, record the times of the high tide and low tide that occur before and after your salinity measurement is taken. Also record the place where the times from your Tide Table occur.
3. Put on gloves.
4. Rinse the 500-mL cylinder with sample water twice.
5. Fill the cylinder with sample water to within 2 or 3 cm of the top.
6. Measure and record the temperature of the water in the cylinder. (See *Hydrology Investigation, Water Temperature Protocol Field Guide*)
7. Gently put the hydrometer into the cylinder.
8. Wait for the hydrometer to stop bobbing. It should not touch the sides of the cylinder.
9. Read the hydrometer at the bottom of the meniscus. Read the specific gravity to three decimal places. Record the specific gravity on the *Hydrology Investigation Data Sheet*.
10. Look up the specific gravity and water temperature on the Conversion Table to find the salinity of the water. Record the salinity on the *Hydrology Investigation Data Sheet* as *Observer 1*.
11. Repeat Steps 3-9 using new samples of water. Record the salinity measurements as *Observers 2* and *3*.
12. Calculate the average of the three measurements.
13. Each of the three measurements should be within 2 ppt of the average. If one or more of the observations is not within 2.0 ppt, do the measurement again and calculate a new average. If the measurements are still not within 2.0 ppt of the new average, talk to your teacher about possible problems.

Table HY-SA-2: Salinity (parts per thousand) as a function of specific gravity and temperature (as of 2/2002)

Observed Reading	Temperature of Water (°C)																
	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.998																	
0.999																	
1																	
1.001	2	1.9	1.9	1.8	1.8	1.5	1.5	1.5	1.5	1.5	1.5	1.8	1.8	1.9	1.9	2	2.1
1.002	3.3	3.2	3.2	3.1	2.9	2.9	2.9	2.8	2.8	2.9	2.9	2.9	3.1	3.2	3.3	3.4	3.6
1.003	4.6	4.5	4.4	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.4	4.5	4.6	4.7	4.9
1.004	5.8	5.7	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.5	5.5	5.7	5.8	5.9	6.1	6.2
1.005	7.1	7	6.8	6.7	6.7	6.7	6.6	6.6	6.7	6.7	6.7	6.8	6.8	7	7.1	7.2	7.5
1.006	8.3	8.1	8.1	8	7.9	7.9	7.9	7.9	7.9	8	8	8.1	8.1	8.3	8.4	8.5	8.8
1.007	9.4	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.3	9.4	9.4	9.6	9.7	9.8	10.1
1.008	10.7	10.6	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.6	10.6	10.7	10.9	11	11.1	11.3
1.009	11.9	11.8	11.8	11.7	11.7	11.7	11.7	11.7	11.8	11.8	11.9	11.9	12	12.2	12.3	12.4	12.6
1.01	13.2	13.1	13	13	13	13	13	13	13	13.1	13.1	13.2	13.3	13.5	13.6	13.7	13.9
1.011	14.4	14.3	14.3	14.1	14.1	14.1	14.1	14.3	14.3	14.4	14.4	14.5	14.7	14.8	14.9	15	15.2
1.012	15.6	15.6	15.4	15.4	15.4	15.4	15.4	15.4	15.6	15.6	15.7	15.8	16	16.1	16.2	16.3	16.5
1.013	16.9	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.9	17	17.1	17.1	17.3	17.5	17.6	17.8	
1.014	18	18	17.9	17.9	17.9	17.9	17.9	18	18	18.2	18.3	18.3	18.4	18.6	18.8	19	19.1
1.015	19.3	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.3	19.3	19.5	19.6	19.7	19.9	20.1	20.3	20.4
1.016	20.5	20.5	20.4	20.4	20.4	20.4	20.5	20.5	20.6	20.6	20.8	20.9	21	21.2	21.4	21.6	21.7
1.017	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.8	21.8	21.9	22.1	22.2	22.3	22.5	22.6	22.9	23
1.018	23	23	23	22.9	22.9	23	23	23	23.1	23.3	23.4	23.5	23.6	23.8	23.9	24.2	24.3
1.019	24.2	24.2	24.2	24.2	24.2	24.2	24.3	24.3	24.4	24.6	24.7	24.8	24.9	25.1	25.2	25.5	25.6
1.02	25.5	25.5	25.5	25.3	25.5	25.5	25.5	25.6	25.6	25.7	25.9	26	26.1	26.4	26.5	26.8	26.9
1.021	26.6	26.6	26.6	26.6	26.6	26.8	26.8	26.9	26.9	27	27.2	27.3	27.4	27.7	27.8	28.1	28.2
1.022	27.9	27.9	27.9	27.9	27.9	27.9	28.1	28.1	28.2	28.3	28.5	28.6	28.7	29	29.1	29.4	29.5
1.023	29.1	29.1	29.1	29.1	29.1	29.2	29.2	29.4	29.5	29.6	29.8	29.9	30	30.2	30.4	30.7	30.8
1.024	30.4	30.4	30.4	30.4	30.4	30.4	30.5	30.7	30.8	30.8	31.1	31.2	31.3	31.5	31.7	31.9	32.1
1.025	31.6	31.6	31.6	31.6	31.7	31.7	31.9	31.9	32	32.1	32.2	32.4	32.6	32.8	33	33.2	33.4
1.026	32.9	32.9	32.9	32.9	32.9	33	33	33.2	33.3	33.4	33.5	33.7	33.9	34.1	34.3	34.5	34.7
1.027	34.1	34.1	34.1	34.2	34.2	34.2	34.3	34.5	34.6	34.7	34.8	35	35.2	35.4	35.6	35.8	36
1.028	35.2	35.4	35.4	35.4	35.4	35.5	35.6	35.8	35.8	36	36.1	36.3	36.4	36.7	36.9	37.1	37.3
1.029	36.5	36.5	36.5	36.7	36.7	36.8	36.8	36.9	37.1	37.2	37.5	37.6	37.7	38	38.1	38.4	38.6
1.03	37.7	37.8	37.8	37.8	38	38	38.1	38.2	38.4	38.5	38.6	38.9	39	39.3	39.4	39.7	39.9
1.031	39	39	39	39.1	39.1	39.3	39.4	39.5	39.7	39.8	39.9	40.2	40.3	40.6	40.7	41	41.2

Table HY-SA-2: Salinity (parts per thousand) as a function of specific gravity and temperature (as of 2/2002)- continued

Observed Reading	Temperature of Water (° C)																
	15	16	17	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5	24	24.5
0.998																	
0.999										1.3	1.4	1.5	1.6	1.8	1.9	2	
1		1.3	1.5	1.6	1.8	1.9	2	2.1	2.3	2.4	2.5	2.7	2.8	2.9	3.1	3.2	3.3
1.001	2.3	2.5	2.8	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.8	3.8	4	4.1	4.2	4.4	4.5
1.002	3.7	3.8	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5	5.1	5.3	5.4	5.5	5.7	5.9	6.1
1.003	5	5.1	5.4	5.5	5.7	5.8	5.9	6.1	6.2	6.3	6.4	6.6	6.7	6.8	7.1	7.2	7.4
1.004	6.3	6.4	6.7	6.8	7	7.1	7.2	7.4	7.5	7.6	7.7	7.9	8	8.3	8.4	8.5	8.7
1.005	7.6	7.9	8	8.3	8.4	8.4	8.5	8.7	8.8	8.9	9	9.2	9.4	9.6	9.7	9.8	10
1.006	8.9	9.2	9.3	9.6	9.7	9.8	10	10.1	10.2	10.4	10.5	10.6	10.7	10.9	11	11.1	11.4
1.007	10.2	10.5	10.6	10.9	11	11.1	11.3	11.4	11.5	11.7	11.8	11.9	12	12.2	12.3	12.6	12.7
1.008	11.5	11.8	11.9	12.2	12.3	12.4	12.6	12.7	12.8	13	13.1	13.2	13.3	13.5	13.7	13.9	14
1.009	12.8	13.1	13.2	13.5	13.6	13.7	13.9	14	14.1	14.3	14.4	14.5	14.7	14.9	15	15.2	15.3
1.01	14.1	14.4	14.5	14.8	14.9	15	15.2	15.3	15.4	15.6	15.7	15.8	16.1	16.2	16.3	16.5	16.6
1.011	15.4	15.7	15.8	16.1	16.2	16.3	16.5	16.6	16.7	16.9	17	17.3	17.4	17.5	17.6	17.8	18
1.012	16.7	17	17.1	17.4	17.5	17.6	17.8	17.9	18	18.3	18.4	18.6	18.7	18.8	19	19.2	19.3
1.013	18	18.3	18.4	18.7	18.8	19	19.1	19.2	19.3	19.6	19.7	19.9	20	20.1	20.4	20.5	20.6
1.014	19.3	19.6	19.9	20	20.1	20.3	20.4	20.6	20.8	20.9	21	21.2	21.3	21.4	21.7	21.8	21.9
1.015	20.6	20.9	21.2	21.3	21.4	21.7	21.8	21.9	22.1	22.2	22.3	22.5	22.6	22.9	23	23.1	23.3
1.016	21.9	22.2	22.5	22.6	22.7	23	23.1	23.3	23.4	23.5	23.6	23.8	24	24.2	24.3	24.6	24.7
1.017	23.3	23.5	23.8	24	24.2	24.3	24.4	24.6	24.7	24.8	24.9	25.1	25.3	25.5	25.6	25.9	26
1.018	24.6	24.8	25.1	25.3	25.5	25.6	25.7	25.9	26	26.1	26.2	26.5	26.6	26.8	26.9	27.2	27.3
1.019	25.9	26.1	26.4	26.6	26.8	26.9	27	27.2	27.3	27.4	27.7	27.8	27.9	28.1	28.3	28.5	28.6
1.02	27.2	27.4	27.7	27.9	28.1	28.2	28.3	28.5	28.6	28.7	29	29.1	29.2	29.5	29.6	29.8	29.9
1.021	28.5	28.7	29	29.2	29.4	29.5	29.6	29.8	29.9	30.2	30.3	30.4	30.5	30.8	30.9	31.1	31.3
1.022	29.8	30	30.3	30.5	30.7	30.8	30.9	31.1	31.3	31.5	31.6	31.7	32	32.1	32.2	32.5	32.6
1.023	31.1	31.3	31.6	31.9	32	32.1	32.2	32.5	32.6	32.8	32.9	33	33.3	33.4	33.5	33.8	33.9
1.024	32.4	32.6	32.9	33.2	33.3	33.4	33.5	33.8	33.9	34.1	34.2	34.5	34.6	34.7	35	35.1	35.2
1.025	33.7	33.9	34.2	34.5	34.6	34.7	35	35.1	35.2	35.4	35.5	35.8	35.9	36	36.3	36.4	36.5
1.026	35	35.2	35.5	35.8	35.9	36	36.3	36.4	36.5	36.7	36.9	37.1	37.2	37.3	37.6	37.7	38
1.027	36.3	36.5	36.8	37.1	37.2	37.5	37.6	37.7	37.8	38	38.2	38.4	38.5	38.8	38.9	39.1	39.3
1.028	37.6	37.8	38.1	38.4	38.5	38.8	38.9	39	39.1	39.4	39.5	39.7	39.8	40.1	40.2	40.4	40.6
1.029	38.9	39.1	39.4	39.7	39.9	40.1	40.2	40.3	40.4	40.7	40.8	41	41.2	41.4	41.5	41.8	41.9
1.03	40.2	40.4	40.7	41	41.2	41.4	41.5	41.6	41.9	42	42.1	42.3	42.5	42.7	42.9	43.1	43.2
1.031	41.5	41.8	42	42.3	42.5	42.7	42.8	43.1	43.2	43.3	43.4	43.6	43.8				

Table HY-SA-2: Salinity (parts per thousand) as a function of specific gravity and temperature (as of 2/2002)- continued

Observed Reading	Temperature of Water (° C)																
	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33
0.998			1.4	1.5	1.6	1.9	2	2.1	2.4	2.5	2.8	2.9	3.2	3.3	3.6	3.7	
0.999	2.1	2.3	2.5	2.7	2.8	3.1	3.2	3.3	3.6	3.7	3.8	4.1	4.2	4.5	4.7	4.9	5.1
1	3.4	3.7	3.8	4	4.2	4.4	4.5	4.7	4.9	5	5.3	5.4	5.7	5.8	6.1	6.2	6.4
1.001	4.7	4.9	5.1	5.3	5.5	5.7	5.8	6.1	6.2	6.4	6.4	6.7	6.8	7.1	7.2	7.5	7.7
1.002	6.2	6.3	6.4	6.7	6.8	7	7.2	7.4	7.6	7.7	7.9	8.1	8.3	8.5	8.8	8.9	9.2
1.003	7.5	7.6	7.9	8	8.1	8.4	8.5	8.7	8.9	9	9.3	9.4	9.7	9.8	10.1	10.4	10.5
1.004	8.8	9	9.2	9.3	9.6	9.7	9.8	10.1	10.2	10.5	10.6	10.9	11	11.3	11.4	11.7	11.8
1.005	10.2	10.4	10.5	10.6	10.9	11	11.3	11.4	11.5	11.8	11.9	12.2	12.3	12.6	12.8	13	13.2
1.006	11.5	11.7	11.8	12	12.2	12.3	12.6	12.7	13	13.1	13.3	13.5	13.7	13.9	14.1	14.4	14.5
1.007	12.8	13	13.2	13.3	13.5	13.7	13.9	14.1	14.3	14.4	14.7	14.9	15	15.3	15.4	15.7	16
1.008	14.1	14.3	14.5	14.7	14.9	15	15.2	15.4	15.6	15.8	16	16.2	16.5	16.6	16.9	17	17.3
1.009	15.4	15.7	15.8	16	16.2	16.3	16.6	16.7	17	17.1	17.4	17.5	17.8	17.9	18.2	18.4	18.6
1.01	16.9	17	17.1	17.4	17.5	17.8	17.9	18	18.3	18.4	18.7	18.8	19.1	19.3	19.5	19.7	20
1.011	18.2	18.3	18.6	18.7	18.8	19.1	19.2	19.5	19.6	19.9	20	20.3	20.4	20.6	20.9	21	21.3
1.012	19.5	19.6	19.9	20	20.3	20.4	20.6	20.8	20.9	21.2	21.4	21.6	21.8	21.9	22.2	22.5	22.6
1.013	20.8	21	21.2	21.3	21.6	21.7	21.9	22.1	22.3	22.5	22.7	22.9	23.1	23.4	23.5	23.8	24
1.014	22.2	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.6	23.9	24	24.3	24.4	24.7	24.9	25.1	25.3
1.015	23.5	23.6	23.8	24	24.2	24.4	24.6	24.8	24.9	25.2	25.3	25.6	25.9	26	26.2	26.5	26.6
1.016	24.8	24.9	25.2	25.3	25.6	25.7	26	26.1	26.4	26.5	26.8	26.9	27.2	27.4	27.6	27.8	28.1
1.017	26.1	26.4	26.5	26.6	26.9	27	27.3	27.4	27.7	27.8	28.1	28.3	28.5	28.7	29	29.1	29.4
1.018	27.4	27.7	27.8	28.1	28.2	28.5	28.6	28.9	29	29.2	29.4	29.6	29.8	30	30.3	30.5	30.7
1.019	28.9	29	29.1	29.4	29.5	29.8	29.9	30.2	30.3	30.5	30.8	30.9	31.2	31.3	31.6	31.9	32.1
1.02	30.2	30.3	30.5	30.7	30.9	31.1	31.3	31.5	31.7	31.9	32.1	32.2	32.5	32.8	32.9	33.2	33.4
1.021	31.5	31.6	31.9	32	32.2	32.4	32.6	32.8	33	33.3	33.4	33.7	33.8	34.1	34.3	34.6	34.7
1.022	32.8	33	33.2	33.3	33.5	33.8	33.9	34.2	34.3	34.6	34.7	35	35.2	35.4	35.6	35.9	36.1
1.023	34.1	34.3	34.5	34.7	34.8	35.1	35.2	35.5	35.8	35.9	36.1	36.3	36.5	36.8	36.9	37.2	37.5
1.024	35.5	35.6	35.8	36	36.3	36.4	36.7	36.8	37.1	37.2	37.5	37.7	37.8	38.1	38.4	38.5	38.8
1.025	36.8	36.9	37.2	37.3	37.6	37.7	38	38.1	38.4	38.5	38.8	39	39.1	39.4	39.7	39.9	40.1
1.026	38.1	38.2	38.5	38.6	38.9	39	39.3	39.5	39.7	39.9	40.1	40.3	40.6	40.7	41	41.2	41.5
1.027	39.4	39.7	39.8	40.1	40.2	40.4	40.6	40.8	41.1	41.2	41.5	41.6	41.9	42.1	42.3	42.5	42.8
1.028	40.7	41	41.1	41.4	41.5	41.8	42	42.1	42.4	42.5	42.8						
1.029	42.1	42.3	42.5	42.7	42.9	43.1											

Salinity Protocol – Looking at the Data

Are these data reasonable?

Fresh water usually has a salinity level of 0-0.5 ppt. Brackish water usually has salinity levels of 0.5-25 ppt. The average salinity of the ocean is 34.5 ppt and generally ranges from 32 ppt to 37 ppt. Commonly, salinity will vary at a site depending on the addition or removal of fresh water. Estuaries show the greatest variability in salinity.

On average, the ocean is least salty at the poles and the equator, and most salty in subtropical oceans. The association of salinity with latitude has to do with the relative amounts of rainfall and evaporation around the globe. Salinity is lowered where fresh water enters the ocean by rainfall, ice melt, and river outflow. Salinity increases where fresh water leaves the ocean by evaporation and ice formation. Each of these factors is influenced by weather patterns around the globe.

Salinity values decrease toward the equator to 34-35 ppt because of the abundant rainfall and relatively low evaporation rates that occur there. Salinity can be less than 34 ppt in cooler latitudes with heavy rainfall. Coastal waters can have some of the lowest salinity values because of fresh water input from rivers and melting ice. Coastal waters can have some of the highest salinities as well due to ice freezing and evaporation of shallow waters during the summer. Wind can blow salt water onto land where it covers plant leaves and soil.

Salinity can vary over a tidal cycle as well. At low tide during the summer months, evaporation can cause salinity to rise in a tide pool until the ocean returns as the tide comes in and dilutes the tide pool water, returning it to normal salinity. In estuaries, salinity is strongly influenced by the tides. As the tide is rising towards high tide, the ocean flows up the river and raises salinity in an estuary or river mouth. As the tide falls during an outgoing tide, the river is drained of ocean water and salinity goes down. Salinity in estuaries is influenced by depth as well. Salty water is heavier than fresh water and sinks toward the bottom.

This keeps the salinity in the sediment in estuaries relatively high and protects coastal animals that live in the mud from having to adjust to a large change in salinity with each tidal cycle.

We expect salinity to show a seasonal pattern, rising in the summer and lowering in the winter due to increased evaporation in summer months as water temperature rises. To test this, we can look at the data and see if salinity is higher in the summer and lower in the winter. We can also look to see if a change in salinity is correlated with a change in air and water temperature.

A good data set for looking at this prediction is that collected at Tabor Academy located on the Atlantic coast in Marion, Massachusetts, USA. Tabor Academy recorded salinity and water temperature from 1997-2001 at a coastal site called “Schaeffer Sea Wall”. They also measured air temperature at their school location. The graph below of the averages of air temperature, water temperature and salinity shows a seasonal pattern. As air and water temperatures go up in the spring and summer, so does salinity. As air and water temperatures go down in the autumn and winter, so does salinity. In addition, looking at the graph, it appears that air temperature goes up first, followed by water temperature, followed by salinity. This makes sense since salinity probably rises due to increased evaporation caused by an increase in water temperature, which in turn is caused by an increase in air temperature. To further support the hypothesis, all three years show the same pattern.

What do the scientists look for in these data?

What are the long-term trends in salinity in estuaries? There are increasingly more demands on the fresh water that supplies estuaries, so they may be becoming more saline over time.

At ocean sites, we expect changes in salinity to be related to changes in temperature. An increase in temperature can cause an increase in evaporation. This results in an increase in salinity. Near the poles, however, an increase in temperature may cause an increase in the melting of fresh water ice and result in a decrease in salinity.



Latitudinal distribution of salinity may also be related to large-scale weather pattern, as precipitation and evaporation can affect salinity. Salinity tends to be highest around 20-30 N and 15-20 S, and lowest at the poles and near the equator.



Example of a Student Research Project **Forming a Hypothesis**

Students studying the salinity in estuaries are looking at the salinity at three sites shown in Figure HY-SA-3. The first two are in Mobile Bay, one at Mary Ann Beach near Robertsdale, Alabama and the second, the “Boat Ramp” site, near the convergence of the Tensaw River with the Mobile Bay. The third site is the Bayou St. John in New Orleans, Louisiana. It is listed as a freshwater site, but the Bayou St. John is an estuary connected to the Gulf of Mexico and the students have been collecting salinity data. The measurements at the first two sites were collected by Robertsdale High School and Cabrini High in New Orleans took measurements at the third site.



Students at Robertsdale High School were curious to see how their measurements compare with the other two sites and formed the following hypothesis.

Hypothesis: Salinity will be highest at Mary Ann Beach and lowest at the nearby Boat Ramp, which should receive the highest amount fresh water. Salinity at Bayou St. John (part of the delta of the Mississippi River) will be in between.



Collecting and Analyzing Data

The students plot time series of salinity for the three sites. Although Robertsdale High School usually used the hydrometer to measure salinity, sometimes they used the salinity titration method as well. The measured values collected with the titration were similar to those collected using the hydrometer (Figure HY-SA-4) so they decided to concentrate on just the hydrometer readings.



They plot the monthly average salinity at the three sites (Figure HY-SA-5).

The average monthly salinity at the boat site is always less than 5 ppt and definitely the lowest of the three sites. The salinity at Bayou St. John

ranged from 5 to 10 ppt. However, the salinity at Mary Ann Beach ranges from 5 to 25 ppt. This is too low to be considered ocean waters. The students are surprised to see how much fluctuation in salinity occurs at the beach, but realize upon further research that it is fairly typical of estuary environments.

Discussion and Conclusions

They decide that their hypothesis is mostly correct. The salinity at the boat site is the lowest and Bayou tends to be lower than at Mary Ann Beach, although there are some overlapping values.

They are not sure whether the fluctuations in salinity are due to tides (lower tides might lead to lower salinity) or temperature, or perhaps both.

They plot the average monthly water temperature and hydrometer salinity (Figure HY-SA-6). There are some similarities in pattern, but the temperature –salinity relationship is not as obvious here as at some other sites (such as in the Tabor Academy example), so they know some other factors such as tide and freshwater influx must be influencing salinity as well.

Communicating Results

The students print out their graphs and write a report discussing their results. They also give an oral report to their class.

Thoughts for Future Research

All three sites are examples of different estuarine conditions that exist in a river mouth habitat. Are other estuaries being studied by GLOBE schools? Can they find data from other estuaries on the web or in books? How does salinity vary at these sites?



Figure HY-SA-2

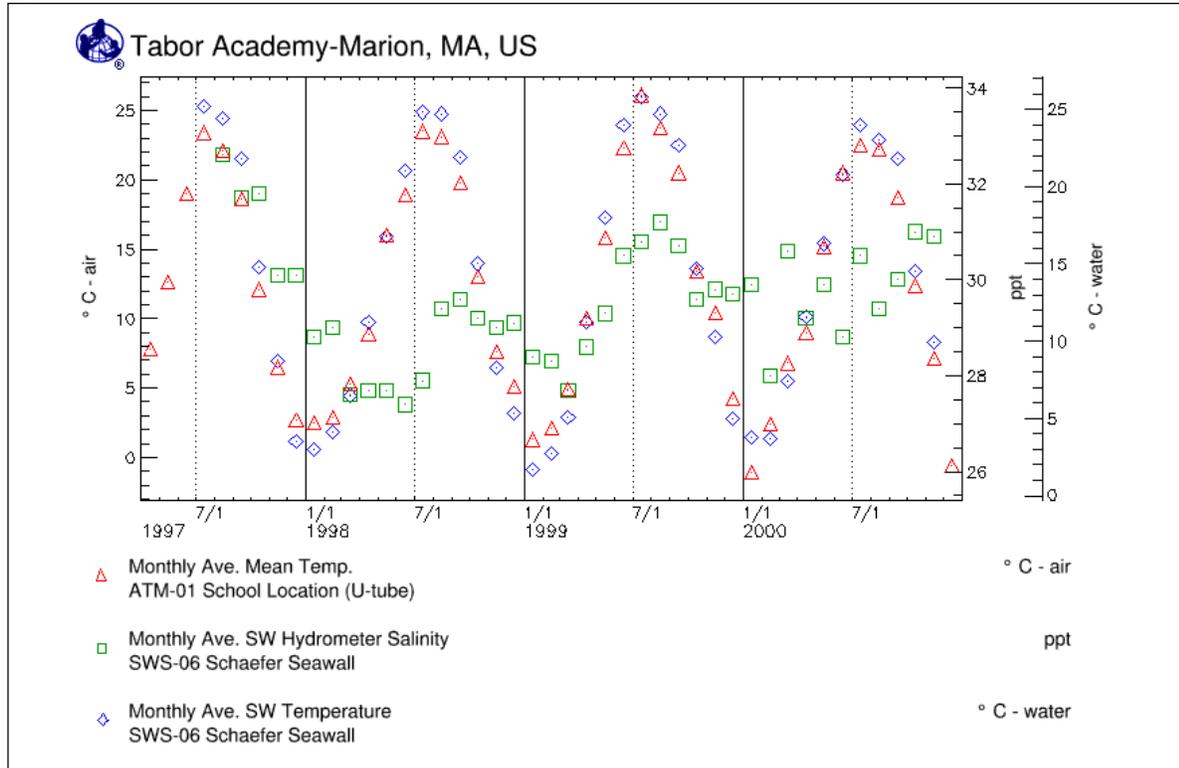


Figure HY-SA-3

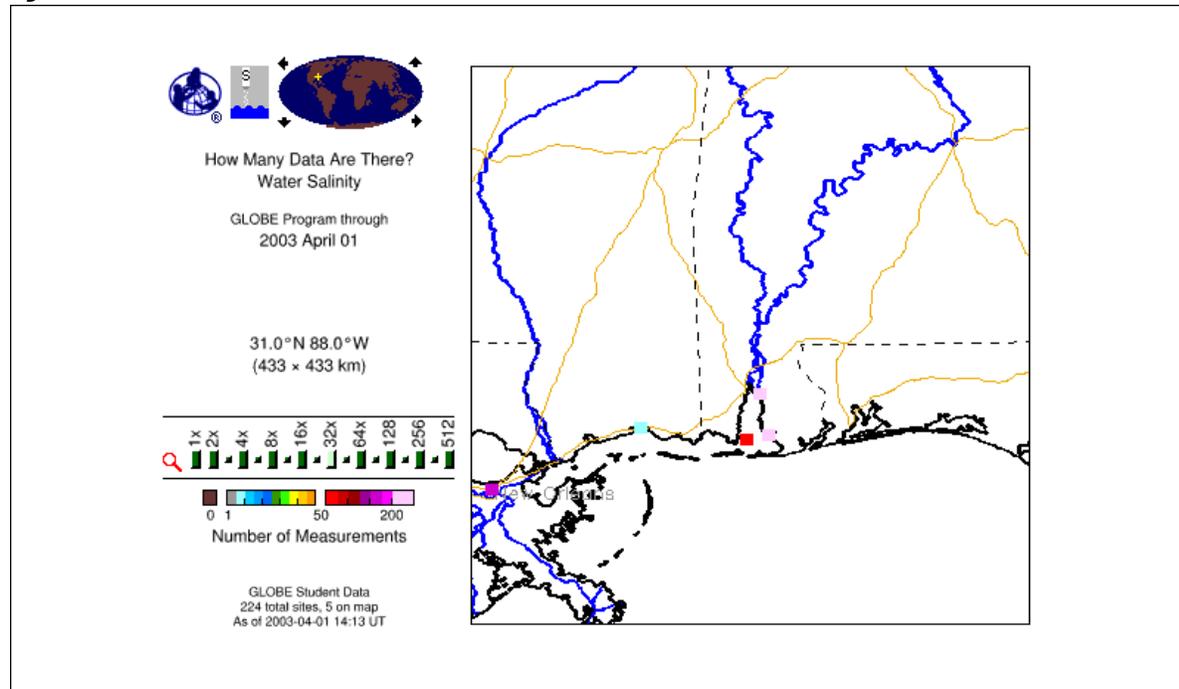


Figure HY-SA-4

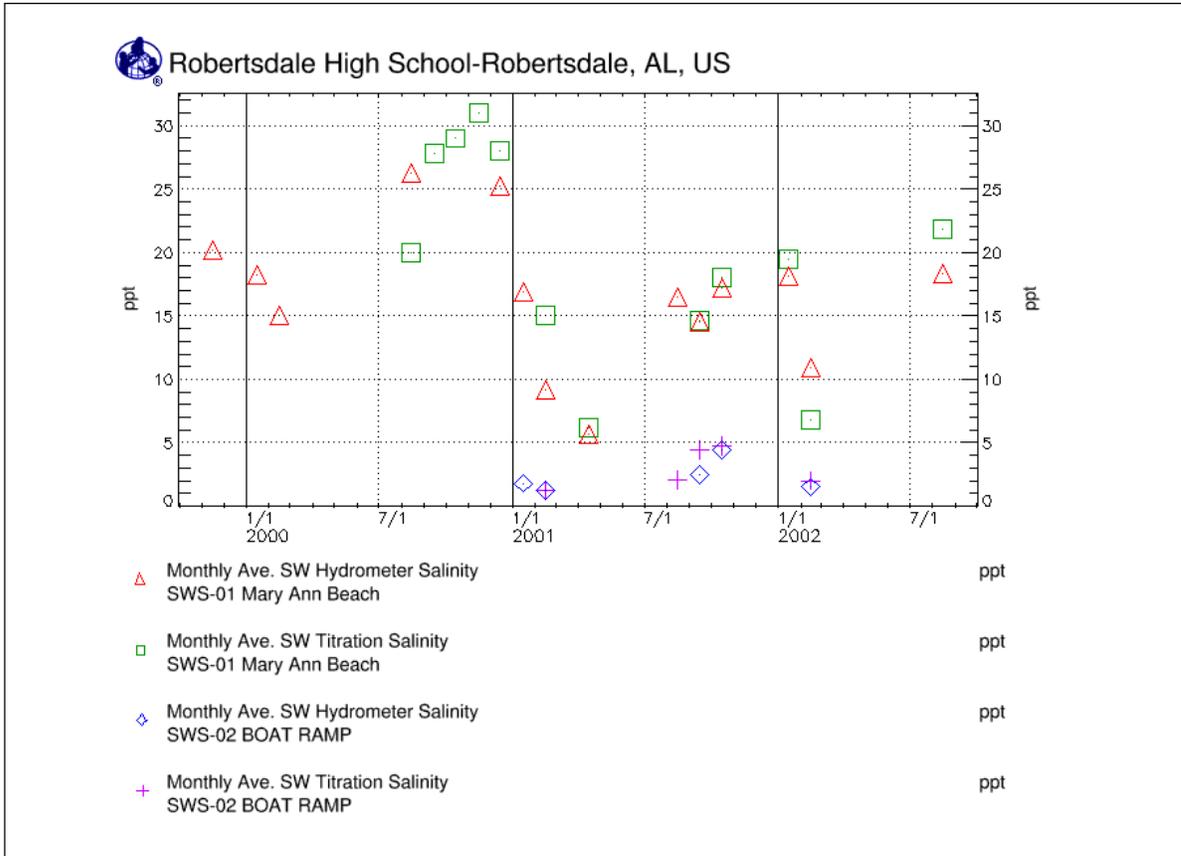


Figure HY-SA-5

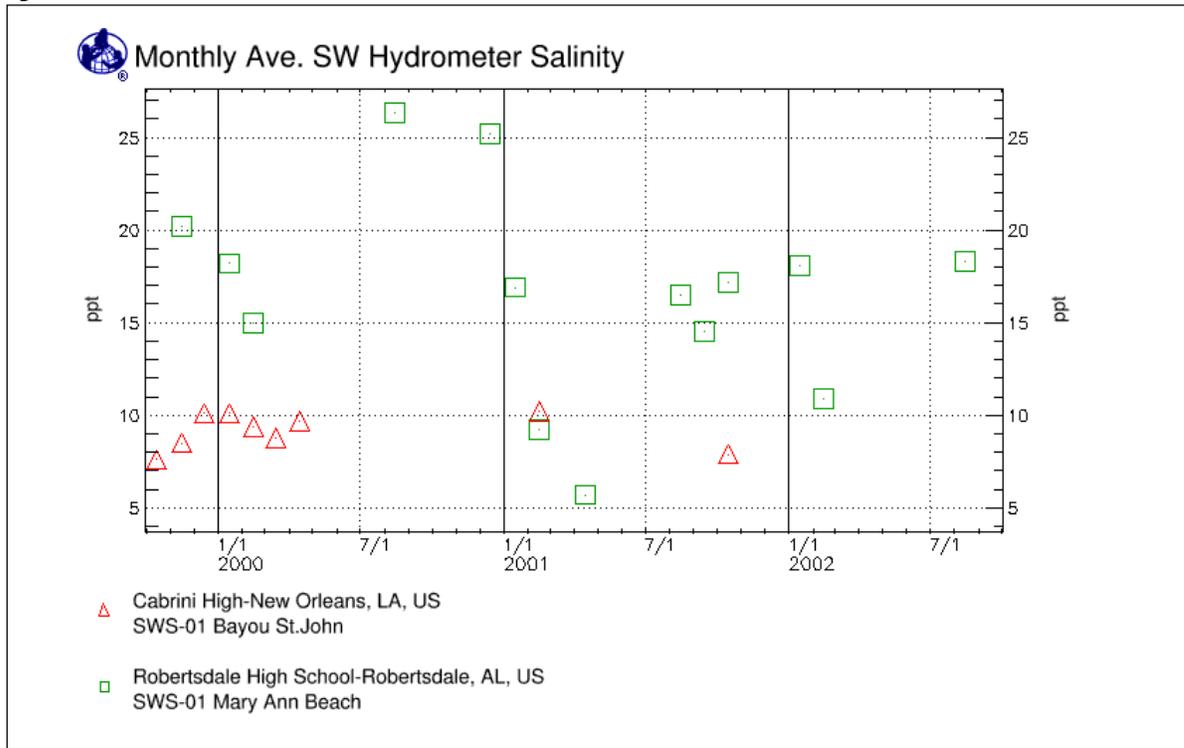
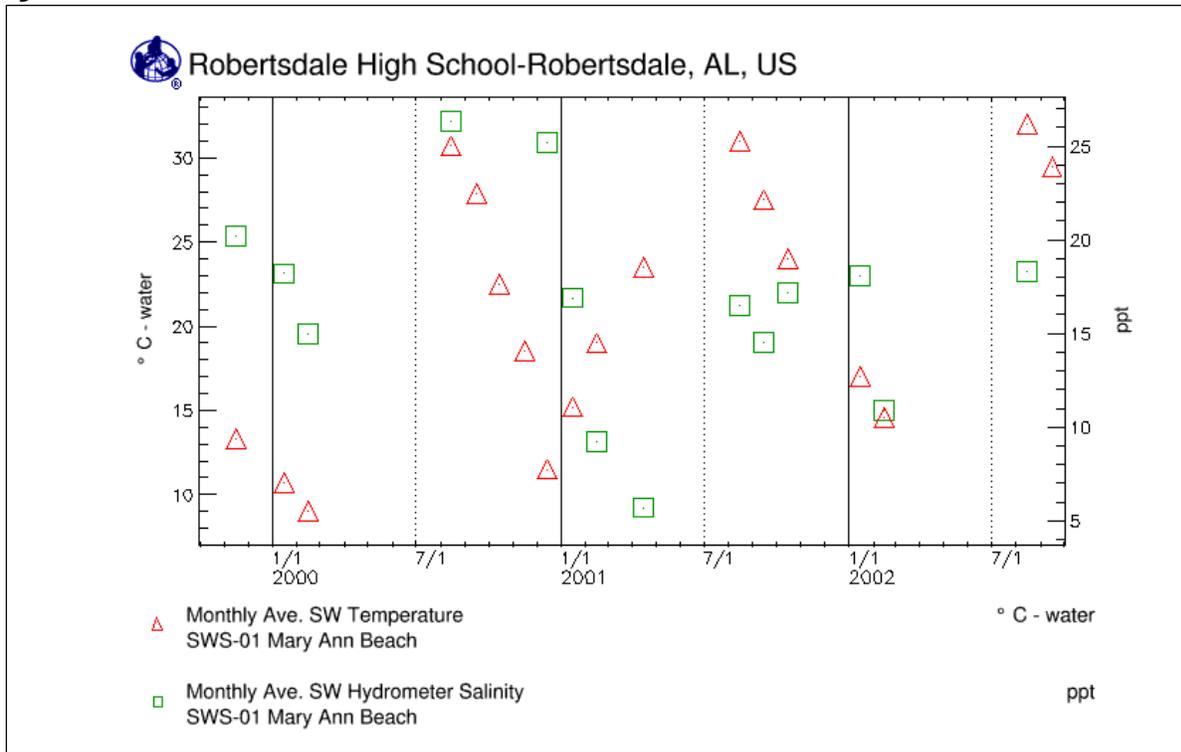


Figure HY-SA-6



pH Protocol



Purpose

To measure the pH of water

Overview

Students will use either a pH meter or pH paper to measure the pH of water. If using the pH meter, the meter needs to be calibrated with buffer solutions that have pH values of 4, 7, and 10.

