

THE HYDROLOGIC (WATER) CYCLE

OBJECTIVES

The student will do the following:

1. Construct a model of the hydrologic cycle.
2. Observe that water is an element of a cycle in the natural environment.
3. Explain how the hydrologic cycle works and why it is important.
4. Compare the hydrologic cycle to other cycles in nature such as nitrogen cycle, carbon cycle.

BACKGROUND INFORMATION

Because the Earth is essentially a closed system containing all the water we will ever have, all of this water moves in a pattern called the Hydrologic or Water Cycle. This activity will demonstrate some of the ways water moves through natural systems, how water and the atmosphere are polluted and purified, how the water cycle purifies polluted water, and what role plants and soil have in the processes.

The form of water is always changing. Water moves from sky to Earth and back to the sky again. This is called the water cycle. Water falls to Earth as rain, snow, sleet, or hail. Some of the water soaks into the ground and is stored as groundwater. The rest flows into streams, lakes, rivers, and oceans. The sun warms surface water and changes some of it into water vapor. This process is called evaporation. Plants give off water vapor in a process called transpiration. The heated water vapor rises into the sky and forms clouds. When the vapor in the clouds condenses, it falls back to the Earth as rain or snow. The water cycle has then come full circle and begins again.

The water cycle can be demonstrated using two-liter soft drink bottles and other materials. Through capillary action, water moves up the wick from the bottom bottle unit into the soil. From there it evaporates and becomes water vapor in the central bottle unit. Water vapor exits from plants growing in the bottle

SUBJECTS:

Science (Chemistry, Biology, Earth Science)

TIME:

1 class period

MATERIALS:

three 1- or 2- liter bottles, two bottle caps
60 cm heavy cotton string (wick)
one clear 35mm film can
soil, water, ice, moss and plant seedstools to
convert bottles: wax pencil, clear tape,
scissors, box top, paper punch, tapered
reamer, poke, awl, silicone sealant, razor in
a safety holder
Plexiglas™ sheet

through transpiration caused by the evaporation of water from the leaves of the plants. This water vapor is cooled by the ice above that causes it to condense onto the cold surface of the inverted bottle, just as water vapor condenses around particles in the atmosphere and forms clouds. These drops of condensation eventually run down the bottle and flow down the string -- precipitation. Precipitating water then collects in the film can, just as falling rain or snow collects in ponds, lakes, springs, seas, and oceans.

Terms

capillary action: the action by which the surface of a liquid where it is in contact with a solid (as in a capillary tube) is elevated or depressed depending on the relative attraction of the molecules of the liquid for each other and for those of the solid

condensation: (1) the process of changing from a vapor to a liquid; (2) a liquid obtained by the coming together of a gas or vapor

evaporate: to pass off in vapor or in invisible minute particles (to cause evaporation)

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow

transpiration: process in which water absorbed by the root systems of plants, moves up through the plants, passes through pores (stomata) in their leaves or other parts, and then evaporates into the atmosphere as water vapor; the passage of water vapor from a living body through a membrane or pores

water vapor: water in a gaseous (vapor) form and diffused as in the atmosphere

ADVANCE PREPARATION

- A. Gather the materials and have them laid out for students to use at stations.
- B. Caution students on use of scissors.

PROCEDURE

- I. Setting the stage
 - A. Remove labels from three bottles by using a hair dryer set on low. Hold it about 15cm away from blowing nozzle and move it rapidly up and down so that the air warms the seam

of the label.