Student Outcomes

Students will learn to,

- use either a pH meter or pH paper ;
- understand the differences among acid, basic and neutral pH values;
- examine reasons for changes in the pH of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Organisms change the environment in which they live.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a chemical test strip or pH meter to measure pH.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes

Level

All

Frequency

Weekly

Materials and Tools

For measuring pH with pH paper:

- *Hydrology Investigation Data Sheet*
- *Using pH Paper (Electrical Conductivity Greater Than 200mS/cm) Field Guide*
OR *Using pH Paper (Electrical Conductivity Less Than 200mS/cm) Field Guide*
- pH paper
- 50-mL or 100-mL beaker
- Latex gloves

For measuring pH with the pH meter:

- *Hydrology Investigation Data Sheet*
- *Using a pH Meter (Electrical Conductivity Greater Than 200mS/cm) Field Guide*
OR *Using a pH Meter (Electrical Conductivity Less Than 200mS/cm) Field Guide*
- pH meter



- Distilled water
- Clean paper towel or soft tissue
- pH 7.0, 4.0, and 10.0 buffer solutions
- Three 100-mL jars with lids
- 100-mL beaker

Preparation

Meters must be calibrated before each use.
 Recommended Learning Activities: *Practicing Your Protocols: pH (e-guide only)* and *The pH Game (e-guide only)*

Prerequisites

Electrical Conductivity Protocol

pH Protocol – Introduction

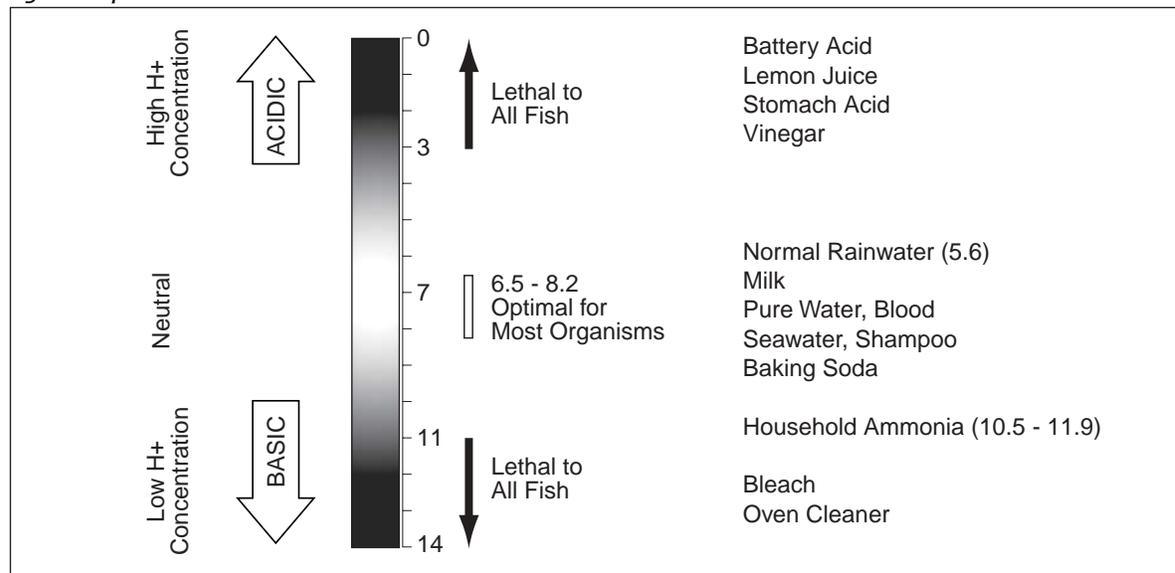
pH measures the acid content of water. The pH scale (measured from 0.0 – 14.0 pH units) is a logarithmic scale of the hydrogen ion concentration. Solutions with a pH greater than 7.0 are classified as basic and ones with a pH less than 7.0 as acidic. A pH of 7.0 is neutral. Each pH unit is ten times greater in hydrogen ion concentration than the next. For example, a pH 4.0 water has 10 times the hydrogen ion concentration of water with a pH 5.0. A pH of 3.0 contains 100 times the acid content of pH 5.0. For this reason a small change in pH could have significant effects in water quality.

Most lakes and streams have pH values that range between 6.5 and 8.5. Pure water that is not in contact with air has a neutral pH value of 7.0. Water with impurities may also have a pH of 7.0

if the acids present are in balance with the bases. Oceans are well buffered and have a constant pH of about 8.2. One can find waters that are naturally more acidic in areas with certain types of minerals present (e.g., sulfides). Mining activity can also release acid causing minerals to water bodies. Naturally occurring basic waters are found typically in areas where the soil is rich in minerals such as calcite or limestone. Acids and bases can also enter water bodies as by-products of human activities.

pH affects most chemical and biological processes in water. pH has a strong influence on what can live in the water; aquatic organisms have certain pH ranges they prefer or require. Salamanders, frogs and other amphibian life, as well as many macroinvertebrates, are particularly sensitive to extreme pH levels. Most insects, amphibians and fish are absent in water bodies with pH below 4.0 or above 10.0. Figure HY-pH-1 shows the pH values of some common substances and the lethal limits for fish species.

Figure HY-pH-1



Teacher Support

Special Note on Electrical Conductivity

The accuracy of pH papers and pH meters depends on the electrical conductivity of the water. The electrical conductivity of the water needs to be at least 200 mS/cm for the paper and pH meter to measure accurately. Oceans and brackish waters have conductivity values much higher than 200 mS/cm. If you are not sure if the fresh water at your Hydrology Site has a conductivity value high enough for the measurement technique (paper or meter), measure the electrical conductivity before taking your pH measurements. After you know the electrical conductivity value of the water, use the appropriate pH field guide. There are four field guides to choose from:

- Using pH paper with water that has an electrical conductivity greater than 200 mS/cm.
- Using pH paper with water that has an electrical conductivity less than 200 mS/cm.
- Using a pH meter with water that has an electrical conductivity greater than 200 mS/cm.
- Using a pH meter with water that has an electrical conductivity less than 200 mS/cm.

If you do not have an electrical conductivity meter and you would like to measure the pH, you run the risk of the data not being accurate, and so it is highly recommended that you take electrical conductivity measurements. If your water has a low transparency (lots of dissolved solids), it is likely that the water has a conductivity value greater than 200 mS/cm. If you are close to the source of the water (for example, snow melt or high elevations), then you can add a small amount of salt as indicated in the pH paper and meter field guides for conductivity values less than 200 mS/cm.

Advance Preparation

Younger students may have difficulty with the concept of acid and bases. But they will be familiar with the characteristic taste of acids such as lemon juice and vinegar and of bases such as milk and

soap. Use *The pH Game Learning Activity* to introduce your students to the concept of pH. To insure accuracy of the pH data in fresh water, it is necessary to take an electrical conductivity measurement beforehand. Have your students review the *Electrical Conductivity Protocol*.

Measurement Procedure

The *Field Guide* you use depends on the electrical conductivity of water and whether you are using a pH meter or pH paper. If you know that the water at your hydrology site has a high electrical conductivity, then it is not necessary to measure the electrical conductivity before the pH. If you are not sure, do the electrical conductivity measurement before the pH measurement. You may need to take a sample of water back to the lab to get the temperature of the water between 10°C and 20°C (see *Electrical Conductivity Protocol*).

Paper vs. Meter: Which instrument should you use?

There are two methods of measuring pH in GLOBE. The advantages and disadvantages of the methods are,

pH paper

Advantages

- easy for young children to use
- does not need calibration

Disadvantages

- resolution is not as good as meters (reads in 0.5 pH unit increments)
- it is not temperature compensated.

If you are buying pH paper for use in collecting GLOBE data, pay special attention to the quality of paper you choose. The GLOBE Hydrology team maintains a Web site that may be accessed through the Scientist's Corner on the GLOBE Web site where information may be found on pH papers that have been tested by the scientists.

pH meter

Advantages

- measures to 0.1 pH units.
- may be temperature compensated

Note: Avoid using meters with a one point calibration.



Disadvantages

- the meter must be calibrated with buffer solutions before each use.
- more expensive than pH paper.
- performance deteriorates over time.



Better meters have at least a two point calibration and have an automatic temperature compensation (ATC). Buffer solutions may be ordered in liquid or powdered form. The liquid is more expensive and has a shorter shelf life, but may be more convenient than mixing the powdered buffers. Most meters require the small, flat 'watch-type' batteries. Although the batteries last a long time, if the meter is turned off when not in use, it is a good idea to have an extra set of batteries on hand.

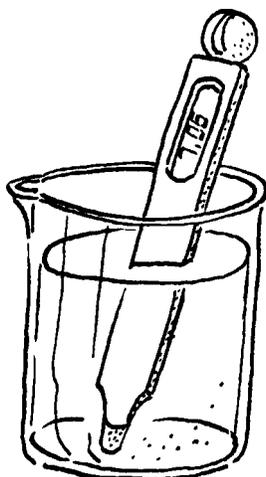


Calibrating pH Meters

Your pH meter must be calibrated before every use. If you are measuring the pH at the hydrology site, then the meter should be calibrated at the hydrology site as well. If you are measuring the pH in the lab, then calibrate in the lab before taking the measurement. Instruments vary in the calibration procedure, so you must carefully read the instructions for calibration that came with your meter.



NEVER report pH data taken with an instrument that has not calibrated!



Follow the instructions that come with your pH meter for conditioning the electrode of your pH meter. Most meters require soaking the electrode in water for at least 30 minutes before each use.

Calibrating pH Paper

You do not calibrate pH paper. However, to make sure that your pH paper is reading correctly, you can compare the results of the pH paper with the results from using a calibrated pH meter (if you have one). If you do not have a meter, use a strip of pH paper to test a known standard such as a pH buffer solution or a fresh soda at room temperature.

Some known values are:

- Coca-Cola 2.5
- RC-cola 2.5
- Mr. Pibb 2.8
- Pepsi-Cola 2.5
- Sprite 3.2

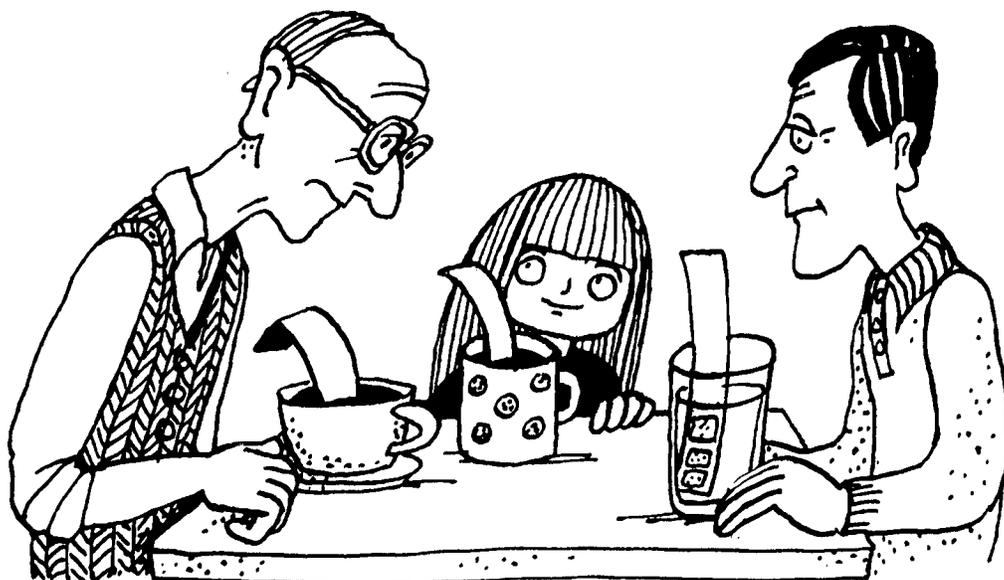
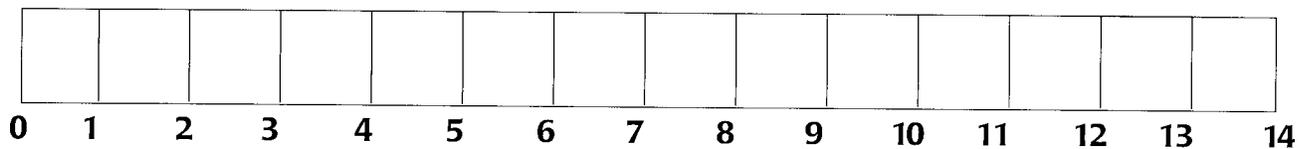
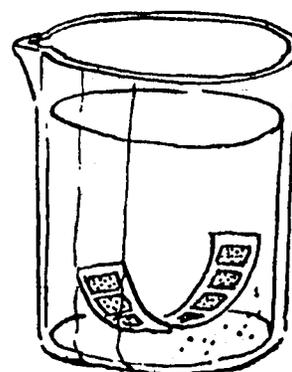
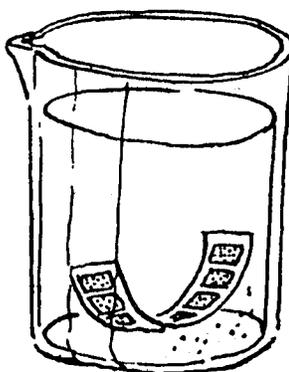
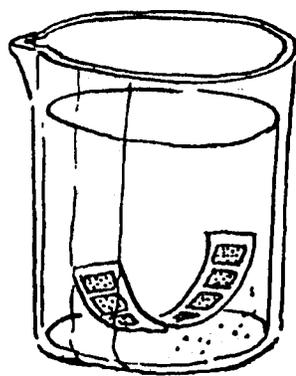
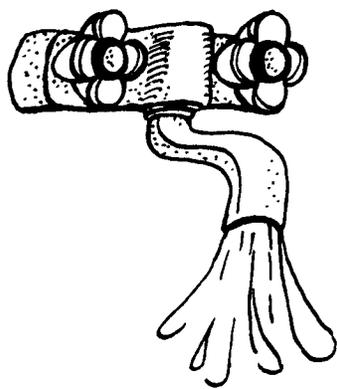
Supporting Protocols

Atmosphere and Soil: GLOBE students take pH of water, precipitation and soil. It is interesting for students, and informative for the scientists, to collect and compare all three measurements.

Hydrology: For a better understanding of your pH data, it is useful to also measure alkalinity. Alkalinity is a measure of the buffering capacity of the water, indicating whether the site will be sensitive to influxes of acid. It is also helpful to know the soil or rock type and land cover in your area.



Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic



Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic



Instrument Maintenance

pH paper

The pH paper should be stored in its own box in a dry place. It should not be stored in too hot or wet environments. Discard the paper if it gets wet or damp during storage.



pH meter

1. Follow the manufacturer's directions for caring for your instrument.
2. Make sure to condition your meter according to the manufacturer's directions but do not store the instrument standing in water.
3. Turn it off when not in use.
4. Replace cap after use to protect the electrode.
5. Do not submerge the whole instrument in water during use. Only the tip of the instrument, where the electrode is located, should be placed under water.
6. Do not drop or handle roughly. Store in a safe place.
7. The meter has started to deteriorate if it will not keep its calibration. Replace it if this happens.



pH buffer solutions

1. Pre-mixed, unused solutions can be stored for one year as long as they have not been contaminated. Keep them in a tightly capped bottle.
2. Buffer solutions that use a powder mixed with distilled water may be stored for one month in a tightly capped bottle after mixing.



Questions for Further Investigation

What changes in your watershed could have an affect on the pH reading at your water site?

How do the pH values at your site compare with values from other sites within your watershed?

What animals and plants would live in your water at the current pH reading? Are there animals and plants that would not live here?

How might your alkalinity measurement help you to understand your pH measurement?

How does the pH of your water compare to the pH of the soil and rainfall near your school?

Using pH Paper (Electrical Conductivity Greater than 200 mS/cm)

Field Guide

Task

Measure the pH of your water sample using pH paper.

What You Need

- Hydrology Investigation Data Sheet
- pH paper
- 100-mL beaker
- Latex gloves
- Pen or pencil

In the Field

1. Fill in the top part of your *Hydrology Investigation Data Sheet*.
2. In the pH section of the *Data Sheet*, check the box next to 'pH paper'.
3. Put on latex gloves.
4. Rinse the beaker with sample water three times.
5. Fill the beaker halfway with sample water.
6. Follow the instructions that come with your paper for testing the pH of the sample.
7. Record your pH on the *Data Sheet* as *Observer 1*.
8. Repeat steps 4-6 using new water samples and new pieces of paper. Record the data on the *Data Sheet* as *Observer 2* and *Observer 3*.
9. Find the average of the three observations.
10. Check to make sure that each observation is within 1.0 pH units of the average. If they are not within 1.0 units of the average, repeat the measurements. If your measurements are still not within 1.0 pH units of the average, discuss possible problems with your teacher.
11. Discard used pH paper and gloves in a waste container. Rinse the beaker with distilled water.

Using pH Paper (Electrical Conductivity Less than 200 mS/cm)

Field Guide

Task

To use pH paper to measure the pH of your fresh water sample with electrical conductivity values less than 200 mS/cm

What You Need

- | | |
|---|---|
| <input type="checkbox"/> Hydrology Investigation Data Sheet | <input type="checkbox"/> Clean paper towel or soft tissue |
| <input type="checkbox"/> Electrical Conductivity Protocol Field Guide | <input type="checkbox"/> Latex gloves |
| <input type="checkbox"/> Latex gloves | <input type="checkbox"/> Tweezers |
| <input type="checkbox"/> pH paper | <input type="checkbox"/> Salt crystals* or table salt |
| <input type="checkbox"/> Pen or pencil | <input type="checkbox"/> Stirring rod or spoon |
| <input type="checkbox"/> Electrical conductivity tester | <input type="checkbox"/> Thermometer |
| <input type="checkbox"/> Two 100-mL beaker or cups | <input type="checkbox"/> Pen or pencil |

In the Field

1. Fill in the top part of your *Hydrology Investigation Data Sheet*. In the pH section of the sheet, check the box next to 'pH paper'.
2. Put on latex gloves.
3. Rinse tweezers in sample water and dry with paper towel.
4. Rinse two beakers or cups with sample water three times.
5. Fill one beaker or cup with about 50 mL of sample water
6. Using the tweezers, place one crystal of salt in the sample water. (If you do not have salt crystals, fill this letter O with table salt and pour that into the sample water).
7. Stir thoroughly with stirring rod or spoon.
8. Measure the electrical conductivity of the treated sample water using the *Electrical Conductivity Protocol*.
 - a. If the electrical conductivity is at least 200 mS/cm, record value on *Data Sheet*. Go to step 9.
 - b. If the electrical conductivity is still less than 200 mS/cm, go to step 6 and repeat until you get a value that is at least 200 mS/cm. Record conductivity value on *Data Sheet*.
9. Follow the instructions that come with your paper for testing the pH of the sample.
10. Record your pH on the *Data Sheet* as *Observer 1*.
11. Repeat steps 3-9 using new water samples and new pieces of paper. Record the data on the *Data Sheet* as *Observer 2* and *Observer 3*.
12. Find the average of the three observations.
13. Check to make sure that each observation is within 1.0 pH units of the average. If they are not within 1.0 units of the average, repeat the measurements. If your measurements are still not within 1.0 pH units of the average, discuss possible problems with your teacher.
14. Discard used pH paper and gloves in a waste container. Rinse the beaker with distilled water.

* A note regarding salt crystals. Crystal of about 0.5 – 2.0 mm in diameter are much easier to work with than the very finely ground "table salt" used in some countries. In North America, the larger salt crystals are often marketed as "sea salt".

Frequently Asked Questions

1. Why could I not find a color match with the pH paper?

The conductivity of your water might be low (see *Electrical Conductivity Protocol*). The pH paper takes longer to react with the water if the conductivity is less than 400 microSiemens/cm (mS/cm). If your water has a conductivity of less than 300 mS/cm, some pH paper does not work well. Another reason you may have problems is if your pH paper is old or has not been stored properly.

2. What do I do if the pH seems to be between two color matches on the box?



Report the match that is the closest. This is the reason we have three students do the protocol. Taking the average of the three readings gives a more accurate measurement.

Using A pH Meter (Electrical Conductivity Greater than 200 mS/cm)

Field Guide

Task

Measure the pH of your water sample using a pH meter.

What You Need

- Hydrology Investigation Data Sheet
- pH meter
- 100-mL beaker
- 25 mL of pH 7.0 buffer solution in a jar with a lid - this jar should be labeled *pH 7.0*
- 25 mL of pH 4.0 buffer solution in a jar with a lid - this jar should be labeled *pH 4.0*
- 25 mL of pH 10.0 buffer solution in a jar with a lid - this jar should be labeled *pH 10.0*
- Distilled water in wash bottle
- Clean paper towel or soft tissue
- Latex gloves
- Pen or pencil

Note: Each jar should have an opening large enough to immerse the pH meter

In the Field

1. Fill in the top portion of the *Hydrology Investigation Data Sheet*. Check pH meter as your instrument.
2. Put on the latex gloves.
3. Remove the cap from the meter that covers the electrode (the glass bulb on the pH meter).
4. Rinse the electrode on the meter and the area around it with distilled water in the wash bottle. Blot the meter dry with a clean paper towel or tissue. **Note:** Do not rub the electrode or touch it with your fingers.
5. Rinse the electrode with distilled water and blot dry again.
6. Calibrate the pH meter according to the manufacturer's directions.
7. Rinse a 100-mL beaker three times with sample water.
8. Pour 50 mL of sample water into the 100-mL beaker.
9. Put the electrode part of the meter into the water.
10. Stir once with meter. Do not let the meter touch the bottom or sides of the beaker. Wait for one minute. If the pH meter is still changing numbers, wait another minute.

11. Record the pH value on the *Data Sheet* under *Observer 1*.
12. Repeat steps 4-10 twice using new water samples. Record data on the *Data Sheet* as *Observer 2* and *Observer 3*.
13. Rinse the electrode with distilled water and blot dry. Turn off the meter. Put on the cap to protect the electrode.
14. Calculate the average of the three observations.
15. Check to see if each of the three observations is within 0.2 of the average. If all three are within 0.2, record the average on the *Data Sheet*. If all three observations are not within 0.2, repeat the measurements. Calculate a new average. Check to see if all three observations are within 0.2. If they are, record the average. If they are not, talk to your teacher about possible problems.

Using A pH Meter (Electrical Conductivity Less than 200 mS/cm)

Field Guide

Task

To use a pH meter to measure the pH of your fresh water sample with electrical conductivity values less than 200 mS/cm

What You Need

- | | |
|--|---|
| <input type="checkbox"/> Hydrology Investigation Data Sheet | <input type="checkbox"/> Standard solution for electrical conductivity tester |
| <input type="checkbox"/> Electrical Conductivity Protocol Field Guide | <input type="checkbox"/> Distilled water in wash bottle |
| <input type="checkbox"/> pH meter | <input type="checkbox"/> Clean paper towel or soft tissue |
| <input type="checkbox"/> Electrical conductivity tester | <input type="checkbox"/> Latex gloves |
| <input type="checkbox"/> Two 100-mL beaker | <input type="checkbox"/> Salt crystals* or table salt |
| <input type="checkbox"/> 25 mL of pH 7.0 buffer solution in a jar with a lid - this jar should be labeled "pH 7.0" | <input type="checkbox"/> Tweezers |
| <input type="checkbox"/> 25 mL of pH 4.0 buffer solution in a jar with a lid - this jar should be labeled "pH 4.0" | <input type="checkbox"/> Stirring rod or spoon |
| <input type="checkbox"/> 25 mL of pH 10.0 buffer solution in a jar with a lid - this jar should be labeled "pH 10.0" | <input type="checkbox"/> Thermometer |
| | <input type="checkbox"/> Pen or pencil |

Note: Each jar should have an opening large enough to immerse the pH meter

In the Field

1. Fill in the top part of your *Hydrology Investigation Data Sheet*. In the pH section of the sheet, check the box next to 'pH meter'.
2. Put on latex gloves.
3. Rinse tweezers in sample water and dry with paper towel.
4. Rinse two beakers or cups with sample water three times.
5. Fill one beaker or cup with about 100 mL of sample water
6. Using the tweezers, place one crystal of salt in the sample water. (If you do not have salt crystals, fill this letter O with table salt and pour that into the sample water).
7. Stir thoroughly with stirring rod or spoon.

* A note regarding salt crystals. Crystal of about 0.5 – 2.0 mm in diameter are much easier to work with than the very finely ground "table salt" used in some countries. In North America, the larger salt crystals are often marketed as "sea salt".

8. Measure the electrical conductivity of the treated sample water using the *Electrical Conductivity Protocol*.
 - a. If the electrical conductivity is at least 200 mS/cm, record value on *Data Sheet*. Go to step 9.
 - b. If the electrical conductivity is still less than 200 mS/cm, go to step 6 and repeat until you get a value that is at least 200 mS/cm.
9. Remove the cap from the meter that covers the electrode (the glass bulb on the pH meter).
10. Rinse the electrode on the meter and the area around it with distilled water from the rinse bottle. Blot the meter dry with a clean paper towel. **Note:** Do not rub the electrode or touch it with your fingers.
11. Rinse the electrode with distilled water and blot dry again.
12. Calibrate the pH meter according to the manufacturer's directions.
13. Put the electrode part of the pH meter into the treated sample water.
14. Stir once with meter. Do not let the meter touch the bottom or sides of the beaker. Wait for one minute. If the pH meter is still changing numbers, wait another minute.
15. Record the pH value on the *Data Sheet* under *Observer 1*.
16. Repeat steps 3-14 using new water samples. You do NOT need to calibrate the pH meter again. Record conductivity and pH values on *Data Sheet* as *Observer 2* and *Observer 3*.
17. Rinse the electrode with distilled water and blot dry. Turn off the meter. Put on the cap to protect the electrode.
18. Calculate the average of the three observations.
19. Check to see if each of the three observations is within 0.2 of the average. If all three are within 0.2, record the average on the *Data Sheet*. If all three observations are not within 0.2, repeat the measurements. Calculate a new average. Check to see if all three observations are within 0.2. If they are, record the average. If they are not, talk to your teacher about possible problems.



Frequently Asked Questions

1. What things might affect the accuracy of my pH meter reading?

- The pH meter will not work well if the conductivity of the water is less than 100 mS/cm. See *Electrical Conductivity Protocol*.
- The pH meter must be calibrated every time it is used.
- The batteries may need to be replaced.

2. Does water temperature affect my pH reading?

A change in water temperature can actually change the pH value of your water. Since we want to know the actual pH value, we do not correct for this change.

Temperature can also affect the performance of the meter. The electrode is designed so there is no temperature sensitivity when the pH is 7.0. As the pH moves away from this value, the water temperature affects meter accuracy. Meters with automatic temperature compensation (ATC) correct for the temperature of the water at values above and below 7.0 by a factor of 0.003 pH/°C/pH unit away from pH 7. They correct for meter error. They do not correct for actual changes in pH.



3. Does high salt concentration affect pH?



Salt concentration can affect pH. As salt concentration increases, pH can increase. This is not a linear relationship, but can be important in estuaries, where the salinity varies with the tide. Taking into account salinity or conductivity data may be useful in understanding variations in your pH measurements.

4. Why may pH measurements be inaccurate in low conductivity waters?

To measure the hydrogen ion concentration, you are actually measuring the potential of the hydrogen ions. Other ions have to be present to pass the current to make this measurement. When they are at too low of a concentration the meter slowly drifts and if the drift is really slow, the meter locks in on an incorrect measurement.

pH Protocol – Looking at the Data

Are the data reasonable?

The pH values for your water site will depend on the geology of your area, soil and vegetation of your watershed, and other inputs into your water body. Where air masses come from may affect the pH of the water. Many water bodies are slightly acidic, with values ranging from 5.0 to 7.0. Areas with deposits of limestone or other calcium carbonate rock forms may be more basic, with values from 7.0 to 9.0. Oceans are well buffered and have a constant pH of about 8.2.

When examining the pH data in the GLOBE database, it is important to keep in mind the different instruments that students may be using. Elementary schools using pH paper may seem to have pH data that appear more variable. Their data may vary by a whole or one half pH unit on a weekly basis since the paper only measures in whole or half units.

What do scientists look for in the data?

Since most organisms are sensitive to changes in water pH, scientists monitor unusual decreases or increases in the pH of water bodies. pH does not normally change a great deal, although you may find some seasonal trends due to changes in temperature, rainfall patterns, or land cover.

Alkalinity is a buffer against acid influx into a water body. A sudden decrease in pH should correspond with decreasing alkalinity. Waters with higher alkalinity should show less pH drop after an addition of acid, like acid rain.

Example of a Student Research Project Forming a Hypothesis

A student is examining the pH of streams and lakes in Europe. He knows that much of the acidity in the water comes from acid rain. The acid rain deposition may be unevenly distributed throughout the year due to seasonally varying amounts of precipitation, as well as differences in the prevailing wind direction. He hypothesizes that annual trends might be present in the pH data for certain water bodies in Europe.

Collecting and Analyzing Data

His first task is to locate an area that is likely to be susceptible to acid precipitation. After researching the topic, the student discovers that the northwestern part of Europe receives the most acid rain for this continent. This is most likely to be an area that the water in lakes and streams is already fairly acidic.

He starts by examining the GLOBE map for Europe. He makes maps showing the monthly averages for pH over this region for each month out of the year 2001 (Figure HY-pH-1). He notices that certain schools in Scandinavia appear to show what might be considered an annual trend in pH. He then looks at the Scandinavian schools independently by plotting GLOBE graphs for each school. He chooses four schools that appear to show the strongest trend in pH. The schools chosen are: Husbyskolan in Kista, Sweden; St. Eriks Gymnasium, in Stockholm, Sweden; Sem skole (13-16) in Sem, Norway; and Vang barne-og ungdomsskule (6-16) in Valdres, Norway. The pH plots for these schools from 1999 to 2002 are shown in Figure HY-pH-2. It appears from these graphs that the pH values are higher in the summer and lower in the winter for the chosen sites.

In order to examine this more carefully, the student downloads the data from these graphs into a spreadsheet (Table HY-pH-1, column 1-5). He then calculates the average pH for the year for each school. He then creates a column (Table HY-pH-1, last row) for each school that shows deviations for each data point from the calculated averages:

$$\text{Deviation} = \text{Observed pH} - \text{average pH}$$

The student then counts the number of positive and negative deviations for each month from the data obtained and records them in Table HY-pH-2.

By viewing the data in this manner the student is able to see that the months December through March show more negative deviations than positive deviations. Negative deviations are below the average while positive deviations are above the average. So between December and March, the pH was generally below the average pH value.



The months May through October show more positive deviations from the average than negative deviations, which indicates that they were higher in pH than the average value. The months April and November have equal and near equal positive and negative deviations.



He concludes that in Scandinavia, the cooler months show pH values below average and the summer months show pH values above average. Therefore, the student's hypothesis was correct: an annual trend in pH can be detected in northern European GLOBE schools.



Future Work

The student would like to investigate further and find out if these findings can be explained by rainfall patterns and precipitation pH values for this part of Europe.



Figure HY-pH-2: Monthly pH Values for Some European GLOBE Schools

2001

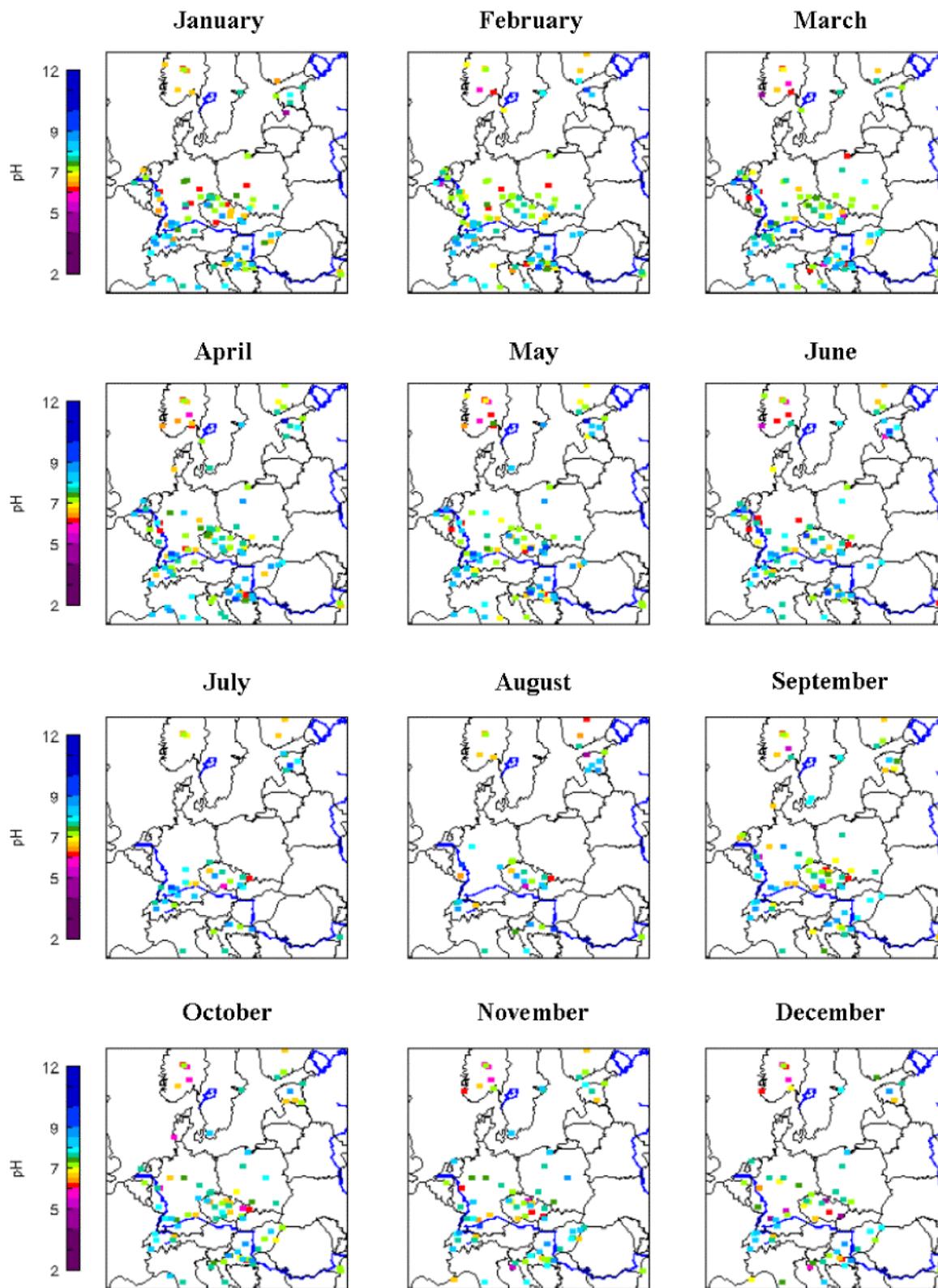


Figure HY-pH-3: Temporal pH Data for Certain Scandinavian GLOBE Schools

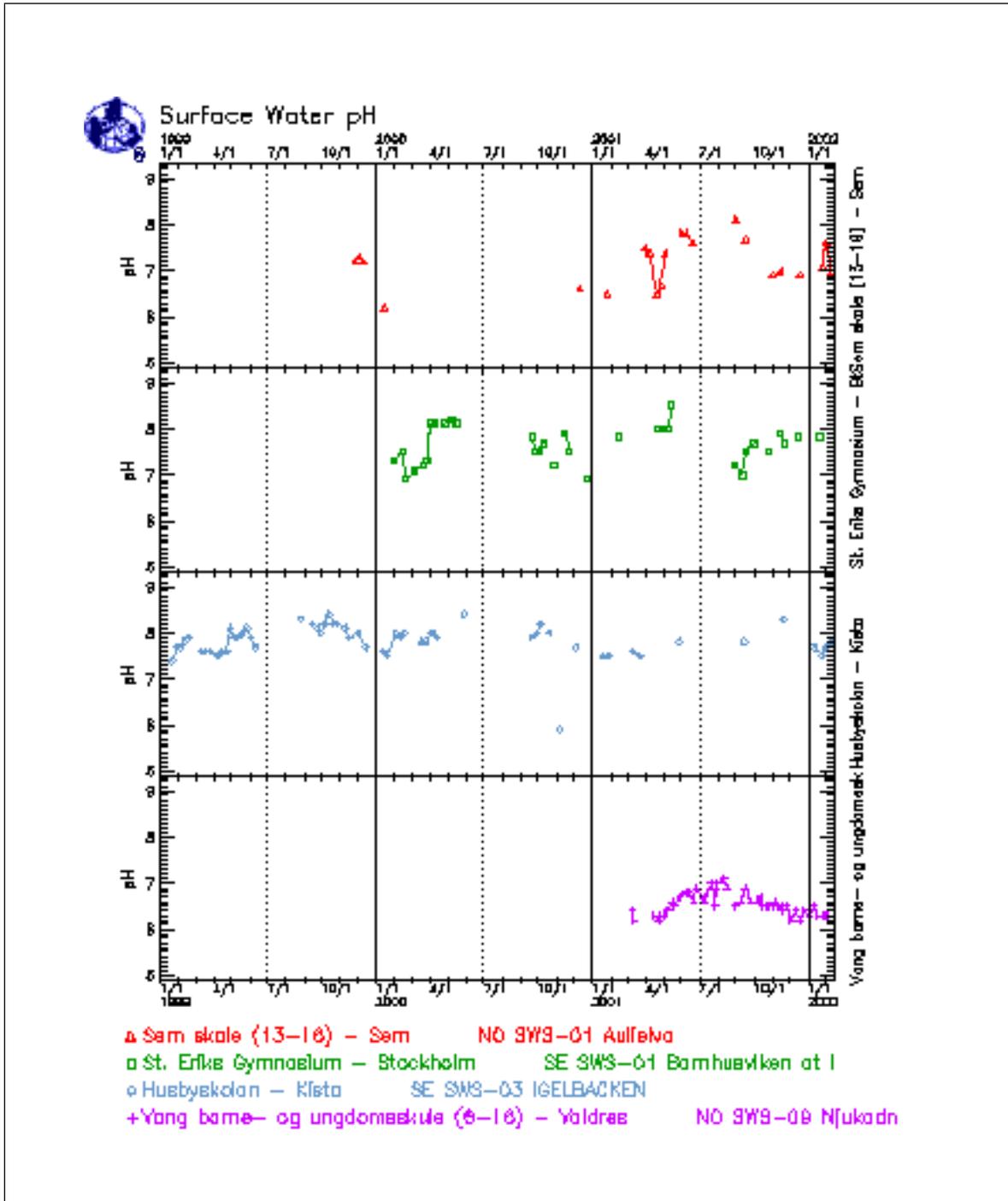


Table HY-pH-1: Measured Values and Deviations from Mean Values for Certain Scandinavian Schools

Date	Measured Values			Deviations from Mean				
	Sem	Stockholm	Kista	Valdres	Sem	Stockholm	Kista	Valdres
1/21/1999			7.4				-0.43	
1/28/1999			7.7				-0.13	
2/4/1999			7.7				-0.13	
2/10/1999			7.8				-0.03	
2/18/1999			7.9				0.07	
3/11/1999			7.6				-0.23	
3/18/1999			7.6				-0.23	
3/25/1999			7.6				-0.23	
4/8/1999			7.5				-0.33	
4/15/1999			7.6				-0.23	
4/22/1999			7.6				-0.23	
4/29/1999			8.1				0.27	
5/6/1999			7.9				0.07	
5/12/1999			7.9				0.07	
5/20/1999			8				0.17	
5/27/1999			8.1				0.27	
6/3/1999			7.9				0.07	
6/11/1999			7.7				-0.13	
8/26/1999			8.3				0.47	
9/15/1999			8.2				0.37	
9/24/1999			8.1				0.27	
9/29/1999			8				0.17	
10/6/1999			8.2				0.37	
10/13/1999			8.4				0.57	
10/20/1999			8.2				0.37	
10/27/1999			8.2				0.37	
11/10/1999			8.1				0.27	
11/17/1999			7.9				0.07	
11/26/1999	7.2				0.02			
12/1/1999			8				0.17	
12/3/1999	7.3				0.12			
12/10/1999	7.2				0.02			
12/15/1999			7.7				-0.13	
1/13/2000			7.6				-0.23	
1/14/2000	6.2				-0.98			
1/20/2000			7.5				-0.33	
1/31/2000		7.3				-0.33		
2/3/2000			8				0.17	
2/10/2000			7.9				0.07	
2/14/2000		7.5				-0.13		
2/17/2000			8				0.17	
2/21/2000		6.9				-0.73		
3/6/2000		7.1				-0.53		

Table pH-1: continued

Measured Values					Deviations from Mean			
Date	Sem	Stockholm	Kista	Valdres	Sem	Stockholm	Kista	Valdres
3/17/2000			7.8				-0.03	
3/20/2000		7.2				-0.43		
3/24/2000			7.8				-0.03	
3/27/2000		7.3				-0.33		
4/3/2000		8.1				0.47		
4/5/2000			8				0.17	
4/10/2000		8.1				0.47		
4/13/2000			7.9				0.07	
4/26/2000		8.1				0.47		
5/8/2000		8.2				0.57		
5/15/2000		8.1				0.47		
5/29/2000			8.4				0.57	
9/20/2000		7.8	7.9			0.17	0.07	
9/28/2000		7.5				-0.13		
9/29/2000			8				0.17	
10/2/2000		7.5				-0.13		
10/5/2000			8.2				0.37	
10/10/2000		7.7				0.07		
10/20/2000			8				0.17	
10/26/2000		7.2				-0.43		
11/6/2000			5.9				-1.93	
11/15/2000		7.9				0.27		
11/23/2000		7.5				-0.13		
12/4/2000			7.7				-0.13	
12/11/2000	6.6				-0.58			
12/21/2000		6.9				-0.73		
1/19/2001			7.5				-0.33	
1/26/2001	6.5				-0.68			
1/29/2001			7.5				-0.33	
2/15/2001		7.8				0.17		
3/9/2001			7.6	6.4			-0.23	-0.14
3/12/2001				6.2				-0.34
3/23/2001			7.5				-0.33	
3/30/2001	7.5				0.32			
4/6/2001	7.4				0.22			
4/16/2001				6.3				-0.24
4/20/2001	6.5				-0.68			
4/23/2001		8		6.2		0.37		-0.34
4/27/2001	6.7			6.3	-0.48			-0.24
5/2/2001				6.3				-0.24
5/4/2001	7.4				0.22			
5/7/2001		8				0.37		
5/8/2001				6.4				-0.14
5/15/2001		8.5		6.6		0.87		0.06
5/20/2001				6.5				-0.04
5/28/2001			7.8				-0.03	
5/29/2001				6.7				0.16
6/1/2001	7.8				0.62			

Table pH-1: continued

Measured Values					Deviations from Mean			
Date	Sem	Stockholm	Kista	Valdres	Sem	Stockholm	Kista	Valdres
6/7/2001				6.8				0.26
6/8/2001	7.8				0.62			
6/13/2001				6.8				0.26
6/20/2001	7.6				0.42			
6/21/2001				6.6				0.06
6/26/2001				6.9				0.36
7/7/2001				6.6				0.06
7/11/2001				6.7				0.16
7/22/2001				7				0.46
7/27/2001				6.5				-0.04
7/29/2001				6.9				0.36
7/31/2001				7				0.46
8/11/2001				7.1				0.56
8/16/2001				6.9				0.36
8/30/2001		7.2				-0.43		
8/31/2001	8.1			6.5	0.92			-0.04
9/9/2001				6.6				0.06
9/11/2001		7				-0.63		
9/14/2001			7.8				-0.03	
9/16/2001	7.7				0.52			
9/17/2001				6.9				0.36
9/18/2001		7.5				-0.13		
9/27/2001				6.6				0.06
10/1/2001		7.7				0.07		
10/6/2001				6.6				0.06
10/12/2001				6.7				0.16
10/16/2001				6.5				-0.04
10/22/2001				6.5				-0.04
10/26/2001		7.5				-0.13		
10/28/2001				6.5				-0.04
11/2/2001	6.9				-0.28			
11/3/2001				6.5				-0.04
11/5/2001				6.6				0.06
11/11/2001				6.5				-0.04
11/16/2001	7	7.9			-0.18	0.27		
11/17/2001				6.4				-0.14
11/19/2001				6.5				-0.04
11/20/2001			8.3				0.47	
11/21/2001		7.7				0.07		
11/25/2001				6.5				-0.04
12/2/2001				6.2				-0.34
12/11/2001				6.4				-0.14
12/14/2001		7.8				0.17		
12/18/2001	6.9			6.2	-0.28			-0.34
12/25/2001				6.4				-0.14
1/4/2002				6.3				-0.24
1/11/2002			7.7	6.5			-0.13	-0.04
1/17/2002				6.3				-0.24

Table pH-1: continued

Measured Values					Deviations from Mean			
Date	Sem	Stockholm	Kista	Valdres	Sem	Stockholm	Kista	Valdres
1/19/2002		7.8				0.17		
1/25/2002	7.1		7.5		-0.08		-0.33	
1/26/2002				6.3				-0.24
2/1/2002	7.6		7.7	6.3	0.42		-0.13	-0.24
2/3/2002				6.3				-0.24
2/8/2002	7		7.8		-0.18		-0.03	
Means	7.18	7.63	7.83	6.54				

Table HY-pH-2: Monthly Deviation Totals from Four Scandinavian GLOBE Schools

	# Neg. Dev.	# Pos. Dev.
Jan	16	1
Feb	9	6
Mar	12	1
Apr	8	8
May	4	12
Jun	1	8
Jul	1	5
Aug	2	4
Sep	4	10
Oct	6	10
Nov	9	8
Dec	9	4

Alkalinity Protocol



Purpose

To measure the alkalinity of a water sample

Overview

Students will use an alkalinity kit to measure the alkalinity in the water at their hydrology site. The exact procedure depends on the instructions in the alkalinity kit used.

Student Outcomes

Students will learn to,

- use an alkalinity kit;
- examine reasons for changes in the alkalinity of a water body;
- explain the difference between pH and alkalinity;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met. Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a chemical test kit to measure alkalinity.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

15 minutes

Quality Control Procedure: 20 minutes

Level

Middle and Secondary

Frequency

Weekly

Quality Control Procedure: twice a year

Materials and Tools

Alkalinity test kit

Hydrology Investigation Data Sheet

Making the Baking Soda Alkalinity Standard

Lab Guide (optional)

Alkalinity Protocol Field Guide

Distilled water in wash bottle

Latex gloves

Safety goggles

For Quality Control Procedure, the above plus:

- Alkalinity standard

- *Hydrology Investigation Quality Control Procedure Data Sheet*

- *Quality Control Procedure for Alkalinity Lab Guide*

Preparation

Suggested activities: *Practicing Your Protocols: Alkalinity (e-guide only)*

Prerequisites

Discussion of safety procedures when using chemical test kits



Alkalinity Protocol – Introduction

Alkalinity and pH are properties of water that are related, but different. Alkalinity is the measure of the pH buffering capacity of the water. pH, on the other hand, is the acidity of water. (refer to *pH Protocol*). pH is a very important water quality parameter. Many plants and animals have very specific pH requirements and are harmed by sudden pH changes or extreme pH values. What happens to the pH of your water if acid is added? The answer depends on how much alkalinity is in the water and how much acid is added.



Alkalinity is expressed as the amount of calcium carbonate (CaCO_3) in your water, although other substances can contribute to alkalinity as well. The units of alkalinity are either part per million (ppm) or mg/L. These units are equivalent, as 1 ppm = 1 mg/L.



Let us say your water has a high alkalinity. When acid is added to the water, the alkalinity *neutralizes* the acid. Some of the alkalinity will be used up, so that alkalinity will go down. If more acid is added, the alkalinity will continue to decrease. Eventually, when the alkalinity is low enough, adding acid will cause the pH to decrease.



When water has high alkalinity, we say that it is *well buffered*. It resists a decrease in pH when acidic water, such as rain or snowmelt, enters it. Alkalinity comes from dissolved rocks, particularly limestone (CaCO_3), and soils. It is added to the water naturally as water comes in contact with rocks and soil. Water dissolves the CaCO_3 , carrying it into streams and lakes. Lakes and streams in areas rich in limestone bedrock will tend to have a higher alkalinity than those in regions with non-carbonate bedrock.



If water has an alkalinity below about 100 mg/L as CaCO_3 , it is *poorly buffered* and *pH sensitive*. A big rainfall or snowmelt event could add enough acid to lower the pH in a sensitive system. This could be harmful to the plants and animals that live there, particularly at certain times of the year (e.g., when fish or insect larvae are hatching).



Teacher Support

Advance Preparation

The *Practicing Your Protocols: Alkalinity Learning Activity*, will help students understand the variables that may affect their measurements.

Perform the Quality Control Procedure if it has not been done within six months.

Measurement Procedures

These kits are based on the technique of adding a pH sensitive color indicator to the sample and then adding an acid titrant solution drop by drop until a color change is observed.

There are a number of techniques the students should follow to take quality data.

1. Have the students read the directions before they begin to make sure they understand the procedure.
2. Measure carefully. Read the volume of the sample in the sample bottle at eye level. Read at the bottom of the meniscus.
3. If using a titrator, make sure that the titrator is being read correctly. Most kits include instructions for the proper use of titrators. Make sure the students are familiar with the units on the titrator.
4. If the alkalinity kit uses drops, hold the dropper bottle vertically so that all of the drops are the same size.
5. During the Quality Control Procedure and actual water testing, be sure to note the color change that gives the correct alkalinity. In many kits, it is an intermediate color change that gives the correct alkalinity and not the final color. For kits with an intermediate color (such as a LaMotte kit), if you are not sure when the intermediate color change occurs, read the titrator or write down the number of drops when you think it might be first occurring. For kits with only one color change during titration, add one more drop to see if the color changes further. If it does not, use the previous number you wrote down.

Quality Control Procedure

For the Quality Control Procedure, you may make your own baking soda standard (*Making the Baking Soda Alkalinity Standard Lab Guide*). Alternatively, you may purchase a ready-made alkalinity standard solution. Please make sure to note which standard you are using in the *Hydrology Quality Control Procedure Data Sheet*.

The alkalinity of the baking soda standard is approximately 84 mg/L. It is the sum of the true alkalinity of the baking soda added (70 mg/L) plus the alkalinity of the distilled water used (usually 14 mg/L or less):

$$70 \text{ mg/L} + 14 \text{ mg/L} = 84 \text{ mg/L}$$

The purity of distilled water available worldwide varies significantly. As a result, its alkalinity is also variable. Unfortunately, most alkalinity test kits are not capable of producing accurate measurements for samples of very low alkalinities (i.e., less than 30 mg/L). As a result, it is very difficult to determine the actual alkalinity of your distilled water and therefore the alkalinity of your baking soda standard solution. To account for this, the actual measurement of your baking soda standard should be 84 mg/L \pm 10 mg/L. If the alkalinity of your baking soda standard is measured to be less than 74 mg/L or greater than 94 mg/L, prepare a new standard making sure your weights and dilutions are accurate. If you are still off by more than \pm 10 mg/L, you may need to replace the reagents of your test kit.

Ready-made alkalinity standards have a precisely known alkalinity. During the Quality Control Procedure, your resultant measurement should be the actual alkalinity of your standard plus or minus the maximum acceptable difference for your test kit.

Alkalinity Kit Precisions

Different alkalinity test kits have different precisions. Below are values for the maximum acceptable differences for some common test kits.

LaMotte	\pm 8 mg/L
Hach	\pm 6.8 mg/L (Low Range, 0–10 mg/L)
	\pm 17 mg/L (High Range, 0–50 mg/L)

If your alkalinity test kit is not listed in the table above and you are not certain how to determine the precision of your kit, please contact your GLOBE Country Coordinator or the GLOBE Help Desk and provide them with the manufacturer and model of your kit.

Safety Precautions

- Students should wear gloves when handling chemicals and water that may contain potentially harmful substances.
- Students should wear goggles when working with chemicals.
- Local authorities should be consulted on the proper disposal of used chemicals.

Supporting Protocols

pH: Alkalinity is directly related to pH; waters with higher alkalinity are more resistant to changes in pH from the influx of acid. It is, therefore, important to collect accurate pH data to compare with your alkalinity data.

Atmosphere: Atmosphere measurements, especially precipitation and temperature, are also important for interpreting your alkalinity data. Heavy rain or snowmelt, resulting in an influx of large amounts of freshwater to the system, may decrease your water's alkalinity.

In addition, knowing the geology and soil types of your area may be important for interpreting your alkalinity data.



Helpful Hints

- If your students are using multiple kits, mark the items in each kit with a dot of the same color. Use a different color for each kit. This will help avoid kit contamination by exchanging chemicals or titrators between kits.



Instrument Maintenance

1. The alkalinity kit should be kept in a dry place away from direct heat.
2. All chemicals should be kept tightly capped.
3. Chemicals in the kits should last a year if they are not contaminated, and are stored in a dry area away from extreme heat.
4. The alkalinity standard should be kept refrigerated after opening and discarded after one year.
5. Store the titrator with the plunger removed to avoid the rubber end sticking in the tube.



Questions for Further Investigation

What is the relationship between changes in pH and changes in alkalinity at your site?

How might the type of rocks and soil in your watershed affect the alkalinity of your water site?

What factors in your environment do you think might cause a change in the alkalinity at your site?

Does the alkalinity at your site have a seasonal pattern? Does this same pattern exist at other sites?



Making the Baking Soda Alkalinity Standard

Lab Guide

What You Need

- Baking soda (1.9 g)
- Balance
- 500-mL graduated cylinder
- Distilled water
- Stirring rod
- 100-mL graduated cylinder
- Pen or pencil
- 500-mL beaker

In the Lab

1. Weigh out 1.9 g baking soda and add it to the 500-mL graduated cylinder.
2. Pour distilled water into the cylinder with the baking soda to the 500-mL mark.
3. Pour this baking soda solution into the 500-mL beaker, and stir it with a stirring rod to make sure all of the baking soda has dissolved.
4. Rinse the 500-mL graduated cylinder with distilled water. Measure 15 mL of baking soda solution with the 100-mL graduated cylinder and pour it into the clean 500-mL graduated cylinder.
5. Add distilled water to the solution in the 500-mL graduated cylinder to the 500-mL mark.
6. This solution is your standard and has an alkalinity of approximately 84 mg/L.

Quality Control Procedure for Alkalinity

Lab Guide

Task

Check the accuracy of your alkalinity kit. Practice using the alkalinity test kit correctly.

What You Need

- Hydrology Quality Control Data Sheet
- Alkalinity test kit
- Alkalinity standard (A standard may be purchased or you can mix a standard following the *Making the Baking Soda Alkalinity Standard Lab Guide*.)
- Distilled water in wash bottle
- Goggles
- Pen or pencil
- Latex gloves
- 100-mL graduated cylinder

In the Lab

1. Put on the gloves and goggles
2. Fill in the top part of the *Hydrology Quality Control Data Sheet*. Make sure to note the type of alkalinity standard you are using, as well as your kit's manufacturer and model number.
3. Measure the alkalinity of your standard solution following your kit's directions.
Note: Use the alkalinity standard as your water sample.
4. Record the results on the *Hydrology Quality Control Data Sheet*.
5. Compare your results with the value of your alkalinity standard:
 - if you using the baking soda standard, your results should be $84 \text{ mg/L} \pm 10 \text{ mg/L}$.
 - if you are using a ready-made standard, your results should be the actual alkalinity of your standard plus or minus the maximum acceptable difference for your test kit.

Maximum acceptable differences for common alkalinity test kits

LaMotte	$\pm 8 \text{ mg/L}$
Hach	$\pm 6.8 \text{ mg/L}$ (Low Range, 0–10 mg/L)
	$\pm 17 \text{ mg/L}$ (High Range, 0–50 mg/L)

6. If your measured values are not within the expected range, try doing the procedure again using a fresh standard sample.
7. If your value is still not within range, discuss possible problems with your teacher.

Alkalinity Protocol

Field Guide

Task

Measure the alkalinity of your water sample.

What You Need

- Hydrology Investigation Data Sheet
- Alkalinity test kit
- Gloves
- Distilled water in wash bottle
- Goggles
- Pen or Pencil

In the Field

1. Fill out the top portion of your *Hydrology Investigation Data Sheet*.
2. Put on the gloves and goggles
3. Follow the instructions in your alkalinity kit to measure the alkalinity of your water.
4. Record your measurement on the *Hydrology Investigation Data Sheet* as *Observer 1*.
5. Repeat the measurement using fresh water samples.
6. Record as *Observers 2* and *3*.
7. Calculate the average of the three measurements.
8. Each of your individual measurements should be within the acceptable range of the average.

Maximum acceptable differences for common alkalinity test kits

LaMotte	± 8 mg/L
Hach	± 6.8 mg/L (Low Range, 0–10 mg/L)
	± 17 mg/L (High Range, 0–50 mg/L)

9. If one measurement is outside this range, discard that measurement and find the average of the other two.
10. If they are still in range, report only the two measurements.
11. If more than two of your measurements are not in range, repeat from Step 3.



Frequently Asked Questions

1. How can I be sure when the color change has happened?

Become familiar with the color change by doing the Quality Control Procedure.



2. Should I worry if my water site has very low alkalinity?



Some areas will naturally have low alkalinity. This might be true in mountain streams. The waters have not contacted rocks or soil long enough for the rocks to dissolve. This just means that these areas are more sensitive to acid additions.

Alkalinity Protocol – Looking at the Data

Are the Data Reasonable?

Alkalinity values range from close to 0.0 ppm to more than 500 ppm, although most water bodies will have values between 40-300 ppm. Discovering unusual values in the data often depends on knowledge of typical patterns at a site. If a site has been measured with almost no alkalinity for many months, then suddenly has 300 ppm, students should recognize a deviation from the normal pattern and investigate further. Other sites may naturally have large swings in alkalinity in response to precipitation, snowmelt, or other inputs into the system.

What Do the Scientists Look for in the Data?

Scientists are interested in how well a water body may be buffered against acid input. Streams with naturally low alkalinity are more sensitive. The pH may drop dangerously low with a relatively small acid input. Scientists would also be interested in investigating areas that show large swings in alkalinity. These areas may be receiving very large amounts of acid. Even though a stream has alkalinity to help buffer the acid input, alkalinity will eventually be neutralized by the acid, resulting in a lower pH.

Example of a Student Research Project

Forming a Hypothesis

A student is looking at the alkalinity data from SWS-02 at Crescent Elk School in California. This water body is Elk Creek, a small freshwater creek. She notices that although there is a lot of scatter in the data, the values seem to be highest in the summer, and lowest in the winter. She knows that precipitation can sometimes affect alkalinity, so she plots rainfall and alkalinity as stacked graphs, shown in Figure HY-AL-1. Precipitation is clearly highest from November through March, and lowest in July and August.

She forms her hypothesis: *In Elk Creek, alkalinity is highest when rainfall is lowest and alkalinity is lowest when rainfall is highest.*

Collecting Data

The student examines the daily data. Three of the alkalinity data points seem very low. On August 15, 1997 the reported alkalinity was 1 mg/L and on September 15 and September 18 1998 it was 9 mg/L. These values seem very low compared to the rest of the values. However, she decides to go ahead with her analysis and hope the data are correct.

She wants to eliminate some of the noise (scatter) in the plot in order to see the relationship more clearly. She plots the monthly average total rainfall and average alkalinity for the five full years of the record, 1997-2001. See Figure HY-AL-2. She then downloads the monthly data (total rainfall, number of days rainfall was measured, average alkalinity and number of days alkalinity was measured) and imports them into a spreadsheet.

Analyzing Data

The student notices that not all months had rainfall data recorded every day. Instead of looking at total rainfall for each month, she decides it will be more appropriate to look at the average rainfall per day. By doing this, she assumes that any missing days will have about the same amount of average rainfall as the rest of the days of the month. She calculates the average by dividing the total amount of rainfall (mm) by the number of days the measurement was reported. [For example, the total precipitation in April 1997 was 113.4 mm, measurements were reported on 30 days, and so the average precipitation was 3.78 mm/day].

Then she eliminates months for which there is no value for either total precipitation or average alkalinity. Six of the 60 months have no average alkalinity data, 3 months have no total precipitation data, and 1 month, Oct-2001, does not have either. After she does this, she has 50 months left of data.

She sorts her data by precipitation as shown in Table HY-AL-1 and then calculates the average precipitation and alkalinity for each 10-month block. The ten months with the highest average rainfall include one November, two Decembers, three Januarys, three Februarys and a March, with an average rainfall rate of 12.7 mm/day. Alkalinity ranges from 55 to 72 ppm, with an average of 66



during these months. As rainfall decreases for the next three sets of months (from 5.5 to 3.3 to 1.4 mm/day), the 10-month average alkalinity is in the 70s: 74, 79 and 76 mg/L. During the 10 months with the lowest precipitation (10-month average only 0.1 mm/day), the alkalinity ranges from 66 to 99, with an average of 86 mg/L. These months include one June, three Julys, four Augusts, and two Septembers. So, she is satisfied that, on average, the alkalinity is higher during months with very little rainfall than it is during months with high rainfall.



Next, she takes the same data and sorts them by alkalinity rather than rainfall, and again calculates 10-month averages, as shown in Table HY-AL-2. The sorted 10-month averages show a good trend. For average alkalinities of 94, 81, 75, 70 and 61 mg/L, the average rainfall is 1.6, 2.7, 3.5, 6.5 and 8.7 mm/day, respectively. Most of the ten highest alkalinities occur from June through September, although there is one March and one April. Monthly average rainfall associated with the 10 highest transparencies range from 0.0 to 4.4 mm/day. Eight of the 10 lowest alkalinities were recorded from November to March; the other two months were in May and in August, both of which had low rainfall. Monthly average rainfall ranges from 0.0 to 16.9 mm/day (the lowest and highest values) despite the high 10-month average.



The student feels she has enough data to support her hypothesis. She prints out her plots and tables and writes her results as a report and submits it to the GLOBE Web site under *Student Investigations*.



Further Thoughts and Future Research

There are some other aspects this student needs to consider. To what extent is the stream affected by snowmelt? How much does snowfall contribute to total precipitation in this watershed? How might the snowmelt during the spring affect the alkalinity even in months with little rainfall?



This site has fairly low alkalinity all year long (less than 100 mg/L as CaCO₃). Would a site with higher alkalinity show as much change? How about a site with more seasonal precipitation?



Figure HY-AL-1

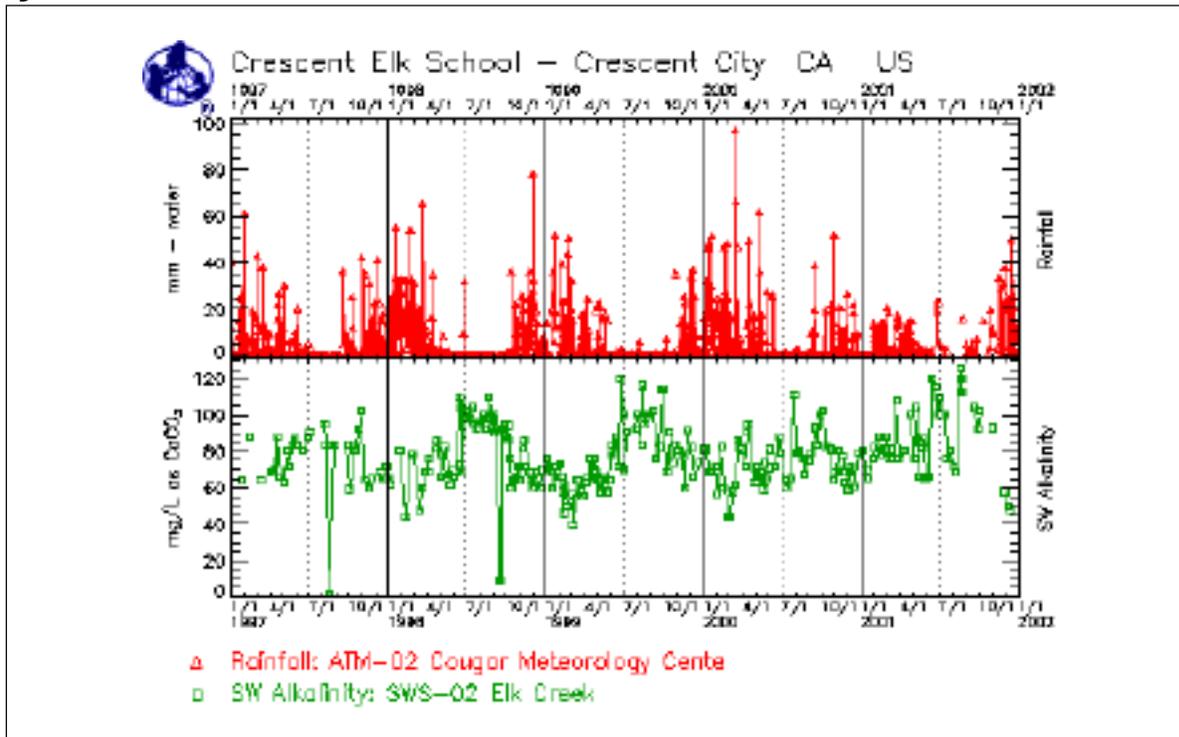


Figure HY-AL-2

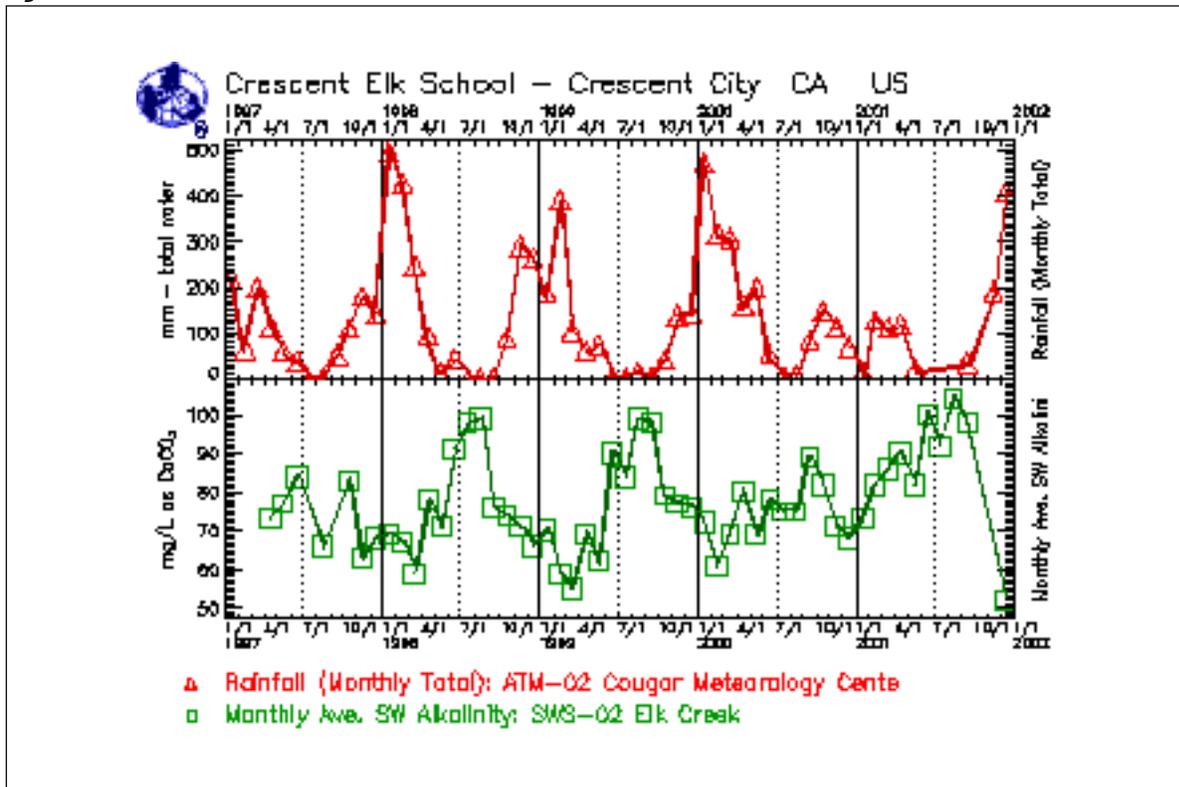


Table HY-AL-1:

1997-2001 Monthly Average Rainfall and Alkalinity, Sorted By Descending Average Rainfall

Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as CaCO ₃)	10-Month Average Alkalinity	Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as CaCO ₃)	10-Month Average Alkalinity
Dec-01	16.9	12.7	52	66	May-99	2.3	1.4	62	76
Jan-98	16.0		69		Dec-00	2.2		68	
Feb-98	15.8		67		Apr-99	1.9		69	
Jan-00	15.2		72		Jun-00	1.8		78	
Feb-99	13.9		59		Oct-99	1.5		79	
Feb-00	10.9		61		Jun-98	1.4		91	
Nov-98	10.7		71		Jun-97	1.4		84	
Mar-00	10.2		69		May-01	0.8		82	
Jan-99	9.0		70		May-98	0.4		71	
Dec-98	8.8		66		Jan-01	0.4		73	
Mar-98	7.7	5.5	59	74	Aug-99	0.4	0.1	99	86
May-00	6.4		69		Aug-00	0.3		75	
Nov-97	6.4		63		Jun-99	0.2		90	
Apr-00	5.3		80		Sep-99	0.1		98	
Nov-99	5.3		77		Jul-00	0.1		75	
Dec-99	4.9		76		Jul-99	0.0		84	
Oct-00	4.9		82		Aug-97	0.0		66	
Dec-97	4.7		68		Jul-98	0.0		98	
Feb-01	4.5		82		Aug-98	0.0		99	
Mar-01	4.4		86		Sep-98	0.0		76	
Mar-99	4.3	3.3	55	79					
Apr-01	3.9		90						
Apr-97	3.8		73						
Nov-00	3.7		71						
Oct-97	3.5		83						
Oct-98	3.2		74						
Apr-98	3.1		78						
Sep-00	2.8		89						
Sep-01	2.4		98						
May-97	2.3		77						

Table HY-AL-2:

1997-2001 Monthly Average Rainfall and Alkalinity, Sorted By Descending Alkalinity

Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as CaCO ₃)	10-Month Average Alkalinity	Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as CaCO ₃)	10-Month Average Alkalinity
Aug-99	0.4	1.6	99	94	Nov-98	10.7	6.5	71	70
Aug-98	0.0		99		Nov-00	3.7		71	
Sep-01	2.4		98		May-98	0.4		71	
Sep-99	0.1		98		Jan-99	9.0		70	
Jul-98	0.0		98		Jan-98	16.0		69	
Jun-98	1.4		91		Mar-00	10.2		69	
Apr-01	3.9		90		May-00	6.4		69	
Jun-99	0.2		90		Apr-99	1.9		69	
Sep-00	2.8		89		Dec-97	4.7		68	
Mar-01	4.4		86		Dec-00	2.2		68	
Jun-97	1.4	2.7	84	81	Feb-98	15.8	8.7	67	61
Jul-99	0.0		84		Dec-98	8.8		66	
Oct-97	3.5		83		Aug-97	0.0		66	
Oct-00	4.9		82		Nov-97	6.4		63	
Feb-01	4.5		82		May-99	2.3		62	
May-01	0.8		82		Feb-00	10.9		61	
Apr-00	5.3		80		Feb-99	13.9		59	
Oct-99	1.5		79		Mar-98	7.7		59	
Apr-98	3.1		78		Mar-99	4.3		55	
Jun-00	1.8		78		Dec-01	16.9		52	
Nov-99	5.3	3.5	77	75					
May-97	2.3		77						
Dec-99	4.9		76						
Sep-98	0.0		76						
Aug-00	0.3		75						
Jul-00	0.1		75						
Oct-98	3.2		74						
Apr-97	3.8		73						
Jan-01	0.4		73						
Jan-00	15.2		72						

Nitrate Protocol



Purpose

To measure the nitrate-nitrogen ($\text{NO}_3\text{-N}$) of water

Overview

Students will use a nitrate kit to measure the nitrate-nitrogen in the water at their hydrology site. The exact procedure depends on the instructions in the nitrate kit used.

Student Outcomes

Students will learn to,

- use a nitrate kit;
- examine reasons for changes in the nitrate of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Organisms change the environment in which they live.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a chemical test kit to measure nitrates.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

20 minutes for nitrate test

Quality Control Procedure: 20 minutes

Level

Middle and Advanced

Frequency

Weekly

Quality control every 6 months

Materials and Tools

Nitrate Test Kit (if you have salt or brackish water, be sure to use an appropriate test kit)

Nitrate Protocol Field Guide

Hydrology Quality Control Sheet

Hydrology Investigation Data Sheet

Clock or watch

Latex gloves

Goggles

Surgical mask (if using powdered reagents)

Distilled water

For Quality Control Procedure, the above plus:

- *Quality Control Procedure Field Guide*

- *Quality Control Procedure Data Sheet*

- *Making the 2 ppm Nitrate Standard Lab Guide*

- Standard nitrate solution (1000 mg/L nitrate-nitrogen)

- Equipment depends on how the standard is made (see *Making the 2 ppm Nitrate Standard Lab Guide*)

Preparation

Suggested activity: *Practicing Your Protocols, Nitrate Protocol (e-guide only)*

Prerequisites

Discussion of the differences among nitrate, nitrate-nitrogen, and nitrite

Discussion of safety procedures when using chemical test kits.



Nitrate Protocol – Introduction

Nitrogen can have many chemical forms in water bodies. Nitrogen can be found as dissolved molecular nitrogen (N_2), as organic compounds (both dissolved and particulate), and as numerous inorganic forms such as ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Nitrate (NO_3^-) is usually the most important inorganic form of nitrogen because it is an essential nutrient for the growth and reproduction of many algae and other aquatic plants. Nitrite (NO_2^-) is usually found only in waters with low dissolved oxygen levels, called suboxic waters.



Scientists often call nitrogen a “limiting nutrient” because in low amounts, plants use up all the available nitrogen in the water and cannot grow or reproduce anymore. So, it “limits” the amount of plants in the water. Many plants that use nitrogen are microscopic algae, or phytoplankton. Additional amounts of nitrogen added to the water may allow the plants to grow and reproduce more.



The nitrate form of nitrogen found in natural waters comes from the atmosphere in rain, snow, fog or dry deposition by wind, from groundwater inputs, and from surface and below surface runoff that flows off and through surrounding land cover and soils. As well, the decay of plant or animal matter in soil or sediments creates nitrates. Human activities can greatly affect the amounts of nitrate in water bodies.



When an excess amount of a limiting nutrient such as nitrogen is added to a lake or stream the water becomes highly productive. This may cause tremendous growth of algae and other plants. This process of enriching the water is called *eutrophication*. The resulting excess plant growth can cause taste and odor problems in lakes used for drinking water or can cause nuisance problems for users of the water body.



Although plants and algae add valuable oxygen to the water, overgrowth can potentially lead to reduced light levels in the water body. As plants and algae die and decay, bacteria multiply and use the dissolved oxygen in the water. The amount of available dissolved oxygen in the water may become very low and harm fish and other aquatic animals.



Teacher Support

Understanding the Chemistry of the Nitrate Kits

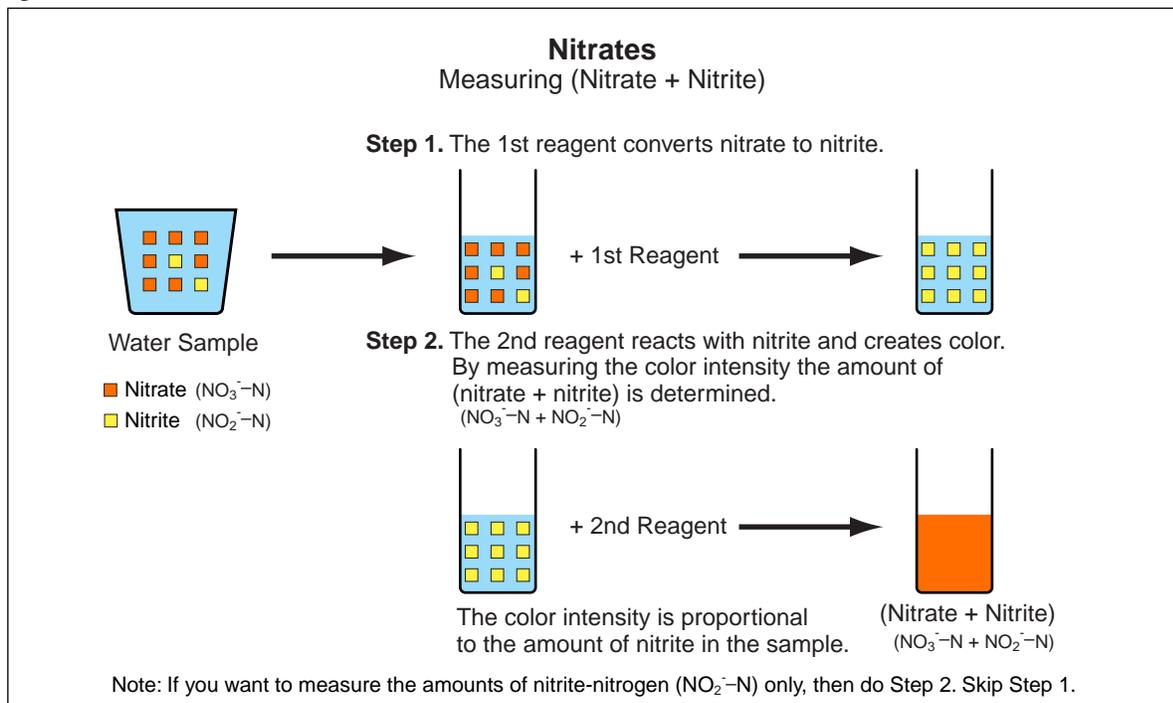
Nitrate (NO_3^-) is very difficult to measure directly, whereas nitrite (NO_2^-) is easier to measure. So, in order to measure nitrate (NO_3^-) nitrate kits convert the nitrate (NO_3^-) in the water sample to nitrite (NO_2^-). As explained in the instructions for the nitrate kits, you will add a chemical (such as cadmium) to the water sample, and this will change the nitrate (NO_3^-) in the water to nitrite (NO_2^-). A second chemical is then added to the water sample and reacts with the nitrite (NO_2^-) to cause a color change. The resulting color change of the water sample is proportional to the amount of nitrite in the sample.

The measurement in the nitrate kits gives the combined concentration of nitrite (if present) and nitrate (remember the nitrate, NO_3^- , has been converted to nitrite, NO_2^-). In the 1997 Teacher’s Guide, we asked you to measure both the nitrite (NO_2^-) and the combined nitrate and nitrite forms (the procedure described above). We are now only asking you to report the combined nitrate and nitrite forms. If the water at your site has very low dissolved oxygen levels, we encourage you to measure the nitrite (NO_2^-) amount. To measure nitrite (NO_2^-), you do not add the first chemical (such as cadmium). Instead, you only add the second chemical that reacts with the nitrite (NO_2^-) to cause a color change. The instructions in the nitrate kit should explain what to do. See Figure HY-NI-1.

The chemical reaction that causes nitrate (NO_3^-) to change to nitrite (NO_2^-) is called an oxidation – reduction reaction. These types of reactions are very common and involve the exchange of electrons from one molecule to another molecule. Often, the kits will say that they use a cadmium reduction method. This means that the cadmium has removed electrons from nitrate (NO_3^-) to form nitrite (NO_2^-).

The hydrology investigation team has tested kits that use either cadmium or zinc as a reduction element. Cadmium-based kits provide a finer resolution of 0.1 or 0.2 ppm. In other words, the

Figure HY-NI-1



value you measure will have an accuracy of 0.2 ppm. The zinc-based kits that have been tested generally have a coarser resolution of 0.25 ppm. Cadmium, however, is a carcinogen and may not be allowed or recommended by your school. The kits are designed to minimize exposure to cadmium or zinc. Please check your school policy before ordering these kits. We are watching for kits to be developed using different chemistry.

For GLOBE, concentrations of nitrate are expressed as the amount of elemental nitrogen in the form of nitrate. Concentrations are expressed as nitrate-nitrogen ($\text{NO}_3^- \text{-N}$) in milligrams per liter.

Milligrams per liter (mg/L) is the same as parts per million (ppm). For example, a concentration would be reported as 14 g of nitrogen per mole of NO_3^- and not as grams of NO_3^- (which would be 62 g per mole (NO_3^-)). It might be useful to review the Periodic Chart of chemical elements. The weight of nitrogen is 14 g and that of NO_3^- is 62 g (O = 16 g). The nitrate kits are designed to measure nitrate-nitrogen and we ask you to report nitrate values in the form of nitrate-nitrogen as well.

For your own exercise, you can convert mg/L nitrate-nitrogen to mg/L nitrate. Simply multiply your measured value by 4.4. This value is the ratio of nitrate/nitrogen molecular weights (62g/14g). For example, say you measured 10 mg/L $\text{NO}_3^- \text{-N}$. Multiplying 10 by 4.4 gives you 44 mg/L NO_3^- .

Measurement Procedure

- Most natural waters have nitrate levels under 1.0 mg/L nitrate-nitrogen, but concentrations over 10 mg/L nitrate-nitrogen are found in some areas. If your kit has a low range (0-1 ppm) and a high range (1-10 ppm), most likely you will only use the low range test. If you are not sure what the nitrate levels are, first use the low range. Students should note the range of their test in their metadata. Values above 10 ppm $\text{NO}_3^- \text{-N}$ may be rejected unless a school indicates that their results are valid above this level.
- If your kit measures nitrate-nitrogen ($\text{NO}_3^- \text{-N}$), you do NOT multiply the value you measure by 4.4. Report the value directly from the kit.
- If the nitrate kit requires you to shake the sample, it is important to shake for the



exact time stated in the instructions. Use a watch or clock to measure the time. Have one student shake while another watches the time.

- Do not report any value if the water was not tested for nitrate. A value of 0.0 ppm indicates that the water was tested and no nitrate was detected.
- If there are low values of dissolved oxygen (e.g., less than 3.0 mg/L) and you have detected amounts of nitrate-nitrogen (NO_3^- -N), you may want to measure the amounts of nitrite-nitrogen (NO_2^- -N).
- If your site has brackish or salt water, you need to make sure that you have a kit that can be used in brackish or salt water. If you already have a kit, look at the instructions in the nitrate kit. Some kits cannot be used in brackish and salt water.

Quality Control Procedure

To perform the quality control procedure, you need to buy a standard nitrate-nitrogen. You can use either a liquid standard solution or a dry stock standard solution. The liquid standard you buy has a high concentration of NO_3^- -N (1000 ppm). The lab guide explains how to dilute the standard to 2 ppm. Students can then measure the concentration of the NO_3^- -N in the standard and compare their result to the expected standard value of 2 ppm.

The *Making the Nitrate Standard Lab Guide* provides two options for making the 2 ppm nitrate-nitrogen standard. Option 2 uses less stock solution and has less wastage but requires more skill to make.

After your students have completed the quality control procedure using the 2 ppm standard, discard the remaining unused 2 ppm and 100 ppm standards. The standard nitrate solution should be made fresh each time quality control procedures are done.

Lastly, the *Making the 1000 ppm Stock Standard Nitrate-Nitrogen Solution Lab Guide* shows you how to make the concentrated 1000 ppm standard from potassium nitrate (KNO_3). This method is recommended only if you have a chemistry lab.

Supporting Protocols

Hydrology: Students may explore relationships among transparency, temperature and dissolved oxygen and the amount of nitrates in the water.

Land Cover/Biology: Examining the types of land cover in the watershed may help to explain patterns you find in your water body.

Atmosphere: The amount of precipitation will affect the amount of runoff and the nutrients that are carried in the runoff.

Safety Procedures

1. Students should wear gloves when handling chemicals and the water sample.
2. Students should wear goggles when working with chemicals. They should also wear surgical masks when opening powdered reagents.
3. School authorities should be consulted on the proper disposal of used chemicals.

Instrument Maintenance

- All chemicals should be kept tightly capped and away from direct heat. Replace chemicals after one year.
- Glassware in the kit should be rinsed with distilled water before storing.
- Perform the quality control procedure with the kit every 6 months to insure that chemicals are still good.

Questions for Further Investigation

Why do you think there may be a seasonal pattern in nitrate data?

Is there a relationship between the amount of nitrate at your site and the type of land cover in your watershed?

Does temperature affect the amount of nitrate in water?

Is there a relationship between the types of soil in the watershed and the amount of nitrate in the water body?

Making the 2 ppm Nitrate Standard

Option 1

Lab Guide

Task

Make the nitrate-nitrogen standard for the quality control procedure using 5 mL stock nitrate-nitrogen solution.

What You Need

- | | |
|--|--|
| <input type="checkbox"/> Standard nitrate-nitrogen solution (1000 ppm) | <input type="checkbox"/> Goggles |
| <input type="checkbox"/> 100-mL beaker (or larger) | <input type="checkbox"/> Pipette |
| <input type="checkbox"/> 100-mL graduated cylinder | <input type="checkbox"/> Stirring rod (optional) |
| <input type="checkbox"/> 500-mL beaker or flask | <input type="checkbox"/> Distilled water |
| <input type="checkbox"/> 500-mL graduated cylinder | <input type="checkbox"/> 250-mL bottle or jar with lid |
| <input type="checkbox"/> Latex gloves | |

In the Lab

1. Put on gloves and goggles
2. Rinse a 100 mL cylinder and 100 mL beaker with distilled water. Dry.
3. Using a pipette (if possible), measure 5 mL of the 1000 stock nitrate solution into the 100-mL graduate cylinder. Dilute with distilled water to 50 mL.
4. Pour into a 100 mL beaker and mix (swirl or use clean stirring rod). Label this *100-ppm nitrate standard*.
5. Rinse 100-mL graduated cylinder with distilled water.
6. Measure out 10 mL of the 100 ppm nitrate standard using the 100-mL graduated cylinder. Pour into 500 mL flask or beaker. Measure out 490 mL of distilled water in the 500 mL graduate cylinder. Add to the 500 mL flask or beaker.
7. Carefully swirl the solution to mix. Pour into a bottle with a lid and label as *2.0 ppm nitrate-nitrogen standard*.

Making the 2 ppm Nitrate Standard

Option 2

Lab Guide

Task

Make the nitrate-nitrogen standard for the quality control procedure using 1 mL stock nitrate-nitrogen solution.

What You Need

- | | |
|--|--|
| <input type="checkbox"/> Standard nitrate-nitrogen solution (1000 ppm) | <input type="checkbox"/> Pipette |
| <input type="checkbox"/> 100-mL beaker (or larger) | <input type="checkbox"/> Distilled water |
| <input type="checkbox"/> 500-mL beaker or flask | <input type="checkbox"/> Balance |
| <input type="checkbox"/> Latex gloves | <input type="checkbox"/> 250-mL bottle or jar with lid |
| <input type="checkbox"/> Goggles | |

In the Lab

1. Put on the gloves and goggles
2. Rinse a 100 mL beaker and a 500 mL cylinder with distilled water. Dry.
3. Measure the mass of the 100 mL beaker with a balance. Leave the beaker on the balance.
4. Using a pipette, add 1.0 g of 1000 ppm nitrate-nitrogen solution to the beaker on the balance.
5. Take beaker off balance and fill to the 100 mL line with distilled water. Stir the solution. Label this solution *10 ppm nitrate standard*.
6. Measure the mass of the 500-mL graduated cylinder. Leave the cylinder on the balance.
7. Measure 40 g of the 10 ppm nitrate standard into the 500-mL graduated cylinder. Use a clean pipette to add the last few grams of standard so you do not exceed 40 g.
8. Add distilled water until there is 200 g (10 ppm nitrate standard + distilled water) in the graduated cylinder. Use a clean pipette to add the last few grams of water so you do not exceed 200 g.
9. Swirl to mix. Pour into a bottle with a lid and label as *2.0 ppm nitrate-nitrogen standard*.
10. Rinse all glassware and pipettes with distilled water and store.

Making the 1000 ppm Nitrate Standard

Lab Guide

Task

Make the 1000 ppm stock nitrate-nitrogen standard for the quality control procedure using KNO_3 (potassium nitrate).

What You Need

- Potassium nitrate (KNO_3)
- Distilled water
- Drying oven
- 500-mL graduated cylinder
- 500-mL bottle or jar with lid
- Balance
- Chloroform (optional)

In the Lab

1. Dry KNO_3 (potassium nitrate) in an oven for 24 hours at 105 degrees C.
2. Measure 3.6 g of KNO_3
3. Dissolve 3.6 g of KNO_3 in 100 mL of distilled water.
4. Pour solution into a 500 mL graduated cylinder. Fill cylinder to the 500 mL line with distilled water.
5. Carefully swirl to mix. (Do not shake).
6. Pour into a jar and label as 1000 mg/L nitrate-nitrogen solution. Put the date on the label.
7. The stock nitrate solution can be preserved for up to six months using chloroform (CHCl_3). To preserve a stock nitrate standard add 1 mL of chloroform to 500 mL of stock nitrate solution.

Note: To calculate nitrate-nitrogen (NO_3^- -N), take into account the molecular composition of KNO_3 (the ratio of the molecular weight of N to NO_3 is 0.138): $7200 \text{ mg/L } \text{KNO}_3 \times 0.138 = 1000 \text{ mg/L nitrate nitrogen solution}$.

Nitrate Quality Control Procedure

Task

Check the accuracy of the nitrate test kit.

What You Need

- Nitrate Test Kit
- Goggles
- Hydrology Quality Control Data Sheet*
- Distilled water
- 2 ppm Nitrate standard
- Surgical mask (if using powdered reagents)
- Latex gloves
- Chemical waste bottle
- Clock or watch

In the Lab

1. Fill out the top portion of the *Hydrology Quality Control Data Sheet*. In the *Nitrate* section fill in the name of the kit manufacturer and model.
2. Put on gloves and goggles.
3. Follow the directions in the nitrate test kit to measure the nitrate-nitrogen in the 2 ppm standard. If your test kit has directions for both a Low Range (0-1) and High Range (0-10) test, use the High Range directions for the calibration. Use the standard where it says 'sample water'. If using powdered reagents, use the surgical mask when opening these products. Use clock or watch to measure the time if your kit requires you to shake your sample.
4. Match the color of the treated sample water with a color in the test kit. Record the value as ppm nitrate-nitrogen for the matching color on the *Hydrology Quality Control Data Sheet*. Note: If you are not sure about the best matching color ask other students for their opinions.
5. Repeat steps 3 and 4 with fresh water samples. You will have a total of three nitrate-nitrogen measurements.
5. Calculate the average of the three measurements.
6. If your measurement is not + or – 1 ppm (high range) of the standard, repeat the measurement. If your measurement is still not within range, talk with your teacher about possible problems.
7. Put used chemicals in a waste container. Rinse glassware with distilled water. Cap all chemicals tightly.

Nitrate Protocol

Field Guide

Task

Measure the nitrate in your water sample.

What You Need

- | | |
|---|---|
| <input type="checkbox"/> Hydrology Investigation Data Sheet | <input type="checkbox"/> Goggles |
| <input type="checkbox"/> Nitrate test kit | <input type="checkbox"/> Distilled water |
| <input type="checkbox"/> Latex gloves | <input type="checkbox"/> Surgical mask (if using powdered reagents) |
| <input type="checkbox"/> Clock or watch | <input type="checkbox"/> Chemical waste bottle |

In the Field

1. Fill out the top portion of your *Hydrology Investigation Field Sheet*. In the *Nitrate* section fill in the kit manufacturer and model.
2. Put on gloves and goggles.
3. Follow the instructions in your kit to measure the nitrate nitrogen. You should use the Low Range Test (0 – 1 mg/L) unless previous results indicate that your site typically has greater than 1 mg/L nitrate nitrogen. If using powdered reagents, use the surgical mask when opening these products. Use clock or watch to measure the time if your kit requires you to shake your sample.
4. Match the color of the treated sample water with a color in the test kit. Record the value as ppm nitrate-nitrogen for the matching color. Have two other students match a color with the treated sample water for a total of three observations. Record all three nitrate-nitrogen values on the data sheet.
5. Calculate the average of the three measurements.
6. Check to see if each of the three measurements is within 0.1 ppm of the average (or within 1.0 ppm of the average if using the high range test). If they are, record the average on the data sheet. If they are not, read the color measurements again (**Note:** do not read again if it has been more than 5 minutes). Calculate a new average. If the measurements are still not within range discuss possible problems with your teacher.



Frequently Asked Questions

1. Is it okay for my water to have a nitrate measurement of 0?

Yes, a 0 ppm value indicates that the amount of nitrate (if any) in the water is below the detection limit (usually 0.1 ppm N-NO₃) of the nitrate kit you are using. Many water bodies may have 0 ppm N-NO₃ most of the year.



2. What happens if my water turns a different color, instead of pink, during the testing process?

You probably cannot use the kit you are currently using. Please contact the hydrology team at the University of Arizona to see if they want a sample of your water.



3. Is it okay for nitrate values to fluctuate a lot in a short period of time?



Yes, after precipitation events run-off from surrounding land cover and soils containing nitrates can go into a stream, lake, or estuary and cause the nitrate levels to rise. After the storm or snow melt, the levels may decline.

5. Is it OK to use a zinc-based nitrate kit?

Yes. While the cadmium-based kits give more accurate values in the low nitrate waters, we realize that school regulations do not allow some GLOBE schools to use the cadmium-based kits. If this is the situation at your school, use the zinc-based kits. Please designate on the site definition page the type of kit you are using.

Nitrate Protocol – Looking at the Data

Are the data reasonable?

Nitrate values generally range from 0.0 to 10.0 ppm. A value of 0.0 ppm is possible and should be reported. Repeated values of 0.0 ppm (as seen in Figure HY-NI-2) are not unusual. It is possible to have values above 10.0 ppm. However, the web site may reject these values as part of the quality control features. Please recheck values above 10.0 ppm to make sure that you are certain they are correct. If correct, contact the hydrology team.

What do scientists look for in the data?

The levels of nitrate can affect the ecology of the water body as well as affect how humans use the water. Scientists monitor nitrate in drinking water for public safety. Different countries have different standards of nitrate allowable in the drinking water. Scientists and resource managers also monitor water sites for high nitrate levels that might lead to eutrophication of the water body. High levels of nitrate may eventually lead to low levels of oxygen, which may then lead to harm to aquatic animals such as fish kills. Phosphate can be a common cause of eutrophication in water bodies, particularly in freshwater lakes and ponds

Sites often have seasonal fluctuations (see Figure HY-NI-3). Scientists commonly look at atmosphere, land cover, soil data, and human activities to find relationships with seasonal nitrate amounts.

Figure HY-NI-2

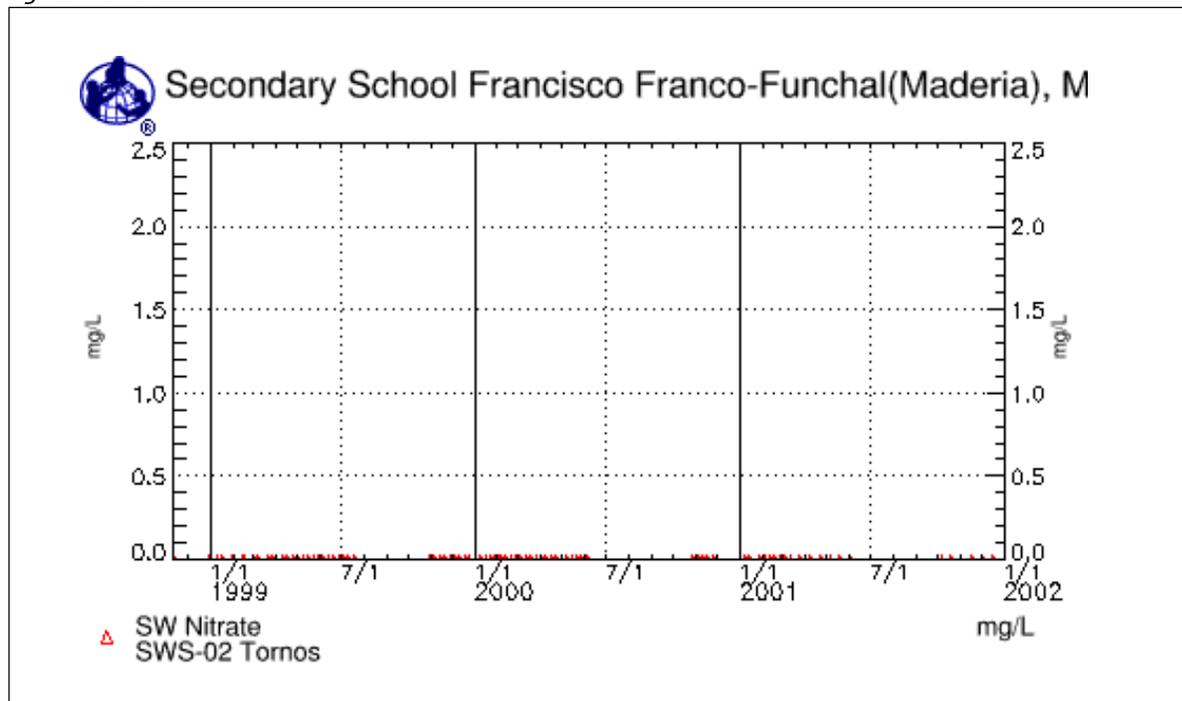
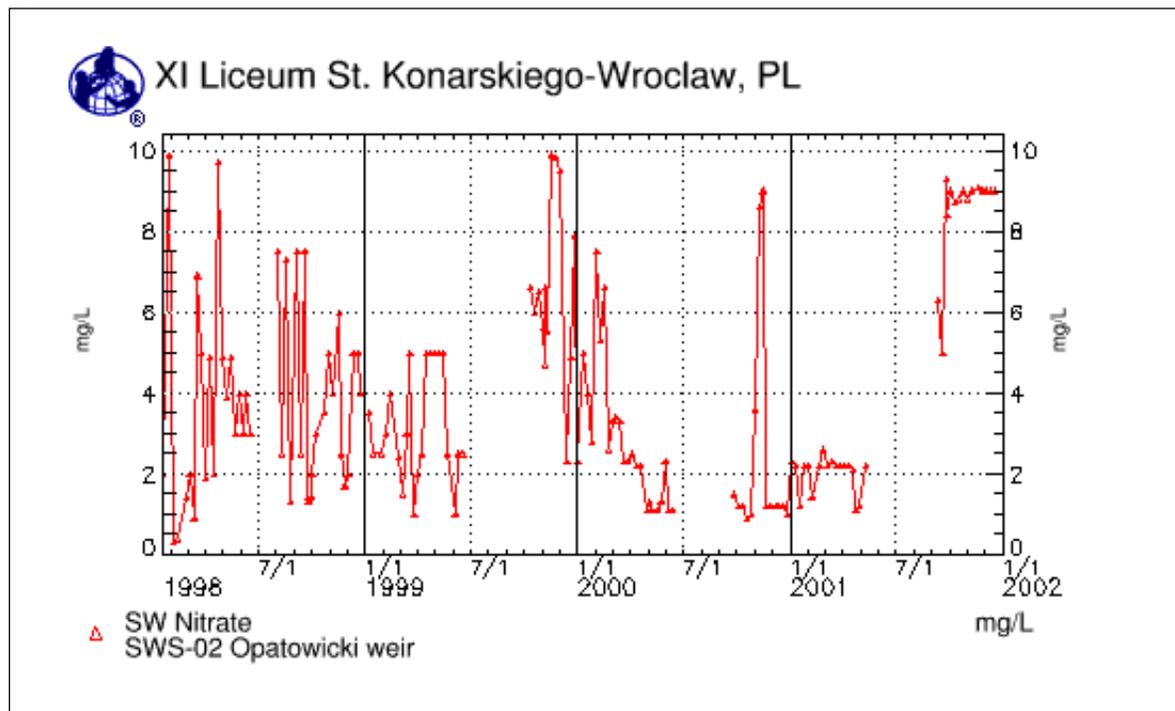




Figure HY-NI-3



Examples of Student Research Investigation

Investigation #1

Forming a Hypothesis

Students are examining the nitrate data collected at the Warta River by the Complex of Schools C. K. Norwida in Czestochowa, Poland over a period of three years (Figure HY-NI-4, top graph). Some of the students think they see an annual cycle, with higher values in the middle of the year, and lower values in winter. Not all the students are convinced because there is a lot of scatter in the data. However, they all agree to hypothesize that *nitrate levels in Warta River have an annual cycle.*

Collecting and Analyzing Data

The students begin by plotting the monthly averaged nitrate-nitrogen on the GLOBE server (Figure 3, lower graph). This makes an annual pattern seem more apparent. They create a table of the data shown in the graph on the web site and download the monthly average nitrate-nitrogen data. They import the data in a spreadsheet and create a table of the data with one row for each month and one column for each

year (shown in Table HY-NI-1). After this they calculate the monthly average for all years shown in the last column to the right.

The students use the spreadsheet program to plot the monthly data using a different symbol for each year and a line to show the average data (Figure HY-NI-5). It is now much easier to see the annual cycle. Average nitrate-nitrogen is lowest (~2 ppm) from January to March and highest (~7 ppm) from May to August. Intermediate values (~4 ppm) are measured between September and December. For most of the months, the nitrate for any given year is within ± 2 ppm $\text{NO}_3^- \text{N}$ of the average, except for June and November.

Communicating Results

The students write a report and present their results to their class.

Future Research

This site has an annual cycle for nitrate-nitrogen, but the students are not sure why. They decide to get precipitation data for the area and see when the rainiest months are. Will they coincide with months with the highest nitrate levels?

Investigation #2

Forming a Hypothesis

A student research team has been looking at nitrate-nitrogen levels in the Warta River, in Czestochowa, Poland, using data collected by the Complex of Schools C. K. Norwida. They have already determined that the observed mean monthly nitrate-nitrogen has an annual cycle with highest average values occurring from May to August, and lowest from January to March.

They believe that nitrate-nitrogen levels may be related to the amount of runoff after precipitation events.

They hypothesize that: *average nitrate is highest during months with the heaviest rainfall.*

Collecting and Analyzing Data

Their first task is to find precipitation data for this region. The school that collected nitrate-nitrogen data has an excellent multi-year surface water data set, but students did not collect atmosphere data. The students first check for nearby schools on the GLOBE server. There are no other schools in Czestochowa, but there are several GLOBE schools in nearby cities with precipitation data such as XI Liceum St. Konarskiego in Wroclaw, Silesian Technical Scientific Schools in Katowice, and Gimnazjum No 9 in Rzeszow. They plot the total monthly precipitation data for the three schools. See Figure HY-NI-5. They do not see any patterns common to all three sites. Although the data from Rzeszow show the trend they were expecting (high precipitation during the summer), not all the months have data. The data from Wroclaw show that extremely high precipitation occurred during the winter months of 2000 and 2001 while the data from Katowice show no apparent trend and are missing the summer months.

Next, the students decide to search for data for Czestochowa on the Internet. They find a site that contains weather averages for many cities and get the average monthly precipitation for Czestochowa.

These data are not for the same period as the nitrate-nitrogen data (1997-2001) but instead are

the average monthly precipitation values over a longer unknown period of time. They enter the values in the table with the nitrate-nitrogen data.

	Nitrate (ppm)	Precipitation (mm)
Jan	2.2	33.0
Feb	1.7	30.5
Mar	2.6	30.5
Apr	5.6	38.1
May	7.1	68.6
Jun	6.8	81.3
Jul	7.1	86.4
Aug	6.6	76.2
Sep	3.9	48.3
Oct	3.9	40.6
Nov	3.7	40.6
Dec	4.3	38.1

The four months from May to August have the highest average nitrate-nitrogen and the highest precipitation. The three months with the lowest nitrate-nitrogen levels (January-March) have the lower average precipitation. They conclude that their hypothesis is correct - average nitrate-nitrogen is highest during months with the most rainfall.

Discussion and Future Research

The students make one final plot, showing long-term average precipitation and 3-year average nitrate-nitrogen versus time on the same plot. See Figure HY-NI-6. One student wonders why the nitrate levels start to go up in April before the precipitation increases.

They come up with several possible ideas, and discuss what other information they would need to get to test them.

Perhaps snowmelt is occurring in April and is responsible for washing the nitrates into the water. (They would need to research the snow pack



upstream of their site and look at a temperature record to determine when it may have started melting.)



Perhaps there was more rain in April 1998-2000 than in some of the other April used in calculating the average precipitation. (They would need to find data just for 1998-2000 to check this).

Perhaps agriculturalists start fertilizing heavily in April. (They would need to determine when fertilizing starts upstream and what is in the fertilizers.)

Communicating Results



The students write a report and present their results to their class. As well, they submit their report to the GLOBE Web site under *Student Investigations*.



Figure HY-NI-4

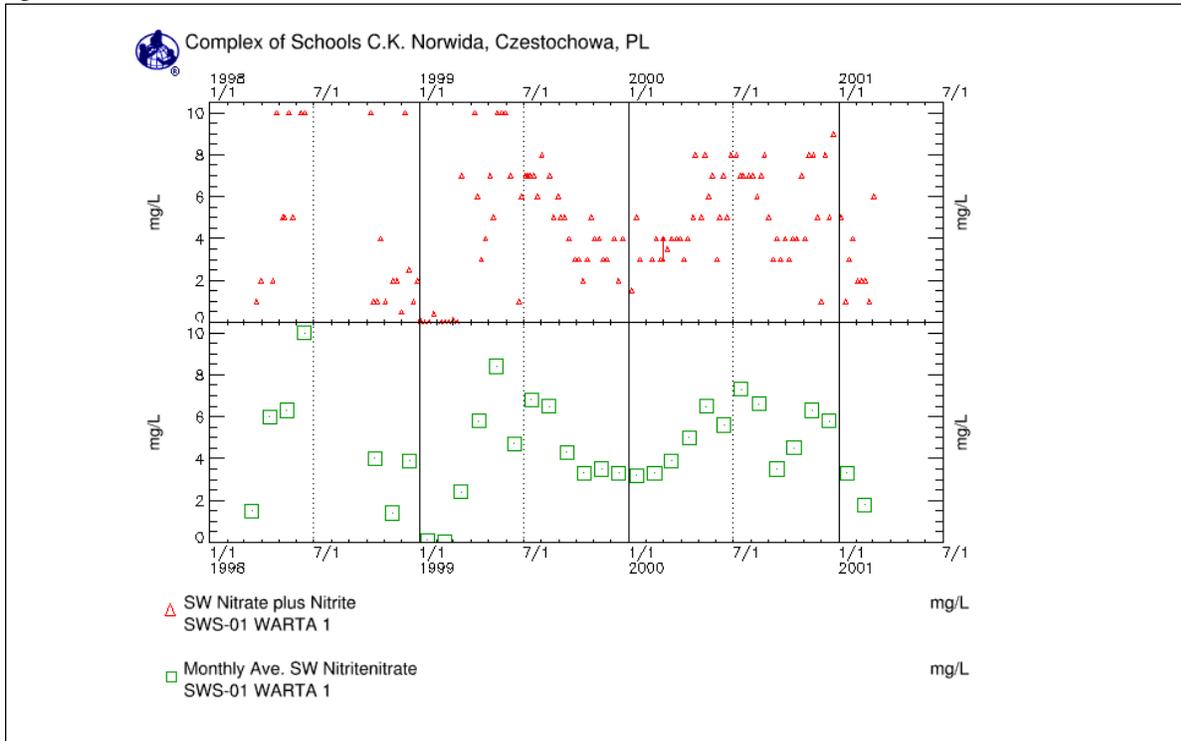


Table HY-NI-1

Average Monthly Nitrate at Warta River (ppm)					
Month	1998	1999	2000	2001	Average
Jan		0.1	3.2	3.3	2.2
Feb		0	3.3	1.8	1.7
Mar	1.5	2.4	3.9		2.6
Apr	6	5.8	5		5.6
May	6.3	8.4	6.5		7.1
Jun	10	4.7	5.6		6.8
Jul		6.8	7.3		7.1
Aug		6.5	6.6		6.6
Sep		4.3	3.5		3.9
Oct	4	3.3	4.5		3.9
Nov	1.4	3.5	6.3		3.7
Dec	3.9	3.3	5.8		4.3

Figure HY-NI-5

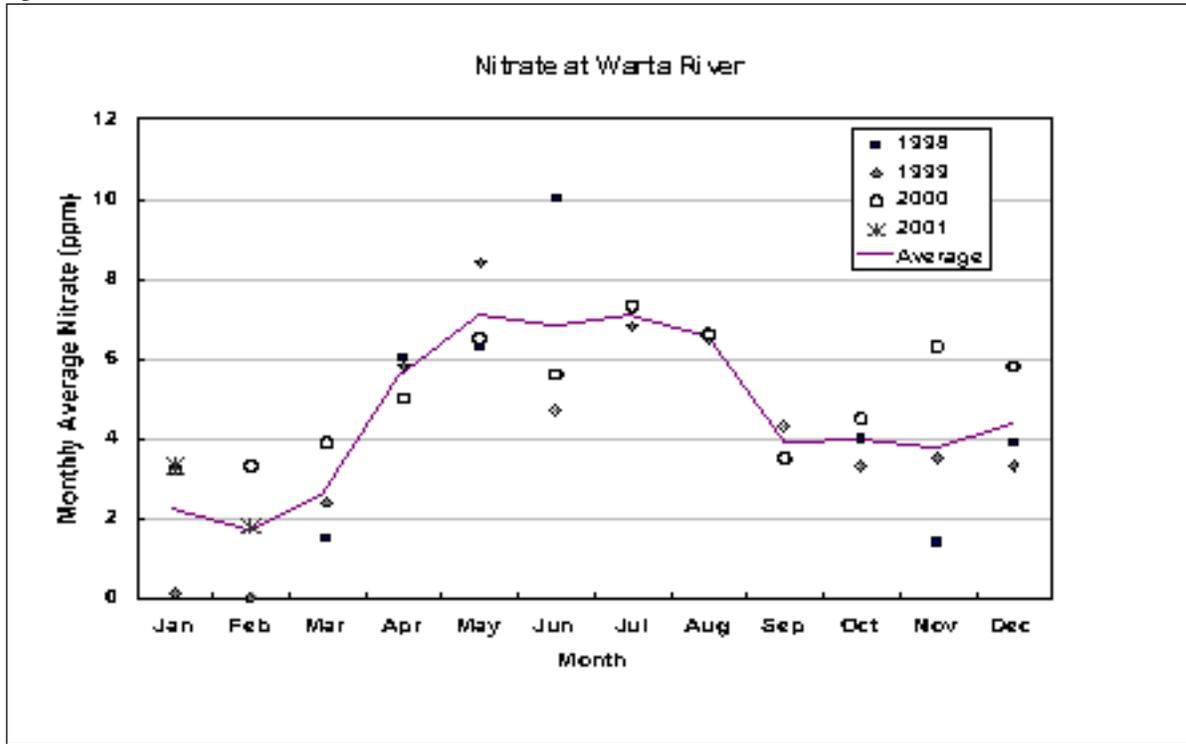


Figure HY-NI-6

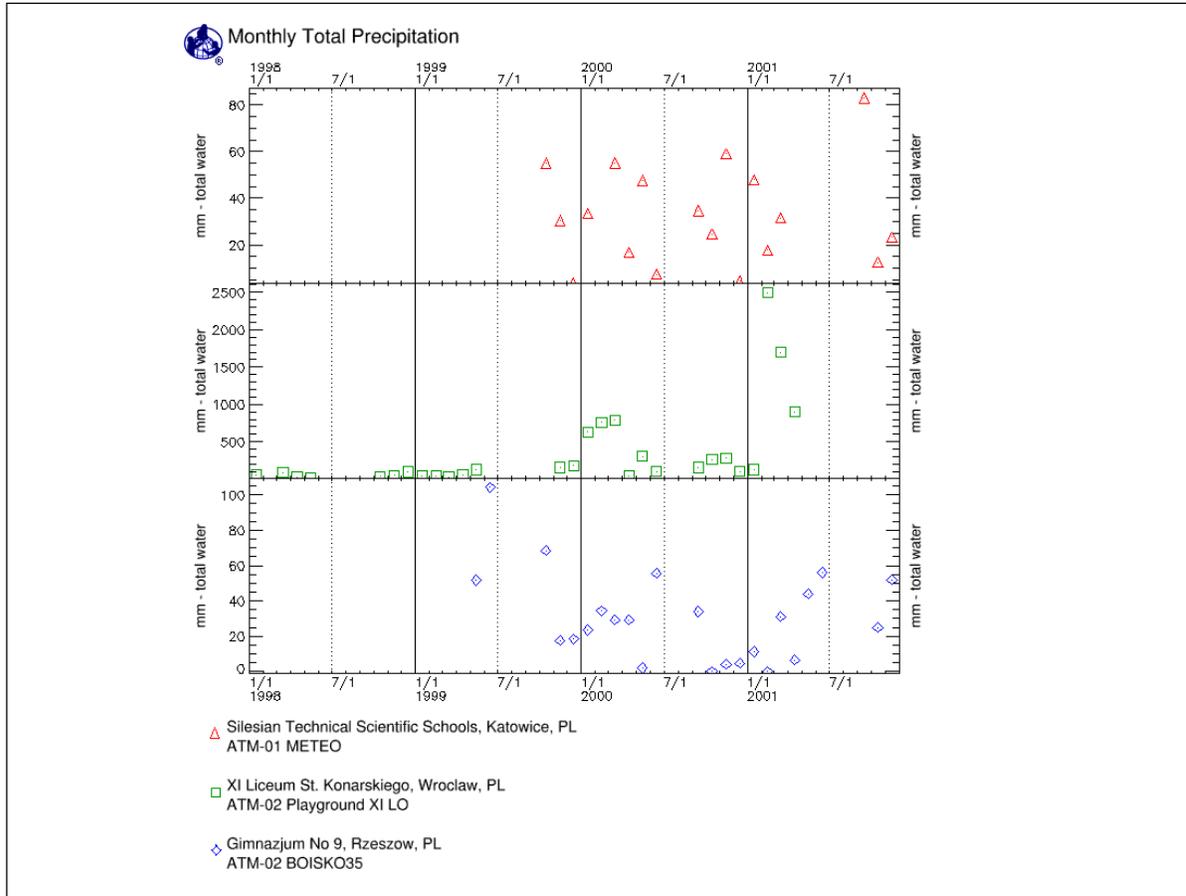
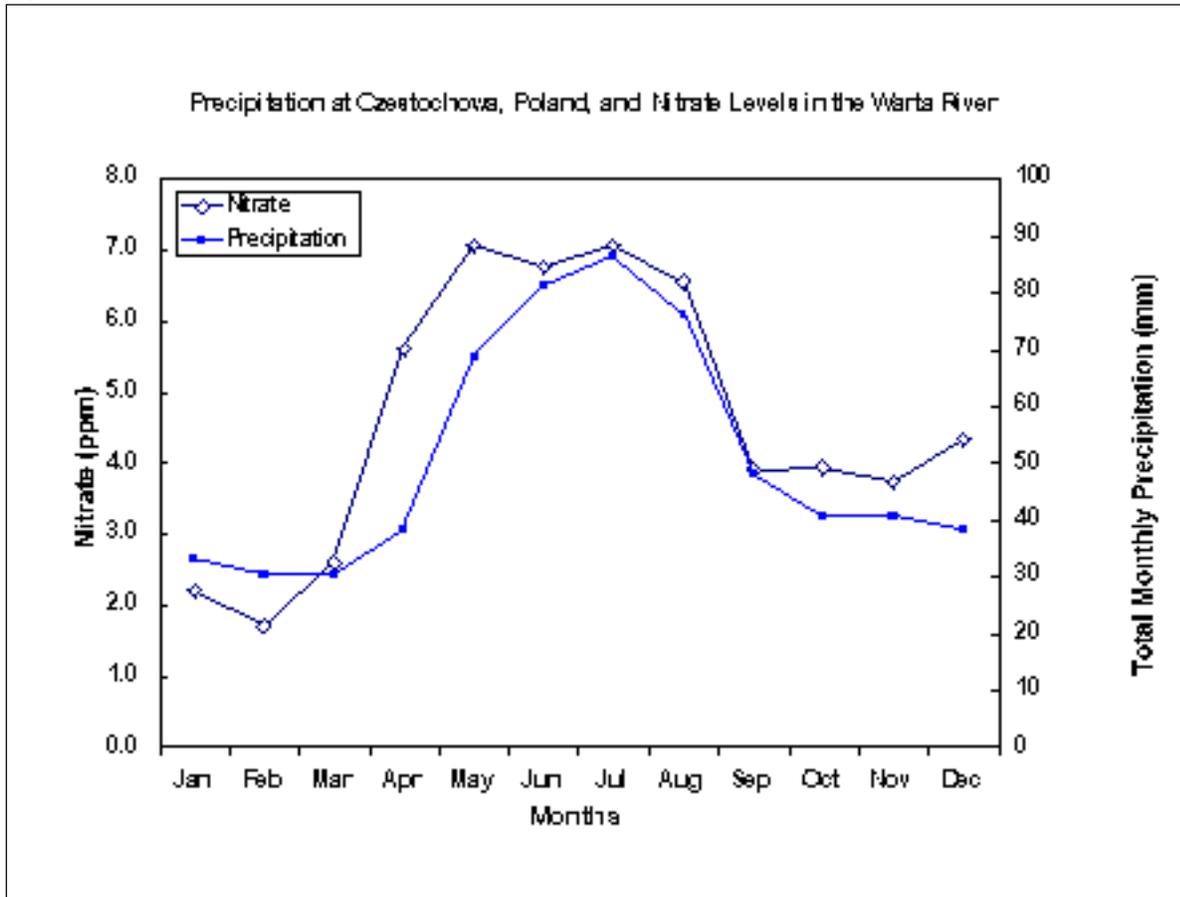


Figure HY-NI-7



Freshwater Macroinvertebrates Protocol



Purpose

To sample, identify and count macroinvertebrates at your Hydrology Site

Overview

Students will collect, sort, identify, and count macroinvertebrates from habitats at their site.

Student Outcomes

Students will learn to,

- identify taxa of macroinvertebrates at their site;
- understand the importance of representative sampling;
- use biodiversity and other metrics in macroinvertebrate research (advanced);
- examine reasons for changes in the macroinvertebrate community at their Hydrology Site (advanced);
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Sciences

Soils have properties of color, texture and composition; they support the growth of many kinds of plants.

Soils consist of weathered rocks and decomposed organic matter.

Life Sciences

Organisms have basic needs.

Organisms can only survive in environments where their needs are met.

Earth has many different kinds of environments that support different combinations of organisms.

Organisms functions relate to their environment.

Organisms change the environment in which they live.

Humans can change natural environments.

Ecosystems demonstrate the complementary nature of structure and function.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

All populations living together and the physical factors with which they interact constitute an ecosystem.

Populations of organisms can be categorized by the function they serve in the ecosystem.

Living systems require a continuous input of energy to maintain their chemical and physical organizations.

The interaction of organisms have evolved together over time.

Scientific Inquiry Abilities

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

3 to 6 hours to collect samples, count, identify, and preserve specimens

Time will vary with the abundance and diversity of organisms.



Level

Middle and Secondary

Frequency

2 times a year

Materials and Tools

Macroinvertebrate Identification Data Sheet

Equipment used to collect water
chemistry measurements at your
Hydrology Site (optional)

Latex gloves

Many clear plastic jars (0.5 to 3 L)

Many small plastic vials.

One to four plastic squirt or spray bottles
(1 to 2 L)

Many 20-mL bulb basting syringes (end
should be approximately 5 mm
diameter)

Several eyedroppers (end should be
approximately 2 mm diameter)

Large and small plastic or metal forceps

Several magnifying glasses or loupes

Two to six 5-L white buckets

White trays

Sub-sampling tray (optional)

Two sieves: one 0.5 mm (or smaller), and
one between 2-5 mm

Locally-applicable macroinvertebrate
identification keys

Appropriate footwear

Specimen bottles with preservation
solution (70% ethanol) and tight lids
(optional)

1 x 1 m quadrat (optional)

For Rocky Substrates in Running Water Protocol:

- Kick-net (0.5 mm mesh)

- Stop watch or watch

- Square of white fabric (about 110 cm
by 110 cm)

For Multi-habitat Freshwater Macroinvertebrate Protocol:

- D-net (0.5 mm mesh)

- Trowel or shovel

Preparation

Practice identifying the macroinvertebrates
using local keys to macroinvertebrates.

Make or buy the appropriate net for your
Hydrology Site.

Collect and make materials for sampling.

Collect pictures or books illustrating local
macroinvertebrates.

Prerequisites

None

Freshwater Macroinvertebrates Protocol – Introduction

Macroinvertebrates are small animals without a backbone that can be seen without a microscope. They live around living or dead vegetation, on the surface or in the sediments of water bodies. They include many larvae of insects such as mosquitoes, dragonflies and caddis flies that begin their lives in the water before becoming land dwelling insects when they mature. Other examples of common macroinvertebrates include crustaceans (such as crayfish), snails, worms and leeches. Macroinvertebrates can populate ponds or streams in amazing numbers – some of them up to thousands in a square meter. They are an important part of the food chain.

Macroinvertebrates can tell us a lot about the conditions within a water body. Many macroinvertebrates are sensitive to changes in pH, dissolved oxygen, temperature, salinity, turbidity and other changes in their habitat. Habitat is a place that includes everything that an animal needs to live and grow. It includes food resources, the physical characteristics of the environment, as well as places and materials to build nests, raise young and keep them safe from predators. Habitats include rocks, sticks, dead and decaying vegetation and other living organisms such as plants.

For the *Freshwater Macroinvertebrates Protocols* we want to estimate biodiversity, examine the ecology of the water body and explore relationships among water chemistry measurements and organisms at your Hydrology Site. Most often it is impossible to count all individuals of every species present in a habitat. So, we take samples of organisms in habitats, and calculate the diversity found in these samples to estimate true biodiversity in the habitats. Biodiversity is the number of different kinds of organisms in an ecosystem and the number of individuals of each kind. Often biodiversity is estimated from species data, but it can also be the number in broader categories like the number of different kinds of arthropods.

Scientists often use metrics to learn about the ecology of the water body. Metrics are derived from counts of organisms in samples at your and other sites. A simple metric is the number of organisms. Organisms can also be put into groups such as the percentages of feeding strategies (grazers, filter feeders, and predators), or percentages of long-lived and short-lived taxa.

Taking chemical measurements in a water body is like looking at a picture of what is going on in the water at that time. Taking biological measurements is like watching a movie of things that happened over time in the water in a single visit. Macroinvertebrates record the history of a water body because many are sessile or stay within a small area and live one or more years while the water flows by. Changes in the habitats (including water chemistry) most likely will cause changes in the macroinvertebrate assemblage.



Teacher Support

Advance Preparation

Many teachers and students have little background in the study and identification of freshwater macroinvertebrates, and may be reluctant to begin such a class project. This is not a problem, since students find the critters so fascinating they will be teaching themselves and each other.

There are many local experts to call on. Often, local water quality monitoring groups are willing to work with students. These people can, for example, help with family level identification (which is encouraged but optional) and with discussing important indicator species, as well as endemic and introduced organisms present in your area. Macroinvertebrate identification keys are available on the Internet or in printed manuals and books. Select an identification key that is applicable to your locality.

Contact local experts in the area to make sure that you are not sampling at a site where other people are conducting research or where there are endangered species. You do not want to inadvertently hurt a long-term monitoring site or harm endangered species.

To have the students become familiar with macroinvertebrates before you go to the field, students can bring in macroinvertebrates from their neighborhoods to identify in class.

Site Definition and Mapping

Select a 50-meter section of your stream, pond, or lake where you will sample freshwater macroinvertebrates. Select sites that can be accessed and sampled safely.

It is important to create a map of the 50-meter section that includes all the important features surrounding and within your water body, in particular, the types of habitats where macroinvertebrate sampling will be done (see *Hydrology Site Definition and Mapping Protocol*). Represent all the habitats on your map even if certain habitats cannot be reached. Habitat description and mapping are important for understanding and interpreting your data.

Each time you visit your site and collect macroinvertebrates, describe the habitats at the site at the time of sampling. Over time, habitats may change at your site and this could then affect which macroinvertebrates are found. In addition, if you are using the *Multi-habitat Freshwater Macroinvertebrate Protocol*, the amount and types of habitats at your site will determine your macroinvertebrate sampling strategy. An up-to-date map will allow you to calculate how many samples to collect in each habitat in proportion to the new coverage of all accessible habitats.

Here are some questions to ask yourself to help identify different habitats where macroinvertebrates live.

1. Is the water flowing or stagnant? If both, identify where.
2. If flowing, where would you consider it fast-flowing or slow-flowing (at least relative to the other places within your site)?
3. What and where are the substrates – boulders, cobbles, pebbles, sand or mud?
4. Are plants growing in the water body?
5. Are the banks vegetated?
6. Which areas are being eroded?
7. Where are snags, logs and roots?
8. Does the surrounding vegetation provide shade to the water?

If your site has running water and stones, indicate the riffle habitats, the run habitats, the pool habitats and their substrate: boulder, cobble, or gravel. Other potential habitats in running waters or more stagnant waters and wetlands are: vegetated banks, submerged vegetation, snags, logs, roots, mud, sand, and gravel.

Pool: a deeper region with slower-moving water and smaller sediments.

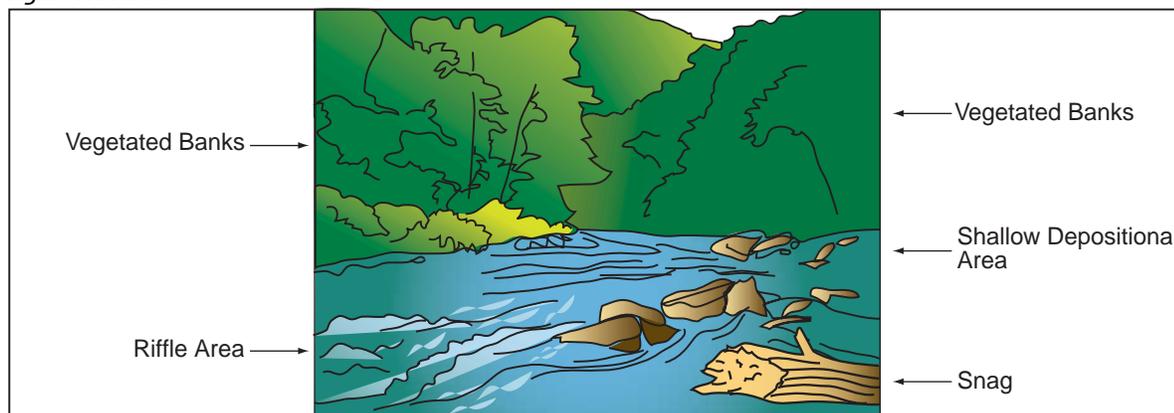
Riffle: a shallower area with faster-flowing water and larger sediments.

Run: an intermediate category between pool and riffle. Water in a run does not have the turbulence of a riffle, but moves faster than in a pool.

Snag: a tree or branch embedded in the bed of the water body.



Figure HY-MA-1



Which Protocol to Use: Rocky-Substrates in Running Water or Multi-habitat

If your hydrology site is a body of visibly running water shallower than 90 cm with a rocky substrate, use the *Rocky Substrate in Running Water Freshwater Macroinvertebrate Protocol*.

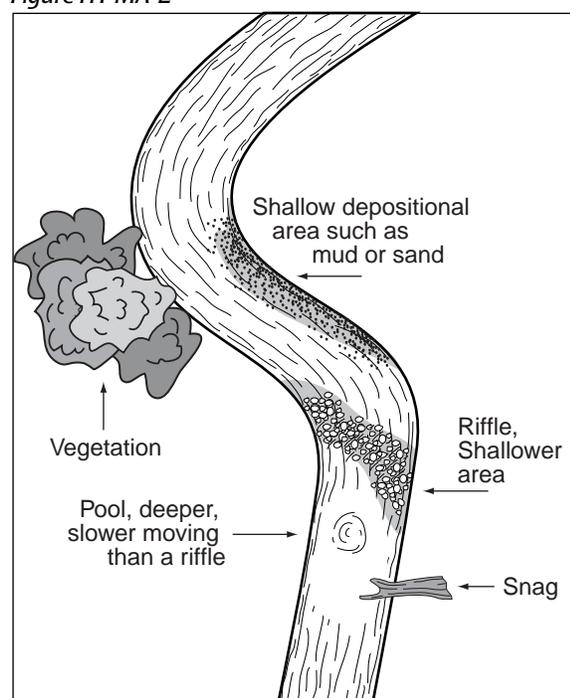
If the water is deeper than 90 cm or if many habitats are present, use the *Multi-habitat Freshwater Macroinvertebrate Protocol*. When mapping, pay special attention to identify all the aquatic habitats present and estimate the area covered by each habitat. The proportion that each accessible habitat covers will determine the number of samples taken in each habitat in the *Multi-habitat Freshwater Macroinvertebrate Protocol*.

When To Go Sampling

You should sample twice a year in different seasons.

Warm/cold seasons: If you have warm/cold seasons, sample in the spring and autumn. Sampling in the spring should be around the time of budburst. Autumn sampling should be done around the start of green-down and before frost. Green-up and green-down are explained in the *Phenology Investigation*. If you wait until you see many insects flying in the Spring, many of the insects will have grown past their aquatic stages and left the water. You will not have them in your sample. If you sample too early, the organisms may be too small and pass through the mesh of the net or be difficult to identify.

Figure HY-MA-2



Wet/dry seasons: If your seasons alternate between wet and dry, choose a date in the second half of the wet season and one date in the dry season six months from the first sampling if possible (or before water body becomes completely dry).

If you have no marked cyclic changes, ask local experts to find out when you should sample to find the peak abundance and diversity of macroinvertebrates in the water. Sample at that time and sample again six months later.

Sampling more than twice a year is not recommended for it may disturb and harm the habitats for the macroinvertebrates and other organisms living in the water.



Supporting Protocols

Hydrology: Students can explore relationships between the water measurements and the types of macroinvertebrates found at their Hydrology Site.



Land Cover/Biology: Students could examine relationships between the types of macroinvertebrates they find and the types of land cover surrounding their Hydrology Site and in the watershed.

Preparing for the Field



There are two sampling methods. It would be a good idea to select a site before the day of sampling and determine which sampling method will be used. The sampling method will determine which type of net you use.



Some or all of the students will be in the water. Those that walk in the water need to be appropriately dressed, in particular the footwear. Students may need waders. If using sneakers or something like sneakers, bring another pair of shoes to wear after sampling. Students may also need a change of clothes.

If available, you can take folding tables or seat desks for the students to handle and count their samples in the field.



Managing Students in the Field

If you have a large class, have students work in multiple teams. Students in a team can be responsible for different tasks. For example, two students can handle the net, one student can handle the bucket, one student can read the instructions aloud, etc.

The most time-consuming tasks are sorting and identifying the organisms. To save time, have one team of students collect a sample and start to sort and identify the organisms using the *Sorting, Identifying and Counting Freshwater Macroinvertebrate Protocol Lab Guide*. While this team is sorting and identifying, another team can be collecting a second sample. A third team can collect a third sample. If you are collecting in riffle/run habitats, then you only need three samples. For multi-habitat environments, more samples



will be collected. The more teams you have, the more buckets and other equipment you will need.

As the students work, look at the jars of sorted organisms to verify that all the students identify organisms in the same way. If not, gather the students and have them discuss the differences and determine the correct taxa.

After all the organisms are sorted and combined from the teams in separate jars for each taxon, have a committee of students and yourself look at the organisms to make sure that you all agree on identifications. Then, proceed to count organisms in each taxon and report the data on one set of data sheets. Collect voucher specimens of three individuals from each taxon, and return the rest of the organisms to the water.

Measurement Procedures

Do not sample habitats that cannot be reached safely. If your students are doing the multi-habitat sampling method, determine which habitats can be sampled safely and evaluate the percentage of coverage of each accessible habitat. Record in metadata which habitats could not be sampled.

When pouring water with macroinvertebrates through sieves or into other buckets, pour slowly and gently so that the macroinvertebrates do not get injured or die. Handle gently with forceps, fingers or syringes.

Students should only sort and count macroinvertebrates. Small fish, tadpoles, and other organisms should be removed from the samples and returned to the water.

Only count macroinvertebrates that are alive. To find out if bivalves and gastropods are alive, look for soft body tissues or for tightly closed shells (a sign that the animal is there and protecting itself). If you see many shells of dead animals, report it on the comment section and on the web site. Do not count arthropods exoskeletons. If there are many of them and it looks like the animals have just emerged out of the water, or many are dead, report this finding on the comment section and on the Web site.

Organisms may break while you process them. Count all the whole organisms first. Discard

organisms that look partially decomposed. With the remaining fresh pieces, match halves of worms or count only the heads of insects for example. If you are very careful with the sieves remove heavy substrates as you go and squirt water gently, you should find most organisms intact.

For all taxa, use the *Freshwater Macroinvertebrate Identification Data Sheet* to report the number of individuals from zero to 100. In cases where you have too many animals to count in the time that you have, you can report >100 or you can take a sub-sample to count. Sub-sampling is described in the *Protocols* section. If you have enough time, count all individuals in your sample. A more accurate count of the number of individuals in each taxon allows better estimates of biodiversity and other analyses by students and scientists.

In the *Multi-habitat Freshwater Macroinvertebrate Protocol*, students can combine the samples collected from all the habitats and record total counts for each taxon, or students can examine the macroinvertebrates within each habitat type separately. By examining the habitat types separately, students can compare the macroinvertebrate assemblages among the habitat types. You can enter the data on the GLOBE Web site as either total counts for each taxon for all habitats combined, or total counts for each taxon for each habitat type.

Voucher specimens are not required, but may help with teaching the students how to properly identify the macrovertebrates before going into the field. As well, by collecting voucher specimens each time, the specimens can be compared to make sure that identifications are being done correctly each time. Specimens are preserved in a 70% ethanol solution.

Equipment Use and Maintenance

All of the sampling materials are available commercially, but students can also enjoy making them using the instructions provided in the *Instrument Construction* section. You can also buy some parts and make others. For example, one can buy a 0.5 mm-mesh replacement net for a D-net and make the pole. This is less expensive than buying the whole device.

Sieves are very useful to remove debris and clean organisms to concentrate organisms from a large amount of water (in the bucket) to a small amount of water. These organisms can then be transferred to a tray or jar for sorting and identifying. Sieves are available commercially, but you can make your own easily (see *Instrument Construction* section). If you cannot find a small quantity of 0.5 mm-mesh netting for the sieves, you can use a piece of fabric that has a mesh visibly smaller than your sampling net (which is 0.5 mm). The smaller mesh size may cause more clogging, so you will have to pour water slowly and check more often to make sure that water does not overflow the sieves. Clogging will also occur more often if the sample has silt or sand.

The quadrat is not necessary to use and can be made out of materials other than PVC pipe. Instructions for making the quadrat are given in the *Instrument Construction* section. The quadrat makes sure that students collect samples within a 1 x 1 meter area.

After each use, rinse and dry the nets and sieves in the air. Make sure that all debris is removed and no organisms remained trapped. It is very important to check the nets and sieves before each use to make sure that the mesh is intact. Tighten pieces that come loose. Repair or replace any piece of equipment that is broken or out of place.

Do NOT use bleach to clean the nets, buckets, sieves, or anything the macroinvertebrates may contact. The bleach, even in small amounts, may harm or kill the macroinvertebrates.

Helpful Hints

As scientists do, have students keep field notes of your procedures to report what you did and if there were any deviations from your plans. Make a photo journal of your trip, and bring parents or older GLOBE students to mentor. Enjoy learning about the diversity of animals in the world around you!

Having the students work in teams will make sample collection, sorting and identifying quicker. To work in groups, though, requires more equipment such as buckets, spray bottles, trays and magnifying glasses.



Ice cube trays can be used for sorting macroinvertebrates instead of vials.



Students can use sticks to mark boundaries of the 1-meter square area when sampling in muddy substrates. Bring a meter stick to measure the 1-meter distances.



Questions for Further Investigation

Could the surrounding plants affect which macroinvertebrates are found at your Hydrology Site?

Are there any relationships among macroinvertebrate samples and your hydrology measurements?

How could the surrounding soils affect macroinvertebrate habitats in the water?

Are there seasonal variations to the abundance and diversity of macroinvertebrates at your site? If so, suggest reasons why.



At what temperature, dissolved oxygen, and pH ranges are greater percentages of insect taxa found?

Are there types of water bodies that have a greater macroinvertebrate diversity than others?



Rocky Substrates in Running Water Macroinvertebrate Protocol Field Guide

Task

Collect three samples of macroinvertebrates. Where you sample depends on what is available at your site.

Select sampling areas in the following order:

1. 3 different riffles
2. 2 different riffles, 1 run
3. 2 different runs, 1 riffle

If there is no combination of 3 different riffles and runs, then include a pool habitat as long as the pool contains a rocky substrate. If pools and other habitats are present, use the *Multi-habitat Freshwater Macroinvertebrate Protocol*.

What You Need

- | | |
|---|---|
| <input type="checkbox"/> <i>Freshwater Macroinvertebrate Identification Data Sheet</i> | <input type="checkbox"/> Forceps |
| <input type="checkbox"/> <i>Sorting, Identifying and Counting Freshwater Macroinvertebrate Protocol Lab Guide</i> | <input type="checkbox"/> Stop Watch or watch |
| <input type="checkbox"/> Hydrology Site Map | <input type="checkbox"/> Latex gloves |
| <input type="checkbox"/> Equipment and <i>Hydrology Data Sheets</i> for collection of water chemistry measurements (optional) | <input type="checkbox"/> Kick-net |
| <input type="checkbox"/> Square of white fabric (at least 110 cm by 110 cm) | <input type="checkbox"/> Sieve (0.5 mm or smaller) |
| <input type="checkbox"/> Two to six 5-L white buckets | <input type="checkbox"/> 1 x 1 meter quadrat |
| | <input type="checkbox"/> One to four spray bottles (1 to 2-L) |

In the Field

1. Locate the areas where you will collect your three samples on your map and in the water.
2. If collecting water chemistry measurements, do before collecting macroinvertebrates. Be careful not to disturb the areas where you will be collecting macroinvertebrates.
3. Fill a bucket with water from the site.
4. While holding the sieve over a second bucket, pour water through the sieve. Use the sieved water to fill (and refill as needed) the plastic squirt or spray bottles. Keep sieved water in the shade.
5. Rinse sieve downstream of the sampling sites.
6. Begin sampling in the area farthest downstream. Work in a team of 3 or 4. Place the 1 x 1 meter quadrat on the bottom of the stream so that two sides are perpendicular to the water flow.

7. You and a partner hold the Kick-net vertically in the water column, perpendicular to the water flow. Press the Kick-net firmly against the bottom of the streambed lined up with the quadrat and one meter downstream of the quadrat. Water must not flow above or under the net.
8. Start working in the part of the quadrat farthest away from the net. Two other students overturn and scrape the undersides of rocks and wood found in the quadrat. The rocks and wood may be placed outside the quadrat until the sample is collected. Place large crustaceans and mollusks directly in the bucket. If large organisms escape outside the quadrat, mentally note their identity and numbers to record on the *Freshwater Macroinvertebrate Identification Data Sheet* later.
9. After scrapping rocks and wood, use your feet, hands or a stick to disturb the stream bottom within the quadrat for exactly 3 minutes. One student watches the time while one or more students kick.
10. Lift the Kick-net from the water by moving the bottom of the frame forward in a scooping motion so that nothing escapes from the net.
11. Return to shore with net.
12. Place the net over the square of white fabric.
13. Carefully remove large organisms and large debris with your hands or forceps and put them in a tray half filled with the sieved water from the site.
14. Two students lift the net while others squirt water on the net to concentrate all organisms and small debris in one corner of the net.
15. Place the corner of the net with the sample into a bucket. Tip the net and squirt water to move all of the contents into the bucket.
16. Rinse the square of white fabric into the bucket to make sure that you have all the macroinvertebrates in the sample.
17. Place the bucket in the shade until you are ready to sort, identify, and count organisms.
18. Repeat steps 6 -17 for the other two samples.
19. Use the *Sorting, Identifying and Counting Freshwater Macroinvertebrate Protocol Lab Guide* to sort, identify and count the macroinvertebrates you collected.

Multi-habitat Freshwater Macroinvertebrate Protocol

Field Guide

Task

Collect macroinvertebrate samples from one or more of following habitat types: vegetated banks, submersed vegetation, snags, logs, roots, mud, sand, and gravel. The number of samples for each habitat type is proportional to the area that habitat type covers at your hydrology site. Collect a total of 20 samples.

What You Need

- Freshwater Macroinvertebrate Identification Data Sheet
- Hydrology Site Map
- Equipment and Hydrology Data Sheets for collection of water chemistry measurements (optional)
- One to four spray bottles (1 to 2-L)
- Two to six 5-L white buckets
- 1 x 1 meter quadrat (for mud, sand and gravel habitats)
- Sieve (0.5 mm or smaller)
- Latex gloves
- Trowel or shovel
- D-net
- Calculator (optional)

In the Field

1. Locate the areas where you will collect your samples on your map and in the water.
2. Estimate the proportion of each accessible habitat type within your hydrology site.
3. Use the *Freshwater Macroinvertebrate Identification Data Sheet* to calculate the number of samples collected within each habitat type for a total of 20 samples.
4. If collecting water chemistry measurements, do before collecting macroinvertebrates. Be careful not to disturb the areas where you will be collecting macroinvertebrates.
5. Fill a bucket with water from the site
6. While holding the sieve over a second bucket, pour water through the sieve. Use the sieved water to fill (and refill as needed) the spray bottles. Keep sieved water in the shade.
7. Rinse sieve downstream of the sampling sites (or away from sites if water is not flowing).
8. Start macroinvertebrate sampling downstream and move upstream as you collect samples from different habitat types. If the water is not visibly moving, collect samples in the order that will minimize the impact of taking one sample on taking the others.

9. Use the *Field Guides* to collect samples in
 - submersed vegetation,
 - vegetated banks or around snags, logs, and roots,
 - muddy bottom, and
 - gravel and sand.
10. Record the number of samples taken in each habitat on the *Freshwater Macroinvertebrate Identification Data Sheet*. The total should be 20 samples. If the number of samples per habitat is different than what was planned, explain why in the comment section.

Freshwater Macroinvertebrate Sampling Technique

for Submersed Vegetation

Field Guide

In the Field

1. Put the D-net in the water until it almost reaches the bottom in front of the vegetation. Make sure that the net is folded out away from the opening and ready to sample.
2. Push the D-net horizontally into the vegetation bouncing the net into the sediments twice.
3. Vertically bring the D-net up through the vegetation at a constant rate until you reach the surface of the water.
4. Slowly lift the D-net out of the water. As the water flows through, make sure that no organisms escape by climbing out. This is one sample.
5. Use the sieved water in squirt bottle to concentrate all organisms and debris at the bottom of the net.
6. Grab the bottom of the net and overturn the net carefully to release all of its content into a bucket. Use the squirt bottles to make sure that all organisms and debris have been transferred to the bucket.
7. Place the bucket(s) in the shade until you are ready to sort, count and identify organisms.
8. Repeat steps 1-7 until you have collected the number of samples you need for this habitat type.

Freshwater Macroinvertebrate Sampling Technique for

Vegetated Banks or Around Snags, Logs, and Roots

Field Guide

In the Field

1. Hold the D-net in the air so that it unfolds and is ready to sample.
2. In a constant motion, submerge the net in the water, move it into the vegetated bank, or around the snag(s), log(s), or root(s) heading towards the bottom.
3. Bounce the net into the sediments twice.
4. Bring the net up through the water.
5. Slowly lift the D-net out of the water. As the water flows through, make sure that no organisms escape by climbing out. This is one sample.
6. Use the sieved water in squirt bottle to concentrate all organisms and debris at the bottom of the net.
7. Grab the bottom of the net and overturn the net carefully to release all of its content into a bucket. Use the squirt bottles to make sure that all organisms and debris have been transferred to the bucket.
8. Place the bucket(s) in the shade until you are ready to sort, count and identify organisms.
9. Repeat steps 1-8 until you have collected the number of samples you need for this habitat type.

Freshwater Macroinvertebrate Sampling Technique

for Muddy Bottom

Field Guide

In the Field

1. Use a quadrat or estimate a 1 x 1 m square.
2. Place the mouth of the D-net inside one side of the quadrat (downstream if moving water) and lower it 4 cm into the sediments.
3. Move the net over the 1 x 1 m square and then slowly lift the D-net partly out of the water.
4. Move the bottom of the net back and forth in the water to wash out some of the sediments.
5. Lift the net out of the water and as the water flows through, make sure no organisms escape by climbing out. One student may have to hold the net itself underneath since it may be quite heavy. This is one sample.
6. Use the sieved water in squirt bottle to concentrate all organisms and debris at the bottom of the net.
7. Grab the bottom of the net and overturn the net carefully to release all of its content into a bucket. Use the squirt bottles to make sure that all organisms and debris have been transferred to the bucket.
8. Place the bucket(s) in the shade until you are ready to sort, count and identify organisms.
9. Repeat steps 1-8 until you have collected the number of samples you need for this habitat type.

Freshwater Macroinvertebrate Sampling Technique

for Gravel and Sand

Field Guide

In the Field

1. Lay the quadrat on the sand or gravel and place the D-net downstream (if moving water) inside and along one side of the quadrat.
2. One student holds the net while another uses a trowel or shovel to lift the top 4 cm of the substrate and place it into the net. Move the net next to where the student is digging until the whole quadrat is sampled.
3. Slowly lift the D-net partly out of the water. Move the bottom of the net back and forth in the water to wash out the finer sediments.
4. Lift the net out of the water and as the water flows through, make sure no organisms escape by climbing out. One student should hold the net itself underneath to prevent the net from ripping since the sample may be heavy. This is one sample.
5. Use the sieved water in squirt bottle to concentrate all organisms and debris at the bottom of the net.
6. Grab the bottom of the net and overturn the net carefully to release all of its content into a bucket. Use the squirt bottles to make sure that all organisms and debris have been transferred to the bucket.
7. Place the bucket(s) in the shade until you are ready to sort, count and identify organisms.
8. Repeat steps 1-7 until you have collected the number of samples you need for this habitat type.

Sorting, Identifying and Counting Freshwater Macroinvertebrate Protocol

Lab Guide

Task

Sort macroinvertebrates into taxonomic groups.

Count or estimate the number of individuals in each taxon.

Preserve three voucher specimens of macroinvertebrates for each taxon (optional).

What You Need

- Several basting syringes (20 ml with end approximately 5 mm diameter)
- Large plastic forceps
- Small forceps
- Several magnifying glasses or loupes or boxes
- Several eyedroppers (3 ml with end approximately 2 mm diameter)
- Many clear plastic jars (0.5 to 3 L) labeled (as you go) with the name of a taxon
- One to four spray bottles (1 to 2-L)
- At least 2 white trays
- Two sieves (0.5 mm (or smaller), and one between 2 and 5 mm) (optional)
- Two – six buckets
- Many small plastic vials
- Small specimen bottles with labels filled with 70% ethanol with lids that are sealing or covered with paraffin
- Permanent markers
- Pencils
- Latex gloves
- Macroinvertebrates identification keys
- Freshwater Macroinvertebrate Identification Data Sheet*

In the Lab

1. Fill out the top portion of the *Freshwater Macroinvertebrates Identification Data Sheet*.
2. Put on gloves.
3. Use a basting syringe or forceps to pick out large organisms from your buckets. Put these organisms in a tray.

Note: You have the option to combine all samples together to sort, identify or keep the samples separated by habitat type.

4. If you have rocks in your sample, take them out of the bucket and use the spray bottle to rinse the rocks over the sample bucket before discarding the rocks.
5. If the water in your buckets is clear, free of debris, and rather a small amount, pour sample on tray to sort. Go to step 13.
6. If you have a lot of water, sediments or debris, pour the samples through the sieves. Place the sieve with the finer mesh size below the other sieve. Hold the sieves inside the top of a clean bucket.
7. Gently and slowly pour the water from the bucket containing the organisms into the sieves. If a sieve is clogged, gently tap the bottom of the clogged sieve to allow water to escape.
8. Every so often, transfer and rinse the contents of the sieves into trays using a squirt bottle. Other students can start sorting organisms in the trays.
9. Rinse twigs over the sieves.
10. Put twigs in a tray with water. Examine twigs for macroinvertebrates.
11. Rinse the bucket several times with your spray bottles and pour the water down the sieves.
12. Invert each sieve over a tray and squirt water on the back of the sieve to remove contents.
13. Work in teams. Use identification keys to identify individuals to the most detailed level possible (Phylum, Class, or Order required and Family, Genus, or Species if possible). Keep in mind that appendages like legs and antennae may be missing because they may have broken in the net or the sieves.
14. Use the vials to sort organisms into different taxa. If you do not know the taxon of an organism, place in a separate vial to examine later under a dissecting scope or with the help of an expert.
15. If organisms are large and clinging to debris, use forceps to gently pull them free. If they are floating or swimming, use a basting syringe or an eyedropper to catch them.
16. If different teams are sorting and identifying organisms, combine the vials of the same taxon. Do this for all the taxa.
17. To count the number of individuals in each taxon, isolate organisms a few at a time using forceps, an eye dropper, or a basting syringe and transfer them into another jar as you go. Keep a tally on paper.
18. Count macroinvertebrates in each taxon up to 100 individuals. If you have more than 100 individuals in a taxon, you can do three things:
 1. report >100,
 2. continue counting,
 3. use the *Freshwater Macroinvertebrate Sub-sampling Field Guide* to estimate the total number of organisms of this taxon.

Note: If possible, count all individuals since it is more accurate than sub-sampling, but sub-sampling is more informative than reporting >100.

19. As you count, look closely at the individuals to make sure that there are no mistakes in identification. If you find an individual that belongs to a different taxon, notify the student who is doing the count for that taxon and transfer the organism.
20. Report the total number of organisms found for each taxon on the *Macroinvertebrates Identification Data Sheet*. Include organisms that were counted at the site but could not be collected because they escaped.
21. Optional: For each taxon you identify, preserve three individuals as voucher specimens for future reference. Place the three organisms in a specimen bottle containing 70% ethanol solution.
22. Label the bottle with:

Name of Sample Site
Date
Phylum, Class, Order (family, genus and species, if known)
70% ethanol

23. Return remaining live macroinvertebrates to the water.

Freshwater Macroinvertebrate Sub-sampling Field Guide

Task

To collect 20% of original sample for each taxon

What You Need

- Sub-sampling grid with level
- Pieces of paper with grid labels
- Hat or bag
- 500-ml beaker

In the Field

1. Record grid volume on *Data Sheet*.
2. Record total number of squares on grid on *Data Sheet*.
3. Multiply total number of squares by 0.2 to calculate the number of grids you need to sample.
4. Write grid numbers on pieces of paper and put in bag or hat. Pick enough for the 20%. Macroinvertebrates will be taken from those squares on the grid.
5. Place all the organisms from the taxon to sub-sample in beaker. The volume of water plus the organisms must equal the grid.
6. Adjust the sub-sampling grid so that it is perfectly leveled.
7. Mix the contents of the jar and pour onto the grid, spreading the sample evenly over the grid. If the grid is leveled and the volume is right, the organisms will be contained in their own 'pools' made from the raised lines on the grid.
8. If the grid is very stable and the number of organisms per square is small, the organisms in the randomly selected squares can be counted on the grid. Otherwise, use a basting syringe to remove the organisms from the randomly selected squares and transfer them to a jar and then count them.
9. Calculate the total number of individuals for this taxon. If you counted 20% of your squares, multiply the number of organisms you counted by 5 to estimate the total number of individuals for this taxon.
10. Report the percent of squares sub-sampled and the estimated total number of individuals that you sampled for this taxon on the *Macroinvertebrate Identification Data Sheet*.

Frequently Asked Questions

1. Do I have to use a 0.5 mm-mesh net?

Yes. If too large of a mesh is used, small macroinvertebrates will be lost from your sample. Everyone needs to use the same mesh size for the nets so that data are comparable among sites.

2. Why do we need to sample from as many habitats as possible?

To get as many different organisms as are present. The variability in organisms found can be greater between habitats than between years. By sampling many habitats, we get a better idea of biodiversity and health of the ecosystem.

3. What if we want to identify macroinvertebrates at the family and genus species levels?

You are encouraged to do so using local books, keys, field guides, and experts to help you. You can write the information on a *Macroinvertebrate Identification Data Sheet*, and additional sheets if you need more space. You can report these data on the data entry page on the GLOBE Web site.

4. Why aren't we counting protists and other groups such as Gastrotrichs?

These organisms also play a very important role in aquatic ecosystems. However, most of the species are very small. Only a few are slightly above 0.5 mm, they are not considered macroinvertebrates.

5. Why are there different levels of identification for different groups of animals?

Classification is very helpful for us to organize objects, thoughts and the world. However, not all organisms fit neatly into groups. You are identifying many organisms to the Order level. For some groups, that level of identification would require extensive knowledge of obscure external or internal features, or using high power microscopy to look at the shape of features such as tiny hairs. The taxonomic level of identification that we suggest is more easily accessible with low magnifying powers. If you enjoy taxonomy and want to identify organisms to the family, genus, or species levels, please do so and report your data on the web.

6. What should we do if the quadrat sinks in the mud and cannot be seen?



You can attach floaters to the quadrat or just estimate the 1 x 1 m area.

Suggested Readings and Web sites:

A Guide to Common Freshwater Invertebrates of North America. J. Reese Voshell, Jr. The McDonald & Woodward Publishing Company. Blacksburg, Virginia. 2002

An Introduction to the Aquatic Insects of North America. R. M. Merritt and K. W. Cummins (eds). Kendall/Hunt Publishing Company. Dubuque, Iowa 1996.

Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives. W. P. McCafferty. Jones and Bartlett Publishers. Sudbury, Massachusetts. 1998.

Fresh-Water Invertebrates of the United States: Protozoa to Mollusca. R. W. Pennak. John Wiley & Sons, Inc. New York. 1989

Save Our Stream (SOS). http://www.sosva.com/download_the_field_sheets_for_th.htm

ECOSTRIMED protocol: Bioassessment to define river's ecological status.
<http://geographyfieldwork.com/ECOSTRIMED%20Protocol%20Procedure.htm>

Two good macroinvertebrate keys for North America can be obtained from the University of Wisconsin's Extension/Wisconsin Department of Natural Resources, and may be reproduce for education non-profit purposes. One is the "Key to Macroinvertebrate Life in the River" and the other is "Key to Life in the Pond".

<http://clean-water.uwex.edu/wav/otherwav/>

<http://clean-water.uwex.edu/wav/otherwav/riverkey.pdf>

<http://clean-water.uwex.edu/wav/otherwav/pondkey.pdf> (contains a few vertebrates)



Freshwater Macroinvertebrates Protocol – Looking at the Data



Are the data reasonable?

When you look at the types of taxa you recorded, make sure that these taxa are found in your region. For example if you live in higher latitudes where water temperatures are relatively cold and recorded a taxon that only lives in warm waters, you might question whether you identified that taxon correctly. Check your voucher specimen to verify your identification.



Check to see if the macroinvertebrate taxa you collected are found in the types of substrate you sampled. If you sampled in a lake with a muddy bottom and found mainly stoneflies that typically live on rocky substrates, you would want to check your voucher specimen to make sure.



Also, if you find a large abundance of a rare taxon, again check your voucher specimen. If you are positive that you identified the taxon correctly, you might want to contact a local expert from a government agency or university because that may be very valuable information.



What do people look for in these data?

Scientists look at macroinvertebrate data for the distinct types of organisms present and the variety of organisms (biodiversity). There are many different types of macroinvertebrates! Certain types of macroinvertebrates are more commonly found in one type of habitat than another. For instance *Oligochaeta* (segmented worms) may be much more abundant in a muddy pond environment than in a gravelly stream whereas the abundance of *Plecoptera* (stoneflies) may be much less.



Scientists can compare water chemistry data and the macroinvertebrate data to see what types of patterns can be found and relate these to habitat conditions such as the water properties measured in GLOBE. Scientists compare different sites to see patterns among these sites, and look at the same site to see what changes happen through the seasons and over the years.



Biodiversity Estimates

To estimate biodiversity, scientists look at both the number of organisms and the number of different taxa. The number of different taxa is called *richness*. The number of organisms is called the abundance. Scientists also look at the relative abundances of the taxa; this is called *evenness*. High richness and high evenness are generally considered by scientists to indicate high biodiversity. The example below illustrates why both the number of different taxa and the number of individuals for each taxon are needed to estimate biodiversity. Students collected data from three streams:

Stream 1	Stream 2	Stream 3
50 worms	25 worms	45 worms
50 leeches	25 leeches	50 leeches
100 total	25 dragonfly larvae	2 dragonfly larvae
	15 caddisfly larvae	2 caddisfly larvae
	10 beetle larvae	1 beetle larvae
	100 total	100 total

All three streams have a total of 100 organisms, but their diversities are different. The biodiversities are greater in Stream 2 and Stream 3 because there are five kinds of organisms (taxa), while there are only two taxa in Stream 1. However, Stream 3 has many worms and leeches and only a few dragonfly, caddisfly and beetle larvae. Stream 2 has a more even distribution of amounts found for each taxon. In this example, Stream 2 has the highest biodiversity since it has a higher evenness than Stream 3.

The only way we can know the exact biodiversity of a stream, lake or pond is to count all the organisms. Generally, this is impossible! So scientists take samples, identify and count the different taxa within the sample, as you have done, and use mathematical equations to calculate the biodiversity in the sample. The biodiversity value of the sample is used as an estimate of the biodiversity in the water body overall.

There are many different mathematical formulas used to estimate biodiversity from a sample of organisms. The Shannon-Weiner Index (shown below) is a commonly used formula. It combines evenness and richness and reaches its maximum value when all species are evenly distributed. Values of the Shannon-Weiner Index, as well as other biodiversity indices, can be compared among different water bodies to evaluate which has the greatest diversity of organisms. In general, greater diversity indicates a more robust ecosystem when you are comparing similar sites, for example, a comparison of two small streams in the same watershed.

Shannon-Weiner Biodiversity Index:

$$BI = -\sum_{i=1}^k x_i \log_2 x_i$$

where:

k = number of taxa you found, and

x_i = the percentage of taxa i

\log_2 = logarithm in base 2

So, let's compare the biodiversities of the three streams.

Stream 1

Taxa	Amount	x = Percentage (Amount/total)	$\log_2 x$	$x \log_2 x$
Worms	50	50/100 = 0.5	-1	-0.5
Leeches	50	50/100 = 0.5	-1	-0.5

$$\begin{aligned}
 DI &= -\sum_{i=1}^k x_i \log_2 x_i \\
 &= -(-0.5 + -0.5) = 1
 \end{aligned}$$

Stream 2

Taxa	Amount	x = Percentage (Amount/total)	$\log_2 x$	$x \log_2 x$
Worms	25	0.25	-2	-0.5
Leeches	25	0.25	-2	-0.5
Dragonfly larvae	25	0.25	-2	-0.5
Caddisfly larvae	15	0.15	-2.74	-0.41
Beetle larvae	10	0.1	-3.32	-0.33



$$BI = -\sum_{i=1}^k x_i \log_2 x_i$$

$$= -(-0.5 + -0.5 + -0.5 + -0.41 + -0.33) = 2.24$$



Stream 3

Taxa	Amount	x = Percentage (Amount/total)	log ₂ x	xlog ₂ x
Worms	45	0.45	-1.15	-0.52
Leeches	50	0.5	-1.00	-0.50
Dragonfly larvae	2	0.02	-5.64	-0.11
Caddisfly larvae	2	0.02	-5.64	-0.11
Beetle larvae	1	0.01	-6.64	-0.07



$$BI = -\sum_{i=1}^k x_i \log_2 x_i$$

$$= -(-0.52 + -0.53 + -0.11 + -0.11 + -0.07) = 1.31$$



So, the biodiversity index for Stream 2 is the highest, 2.24, followed by Stream 3 with a value of 1.31 and then Stream 1 with a value of 1, which confirms what we initially thought.

Using macroinvertebrates to indicate how stressed the water body is:



Scientists studying ecological systems often are interested in what happens to organisms when exposed to different types of stresses. Stresses can be caused by natural events or human activities. An example of a natural stress in an aquatic system is a major storm that causes extensive flooding. Many macroinvertebrates may die or be washed away. The flooding may cause mud to be deposited in areas that were mainly gravel. This will cause a change in the types of macroinvertebrates that can live there.

Macroinvertebrate metrics are often used to examine the types of stresses affecting water bodies. Metrics are defined as easily calculable characteristics of the macroinvertebrate data that respond to stress in some predictable way. The metrics are designed to evaluate responses in the macroinvertebrate community to things affecting their habitats. By combining data on abundance of different taxa with characteristics such as ecological roles of these taxa in the ecosystem and tolerance to stress, one can learn much about the aquatic ecosystem.



To describe the water body and see the extent to which the macroinvertebrates may be living in a habitat that has undergone some sort of stress, scientists analyze macroinvertebrate data to obtain metrics in different categories. These include:

- richness measures,
- composition measures,
- stress tolerance or intolerance measures,
- feeding measures,
- habit measures, and
- life-cycle measures.

Below are explanations of some these used metrics. There are many more that can be found in books and journals.

Richness Measures

A commonly used richness measure for rivers or streams is the number of *Ephemeroptera* (mayflies), *Trichoptera* (caddisflies) or *Plecoptera* (stoneflies) found at a site. For wetlands, scientists often look at the number of *Hemiptera* (water bugs), *Coleoptera* (water beetles), and *Odonata* (damselflies and dragonflies). The abundance of these taxa is expected to decrease with increased stress.

Composition Measures

In rivers and streams, the percentage of macroinvertebrates present in the samples that are *Ephemeroptera* + *Trichoptera* + *Plecoptera* (%EPT) is used. In wetlands, scientists look at the percentage of *Ephemeroptera*, *Trichoptera*, *Sphaeriidae* (fingernail clams), and *Odonata* (%ETSD). Lower percentages may indicate a stressed environment. It would be interesting to see what happens to these percentages during and after a dry year.

Scientists also measure the % *Diptera* (mosquitoes, midges, flies) or % *Chironomidae* (midges). Studies have shown that both tend to increase with increased stress, for example, increased deposits of mud or decreased dissolved oxygen content.

The % Dominant Taxon (%DT) is the number of organisms in the most abundant taxon relative to the total number of organisms in the sample. Higher values may indicate a more stressed environment where only one taxon can flourish.

Tolerance/intolerance Measures

One can also compare the percentage of taxa that are considered tolerant to perturbation with the percentage of taxa that are intolerant. A high ratio of %tolerant/%intolerant indicates a more stressed environment.

Feeding Measures

We can learn a lot about the ecosystem by looking at how the organisms eat. In fast moving waters, the percentages of collectors, filterers, omnivores and scavengers often increase with stress such as a drought that results in slower-moving waters and decreased dissolved oxygen levels, but can represent quite a diverse community in wetlands. A shift from herbivores and filter feeders to scavengers such as worms may indicate that sedimentation is occurring.

Habit Measures

A habit measure often used is the percentage of clingers. These taxa have retreats or attachments that allow them to stay in place in flowing water. Their numbers decrease with stress.

Life-cycle Measures

Life-cycle measures refer to organisms that develop rapidly and live a short time or ones that are long-lived. Many short-lived taxa increase when stress increases while long-lived taxa decrease. Some short-lived taxa are highly seasonal.

As you can see, your data allow you and scientists to explore and learn a great deal about specific aquatic environments!



An Example of Student Research Investigation

Two schools in the same watershed decided to do a collaborative project. They wanted to learn about the types of macroinvertebrates in nearby streams and how the types and abundance of macroinvertebrates varied between two sites in the same watershed. They predicted that the macroinvertebrate data would be similar between the sites. The students were also curious to see if differences would be found between the autumn and spring samples at the same site. They predicted that the types of macroinvertebrate taxa would be different between the autumn and spring samples, but that the biodiversity values would be similar.

Sites were chosen within the watershed that could be safely reached by students at each school. The students coordinated their data collection so that both schools collected macroinvertebrates on the

same day and at about the same time of day. Samples were collected in both the autumn and spring, and students shared their data. Each school analyzed the data separately and compared their results. Here is what students did at School 1.

At School 1, students collected 270 organisms from 13 different taxa in the autumn and 225 organisms from 10 different taxa in the spring (Table 1). In the autumn, the sample contained many *Tricoptera*, *Chironomidae* and *Oligochaeta*, and many other taxa that had only 1 or 2 individuals in each taxon. The spring sample, however, contained a large quantity of *Chironomidae* and many *Plecoptera* (stoneflies), *Ephemeroptera* and *Tricoptera*. The autumn sample contained more organisms overall.



Table HY-MA-1: Macroinvertebrate Abundance Data, Total Number of Taxa and Total Number of Organisms Students Collected in the Autumn and Spring for the Two Schools.

	School 1		School 2	
	Autumn	Spring	Autumn	Spring
<i>Plecoptera</i> (stoneflies)	4	37		
<i>Odonata</i> (dragonflies, damselflies)	0	1		
<i>Ephemeroptera</i> (mayflies)	2	36		
<i>Psephenidae</i> (water pennies)	2	0		
<i>Tricoptera</i> (caddis flies)	51	31		
<i>Chironomidae</i> (midges)	126	96	29	100
<i>Oligochaeta</i> (worms)	80	20	80	74
<i>Turbellaria</i> (planarian)	1	1		
<i>Hirudinea</i> (leeches)	1	0		
<i>Gastropoda</i> (snails)	1	1	200	356
<i>Pelecypoda</i> (clams)	1	1		
<i>Nematomorpha</i> (horsehair worms)	1	0		
<i>Amphipod</i> (scuds)	0	1		
Total # organisms	270	225	309	530
# taxa	13	10	3	3



When the students at School 1 looked at the data from School 2, they quickly noticed large differences with their data. Although the total number of organisms collected in the autumn and spring are much larger at School 2, the sample had only 3 taxa. Furthermore, the same taxa, Oligochaeta, Chironomidae and Gastropoda, are found in both the autumn and spring samples. So, they decided to compare the biodiversities.

Using the Shannon-Weiner biodiversity equation, the students calculated an estimate of biodiversity of 1.83 in the autumn and a biodiversity of 2.25

in the spring for School 1. See Table HY-MA-2. They put the data in a spreadsheet and performed the calculations. The values of -1.83 and -2.25 are the totals within those columns. Multiplying these values by -1 gives the biodiversity values.

They were very surprised to have collected a few more individuals from more taxa in the autumn compared to what they sampled in the spring, and yet obtain a higher estimate of biodiversity in the spring. They rechecked their calculations to make sure that they made no mistakes.

Table HY-MA-2: Calculations of Biodiversity for the Data Collected at School 1

School 1 Taxa	Autumn				Spring			
	Amount	Percentage	$\text{Log}_2(\%)$	$\% \log_2(\%)$	Amount	Percentage	$\text{Log}_2(\%)$	$\% \log_2(\%)$
Plecoptera (stoneflies)	4	0.01	-6.08	-0.09	37	0.16	-2.60	-0.42
Odonata (dragonflies, damselflies)					1	0.004	-7.81	-0.03
Ephemeroptera (mayflies)	2	0.01	-7.08	-0.05	36	0.16	-2.64	-0.42
Psephenidae (water pennies)	2	0.01	-7.08	-0.05				
Trichoptera (caddis flies)	51	0.19	-2.40	-0.45	31	0.14	-2.86	-0.39
Chironomidae (midges)	126	0.47	-1.10	-0.51	96	0.43	-1.23	-0.52
Oligochaeta (worms)	80	0.30	-1.75	-0.52	20	0.09	-3.49	-0.31
Turbellaria (planarian)	1	0.004	-8.08	-0.03	1	0.004	-7.81	-0.03
Hirudinea (leeches)	1	0.004	-8.08	-0.03				
Gastropoda (snails)	1	0.004	-8.08	-0.03	1	0.004	-7.81	-0.03
Bivalve (clams)	1	0.004	-8.08	-0.03	1	0.004	-7.81	-0.03
Nematomorpha (horsehair worms)	1	0.004	-8.08	-0.03				
Amphipod (scuds)					1	0.004	-7.81	-0.03
Total				-1.83				-2.25



The students looked at the data from School 2 to see if there is a similar pattern. They were surprised to see more individuals collected in spring than autumn (the opposite trend of what they found), and yet only 3 different taxa were found at both times (Table HY-MA-3). The biodiversity values for School 2 do not change

significantly between spring and autumn (1.23 and 1.24) and the biodiversity value of 1.24 is much lower than either 1.83 or 2.01, the biodiversities calculated for School 1. These results made them curious to find out why there were such large differences between two sites in the same watershed.



Table HY-MA-3: Calculations of Biodiversity for the Data Collected at School 2

School 2 Taxa	Autumn				Spring			
	Amount	Percentage	Log ₂ (%)	%log ₂ (%)	Amount	Percentage	Log ₂ (%)	%log ₂ (%)
Chronomidae (midges)	29	0.09	-3.41	-0.32	100	0.19	-2.41	-0.45
Oligochaeta (worms)	80	0.26	-1.95	-0.50	74	0.14	-2.84	-0.40
Bivalve (clams)	200	0.65	-0.63	-0.41	356	0.67	-0.57	-0.39
Total				-1.23				-1.24



To see what factors might account for the differences between the sites and seasons, the students looked at the water chemistry measurements taken at the times of macroinvertebrate sampling. Table HY-MA-4 shows the pH, temperature and dissolved oxygen data.

Table HY-MA-4: pH, DO, and Temperature Data Collected When the Macroinvertebrate Samples Were Taken

	School 1		School 2	
	Autumn	Spring	Autumn	Spring
pH	6.8	7.1	8.7	9.6
Temperature	11° C	14° C	10° C	16° C
Dissolved Oxygen	8.5 ppm	8 ppm	7 ppm	5.7 ppm



The pH values at School 2 were higher than at School 1. The pH values at School 1 were near the neutral value of 7 whereas the values at School 2 were basic. The autumn and spring temperature values were similar at both sites. However, one student observed that the temperature difference between the autumn and spring was greater at school 2. The temperature range at school 1 was 3° C and at School 2, it was 6° C. Another student wondered if the temperature difference was because the samples were collected on different days or at different times of the day, but then he

remembered that the two schools were careful to sample at the same time. For the dissolved oxygen, the students noticed that the DO content was lower at school 2 for both autumn and spring.

To help with the interpretation of the chemical data, they looked at the ranges of pH, temperature, and dissolved oxygen necessary for selected macroinvertebrates to live (see Tables HY-MA-5, 6 and 7). They also decided to look at two metrics, %Ephemeroptera, Plecoptera and Tricoptera (EPT) and % dominant taxa (DT).



Table HY-MA-5: Required pH ranges* for Selected Macroinvertebrates

TAXA	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mayfly				XXXXX										
Stonefly				XXXXX										
Caddisfly				XXXXX										
Snails				XXXXXXXXXX										
Clams				XXXXXXXXXX										
Mussels				XXXXXXXXXX										

* pH ranges 1-6 and 10-14 are unsuitable for most macroinvertebrates

Table HY-MA-6: Required Temperature Ranges for Selected Macroinvertebrates

TAXA	Cold Range < 12.8° C	Middle Range 12.8 - 20°C	Warm Range > 20° C
Caddisfly	x	x	x
Stonefly	x	x	
Mayfly	x	x	
Water pennies	x		
Water beetles		x	
Water striders		x	
Dragonfly		x	x

Table HY-MA-7: Required Dissolved Oxygen Ranges for Selected Macroinvertebrates

TAXA	High Range 8 - 10 ppm	Medium Range 4 - 8 ppm	Low Range 0 - 4 ppm
Stonefly	X		
Water penny	X		
Caddisfly	X	X	
Some mayflies	X	X	
Dragonfly		X	
True bugs		X	
Damselfly		X	
Mosquito			X
Midge			X
Tubifex worm			X
Pouch/lung snails			X
Rat-tailed maggot			X



They compared the pH values for the macroinvertebrates shown in Table HY-MA-4 with the data collected by the two schools. The pH is higher than the pH required for mayflies, caddisflies and stoneflies in the stream that School 2 sampled. In addition they noticed that the pH for the stream that School 1 sampled is on the low end needed for clams to live and they wondered if that could be why there are few clams there. In contrast, the other stream has lots of clams and a high pH.

When comparing the temperature data with the required ranges for certain macroinvertebrates, the students couldn't find many reasons to help explain why there is so much difference in the macroinvertebrate assemblages. Perhaps the cool temperatures in streams explained why there was only 1 dragonfly found by the students at School 1 in the spring.

The students then examined the dissolved oxygen content. They noticed that the lower DO values found at School 2 could explain why no stoneflies and water pennies were found. These two taxa require DO concentrations of 8 ppm or greater and the DO values in the stream were 7 ppm and 5.7 ppm.

Lastly, the students looked at two metrics, % dominant taxon (%DT) and % Ephemeroptera + Plecoptera + Tricoptera (%EPT). Table 7 shows the results of their calculations. The stream that School 2 sampled had 0% EPT and higher %DT of 65% and 67%. For the sample collected during spring, School 1 had a value of 47% DT and School 2 had a value of 43%.

Table HY-MA-8: Calculations for % DT and % EPT.

	School 1		School 2	
	Autumn	Spring	Autumn	Spring
Dominant taxon	Chironomidae	Chironomidae	Gastropoda	Gastropoda
# dominant taxon	126	96	200	356
Total Number	270	225	309	530
% DT	$(126/270) \times 100$ = 47%	$(96/225) \times 100$ = 43%	$(200/309) \times 100$ = 65%	$(356/530) \times 100$ = 67%
E + P + T	56	74	0	0
% EPT	$(56/270) \times 100$ = 21%	$(74/225) \times 100$ = 32%	0	0

Based on what a local expert told them, low values of %EPT and high values of %DT indicate habitats undergoing some sort of stress, so they wondered if the stream that School 2 sampled is being stressed. This is also supported by the low diversity found there. From the water chemistry data, they thought that the high pH, in particular, was the main reason that only a few were found there. They were curious why the pH values were so basic and if the large difference in pH values between the streams was due to natural causes or human activities. They were eager to question the students at School 2.

They decided to examine the water chemistry data collected throughout the year to examine any patterns or trends. As well, they were curious to see what, if any, pattern would emerge with samples collected next autumn and spring.

Optional Salinity Titration Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Purpose

To measure the salinity of the water using a salinity titration kit

Overview

Students will use a salinity titration kit to measure the salinity of the water at a hydrology site.

Student Outcomes

Students will be able to measure salinity using a chemical kit, hypothesize about reasons for changes in salinity and provide parameters for interpretation of salinity data.

Science Concepts

Earth and Space Science

- Water is a solvent.
- Tides are caused by gravity.

Physical Science

- Water has characteristic properties, such as density and solubility.

Life Science

- Organisms can survive only in environments where their needs are met.

Scientific Inquiry Abilities

- Use a chemical kit to measure salinity.
- Identify answerable questions.
- Design and conduct scientific investigations.
- Use appropriate mathematics to analyze data.
- Develop descriptions and explanations using evidence.
- Recognize and analyze alternative explanations.
- Communicate procedures and explanations.

Time

- 10 minutes
- Quality control – 10 minutes

Level

All

Frequency

- Weekly
- Quality control check every 6 months

Materials and Tools

- Salinity Titration Test Kit
- Hydrology Investigation Data Sheet
- Quality Control Procedure Data Sheet
- Latex gloves
- For quality control procedure
 - Salt (NaCl)
 - Distilled water
 - Balance
 - 500-mL clear graduated cylinder

Preparation

- Suggested Learning Activities:
 - Practicing Your Protocols: Salinity*
 - Water Detectives*

Prerequisites

- Instruction on reading a tide table



Optional Salinity Titration Protocol – Introduction

Although many different ions in ocean water contribute to salinity, six ions account for over 99% of the dissolved material. In the ocean, these six ions are very well mixed and are found in nearly constant proportions: chloride (Cl⁻), 55.0%; sodium (Na⁺), 30.6%; sulfate (SO₄⁻²), 7.7%; magnesium (Mg⁺²), 3.7%; calcium (Ca⁺²), 1.2%; and potassium (K⁺), 1.2%.

Because these ions are in nearly constant proportions, we can measure the concentration of one major constituent and then estimate the total salinity. Since chloride is the most abundant ion, it is the easiest to measure accurately. The chloride concentration, or *chlorinity*, is expressed in grams of chloride ion per kilogram of seawater. Salinity can be determined from chlorinity by the following formula:

$$\text{Salinity (ppt)} = \text{Chlorinity (ppt)} \times 1.80655$$

Salinity Titration Procedure

Chlorinity is measured by titration in a fairly simple procedure. First an indicator, potassium chromate, is added to a carefully measured volume of sample. This reagent produces a yellow color. Then, a silver nitrate solution of a standard concentration is added as the titrant. The silver reacts with chloride in the sample to form a white precipitate, silver chloride. When all the chloride has been precipitated, the next portion of silver nitrate added forms red-colored silver chromate, producing the pinkish-orange endpoint.

Chloride concentration is calculated from the size of the sample and the concentration and amount of the silver nitrate used. Some test kits incorporate the conversion formula into their design so that salinity may be read directly. These kits will have “direct-read titrators”. Because of the high levels of chloride in most samples, often the sample is diluted with distilled /deionized water to make the titration easier.

Some types of test kits (different indicators, different titrating solutions) may produce different color changes, but the principle is the same.



Teacher Support

Please look at the salinity protocol for the hydrometer method for discussions on salinity and tides.

Notes on Salinity Titration Kits

- Use a salinity titration test kit that meets the Globe Instruments Specifications in the Toolkit. The kits are based on the technique of adding a color indicator to the sample and then adding an acid titrant one drop at a time until color change is observed.
- As always when using chemicals and sample water, use gloves and goggles.
- You will need to read and follow the instructions in the salinity titration kit. The chemical wastes from the salinity titration method are hazardous and need to be disposed of properly. Consult your school authorities for the required procedures you need to follow.

Helpful Hints

Which instrument should you use?

Hydrometer

Advantages

- Easy and quick to use
- No chromium by-products

Disadvantages

- Breakable

Salinity titration

Advantages

- Less math involved
 - Practice in chemistry
- Disadvantages*
- Chromium by-products
 - Takes more time to take measurement

Frequently Asked Questions



1. How come the standard for the salinity titration methods measures 38.6 ppt while the standard for the hydrometer method measures 35 ppt? The standards are made exactly the same way.

The hydrometer measurement is based the actual density of the ocean water. In the titration measurement, you are only measuring chlorine. In seawater, there in a constant ratio between chlorine and other anions, which is taken into account in the values you get when you measure the salinity of ocean water. These other anions are not present in the standard. To calculate the seawater salinity from 17.5 g NaCl in 500 mL (35 ppt NaCl), you need to take into account the molecular composition of NaCl. The ratio of the molecular weight of Cl to NaCl is 0.61. So, $35 \text{ ppt} \times 0.61 = 21.35 \text{ ppt}$ chlorinity of the sample. The kits have been designed to use the constant ratio of chlorine and other anions to convert the chlorinity value to a salinity value. To do this the ppt chlorinity value (here it is 21.35) is multiplied by a conversion constant of 1.80655. $21.35 \text{ ppt} \times 1.80655 = 38.6 \text{ ppt}$.

Quality Control Procedure for Salinity Optional Titration Protocol

Lab Guide

Task

Check your chemical titration skills.

What You Need

- Salinity Titration Test Kit (See *Toolkit*)
- Distilled water
- Quality Control Procedure Data Sheet*
- Masking tape
- Latex gloves
- 500-mL clear plastic graduated cylinder
- 1-liter plastic bottle
- Balance
- Table salt

In the Lab

Mix the 38.6 ppt standard

1. Measure 17.5 g of table salt (NaCl) with the balance.
2. Pour the salt into the 500-mL cylinder.
3. Fill the cylinder to the 500-mL line with distilled water.
4. Gently mix the salt and water until all of the salt is dissolved. This is your 38.6 ppt standard.
Note: This standard may be kept up to one year in a tightly closed bottle.

Check your Test Kit and Technique

1. Follow the directions in your Salinity Titration Test Kit, using the 38.6 ppt standard instead of sample water.
2. Record the value of the standards after testing on the *Quality Control Procedure Data Sheet*.
3. If salinity standards are off by more than 0.4 ppt, prepare new standards and repeat the measurement.

Salinity Protocol (Optional Titration)

Field Guide

Task

Measure the salinity of your water sample

What You Need

- Tide Table for your area
- Latex gloves
- Hydrology Investigation Data Sheet*
- Pen or pencil
- Salinity Titration Test Kit

In the Field

1. Fill out the top portion of your *Hydrology Investigation Data Sheet*.
2. In the Salinity section of the *Data Sheet*, record the times of the high tide and low tide that occur before and after your salinity measurement is taken. Also record the place where the times from your Tide Table occur.
3. Put on gloves.
4. Follow the manufacturer's instructions on the kit. To titrate more saline water than 20 parts per thousand (ppt), you may need to refill the titrator with acid. Keep a record of the total amount of acid used (20 ppt + amount used in refilled titrator).
5. Record the salinity in ppt on the *Hydrology Investigation Data Work Sheet*.
6. Have two other students repeat Steps 3-6, recording their salinity measurements as Observers 2 and 3.
7. Calculate the average of the three measurements.
8. Each of the three measurements should be within 1 ppt of the average. If one or more of the observations is not within 1 ppt, do the measurement again and calculate a new average. If the measurements are still not within 1 ppt of the new average, talk to your teacher about possible problems.
9. Put all liquids in waste bottles and give to your teacher for proper disposal.



Water Walk*

Students become acquainted with their Hydrology Study Site.

Model a Catchment Basin

Students will make a 3-dimensional model of a catchment basin to understand how water moves through the basin and explore how water is affected when there are changes in the basin.

Practicing Your Protocols*

In the classroom, students practice using the instruments or kits for protocols, exploring the range of measurements and sources of variation and error.

Water Detectives*

Students will investigate how they use their senses for observation and why we use instruments to collect data.

pH Game

Students will create mixtures of water samples, soil samples, plants and other natural materials to better understand the importance of pH levels.

Modeling Your Water Balance

Students will model the changes in soil water storage over a year.

* See the full e-guide version of the *Teacher's Guide* available on the GLOBE Web site and CD-ROM.

Water Walk



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Purpose

To become familiar with the hydrology of your locale

Overview

Students will study and visit the Hydrology Study Site, conduct a visual survey to discover information about local land cover, water quality, and document their findings. They will use this initial investigation to raise questions about local land cover and/or water chemistry issues that may require further investigation.

Student Outcomes

Students will learn different methods for finding out about a study site, such as through library research, field visits, and interviews.

Science Concepts

Earth and Space Science

Soils have properties of color, texture and composition; they support the growth of many kinds of plants.

Landforms are the result of destructive and constructive forces.

Soils consist of weathered rocks and decomposed organic matter.

Water circulates through the biosphere, lithosphere, atmosphere and hydrosphere (water cycle).

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Organisms change the environment in which they live.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Identify answerable questions.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

Field trip time plus 2-3 class periods

Level

All

Materials and Tools

Drawing materials for making sketches of the site

Compass

Measuring tape

Other suggested materials: camera or video recorder, plant and animal guides, binoculars

Preparation

Begin to collect materials pertaining to your Hydrology Site, such as:

Topographic and other maps

Satellite imagery of your study site

Newspaper articles, etc. about local water issues

Local animal and plant guides

Invite local experts on water issues to visit your classroom (optional).

Prerequisites

None



Background

Your body of water is part of a catchment basin. A watershed delineates the area drained by a river and its tributaries or other body of water. The area within a watershed is called a catchment basin.



The topography of the area determines the shape of the watershed and catchment basin. The surrounding land cover of this land, such as towns, highways, agricultural, grasslands and forests influences the water chemistry of bodies of water within the watershed.



Many factors can affect the characteristics of the water in a river system, lake, or pond. Characteristics of water *system* include shape, depth and area of the water body, nearby land cover, and the types of rocks and soils near the water body, shape and area of the catchment basin. Characteristics of your water include temperature, chemistry, color, etc. In this protocol, you will be collecting data about water quality as measured by dissolved oxygen, pH, alkalinity and electrical conductivity. Background research and field observations increase the students' ability to conceptualize links between land characteristics and water characteristics. This activity is an introduction to your Hydrology Site.



What To Do and How To Do It

Ask students about their knowledge of local bodies of water. Begin with questions such as:

Is there a lake, river, pond or stream that you visit?

What is your favorite past-time at this place?

Why is this body of water important to you?

Have students begin to research local water sites and water issues in your community. This may include:

Looking at maps of the local area to identify water sites,

Researching water in the community through newspaper articles, periodicals or books; reports from local, state, or federal agencies; or other written sources,

Interviews with long-time residents of the community about what they remember about your Hydrology Site, and



Discussions with local experts on water from local agencies or universities.

Take a Field Trip to your Hydrology Site

For beginning levels:

For the younger students, the goal is to have the students walk around, observe and ask questions about the water in their study site. This includes noticing the direction of flow of rivers or streams, the presence of ponds or lakes, residual water from precipitation, springs and soil moisture. Encourage your students to focus on water in all its forms as they walk around the study site. Take a container and collect a sample of the water. Ask students to observe the color of the water, what they see in the water, whether the water is moving and how fast, what is near the water, whether they can hear the water while they are quiet, whether the water has a smell, whether the water is clear or cloudy, etc.

Have your students draw pictures and/or take notes about the location and size of the study site. Compare the water location to other features on their study site such as trees, hills, etc. Have your students ask questions about where the water came from.

For intermediate and advanced levels:

Assign teams of students to survey different sections of the Hydrology Site. In teams composed of a journalist, a sketcher, and a photographer, students should begin to document what they observe about their section. What is the appearance, smell, nature of the water in their section? Bordering lands should be noted such as urban, agricultural, residential, wooded, and wetlands. Students should map the general contours and characteristics of their sections and record the wildlife and plants in and around its water. What is the slope of the land adjacent to their section of water?

Back in the classroom, students should create a composite display of all the sketches and maps. Look for similarities and differences and discuss observed patterns. Based on their observations, encourage students to think about how the water

got to this location, how it flows through the study site, where it goes from there, how the area surrounding the water influences the properties of the water particularly during periods of rain, snowmelt, and flooding. What questions do they have? Record them on a poster on the classroom wall.

In addition, ask the students to discuss some of the following:

Did you see any discharge into your water body?

What land use activities did you observe and list?

How do you think these activities would change the water characteristics?

Would these activities influence water properties?

What type of water appearance was recorded most often and what might this indicate about the water?

Was there evidence of human uses of the water?

Is there evidence of wildlife and other animals using the water?

Extensions of Basic Learning Activity

As students visit the site weekly to collect data, remind them of their observations during this activity and ask them to note changes in their GLOBE Science Logs.

The information that students gather can become an important archive for the community. Have students use the information, pictures, and other things they have gathered to create a permanent archive for the school about their local water.

Students can create a 'natural history museum' in a display case from the information they have gathered.

Student Assessment

Have students create a visual display of what they know about their body of water, including surrounding land cover and its impact on the water in ways that affect plants, fish, and other animals that depend on the water.

Model a Catchment Basin



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Purpose

To introduce what a catchment basin is and how it works

Overview

Students will construct a 3-dimensional model of a catchment basin. They will use the model to explore catchment basins, water pathways, and manipulate the model to illustrate how catchment basins can change.

Student Outcomes

Students will be able to,

- define the concept of a catchment basin and a watershed;
- give examples of how their model relates to the real world; and
- give examples of basic concepts of catchment basins and watersheds, such as, water runs downhill, hills make divides, low-lying areas create pooling, water quality is affected by what is upstream.

Science Concepts

Earth and Space Science

Soils have properties of color, texture and composition; they support the growth of many kinds of plants.

Landforms are the result of destructive and constructive forces.

Soils consist of weathered rocks and decomposed organic matter.

Water circulates through the biosphere, lithosphere, atmosphere and hydrosphere (water cycle).

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Scientific Inquiry Abilities

Develop descriptions and explanations using evidence.

Communicate procedures and explanations.

Time

Class period

Level

All

Materials and Tools

Miscellaneous objects that may be used to create the model infrastructure

Outdoor models may use: sand, wood, rocks, etc.

Indoor models may use classroom items such as buckets, bowls, rolls of paper towels, etc.

Plastic sheet (2 x 2 meters)

Spray bottle with water

Sponges

Red food coloring

Permanent marker that will write on plastic or black electrical tape

Ruler

Topographic map

Preparation

None

Prerequisites

None



Teacher Support

Introduction

An understanding of the catchment basin (also called a river basin or water basin) is vital to analyzing data from the Hydrology Site. Water chemistry is a synthesis of everything that has happened to the water before it reaches the point at which a measurement is taken. This will include everything the water collects due to physical and chemical interactions with rocks, minerals, soil, and vegetation. It also is affected by contributions from aquatic life. Many natural and human activities that occur on that land can affect the water chemistry. There are so many things that might affect your water. But before you can explore them, you must find where your water comes from. That area is called your catchment basin. The boundary between adjacent catchment basin is called a watershed.

It is often difficult for students to imagine that rivers flow any direction but what their own experience has indicated. Even high school students when asked which direction rivers flow will often respond with a cardinal direction – south or east, for instance. The idea that water responds to the pull of gravity and is channeled by the materials it must pass through is an important concept.

Through manipulation of their basin model, students will gain an understanding of the constraints of a watershed. They will also be able to predict what happens when changes in the catchment basin occur, and test their predictions.

This is an excellent outdoor activity, although it can also be done easily in the classroom. Outdoors in a sandbox or on the grass students can freely rain on, pollute, and manipulate their model without fear of making a mess. Indoors, teachers may want to cover the modeling area floor with plastic in case of spills. Students may want to eventually create a model of their own basin. This may be built more permanently from plaster or clay before being covered with plastic wrap

How to Do Make the Model

1. Find an area about 1 meter square to build a catchment basin model. This could be a tabletop or plywood sheet if you are working inside or a grassy or sandy area outside.
2. You and your students gather the various objects to make the model, such as a plastic sheet, rocks, buckets, sponges, spray bottles with water, and food coloring.
3. Have the students arrange objects of various sizes inside the area. The tallest objects will become 'mountains'. Shorter objects or buckets or bowls may become hills, lakes, or plains.
4. Cover the entire area and all of the objects with a sheet of plastic. Have the students use their hands to mold the plastic loosely around the covered objects. This is a model of a landscape with hills, valleys, and connections between them.
5. Have the students predict what will happen if it 'rains' on their model. Where will the water go? Will it go faster in some places? Will some places form pools? How do you know?
6. Use the spray bottle to 'rain' on the top of your highest 'mountain'. Continue raining until you can see where streams, rivers, and lakes form.
7. Have the students choose a small pool on their model to be their GLOBE Hydrology Site. Mark the site with a marker, stone, or other object.
8. Ask the students to make it rain by using the spray bottle. Ask the students questions. Where does the water come from that flows to your Hydrology Site? Where does water flow away from your Site? What things on the landscape determine what will be part of your basin? What determines the watershed? Explain to the students that the places where water hits and flows into their Hydrology Site are in the catchment basin for their site, the watershed is the basin boundary.



9. Ask students: Where would be a good place on their model to have their school? Where would you like your house to be? Have the students mark these places on the model.
10. Have students explore the consequences of changes in their catchment basin. Here are some things you can do:
 - a. What happens if you dam the stream that flows to your water site? (Use a sponge to create a dam).
 - b. What happens if you plant a forest above your site? (Use a large flat sponge for the forest - it will soak up water for a time just like soil and vegetation) What happens if you remove the forest?
 - c. What happens if someone builds an industry that causes pollution? (Use a small piece of sponge soaked in food color where your industry will be and watch the 'pollution plume' as it rains.)
 - d. What happens if someone decides to use water from your stream for irrigation or urban use? (Make 'canals' that take the water away from your stream to other places.)

Extensions of Basic Learning Activity

Exploring Topographic Maps

This activity will help students better understand topographic maps. You will need a marker, tape, ruler, and topographic map.

Have students,

1. use a permanent marker or small pieces of tape to mark points on the model that are 10 cm above the surface of the table or ground;
2. use a marker to connect all of these points to make a ring around the model that is 10 cm above the surface;
3. measure points above the surface at 20 cm. Use a marker to connect them in a ring around the model;
4. continue measuring points at 30, 40, 50, etc. and connecting them until they reach the highest peak;
5. look at these rings from above. Ask students what they notice. Are they

concentric (the higher ones inside the lower ones)? Are they all the same distance apart?

6. draw the rings on a flat piece of paper as if they were seeing them from above; and
7. examine a topographic map. Ask students if their rings look like topographic lines?

Defining a Watershed from a Topographic Map

Have students,

1. identify their Hydrology Site on a topographic map. Find the elevation of their site from the map;
2. use the topographic lines and benchmarks on the map to identify areas that are uphill from their site; and
3. look for 'ridges' or 'divides'. These are at mountain tops or places where the elevations start to decrease. Ask students to think about whether water falling on that place would flow toward or away from their Hydrology Site.

Student Assessment

After students have completed their model, pose questions about what would happen at the Hydrology Site if you made a change on the landscape.

1. What would happen if you poured a pile of salt on the 'mountain' above their site?

What would happen if you poured the pile on the other side of the mountain?

Ask students to use a marker to outline the watershed for their Hydrology Site.

Have students explain 3 things that might happen in their own basin that would affect their water temperature, transparency, or other GLOBE measurements.

Draw a simple set of concentric contour lines. Ask students to create a small clay model based on the drawing. Ask students to label the highest point on the topographic drawing. Ask them to find the steepest slope.

Practicing Your Protocols



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Purpose

To have students learn to use the hydrology instruments and collect the hydrology data accurately.

Overview

Students will rotate among measurement stations for each of the hydrology protocols that will be done by the class. They will practice using the field guide with the instrument or kit for that particular measurement, exploring sources of variation and error.

Student Outcomes

Students should perform each of the chemistry measurements correctly, relate the units for each measurement, identify approximate ranges for each protocol, understand the importance of quality control, and identify anomalous data

Earth and Space Science

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Life Science

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Organisms change the environment in which they live.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Develop explanations using observations.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Use instruments to gather data accurately.

Time

One to four class periods, depending on how many protocols are done

Level

Varies with the protocol

Materials and Tools

Practicing Your Protocols Activity Sheets

Protocol Field Guides

Equipment is listed on *Activity Sheets* for specific protocols to be done.

Preparation

Ask students to bring in water samples to be tested.

Prerequisites

It would be helpful for the class to have seen the measurements demonstrated. Teachers can use the GLOBE Hydrology video to demonstrate key points.



Background

A quality assurance and quality control (QA/QC) plan is necessary to ensure test results are as accurate and precise as possible. Accuracy refers to how close a measurement is to true value. Precision means the ability to obtain consistent results. Desired accuracy, precision and reliability are ensured by: careful calibration, use, and maintenance of testing equipment, following the specific directions of a protocol exactly as described, repeating measurements to ensure that they are within acceptable limits, minimizing contamination of samples, stock chemicals and testing equipment, keeping track of samples. Together these steps help make the data you collect valid, valuable and meaningful.

To be able to analyze data, students need some baseline knowledge of what data are being collected and expectations of parameters and sources of error. These labs provide students with a baseline knowledge of the data collected in the GLOBE *Hydrology Protocols* by encouraging them to introduce variables into the data collection procedure to determine the data error recorded when the variables are not controlled.

Preparation

Safety: Consult Material Science Data (MSDS) sheets that come with the kits and buffers. Also consult your local school district's safety procedure guidelines. Discuss lab safety with students.

Set up measurement stations for each of the protocols your students will be performing. The materials for each station are listed on the *Activity Sheets*.



What to Do and How to Do It

Divide the students into small groups, optimally three or four per group. Checking each other's work, students should take turns reading directions, making measurements, and recording the data.

Students rotate through each station learning the instruments and protocols and filling in the *Activity Sheets*. The time it takes to do all of the stations will depend on whether your students are familiar with the equipment and how many stations are set up.

After the station rotations are done

Collect all of the *Activity Sheets*. Ask each student group to compile the data from all the student groups for a particular protocol and prepare a report. They should:

- Plot all the data points as a way of demonstrating the concept of precision. When measurements are precise, points are close together. Discuss the range of measurements found and variations among the measurements;
- Lead discussions on the issues of why there are discrepancies;
- Connect explanations with reasons for specific steps in the protocols; and
- If samples were tested from various places (see *Extensions of the Basic Learning Activity*), help the class make sense of their results by placing data on a map of the water sources and considering the history of each sample.

Extensions of the Basic Learning Activity

Have students bring in water samples from near their own homes for testing.

Have students design explorations for testing other variables that may affect the water quality testing.

Student Assessment

Provide students with the following table of hydrology data. (Note that these data are NOT all from the same water body). In Column 3 ask students to decide whether the data are reasonable (yes or no). In Column 4, ask students to provide a comment on how they might interpret the data or potential sources of error for any data they found questionable in Column 3.

Analysis Table

Data type	Measurement	Reasonable? (Yes or No)	Comments: interpretation or suspected sources of error
Turbidity Tube	4 cm		
Water Temperature	67 degrees		
Dissolved oxygen	2 ppm		
pH	7.5		
Conductivity	140 mS/cm		
Salinity	35 ppm		
Alkalinity	350 ppm		
Nitrate	>10 ppm		

Analysis Table (Sample responses)

Data type	Measurement	Reasonable?	Comments
Transparency Tube	4 cm	yes	Water must contain many suspended particles. Maybe soil has washed in recently or there is an algae bloom.
Water Temperature	67 degrees	no	Too high! Maybe read the wrong scale (°F instead of °C)
Dissolved oxygen	2 ppm (or 2 mg/L)	yes	This is very low. We should try the measurement again, then try to determine why the oxygen levels are low if it still measures 2.
pH	7.5	yes	This is optimal for many animals. We should monitor for change over time.
Conductivity	140 μ S/cm	yes	This is fairly low conductivity - not very many dissolved solids in this water.
Salinity	35 ppm	no	Should be ppt
Alkalinity	280 ppm	yes	This is a well-buffered system.
Nitrate	>10 ppm	no	It is possible, but I would check to see if correct since this is above safe levels. Check to see if directions for low or high range tests were used.

Transparency Station

Activity Sheet

Transparency is the measurement of water clarity. The clarity of your water determines how much light can penetrate. The transparency of water at your site will depend on the amount of particles suspended in the water. Typical suspended particles are clays (eroded from soils) and algae. Transparency may change seasonally with changes in growth rates, in response to precipitation runoff, or for other reasons. Since plants require light, transparency is an important measurement in determining productivity of your water site.

Materials

- GLOBE Science Log
- Pen or pencil
- Transparency Field Guide*
- Turbidity tube
- Plastic cup
- Water sample in bucket
- Extra clean bucket
- Stirring spoon
- Silt or clay (three 2-g piles)
- Green food coloring
- Pipette
- Graph paper

What to Do

1. Review the *Transparency Field Guide*. Follow the steps as they are outlined to determine the transparency of your water sample.
2. Move to a part of the room with bright light. Repeat the measurement.
3. Pour half of the water into the clean bucket. Add 2 grams of silt or clay to the water and stir. Repeat the measurement with this water. Add 2 more grams and repeat the measurement. Add 2 more grams and repeat the measurement.
4. Discard the dirty water. Into the remaining fresh water add 2 drops of green food coloring. Repeat the measurement. Try adding 4 drops, then 6 drops.
5. Make a graph with Transparency (cm) on the Y-axis and grams of soil on the X-axis.
6. Make a graph with Transparency (cm) on the Y-axis and drops of food coloring on the X-axis.

Sample	Student #1	Student #2	Student #3
Water in bucket			
Tube placed in bright light			
Water with soil (2 grams)			
Water with soil (4 grams)			
Water with soil (6 grams)			
Green water (2 drops)			
Green water (6 drops)			

Temperature Station

Activity Sheet

Water temperature measures the surface temperature of your water body. Water bodies have different temperatures depending on latitude, altitude, time of day, season, depth of water, and many other variables. Water temperature is important to chemical, biological and physical processes. It can help us understand what may be happening in the water body without directly measuring hundreds of variables.

Materials

- GLOBE Science Log
- Pen or pencil
- Thermometer Calibration Lab Guide*
- Water Temperature Field Guide*
- Water sample in bucket
- Distilled water
- Thermometer(s)
- Crushed ice
- Watch or clock for timing
- Salt
- 500-mL beaker

What to Do

1. Calibrate your thermometer(s) using the *Calibration Lab Guide*.
2. Follow the steps on the *Water Temperature Field Guide* to measure the temperature of your water sample.
3. Pour 500 mL of crushed ice into the water sample. Stir until the ice has melted.
4. Place the thermometer into the cooled water for 5 seconds. Record the temperature.
5. Wait 10 more seconds. Record the temperature.
6. Record the temperature after 3 minutes.
7. Remove the thermometer from the water. Read the temperature. Record the number of seconds it takes before you observe a change in the temperature reading.
8. Place the thermometer into the water for 30 seconds. Remove the thermometer from the water. Read the temperature. Hold the thermometer in front of a fan or blow on it. Record the number of seconds it takes before you observe a change in the temperature reading.
9. Prepare an ice bath with 250 mL water, 250 mL crushed ice and a spoonful of salt. Measure the temperature of the saltwater bath.

Sample	Student #1	Student #2	Student #3
Temperature of water sample			
Temperature of ice water after 5 seconds			
Temperature of ice water after 15 seconds			
Temperature of ice water after 3 minutes			
Time for temperature change to occur			
Time for temperature change to occur (with fan)			
Temperature of ice water with salt			

Dissolved Oxygen Station

Activity Sheet

Most living things depend on molecular oxygen to survive. Molecules of oxygen dissolve in the water. Aquatic animals can use this dissolved oxygen (DO) for respiration. In air, about 20 out of every 100 molecules are oxygen. In water, less than 20 out of every 1,000,000 molecules are oxygen. This is why dissolved oxygen is measured in parts per million (ppm). Different kinds of organisms need different amounts of oxygen, but generally aquatic organisms require at least 6 ppm for normal growth and development.

Water temperature and pressure affect how much oxygen is in the water. Water that has as much oxygen as it can hold for its temperature and pressure (a function of altitude) is said to be in 'equilibrium'. Warm water cannot hold as much oxygen as cold water. At high altitudes, where there is less pressure, water cannot hold as much oxygen as at low altitudes. Look for these patterns in the Temperature and Elevation Tables in the DO quality control sheet.

The actual amount of DO in water may be higher or lower than the equilibrium value. Bacteria in the water use oxygen as they digest decaying plants or animals. This can lower the DO levels of the water. Plants in the water produce oxygen during photosynthesis. This sometimes results in higher DO levels.

Materials

- GLOBE Science Log
- Pen or Pencil
- Dissolved Oxygen Quality Control Lab Guide*
- Dissolved Oxygen Field Guide*
- Fresh bucket of tap water
- Fixed sample of water (fixed sample should be made immediately after the bucket of sample water is collected)
- Bucket of tap water left setting several hours
- Dissolved Oxygen kit(s)
- Distilled water
- 250-mL sample bottle with lid
- Thermometer

What To Do

1. Do the quality control procedure for the DO kit as described in the *Dissolved Oxygen Quality Control Lab Guide*
2. Once you are sure that your procedure and kit are accurate, test a fresh water sample from the tap.
3. Test the water sample that has been standing for several hours.
4. Titrate the fixed sample that was prepared from a similar fresh water sample earlier in the day. Record the DO level.

Sample	Student #1	Student #2	Student #3
Fresh water sample			
Standing water sample			
Fixed water sample			

pH Station

Activity Sheet

pH indicates the acid content of water. The pH scale ranges from 1.0 (acidic) to 14.0 (basic) Neutral is 7.0. The scale is logarithmic. A change of one pH unit means 10 times the acid or base concentration. For instance, a change from 7.0 to 6.0 indicates water 10 times more acidic; a change from 7.0 to 5.0 indicates water 100 times more acidic.

The pH of a water body helps determine what can live in it. Many amphibians, insect larvae and other types of aquatic life are very sensitive to low or high pH.

Materials

- | | |
|---|---|
| <input type="checkbox"/> GLOBE Science Log | <input type="checkbox"/> pH meter(s) |
| <input type="checkbox"/> Pen or pencil | <input type="checkbox"/> Distilled water |
| <input type="checkbox"/> <i>pH Protocol Field Guide</i> | <input type="checkbox"/> Buffers for pH calibration |
| <input type="checkbox"/> Water sample | <input type="checkbox"/> Paper towels |
| <input type="checkbox"/> Box of pH paper | <input type="checkbox"/> Ice |
| <input type="checkbox"/> Cups or 100 mL beakers for buffers and water samples | <input type="checkbox"/> Salt |

What To Do

1. Test the water sample for pH using the *pH Protocol Field Guide (pH paper)*.
2. Do not calibrate the pH meter. Follow the steps in the *pH Protocol Field Guide (pH meter)* to measure the pH of the water sample.
3. Calibrate your pH meter according to the instructions that come with your instrument.
4. Follow the steps in the *pH Protocol Field Guide (pH meter)* and measure the pH of the water sample.
5. Pour 50 mL of sample water into a cup. Place the cup in an ice water bath to cool the sample water. Test the pH of the cooled sample using both pH paper and the meter.
6. Pour 50 mL of distilled water in a clean cup and test the pH using both the paper and the meter.
7. Add a few grams of salt to the distilled water, and test the sample again.
8. Add a few grams of salt to the tap water sample, and test the sample again

Sample	Student #1	Student # 2	Student #3
Sample water - pH paper			
Sample water – without calibration			
Sample water – after calibration			
Cooled sample water - pH paper			
Cooled sample water - pH meter			
Distilled water - pH paper			
Distilled water - pH meter			
Saltwater (was distilled - pH paper)			
Saltwater (was distilled - pH meter)			
Saltwater (was tap – pH paper)			
Saltwater (was tap – pH meter)			

Electrical Conductivity Station

Activity Sheet

Electrical conductivity measures the ability of a water sample to carry an electrical current. Pure water is a poor conductor of electricity. It is the impurities in water, such as dissolved salts, that allows water to conduct electricity. Conductivity is used to estimate the amount of dissolved solids in the water.

Conductivity is measured in a unit called microSiemens/cm ($\mu\text{S}/\text{cm}$). Sensitive plants can be damaged if they are watered with water that has electrical conductivity levels above about 2200-2600 $\mu\text{S}/\text{cm}$. For household use, we prefer water with conductivity below 1100 $\mu\text{S}/\text{cm}$.

Materials

- GLOBE Science Log
- Pen or pencil
- Conductivity meter(s)
- Conductivity Protocol Field Guide*
- Water sample
- Cups or 100-mL beakers for buffers and water samples (vinegar, milk, soda, coffee, sugar water, artificial sweetener, ice water, salt water
- Distilled water
- Paper towels
- Graph paper
- Salt (two piles of 1 g)
- 100-mL graduated cylinder
- Calibration standard

What To Do

1. Do not calibrate the meter. Test the conductivity of the water sample using the *Electrical Conductivity Protocol Field Guide*
2. Calibrate the meter.
3. Test the conductivity of the water sample using the *Electrical Conductivity Protocol Field Guide*
4. Add a gram of salt to 100 mL of distilled water. Measure the conductivity.
5. Add two grams of salt to 100 mL of distilled water. Measure the conductivity.
6. Measure the conductivity of the other samples: vinegar, milk, soda, sugar water, water with artificial sweetener, ice water, coffee

Sample	Student #1	Student #2	Student #3
Fresh water sample – no calibration			
Fresh water sample - calibration			
1 g salt			
2 g salt			
Vinegar			
Milk			
Soda			
Sugar water			
Artificial sweetener			
Ice water			
coffee			

Salinity Protocol

Activity Sheet

Salinity is the measurement of dissolved salts in salty or brackish water. It is measured in parts per thousand (ppt). Salinity may vary with precipitation, snow melt, or proximity to a freshwater source such as a river mouth.

The hydrometer is an instrument which measures the specific gravity or density of a fluid. Its design is based on the principle that the weight loss of a body floating or immersed in a liquid equals the weight of the liquid displaced. The denser your liquid, therefore, the less the weighted bulb must sink to displace its own weight.

Why do you need to take a temperature reading with your hydrometer reading? Water becomes more dense as it approaches freezing. Since we want to measure the effect of dissolved salts on density, we must control the temperature variable.

Materials

- GLOBE Science Log
- Pen or pencil
- Salinity Conversion Table*
- 500-mL graduated cylinder
- Distilled water
- Hydrometer
- Thermometer
- 20 g salt (in two 10-g units)
- Ice

What To Do

1. Fill the 500 mL graduated cylinder to the 500-mL line with distilled water.
2. Gently place the hydrometer into the cylinder of distilled water and read the scale.
3. Remove the hydrometer and add 10 g salt. Mix.
4. Take the water temperature.
5. Replace the hydrometer and read the scale.
6. Find the salinity of the water sample using the *Salinity Conversion Table*
7. Discard the water in the cylinder, rinse with distilled water, then fill the cylinder _ full of ice. Fill to the 500-mL line with distilled water.
8. Place the hydrometer gently into the cylinder and read.
9. Remove the hydrometer and add 10 g salt to the cylinder. Mix.
10. Find the water temperature.
11. Place the hydrometer gently into the cylinder and read.
12. Find the salinity of the water sample using the *Salinity Conversion Table*.

Sample	Student #1	Student #2	Student #3
(2) Hydrometer reading – distilled water			
(4) Water temperature – 10 g salt			
(5) Hydrometer reading – 10 g salt			
(6) Salinity (from table) – 10 g salt			
(8) Hydrometer reading – distilled water, ice			
(10) Temperature – 10 g salt, ice			
(11) Hydrometer reading – 10 g salt, ice			
(12) Salinity of sample – 10 g salt, ice			

Alkalinity Station

Activity Sheet

Alkalinity, measured as ppm calcium carbonate, is a measure of the ability of a body of water to resist changes in pH when acids are added. Acid additions generally come from rain or snow, although soil sources may also be important in some areas. Alkalinity is added to water when water dissolves rocks such as calcite and limestone. The alkalinity of natural waters protects fish and other aquatic organisms from sudden changes in pH.

Materials

- GLOBE Science Log
- Pen or pencil
- Alkalinity Test Kit(s)
- Alkalinity Quality Control Procedure Lab Guide*
- Alkalinity standard
- Alkalinity Protocol Field Guide*
- 100-mL graduated cylinder
- Distilled water
- Baking soda (3 1-g units)
- Vinegar
- Pipette

What To Do

1. Use the *Alkalinity Quality Control Procedure Lab Guide* to check your kit and procedure.
2. Use the *Alkalinity Protocol Field Guide* to measure the alkalinity of the water sample.
3. Add 1 g of baking soda to a 100-ml fresh water sample. Mix well. Test the alkalinity.
4. Repeat step (3) using 2 g of baking soda, then 3 g baking soda.
5. Add a drop of vinegar to fresh 100-ml water sample. Mix well. Test the alkalinity.
6. Repeat step (5) using 2 drops vinegar, then repeat using 3 drops.

Sample	Student #1	Student #2	Student #3
Alkalinity of water sample			
Alkalinity – 1 g baking soda			
Alkalinity – 2 g baking soda			
Alkalinity – 3 g baking soda			
Alkalinity – 1 drop vinegar			
Alkalinity – 2 drops vinegar			
Alkalinity – 3 drops vinegar			

Nitrate Station

Activity Sheet

Nitrogen is one of the three major nutrients needed by plants. Most plants cannot use nitrogen in its molecular form (N_2). In aquatic ecosystems blue-green algae are able to convert N_2 into ammonia (NH_3) and nitrate (NO_3^-), which can then be used by plants. Animals eat these plants to obtain nitrogen that they need to form proteins. When the plants and animals die, protein molecules are broken down by bacteria into ammonia. Other bacteria then oxidize the ammonia into nitrites (NO_2^-) and nitrates (NO_3^-). Under suboxic conditions nitrates can then be transformed by other bacteria into ammonia (NH_3), beginning the nitrogen cycle again.

Typically nitrogen levels in natural waters are low (below 1 ppm nitrate nitrogen). Nitrogen released by decomposing animal excretions, dead plants, and animals is rapidly consumed by plants. In water bodies with high nitrogen levels, eutrophication can occur. Nitrogen levels can become elevated from natural or human-related activities. Ducks and geese contribute heavily to nitrogen in the water where they are found. Man-made sources of nitrogen include sewage dumped into rivers, fertilizer washed into streams or leached into groundwater, and runoff from feedlots and barnyards.

Nitrate levels are measured in parts per million (ppm) nitrate nitrogen.

Remember that nitrate levels can change over time. So it is best to test fresh samples (less than 2 hours old) or refrigerated samples.

Materials

- GLOBE Science Log
- Pen or pencil
- Nitrate Test Kit(s)
- Nitrate standard
- Nitrate Quality Control Procedure Lab Guide
- Nitrate Protocol Field Guide
- Fertilizer
- Water sample from an aquarium

What To Do

1. Use the *Nitrate Quality Control Procedure Lab Guide* to check your kit and procedure.
2. Measure the nitrate of your water sample using the *Nitrate Protocol Field Guide*
3. Dissolve a few grams of nitrogen rich fertilizer in your water sample. Test the nitrate level.
4. Test water from an aquarium.

Sample	Student #1	Student #2	Student #3
Nitrate of water sample			
Nitrate with fertilizer			
Nitrate in aquarium			

Water Detectives



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Purpose

To help students understand that some substances can be identified safely with your senses. For other substances we may need tools to help us identify them.

Overview

Students will try to identify mystery substances in the water.

Student Outcomes

Students will learn to use their senses to make observations and explain why sometimes you need extra tools to expand your senses.

Science Concepts

Earth and Space Science

Water is a solvent.

Physical Science

Objects have observable properties.

Scientific Inquiry Abilities

Develop explanations using observations.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Use instruments to gather data.

Time

One class period

Level

All

Materials and Tools

For each team of 4-5 students:

4 clear plastic cups

4 spoons or straws

Marker to number cups

Distilled or tap water

Water Detectives Work Sheet

“Pollutants” for the water which represent all of the senses. Any safe, nontoxic food can be used, such as:

Sight: drop of yellow food coloring or coffee, carbonated water

Touch: baking soda, clear syrup

Smell: vinegar, lemon/orange juice

Hearing: carbonated water

Preparation

Number the cups for each station from 1 to 5.

Copy the *Water Detective Work Sheet* for each group.

Provide a work station with 4 cups of distilled or tap water with small amounts of a ‘pollutant’ mixed into 4 of the cups.

Lay out spoons or straws for dipping water from the cups.

Prerequisites

None



Background

In the hydrologic cycle, moving water (precipitation, surface water, groundwater) constantly erodes the continents. Part of the eroded material is transported by rivers to oceans, both as suspended solids (e.g. sand, clays, and silts) and dissolved substances (e.g. salts). These can be considered as natural pollutants and can vary from dissolved limestone (calcium carbonate) to dissolved minerals that contain heavy metals such as lead, cadmium, and zinc. Other substances are introduced into the hydrologic system through human activity. Oil, sewage, and chemical fertilizers and pesticides are examples. Once these materials are in the water, all forms of life using that water are subject to the effects of these substances. At the completion of the water cycle, the water evaporates, often leaving the particles it carried behind.

Scientists have developed tests to see if various substances, whether harmful or beneficial, naturally occurring or not, are found in water. These tests involve the use of tools to measure substances or properties that humans can not sense directly.

What to Do and How to Do It

Discuss with students how they use their senses to detect things in their environment. Discuss the advantages and limitations of each of the senses. Questions students may want to think about:

How do we use our eyes to detect danger? When does our sense of sight not work very well? (*when something is out of vision range, in the dark, or so small that it cannot be seen by the human eye...*)

How do we use our ears to detect danger? When do our ears not work very well? (*things that make no sound, when we do not listen or pay attention...*)

How do we use our sense of smell to detect danger? When does it not work very well? (*some things are odorless, when we have a cold...*)

How do we use our sense of touch to detect danger? When does it not work very well? (*when an object is far away, when touching might be dangerous...*)

Hold up a cup of water from one of the stations. Explain what the cup contains (water plus what known substances). Ask students which senses would be most useful for finding out if the water was unaltered tap water (intended for drinking)? Consider the advantages and disadvantages of using each of your senses.

Discuss proper lab procedures for testing substances with your senses.



Doing the Experiment

Explain to students that 4 of the 5 cups contain a mystery food that will be considered a 'pollutant' in the water. You may want to show students the boxes of 'mystery food' which have been put in the water (salt, baking soda, etc.).

Students are to detect which cups contain mystery pollutants and which cup has just water by using their senses. Use the *Water Detectives* sheet to have students record their data.

Ask students what other ways might be used to find out what was in water. Introduce the idea of how we use tools and ask for examples of how we use tools to help our senses. For example, they may think of smoke detectors, microscopes, hearing aids, etc.

Introduce students to pH paper as a tool for sensing water. Have students use pH paper to test their cups of water. What can the pH paper detect?

Extensions of the Basic Learning Activity

Introduce students to pH paper as a tool for testing water. Have students use pH paper to test their cups of water. What can the pH paper detect?

Challenge students to devise their own tests for detecting what is in the water. Examples:

- Shake the water

- Add other substances that might react with things in the water (vinegar)

- Freeze, boil, or evaporate the water

- Test the density

- Look for refraction

- Conduct electricity through the water

Discuss how the GLOBE *Hydrology Protocols* use some of these principals to collect water data.

Student Assessment

Ask students to

- List several substances they might find in the water at their Hydrology Site

- Explain why instruments are sometimes needed to detect substances

- Guess (hypothesize) how various substances might affect things living in the water

- Explain how each sense is good for examining different kinds of materials

Water Detectives Work Sheet

Name: _____

Cup	Look	Listen	Smell	Feel	pH Test
					
1 one					
2 two					
3 three					
4 four					

- Look** at the cups. Put an X next to the cups that do not look like water.
- Listen** to the cups. Put an X next to the cups that do not sound like water.
- Smell** the cups. Put an X next to the cups that do not smell like water.
- Feel** water dipped from the cups. Put an X next to the cups that do not feel like water.

Which cup has ONLY water? _____

The pH Game



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Purpose

To teach students about the acidity levels of liquids and other substances around their school so they understand what pH levels tell us about the environment

Overview

The pH game will engage students in the measurement of the pH of water samples, soil samples, plants and other natural materials from different places. Students will create mixtures of materials in order to collect different pH measurements.

Student Outcomes

Students will identify the pH of common substances, learn how high or low pH levels may result in dangerous conditions in the environment, and examine how pH may be changed.

Earth and Space Science

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Science

Objects have observable properties.

Scientific Inquiry Abilities

Develop explanations using observations.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Use instruments to gather data accurately.

Time

One class period for preparation

One class period for the game

Level

All

Materials and Tools

For each team: (about 4 students)

20 pH strips

3 to 5 small cups

Paper and pencil

Labels to attach results to results board

For the class:

Results board (one line of pH levels from 2 to 9 for each team)

Flip chart with rules

Additional pH strips

Cups of solutions prepared for analysis

Preparation

Gather materials for pH solutions.

Prerequisites

Discussion of lab safety procedures



Teacher Support



Introduction

The level of acidity (pH) significantly influences the vegetation and wildlife in an environment. The pH can be influenced by different factors. The main natural influences are the contributions from rocks and soils. Human activities can also contribute, by releasing basic or acidic substances into the air, water or ground. One particularly important contribution from human activities is acid rain (which forms when acidic compounds released into air combine with water in the atmosphere). Acid rain can lower the pH in water bodies to levels that are dangerous to certain species.



It is important to understand pH. This activity will help your students understand the pH scale. More advanced students will mix acid and basic solutions to produce solutions of intermediate pH, and will also learn about the relationship between alkalinity and pH.



Advance Preparation

You or your students should prepare various acidic and basic mixtures/solutions of natural and processed materials. These solutions should be labeled with the ingredients and a letter, but not their acidic or basic characteristic. Examples of acidic solutions include fermented grass, dilute and concentrated lemon juice, black coffee, vinegar, orange juice, and soft drinks. Basic solutions include salt water, shampoo, baking soda, chlorine bleach, household ammonia, and oven cleaner. Local water and soil solutions should be used as well. Soil water solutions are produced by mixing equal amounts of distilled water with soil, and then allow the soil particles to settle out. You can also produce solutions from materials found around the local school area, such as oil drippings from a vehicle, liquid in a discarded bottle, etc.



Table HY-pH-1

Teams	pH Value								TOTAL
	2	3	4	5	6	7	8	9	
Team 1									
Team 2									
Team 3									



Table HY-pH-2

Teams	pH Value								TOTAL
	2	3	4	5	6	7	8	9	
Team 1	1		1			1	1		4
Team 2		1		1				1	3
Team 3	1				1		1		3



What to Do and How to Do It

Remind students of the difference between hypothesis and results. Encourage them to develop their hypothesis and find a way to test it with results. The *Implementation Guide for Teachers* in the *GLOBE Teachers Guide* contains materials on guiding students in research. Divide your class into separate teams.

The Rules

1. Explain that the objective of the game is for each team to identify solutions that have a pH range of 2-9.
The students should draw a horizontal pH scale line from 0 to 14, marking pH 7 as the neutral point. Each unit should be spaced at least 1 cm apart. They should then draw a box underneath each pH unit from 2 to 9.
Each team finds substances that have a pH corresponding to a box in the pH scale.
2. The teacher draws the following matrix on the board. See HY-pH-1.
3. One point is awarded for each box filled, even if the team finds two samples with the same pH.
4. Students should record all the information about the solution from the labels and the pH they measured.
5. When students are ready to submit a sample for the game results board, they show the teacher their notes and sample. Together they measure the pH with a new pH strip. If the pH agrees with the students' previous measurement, the sample is approved and the points are added to the team's score. The Table HY-pH-2 is an example of results for different teams.
6. The teacher gives a new pH strip for each sample added to the results board.

Extensions to the pH Game

Beginning

For a basic understanding, use salt and sugar and explain to students that salty does not necessarily mean acid and that sweet does not necessarily mean basic. Cola soft drinks are good examples of a sweet and very acid liquid.

Intermediate

Make the game more competitive. For instance, the team that finds or creates the first sample of a particular pH value receives 5 points; subsequently, samples for that pH level receive only 1 point.

Make the game more difficult by limiting the sample sources to only natural materials.

Limit the number of pH strips given to each group and set up a rule for buying a new one with game points.

Advanced

Ask the student which solutions should be mixed together to produce a neutral solution (pH ~7). Explain to the students that pH is a logarithmic scale and is not additive. (For example, mixing equal amounts of unbuffered solution of pH 6 and pH 7 would produce a solution of pH 6.2, not pH 6.5, although if they are using pH paper, they will not be able to tell the difference.). Have them test their hypothesis by mixing some of the labeled solutions together and recording the pH. How much of each solution was used? What was the resulting pH? Is it higher or lower than then expected?

Explain the concept of acid neutralizing capacity (alkalinity). Discuss whether it requires more acidic solution to lower the pH of a solution with high alkalinity or a solution with low alkalinity, when both solutions have the same starting pH. Many of the solutions may have some alkalinity; therefore a higher proportion of the acidic solution will be required to lower the pH of the solution with higher alkalinity. Have students discuss the neutralization capacity of the different solutions. Relate this to buffering capacity (alkalinity) of hydrology sites.



Conduct a similar analysis of samples made from water from different areas of your community. Compare tap water with water from your study site. Compare the pH of water mixed with soil from different soil horizons.



Note: For older students we recommend inviting an expert to answer their questions.

Further Investigations

Examine the Hydrology Study Site for materials in soil, rocks, and vegetation that influence the pH of the water.



Try to identify and quantify influences that are not always present at the study site, such as precipitation or some event upstream of your sampling site. See if the pH of your site changes over the course of a day. Photosynthesis can cause fluctuation in pH (although these will be too small to be measure with most pH paper)



Student Assessment

After the game sit with students around the results board and identify what samples they have found, where the samples were found, and the pH of the samples. Encourage students to present their own ideas about why different samples have different pH values. Emphasize differences among water samples from soils, rocks, artificial surfaces, lakes, rivers, etc. Mention the acid neutralization capacities (alkalinity) of some rocks and the acidic influences of different materials. Ask them why it was difficult to find samples for some pH levels and easy to find others.

Acknowledgments

The pH game was created and tested by the leaders team of TEREZA, the Association for Environmental Education, Czech Republic

Modeling Your Water Balance



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Purpose

To model a soil's water storage over a year

Overview

Students create a physical model illustrating the soil water balance using glasses to represent the soil column. They use data from the GLOBE Data Server to calculate the potential evapotranspiration (the amount of water needed to meet the demand for the month), average monthly temperatures and precipitation for their model. They then construct a model representing the soil water balance for their site.

Student Outcomes

Students will be able to create a model of the physical environment and explain how the model can be used to interpret data and form predictions.

Science Concepts

Earth and Space Science

Soils have properties of color, texture and composition; they support the growth of many kinds of plants.

Soils consist of weathered rocks and decomposed organic matter.

Water circulates through the biosphere, lithosphere, atmosphere and hydrosphere (water cycle).

Scientific Inquiry Abilities

Identify questions.

Design and conduct a scientific investigation.

Use appropriate tools and techniques.

Use data to construct a reasonable explanation.

Recognize and analyze alternative explanations.

Use appropriate mathematics.

Communicate procedures and explanations.

Time

One class period to calculate values

One class period to construct model

One class period for hypothesis testing

Level

Intermediate and advanced

Materials and Tools

Part I: Physical model

14 beakers, glasses, or graduated cylinders (approximately 20-25 cm tall, or tall enough to hold the total precipitation for the wettest month at your model site)

Water

Red and black permanent markers

Ruler

Data from the GLOBE server or from the example below

Part II: Mathematical model

One year of precipitation, temperature, and soil moisture data

Tables and charts from this activity

Preparation

For Part II, find schools which have appropriate data on the GLOBE server.

Prerequisites

Simple math calculations, reading graphs, and using the GLOBE visualization server



Background

The amount of water stored in the soil at your site can be estimated by creating a water balance model for your area. The water content of your soil depends on the balance between water gained due to precipitation and water lost through evaporation and transpiration. The combined amounts of water lost through evaporation and transpiration is *evapotranspiration*. The maximum amount of evapotranspiration, *potential evapotranspiration*, would occur if water were always available. Since at times, for instance during a dry summer, the amount of water evaporated may exceed precipitation, water is not always available to meet demand.

The water content of your soil is a key factor in determining which plants can grow in your area. Several factors control the water content of your soil including temperature, the duration of sunshine, the amount of groundcover and the amount of precipitation. One might think the months of highest precipitation would also be the months with the greatest soil water content. This may not be true, but not always! If the temperatures are so great that most of the water evaporates, a cooler month may actually have higher soil water content. Scientists study the water balance in an area to predict when plants will grow and when they will be under stress due to lack of water.

Teacher Support

Advance Preparation

Discuss with students the importance of water held in the soil. You may want to do the *Just Passing Through* learning activity to illustrate the holding capacity of different soils.

What to Do and How to Do It

Examine the data from 1999 for Reynolds Jr Sr High School. Potential Evapotranspiration (PE) is the amount of water that would be lost through evaporation and transpiration if water was always available. When PE is less than precipitation, water is available to plants. When PE is greater than precipitation, plants must depend on water stored in the soil. PE is calculated for this model using a mathematical formula that includes two variables, temperature and duration of sunlight.

Have the students answer the following questions to interpret the data.

- Which month has the most precipitation? Which has the least?
- Which month is the warmest? Which is the coldest?
- During which months might you expect to have runoff (too much water to store in the soil)?
- During which months would you expect to have a water shortage (not enough water stored in the soil to meet the needs of plants)?

Reynolds Jr Sr High School, Greenville, PA, US, 1999 data

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Monthly Precipitation (mm)	120	70	55	121	63	50	77	84	62	35	109	56
PE (mm) Potential Evapotranspiration	0.0	0.0	0.0	42	85	118	141	109	83	36	20	0.0
Average Monthly Temperature (°C)	-4.6	-0.7	-1.1	9.0	14.8	19.5	22.4	19.2	17.0	8.9	6.2	-1.6

Part I – A Physical Model

Setting Up Your Model

1. Have students set out 12 containers representing months of the year. Label them from January through December. See Figure HY-BA-1.
2. Using the Reynolds data (or other data provided), have the students find the PE for each month. They can use a ruler and a black marker to draw a line on each container indicating the PE in mm for each month.
3. Mark the 13th container as storage. Make a line at 100 mm on the container to indicate when storage is full. The 14th container is for Precipitation.

Using Your Model

Provide the following instructions to your students. Find the amount of precipitation for January in the table. Measure out this amount of water into the precipitation beaker. Then pour the 'precipitation' into the January beaker, using the following rules:

Rule 1: If you have more precipitation than you need for the month, fill the January container to the PE line, then pour the rest of the water into Storage.

Rule 2: The Storage container can only be filled to 100 mm. If January is full to the PE line and the Storage is full, throw away the rest of the water.

Rule 3: If you do not have enough precipitation to fill the January container to the PE line, pour in all the precipitation then take water out of storage to fill up January to the PE line.

Rule 4: If you have used all the precipitation for the month and the Storage is empty, make a red line on the January cup indicating the water line. The difference between the black and red lines is a water shortage.

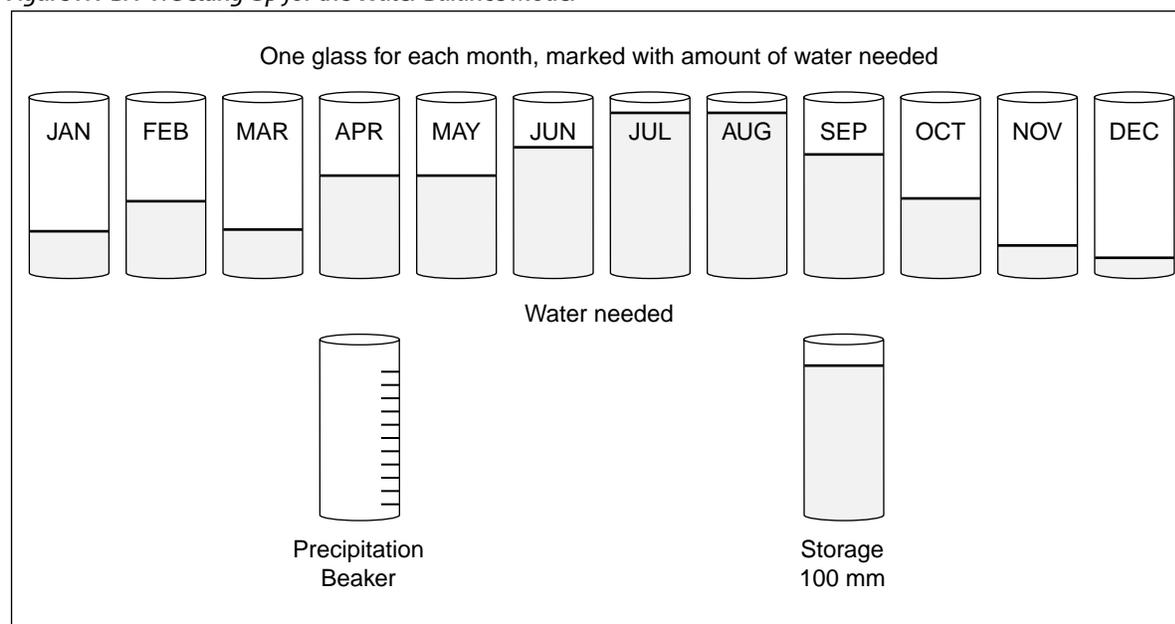
2. Repeat the steps for each month, progressing through the year.

Discuss Your Results

Ask students the following questions,

1. Which months show a water shortage? Did this agree with your hypothesis? Are there any variables you might now take into consideration in forming a hypothesis on water shortages at a site?
2. Are water shortages always in months with the least precipitation?
3. Are water shortages always in months with the highest temperatures?
4. During which months might you expect floods?

Figure HY-BA-1: Setting Up for the Water Balance Model





Testing Hypotheses With Your Model

Have your students form hypotheses that predict how the water balance will change with changes in variables.

Have them consider the following possibilities.

1. What happens if you have a particularly wet winter? (increase the winter precipitation for one winter month)
2. What happens if you have an unusually dry summer? (decrease the summer precipitation for one summer month)
3. What happens if you have an unusually hot summer (increase the water needed (PE) for the summer months)
4. What happens if you increase your storage through building an artificial reservoir? (increase Storage to 150 mm)

Have students test their hypotheses by changing variables in the table and running the model again.

Notes: Have students start the experiment with October as the starting month. Hydrologists sometimes define a “water year” as starting in October (in the northern hemisphere), before the winter snow accumulation season. Is there a different result?

Further Investigations

Using the *Calculating Potential Evapotranspiration Using Graphs Work Sheet* or the formulas at the end of the activity, students can find the PE figures for any GLOBE school with a year of temperature data.

Have students:

1. Use their own school data, or find other GLOBE schools in different parts of the world, to explore differences in the water balance in different ecosystems or biomes.
2. Examine the water balance of one site for several years. Does the water balance change from year to year?

Part II – A Mathematical Model

Have students complete the *Water Balance Table Work Sheet* for their own site or another site using GLOBE data.

Have students do the following steps to fill in the *Work Sheet*:

1. Find the total monthly precipitation for each month and fill in the precipitation row in the table.

2. Find the Potential Evapotranspiration (PE) for each month and fill in the PE row in the table. (PE may be calculated using the *Calculating the Potential Evapotranspiration (PE) Using Graphs Work Sheet* or by using the formulas at the end of the end of this activity.

3. Find the difference between the precipitation and the water needed (PE) for the first month.

- If there is more water than needed, enter the difference in the Extra Water Row.
- Enter this difference into the Storage row, adding it to any water already in Storage from the previous month.

Note: In the first month there is no number to add from the previous month.

Note: Storage cannot be greater than 100. Put the amount over 100 mm into Runoff.

4. If there is less water than needed, enter the difference into the Extra Water Needed row.

- To find the Storage, subtract (Storage from the previous month) – (Extra Water Needed from the current month).

If the difference is greater than 0, enter this number into the Storage box. If the number is less than 0, enter 0 into Storage and the result into Shortage.

Note: Shortages are not cumulative. Do not add them together from previous months.

5. Follow Step 3 across the table for each month.

Note: The months must be done in order.

6. Calculate the actual amount of water loss through evapotranspiration (AE):

If Precipitation > PE:

$$AE = PE$$

If precipitation < PE:

$$AE = PE - \text{Shortage}$$

7. Graph the precipitation, actual evapotranspiration, and PE (3 lines) for the site on one graph using the months on the X-axis, and mm of water on the Y-axis. Examine the graph and shade in areas where you have water surplus, water shortage, recharge, and runoff.



Water Balance Table Work Sheet

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)												
(PE) Potential Evapotranspiration												
Extra Water												
Water Needed												
Storage												
Shortage												
Runoff												
(AE) Actual Evapotranspiration												

Key to Table

Precipitation: Total precipitation for the month

Potential Evapotranspiration (PE): Total amount of water that would be lost through evaporation and transpiration if water were always available. Find the PE using the *Calculating Potential Evapotranspiration Using Graphs Work Sheet* or by using the formulas at the end of the activity.

Extra Water: Precipitation in excess of what is needed to meet monthly demand

$$\text{Extra Water} = (\text{Precipitation} - \text{PE}) \text{ when the difference is positive}$$

Extra Water Needed: Water needed from storage to meet demand

$$\text{Extra Water Needed} = (\text{Precipitation} - \text{PE}) \text{ when the difference is negative}$$

Water in Storage: Water stored in soil. Storage is never less than 0 or greater than field capacity (field capacity is assumed to be 100 mm for this model)

$$\begin{aligned} \text{Storage} &= \text{Storage (previous month)} + \text{Extra Water or} \\ \text{Storage} &= \text{Storage (previous month)} - \text{Extra Water Needed} \end{aligned}$$

Water Shortage: Water needed in excess of precipitation and storage to meet demand

$$\text{Shortage} = \text{Water Needed (current month)} - \text{Storage (previous month)} \text{ when the difference is negative}$$

Runoff: Water lost when precipitation is greater than PE and Storage is at capacity

$$\text{Runoff} = \text{Extra Water (current month)} + \text{Storage (previous month)} \text{ when sum} > 100$$

Actual Evapotranspiration (AE): the amount of water that is actually lost through evaporation and transpiration

$$\text{AE} = \text{PE} - \text{Shortage}$$



Further Investigations

Have students:

1. Examine the GLOBE soil moisture data from the site where they modeled the water balance. What correlation can they find between your model and the soil moisture data?
2. Graph their measurements of water chemistry. Are there any indications of changes in the water balance that may correlate with water quality?
3. Use their model to examine possible effects of a hotter summer or wetter rainy season than normal.
4. Think about other factors that may affect their soil moisture such as vegetative cover, soil type, etc. How could they incorporate these variables into their model?

Have students think about assumptions that are made in this simple model such as 'soil holds 100 mm of water' or 'all water not held in storage runs off'. How might these assumptions affect their results? How could they make the model better?



Example Answers: School: Reynolds Jr Sr High School, Greenville, PA, US, 1999 data)

Completed Water Balance Table

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	120	70	55	121	63	50	77	84	62	35	109	56
Water Needed (PE)	0	0	0	42	85	118	14	109	83	36	20	0
Extra Water	120	70	55	79							88	56
Water Needed					22	68	64	25	21	1		
Storage	100	100	100	100	78	10					88	100
Shortage							53	25	21			
Runoff	20	70	55	79								44
Actual Evapotranspiration	0.0	0.0	0.0	42	85	118	87	84	62	35	20	0
Temperature (°C)	-4.6	-0.7	-1.1	9.0	14.8	19.5	22.4	19.2	17.0	8.9	6.2	-1.6

Completed Potential Evaporation Table

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Monthly Temperature (°C)	-4.6	-0.7	-1.1	9	14.8	19.5	22.4	19.2	17	8.9	6.2	-1.6
Heat Index (from equation)	0	0	0	2.4	5.2	7.9	9.7	7.7	6.4	2.4	1.4	0
UPE (from equation)	0	0	0	38.1	68.2	94.2	110.9	92.5	80.2	37.6	24.6	0
Correction Factor (from table)	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
PE (UPE x CF)	0	0	0	42	85	118	141	109	83	36	20	0

Using the equation method (step 2) – I is the sum of the monthly Heat Indexes. I = 43

And m is an exponent calculated in step 3a.

m = 1.17

Method 1: Calculating Potential Evapotranspiration Using Graphs

Calculating Potential Evapotranspiration (PE) Using Graphs Work Sheet

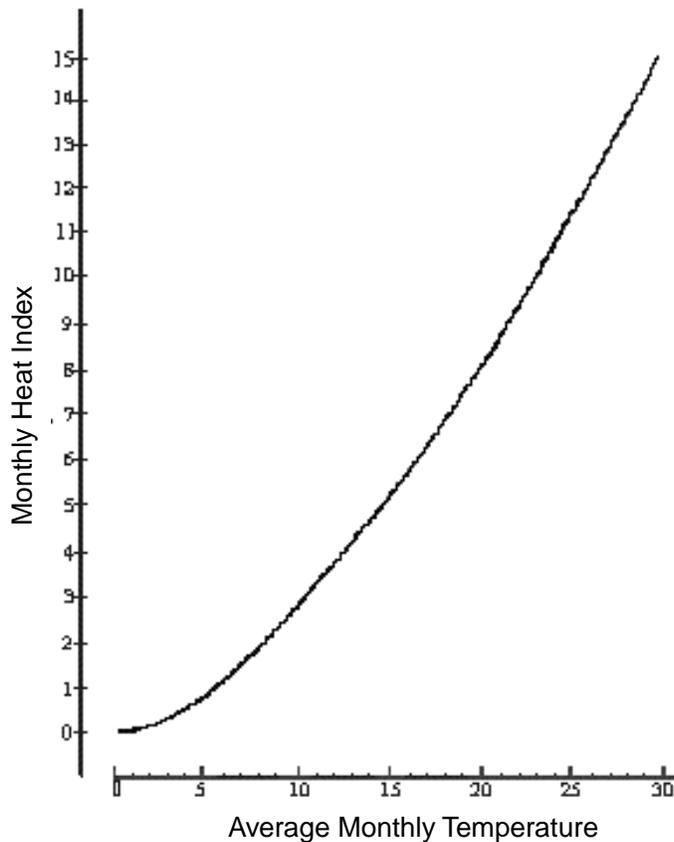
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Monthly Temperature (°C)												
Heat Index (from graph)												
UPE (from graph)												
Correction Factor (from table)												
PE (UPE x CF)												

Step 1

Find the Average Monthly Temperature for your site using the GLOBE data server.

Step 2

Find the **Heat Index** for each month from the graph below.



Month	Average Monthly Temperature	UPE (Unadjusted Potential ET (mm))
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		
Annual Heat Index _____		

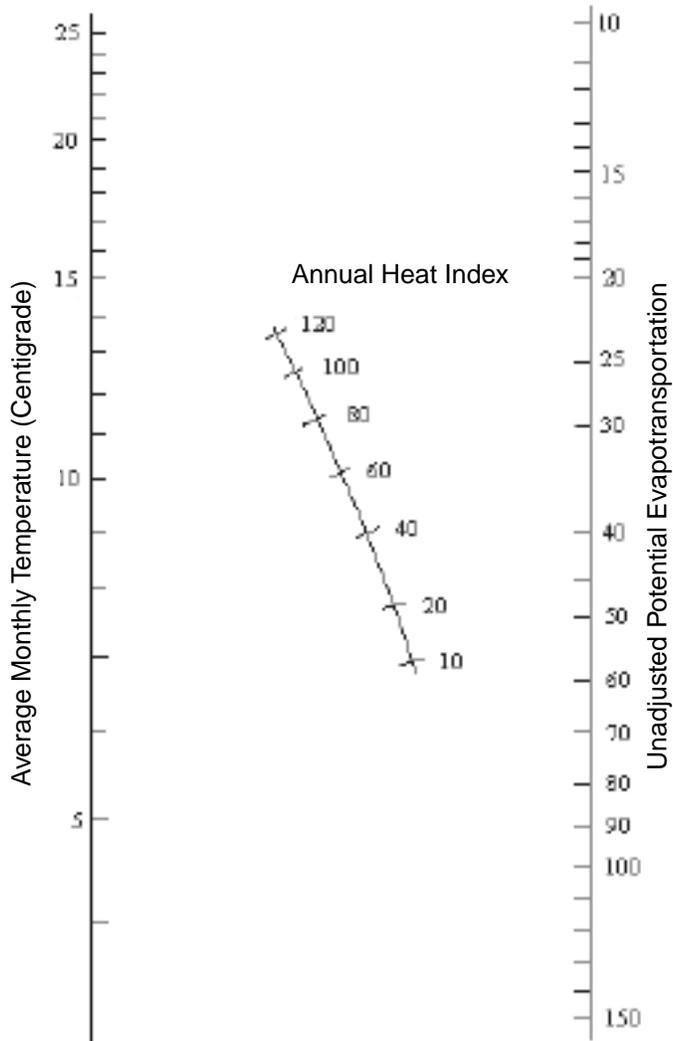
Step 3

Add the Monthly Heat Indexes together to get the Annual Heat Index: _____

Step 4

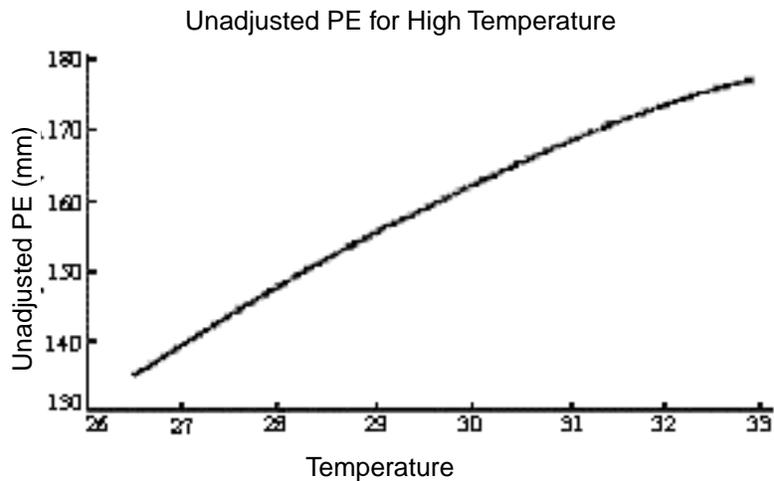
Use the **Annual Heat Index** and the **Average Monthly Temperature** for each month to find the **Unadjusted Potential Evapotranspiration (UPE)** from the graph below. **Note:** If the average temperature for the month <0, the UPE for that month is 0. If the average temperature for the month >25.0, use the **UPE for High Temperatures** graph.

Unadjusted Potential Evapotranspiration



Annual Heat Index _____		
Month	Average Monthly Temperature	UPE (Unadjusted Potential ET (mm))
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

Note: To use the graph above, find your Average Monthly Temperature on the left and your Annual Heat Index in the center. Make a straight line joining the 2 points across the graph and read the UPE on the right.



Note: Draw a vertical line up from temperature to the curve, then a horizontal line left from the curve to the UPE line. For example, a temperature of 27° C would have a UPE of ~ 140 mm

Step 5

Find the latitude of the school. Record the **Correction Factor** for each month from the table below.

Daylight Correction Factors for Potential Evapotranspiration

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.01	1.04
10 N	1.00	0.91	1.03	1.03	1.08	1.06	1.08	1.07	1.02	1.02	0.98	0.99
20 N	0.95	0.90	1.03	1.05	1.13	1.11	1.14	1.11	1.02	1.00	0.93	0.94
30 N	0.90	0.87	1.03	1.08	1.18	1.17	1.20	1.14	1.03	0.98	0.89	0.88
40 N	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
>50 N	0.74	0.78	1.02	1.15	1.33	1.36	1.37	1.25	1.06	0.92	0.76	0.70
10 S	1.08	0.97	1.05	0.99	1.01	0.96	1.00	1.01	1.00	1.06	1.05	1.10
20 S	1.14	1.00	1.05	0.97	0.96	0.91	0.95	0.99	1.00	1.08	1.09	1.15
30 S	1.20	1.03	1.06	0.95	0.92	0.85	0.90	0.96	1.00	1.12	1.14	1.21
40 S	1.27	1.06	1.07	0.93	0.86	0.78	0.84	0.92	1.00	1.15	1.20	1.29
>50 S	1.37	1.12	1.08	0.89	0.77	0.67	0.74	0.88	0.99	1.19	1.29	1.41

Step 6

Multiply the Correction Factor by the UPE to find the Potential Evapotranspiration (PE). Record the PE on the *Water Balance Work Sheet*.

Method 2: Calculating Potential Evapotranspiration Using Formulas

Older students, or schools which have monthly average temperatures outside the range of the graphs, may use the following formulas to find the PE.

Step 1

First calculate a monthly heat index (i) for each month using the following formula

$$i = \left(\frac{T}{5}\right)^{1.514} \quad \text{for } T > 0$$
$$i = 0 \quad \text{for } T \leq 0$$

where T is the average temperature of the month in degrees C.

Step 2

Find the sum of the twelve monthly heat indexes to get the annual heat index (I)

$$I = i_{\text{JAN}} + i_{\text{FEB}} + i_{\text{MAR}} \dots + i_{\text{DEC}}$$

Step 3

- a. First calculate the exponent m , to be used below. m is a number that depends on I . The value of m is given by the formula

$$m = (6.75 \times 10^{-7}) I^3 - (7.71 \times 10^{-5}) I^2 + (1.79 \times 10^{-2}) I + 0.492$$

- b. To get the unadjusted PE use the formula

$$\text{Unadjusted PE (millimeters)} = \begin{cases} 0 & T < 0^\circ\text{C} \\ 16\left(\frac{10T}{I}\right)^m & T \leq 0 \leq 26.5^\circ\text{C} \\ -415.85 + 32.24T - 0.43T^2 & T > 26.5^\circ\text{C} \end{cases}$$

Where T is the average temperature in degrees C for the specific month being considered.

- c. Once the unadjusted PE has been calculated, use the Daylength Correction Table to find the adjusted PE.

*adapted from *Physical Geography Today: A Portrait of a Planet* (1978) Robert A. Muller and Theodore M. Oberlander, Random House: using the Thornthwaite Formula for Potential Evapotranspiration

Method 1: Calculating Potential Evapotranspiration Using Graphs

Calculating Potential Evapotranspiration (PE) Using Graphs Work Sheet

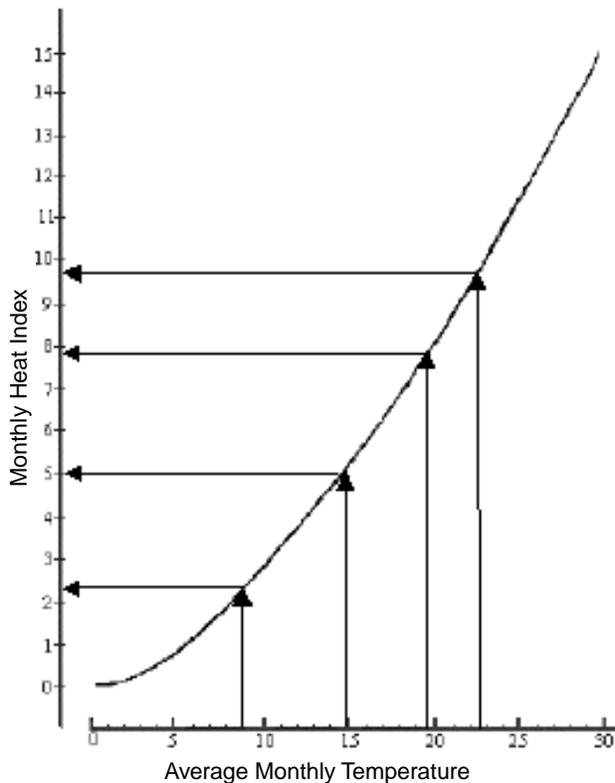
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Monthly Temperature (°C)	-4.6	-0.7	-1.1	9.0	14.8	19.5	22.4	19.2	17.0	8.9	6.2	-1.6
Heat Index (from graph)	0	0	0	38	66	91	108	89	78	37	25	0
UPE (from graph)	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.01	1.04
Correction Factor (from table)	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
PE (UPE x CF)	0	0	0	42	82	114	137	105	81	36	21	0

Step 1

Find the Average Monthly Temperature for your site using the GLOBE data server.

Step 2

Find the **Heat Index** for each month from the graph below.



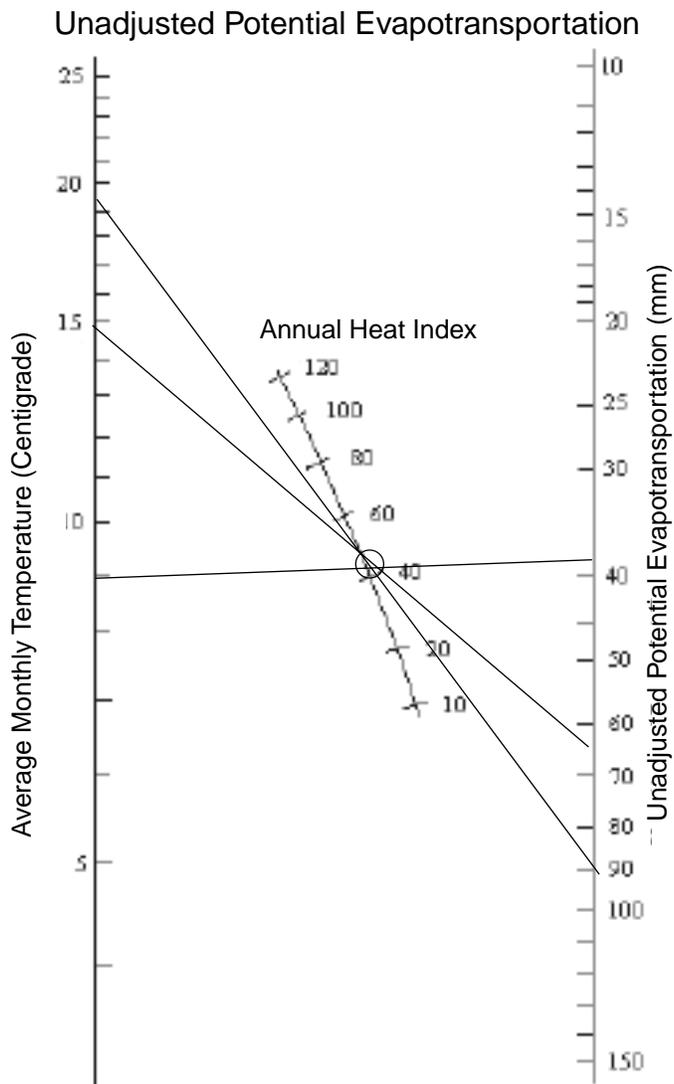
Month	Average Monthly Temperature	UPE (Unadjusted Potential ET (mm))
Jan	-4.6	0
Feb	-0.7	0
Mar	-1.1	0
Apr	9.0	2.3
May	14.8	5.0
Jun	19.5	7.8
Jul	22.4	9.8
Aug	19.2	7.6
Sep	17.0	6.5
Oct	8.9	2.4
Nov	6.2	1.2
Dec	-1.6	0
Annual Heat Index		<u>42.6 (rounds to 43)</u>

Step 3

Add the Monthly Heat Indexes together to get the Annual Heat Index: 43

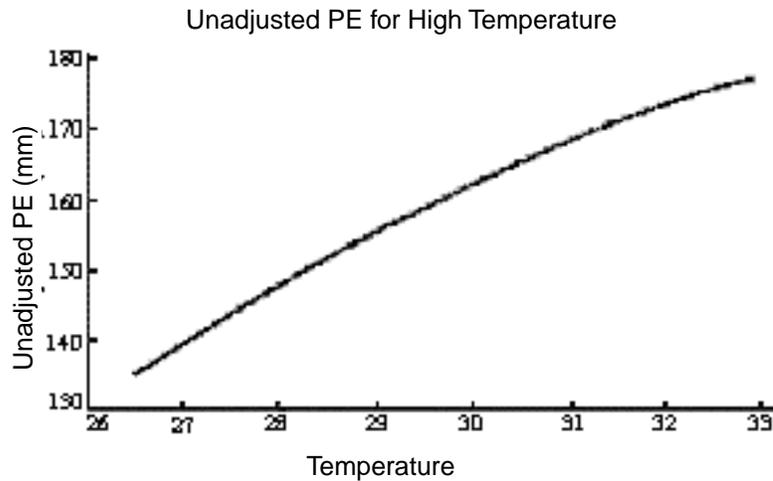
Step 4

Use the **Annual Heat Index** and the **Average Monthly Temperature** for each month to find the **Unadjusted Potential Evapotranspiration (UPE)** from the graph below. **Note:** If the average temperature for the month <0 , the UPE for that month is 0. If the average temperature for the month >25.0 , use the **UPE for High Temperatures** graph.



Annual Heat Index <u>43</u>		
Month	Average Monthly Temperature	UPE (Unadjusted Potential ET (mm))
Jan	-4.6	0
Feb	-0.7	0
Mar	-1.1	0
Apr	9.0	38
May	14.8	66
Jun	19.5	91
Jul	22.4	108
Aug	19.2	89
Sep	17	78
Oct	8.9	37
Nov	6.2	25
Dec	-1.6	0

Note: To use the graph above, find your Average Monthly Temperature on the left and your Annual Heat Index in the center. Make a straight line joining the 2 points across the graph and read the UPE on the right.



Note: Draw a vertical line up from temperature to the curve, then a horizontal line left from the curve to the UPE line. For example, a temperature of 27° C would have a UPE of ~ 140 mm

Step 5

Find the latitude of the school. Record the **Correction Factor** for each month from the table below.

Daylight Correction Factors for Potential Evapotranspiration

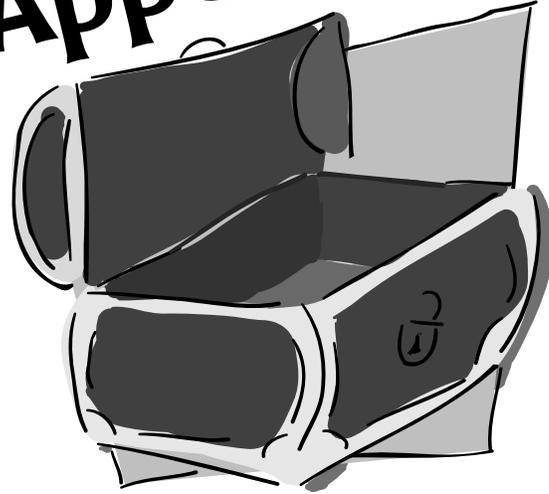
Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.01	1.04
10 N	1.00	0.91	1.03	1.03	1.08	1.06	1.08	1.07	1.02	1.02	0.98	0.99
20 N	0.95	0.90	1.03	1.05	1.13	1.11	1.14	1.11	1.02	1.00	0.93	0.94
30 N	0.90	0.87	1.03	1.08	1.18	1.17	1.20	1.14	1.03	0.98	0.89	0.88
40 N	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
>50 N	0.74	0.78	1.02	1.15	1.33	1.36	1.37	1.25	1.06	0.92	0.76	0.70
10 S	1.08	0.97	1.05	0.99	1.01	0.96	1.00	1.01	1.00	1.06	1.05	1.10
20 S	1.14	1.00	1.05	0.97	0.96	0.91	0.95	0.99	1.00	1.08	1.09	1.15
30 S	1.20	1.03	1.06	0.95	0.92	0.85	0.90	0.96	1.00	1.12	1.14	1.21
40 S	1.27	1.06	1.07	0.93	0.86	0.78	0.84	0.92	1.00	1.15	1.20	1.29
>50 S	1.37	1.12	1.08	0.89	0.77	0.67	0.74	0.88	0.99	1.19	1.29	1.41

Step 6

Multiply the Correction Factor by the UPE to find the Potential Evapotranspiration (PE). Record the PE on the *Water Balance Work Sheet*.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
UPE	0	0	0	38	66	91	108	89	78	37	25	0
Correction Factor	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
PE	0	0	0	42	82	114	137	105	81	36	21	0

Appendix



Site Definition Sheet

Quality Control Procedure Data Sheet

Hydrology Investigation Data Sheet

***Freshwater Macroinvertebrate Identification
Data Sheet***

Hydrology Site Map

Glossary

Hydrology Investigation

Site Definition Sheet

School name: _____ Class or group name: _____

Name(s) of Student(s) filling in Site Definition Sheet: _____

Date: _____ Check one: New Site Metadata Update

Site Name: _____
(create a unique name that describes the location of your site)

Coordinates: Latitude: _____ N or S Longitude: _____ E or W

Elevation: ____ meter

Source of Location Data (check one): GPS Other _____

If Other, describe: _____

Name of Water Body: _____
(Name commonly used on maps)

Water Type:

Salt (> 25 ppt) Brackish (2-25 ppt) Fresh (<2 ppt)

Moving Water:

Stream or river

Other _____

Approximate width of moving water: _____ meters

Standing Water:

Pond Lake Reservoir Bay Ditch Ocean Estuary

Other: _____

Size of Standing Water:

Much smaller than 50 m X 100 m

Roughly 50 m X 100 m

Much larger than 50 m X 100 m

Approximate Area of Standing Water: _____ km²

Average Depth of Standing Water: _____ meters

Sample Location:

Outlet Bank Bridge Boat Inlet Pier

Can you see the bottom?:

Yes No

Channel/Bank Material (Check all that apply):

- Soil Rock Concrete Vegetated bank

Bedrock (Check all that apply):

- Granite Lime stone Volcanics Mixed sediments Don't Know

Freshwater Habitats Present (Check all that apply):

- Rocky substrate Vegetated banks Mud Substrate Sand substrate
 Submersed vegetation Logs

Saltwater Habitats Present (Check all that apply):

- Rocky shore Sandy shore Mud flats/Estuary

Dissolved Oxygen Kit

Manufacturer: Lamotte Hach Other : _____

Model Name: _____

Alkalinity Kit

Manufacturer: Lamotte Hach Other : _____

Model Name: _____

Nitrate Kit

Manufacturer: Lamotte Hach Other : _____

Method: Zinc Cadmium

Model Name: _____

Salinity Titration Kit

Manufacturer: Lamotte Hach Other : _____

Model Name: _____

Comments: General description of your study site and metadata

Hydrology Investigation

Quality Control Procedure Data Sheet

School name: _____

Student group: _____

Date: _____

Dissolved Oxygen:

Temperature of distilled water: _____ °C; Elevation of your site: _____ meters

Dissolved Oxygen for the shaken distilled water:

Observer 1: _____ mg/L Observer 2: _____ mg/L Observer 3: _____ mg/L Average: _____ mg/L

Solubility of oxygen in water
for your temperature at
sea level from Table 3-1:

Calibration value
for your elevation
from Table 3-2:

Expected value
for DO in your
distilled water:

_____ mg/L x _____ = _____ mg/L

Salinity

Salinity of Standard: Observer 1: _____ ppt Observer 2: _____ ppt Observer 3: _____ ppt

Average Salinity: _____ ppt

Alkalinity

Standard used (check one): Baking soda standard: _____ Purchased standard: _____

Alkalinity of standard: _____ mg/L

For kits that read alkalinity directly:

Observer 1: _____ mg/L as CaCO₃ Observer 2: _____ mg/L as CaCO₃ Observer 3: _____ mg/L as CaCO₃

Average: _____ mg/L as CaCO₃

For kits in which drops are counted:

	Observer 1	Observer 2	Observer 3	Average
Number of drops:	_____ drops	_____ drops	_____ drops	_____ drops
Conversion constant for your kit and protocol:	x _____	x _____	x _____	x _____
Total Alkalinity: (mg/L as CaCO ₃)	= _____ mg/L	= _____ mg/L	= _____ mg/L	= _____ mg/L

Nitrate-Nitrogen

Observer 1: _____ mg/L NO₃⁻ - N Observer 2: _____ mg/L NO₃⁻ - N Observer 3: _____ mg/L NO₃⁻ - N

Average: _____ mg/L NO₃⁻ - N

Hydrology Investigation

Data Sheet

School name: _____

Class or group name: _____

Name(s) of Student(s) collecting data: _____

Measurement Time:

Year: _____ Month: _____ Day: _____ Time: ____:____ (UT) Time: ____:____ (Local)

Name of Site : _____

Water State: (check one)

Normal Flooded Dry Frozen Unreachable

Transparency

Cloud Cover (check one):

- | | |
|--|---|
| <input type="checkbox"/> no clouds | <input type="checkbox"/> broken (50%-90%) |
| <input type="checkbox"/> clear (<10%) | <input type="checkbox"/> overcast (>90%) |
| <input type="checkbox"/> isolated clouds (10%-24%) | <input type="checkbox"/> obscured |
| <input type="checkbox"/> scattered (25%-49%) | |

Enter data below, depending on whether you are using the Secchi Disk or the Transparency Tube method.

Secchi Disk

First Secchi Disk Test:

Distance from observer to where disk disappears _____ (m)

Distance from observer to where disk reappears _____ (m)

Distance from observer to water surface _____(m)

- Secchi Disk reaches the bottom and does not disappear.
If checked enter depth to the bottom of the water site _____ (m)

Second Secchi Disk Test:

Distance from observer to where disk disappears _____ (m)

Distance from observer to where disk reappears _____ (m)

Distance from observer to water surface _____(m)

- Secchi Disk reaches the bottom and does not disappear.
If checked enter depth to the bottom of the water site _____ (m)

Third Secchi Disk Test:

Distance from observer to where disk disappears _____ (m)

Distance from observer to where disk reappears _____ (m)

Distance from observer to water surface _____(m)

- Secchi Disk reaches the bottom and does not disappear.
If checked enter depth to the bottom of the water site _____ (m)

Transparency Tube

Note: If the image is still visible when the tube is full, input the length of the tube and check the “Greater than the depth of the turbidity tube”.

Test 1(cm): _____ Greater than depth of transparency tube?

Test 2(cm): _____ Greater than depth of transparency tube?

Test 3(cm): _____ Greater than depth of transparency tube?

Water Temperature

Average: _____ °C	Observer Name	Temperature °C
	1.	
	2.	
	3.	

Dissolved Oxygen

Average: _____ mg/L	Observer Name	Dissolved Oxygen (mg/L)
	1.	
	2.	
	3.	

Conductivity: Temperature of water sample being tested: _____ °C

Average: _____ µS/cm	Observer Name	Conductivity (µS/cm)
	1.	
	2.	
	3.	

Value of Conductivity Standard: _____ MicroSiemens/cm (µS/cm)

Water pH: Measured with: (check one) paper meter

Average: _____	Observer Name	If salt added, conductivity (µs/cm)	pH
	1.		
	2.		
	3.		

Value of buffers used: pH 4 pH 7 pH 10 (Check all used.)

Salinity

Tide Information

Time of tide before measurement: _____ hours and minutes

Check one: High Tide: Low Tide Check one: UT Local time

Time of tide after measurement: _____ hours and minutes

Check one: High Tide: Low Tide Check one: UT Local time

Place where these tides occur: _____

Salinity (Hydrometer Method)

	Test 1	Test 2	Test 3
Temperature of water in 500 mL cylinder	_____ °C	_____ °C	_____ °C
Specific Gravity:	_____	_____	_____
Salinity of Sample:	_____ ppt	_____ ppt	_____ ppt
Average Salinity:	_____ ppt		

Optional Salinity Titration

Salinity of Sample:	Test 1: _____ ppt	Test 2: _____ ppt	Test 3: _____ ppt
Average Salinity:	_____ ppt		

Alkalinity: (For kits that read alkalinity directly)

Average:	Observer Name	Alkalinity (mg/L as CaCO ₃)
_____ mg/L as CaCO ₃	1.	
	2.	
	3.	

Alkalinity: (Hach kits or other kits in which drops are counted)

Observer Name	Number of Drops	x	Conversion constant for your kit	=	Total Alkalinity (mg/L as CaCO ₃)
1.		x		=	
2.		x		=	
3.		x		=	

Average: _____ mg/L as CaCO₃

Total Nitrate + Nitrite ($\text{NO}_3^- \text{-N} + \text{NO}_2^- \text{-N}$)

Average: Nitrate+Nitrite _____ mg/L	Observer Name	Nitrate and Nitrite (mg/L $\text{NO}_3^- \text{-N} + \text{NO}_2^- \text{-N}$)
	1.	
	2.	
	3.	

Nitrite-Nitrogen ($\text{NO}_2^- \text{-N}$) (optional)

Average: $\text{NO}_2^- \text{-N}$ _____ mg/L	Observer Name	Nitrite (mg/L $\text{NO}_2^- \text{-N}$)
	1.	
	2.	
	3.	

Freshwater Macroinvertebrate Identification

Data Sheet

School name: _____

Class or group name: _____

Name(s) of Student(s) collecting data: _____

Date samples collected: Year : _____ Month: _____ Day : _____

Name of Study Site : _____

For a rocky bottom with running water site:

Riffles: Number of samples: _____

Runs: Number of samples: _____

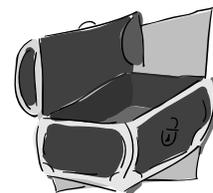
Pools: Number of samples: _____

(Total samples = 3)

For a multi-habitat site:

Habitats	Estimate of % Area	Number of samples ($\frac{\%Area \times 20}{100}$)
Submersed vegetation		
Vegetated banks, around logs, snags, roots		
Muddy bottom		
Gravel or sand		
Total	100%	20 samples

Glossary



Abundance

The number of organisms in a sample or taxon

Accuracy

The closeness of a measured value to a true value (See *precision*)

Acid

Any substance that can donate a hydrogen atom or proton (H^+) to any other substance.

Acid Rain

Rain characterized by pH values below 6

Acidic

Characterized by $pH < 7$

Acidity

1. The amount of strong base (e.g. Sodium Hydroxide) necessary to titrate a sample to a pH of around 10.3; measures the base neutralizing capacity of a water
2. An acid quality or state (Common Usage)

Aerosols

Liquid or solid particles dispersed or suspended in the air

Alkaline

Characterized by $pH > 7$

Alkalinity

The amount of strong acid (e.g. Hydrochloric Acid) necessary to titrate a sample to a pH of around 4.5. Measures the acid neutralizing capacity of a water and is often reprinted as ppm $CaCO_3$.

Aqueous

Containing or contained in water

Background Concentration

The level of chemicals present in a water due to natural processes rather than due to human contribution

Base

Any substance that accepts a proton (H^+) from another substance

Benthic

Pertaining to bottom dwelling water animals or plants

Biodiversity

The variety of organisms

Brackish Water

Water containing dissolved salts at a concentration less than seawater, but greater than fresh water. The concentration of dissolved salts is usually in the range 1000 - 10,000 ppm.

Buffer Solution

One that resists change in its pH when either hydroxide (OH^-) or protons (H^+) are added. The stable and known pH value of these solutions make them suitable for calibrating pH measuring devices.

Calibration

To set or check an instrument against an index or standard of known value through some type of proportional or statistical relationship.

Catchment Basin

1. The part of a river-basin from which rain is collected, and from which the river gets its water. Each catchment basin is with the boundary defined by the watershed. The term watershed is often incorrectly used to describe catchment basins.
2. The area drained by a river or stream

Chlorinity

The chlorine concentration of a solution

Colorimetric Method

Many procedures for measuring dissolved substances depend on color determination. The underlying assumption is that the intensity of the color is proportional to the concentration of the dissolved substance in question.

Conductivity

The ability of an aqueous solution to carry an electrical current. Depends upon the concentration of dissolved salts (ions), the type of ions, and the temperature of the solution. Typical units are microSiemens/cm or micromhos/cm. (These are equivalent).

Denitrification

The act or process of reducing nitrate to ammonia. Nitrite may be an intermediate product.

Density

The ratio of the mass of a substance to its volume

Dissolved Oxygen

The mass of molecular oxygen dissolved in a volume of water. The solubility of oxygen is affected non-linearly by temperature; more oxygen can be dissolved in cold water than in hot water. The solubility of oxygen in water is also affected by pressure and salinity; salinity reduces the solubility of oxygen in water.

Dissolved Solids

Solid particles that have become liquid by immersion or dispersion in a liquid (e.g. salts)

Enrichment

Making a water more productive (e.g. by adding nutrients)

Eutrophication

A high level of productivity in a water body, often due to an increased supply of nutrients

Evaporation (of water)

Change from liquid to vapor at a temperature below the boiling point

Evenness

How equally abundant the taxa are in a sample

Hydrologic Cycle

The series of stages through which water passes from the atmosphere to Earth and returns to the atmosphere. Includes condensation to form clouds, precipitation, accumulation in soil or bodies of water and re-evaporation

Hypothesis

A tentative statement made to test its logical or empirical consequences

In Situ

Situated in its original natural place (Latin)

Lentic

Relating to, or living in standing water (lakes, ponds or swamps)

Logarithmic Scale

A scale in which each unit increment represents a tenfold increase or decrease

Lotic

Relating to, or living in actively moving water (streams or rivers)

Macroinvertebrates

Animals that have no backbone and are visible with the naked eye (>0.5 mm)

MicroSiemens/cm

Metric unit of measurement for conductivity. Equivalent to micromhos/cm

Micromhos/cm

Standard unit of measurement for conductivity. Equivalent to microSiemens/cm

Molar

Unit of measurement for concentration (moles per liter of solution).

Molecule

The smallest fundamental unit (usually a group of atoms) of a chemical compound that can take part in a chemical reaction

Natural Waters

Systems that typically consist of the sediments/minerals and the atmosphere as well as the aqueous phase; they almost always involve a portion of the biosphere.

Neutral

Characterized by pH = 7

Nitrate

A salt of nitric acid (HNO_3). Nitrates are often highly soluble and can be reduced to form nitrites or ammonia.

Nitrate-Nitrogen

Concentrations of nitrate (NO_3^-) are often expressed as mass of nitrogen per volume of water

Nitrite

A salt of nitrous acid (HNO_2). Nitrites are often highly soluble and can be oxidized to form nitrates or reduced to form ammonia

Nitrite-Nitrogen

Concentrations of nitrite (NO_2^-) are often expressed as mass of nitrogen per volume of water.

pH

The negative logarithm of the molar concentration of protons (H^+) in solution

Photosynthesis

The process in which the energy of sunlight is used by organisms, esp. green plants to synthesize carbohydrates from carbon dioxide and water

**Pool**

In a stream or river, a deeper region with slower-moving water and smaller sediments

ppm

Usually parts per million. (Equivalent to milligrams per Liter in GLOBE calculations)

ppm Chlorinity

By weight, equal to milligrams of chlorine per Liter, with the assumption that one Liter of water weighs one kilogram

ppt

Usually parts per thousand. (Equivalent to grams per Liter in GLOBE calculations)

Precipitation

1. The falling products of condensation in the atmosphere. e.g. rain, snow, hail
2. Separation in solid form from a solution due to chemical or physical change (e.g. adding a reagent or lowering the temperature)

Precision

A measurement for the degree of agreement between multiple analyses of a sample (See *accuracy*)

Productivity

The formation of organic matter averaged over a period of time such as a day or a year

Proton

A positively charged elementary particle found in all atomic nuclei. The positively charged hydrogen atom (H⁺)

Reagent

A substance used to cause a reaction, especially to detect another substance

Reduce

In chemical terms, to change from a higher to a lower oxidation state (i.e. gain electrons)

Richness

The number of different taxa

Riffle

In a stream or river, a shallower area with faster-flowing water and larger sediments

Run

In a stream or river, an intermediate category between pool and riffle. A run does not have the turbulence of a riffle, but moves faster than in a pool.

Runoff

The component of precipitation that appears as water, flowing in a stream or river

Saline Water

Water containing salt or salts

Salinity

A measure of the concentration of dissolved salts, mainly sodium chloride, in brackish and salty water

Salts

Ionic compounds which in water solution yield positive (excluding H⁺) and negative (excluding OH⁻) ions ; the most common of which is sodium chloride, or “table salt”

Saturated Solution

A solution that contains the maximum amount of dissolved substances at a given temperature and pressure

Snag

A tree or branch embedded in the bed of the water body

Solubility

The relative capability of being dissolved

Solute

A substance that dissolves in another to form a solution

Solution

A homogeneous mixture containing two or more substances

Solvent

A substance that dissolves another to form a solution

Specific Heat

The heat in calories required to raise the temperature of one gram of a substance by one degree Celsius

Specific Gravity

The ratio of the density of a substance to the density of water (at 25°C and 1 atmosphere)

Standardization

To cause to conform to a standard

Standard

A measure with a value established through outside means for use in calibration; a known reference



Suboxic Water

Very low levels of dissolved oxygen; denitrification occurs (nitrate is converted to ammonia)

Suspended Solids

Solid particles in a fluid that do not dissolve or settle out

Suspensions

A mixture in which very small particles of a solid remain suspended without dissolving

Taxa

Plural of taxon

Taxon

A group of organisms of any particular rank (such as order, family, genus). Singular of taxa

Tides

The periodic rise and fall of the waters of the ocean and its inlets, produced by the attraction of the moon and sun. Occurs about every 12 hours.

Titrant

The reagent added in a titration

Titration

The process of ascertaining the quantity of a given constituent by addition of a liquid reagent of known strength, and measuring the volume of reagent necessary to convert the constituent through a given reaction

Topography

The surficial relief features of an area

Total Dissolved Solids

The total mass of solids remaining when a given volume of filtered water is evaporated to total dryness following an accepted protocol

Transparency

Having the property of transmitting rays of light through its substance so that bodies located behind can be distinctly seen

Turbid

Not clear, or transparent due to stirred up sediment

Water Quality

A distinctive attribute or characteristic trait of water, described by physical, chemical, and biological properties

Watershed

The line separating the waters flowing into different rivers, river basins or seas; a narrow elevated tract of ground between two drainage areas.; see *catchment basin*

Water Vapor

Water in the gaseous phase