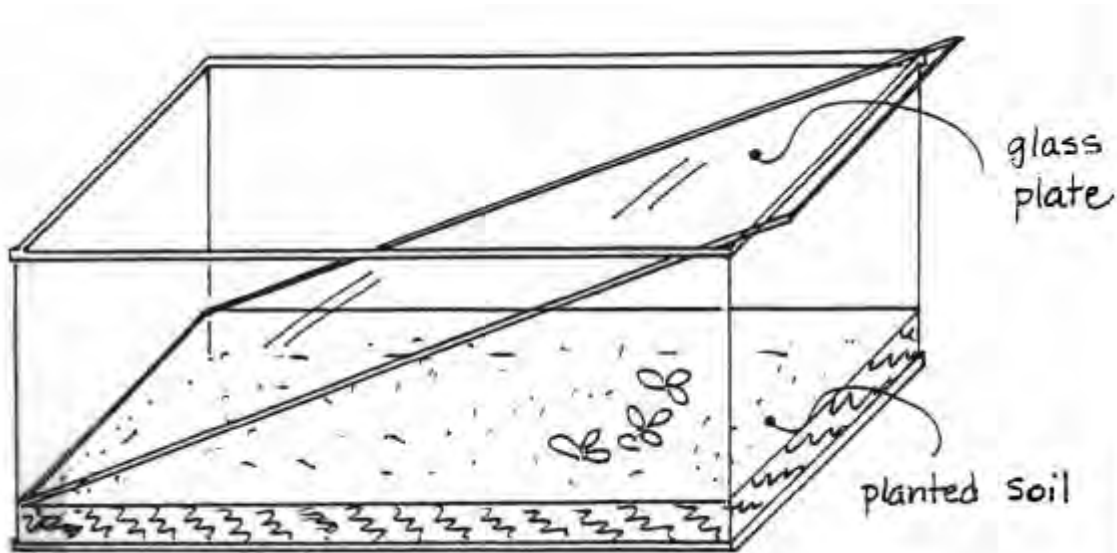
- B. Cut bottle A just below the shoulder or below the curve at the top of the bottle so a straight edge remains on the bottle.
- C. Cut B and C bottles just above the hips or above the black bases so bottles have straight sides.
- D. Poke a hole in one cap on B. Insert a loop of string (about 40cm) so about 5cm hangs down from the cap.
- E. Place a cap with no hole on C. Tie about 20 cm of string around the bottle neck so one end hangs down about 7cm.

II. Activity

- A. Introduce and explain the new terms using the chalkboard. Give everyday examples of each term.
- B. Build a model that will demonstrate the water cycle.
 - 1. Assemble bottles by placing C upside down in bottle B and B upside down in bottle A. (See diagram.)
 - 2. Thoroughly wet both wicks. This will bring a constant source of water from a reservoir to plant roots. Wicking works by capillary action, the way water moves along fibers of paper towels and cotton string. Add about 150ml of water to A. This is the water source for the cycle. Fill B with enough premoistened soil to cover the loop of the string (200cc or 1 cup). String wick should run up into the soil and not be pressed against side of bottle.
 - 3. Plant two or three seeds of a fast growing plant, such as Chinese cabbage or turnip, in the soil around the perimeter of bottle B. When bottle C isn't being used, leave it off bottle B so that air circulates and seeds can sprout and grow.
 - 4. Place clear film can on top of the soil in center of bottle B so that the wick from bottle C hangs into it. Trim the film can or use a bottle cap if a full-sized can will not fit between bottle C and the soil in bottle B.
 - 5. Fill bottle C with ice water or fill it with water and freeze it. Observe the film can after a few hours.

III. Follow-up

- A. Have the students test the water quality in the film can. Test for pH, turbidity, and minerals.
- B. Another way to set up a hydrologic cycle would be in an aquarium. One group of students may choose to set up a model this way.
 1. In a clean, dry, large aquarium, place a soil mixture in one end so it slopes down towards the other end of the aquarium.
 2. Tilt the aquarium so the soil is elevated about 10 cm. Place something under the high end to maintain this position for the entire time (the soil should stay put).
 3. Pour the two liters of H₂O into the other end so that a pool is formed.



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orts in the soil end and mist well with a sprayer to dampen the plants and the soil but not enough to form mud.

5. Place the Plexiglas™ sheet so that it rests on the soil and flush against one end of the aquarium. The other end will rest against the top of the aquarium.

6. Set this near a window that receives indirect (north) light or use a small 2- tube grow light placed over the top of the aquarium.
7. Allow this aquarium, which is now a terrarium, to operate for a day or two. Mark the level of water in the pool.
8. As evaporation occurs from the pool, observe condensation on the diagonal Plexiglas™ sheet. This will represent clouds. As the condensation becomes heavy, drops will collect and run down to the lower end and into the soil. Mosses/liverworts will represent plants of the Earth. If there are indentations in the soil, small pools may form that may fill up, overflow, and form streams to the pool (ocean). Some of the water will penetrate the soil and descend to a certain level. This represents groundwater. This water will also eventually go into the pool (ocean). Preparation of the soil could artificially stimulate the cycling to occur. It is suggested that the system be allowed to operate for several days or weeks without artificial manipulation to see if streams will naturally occur.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

THE HYDROLOGIC (WATER) CYCLE

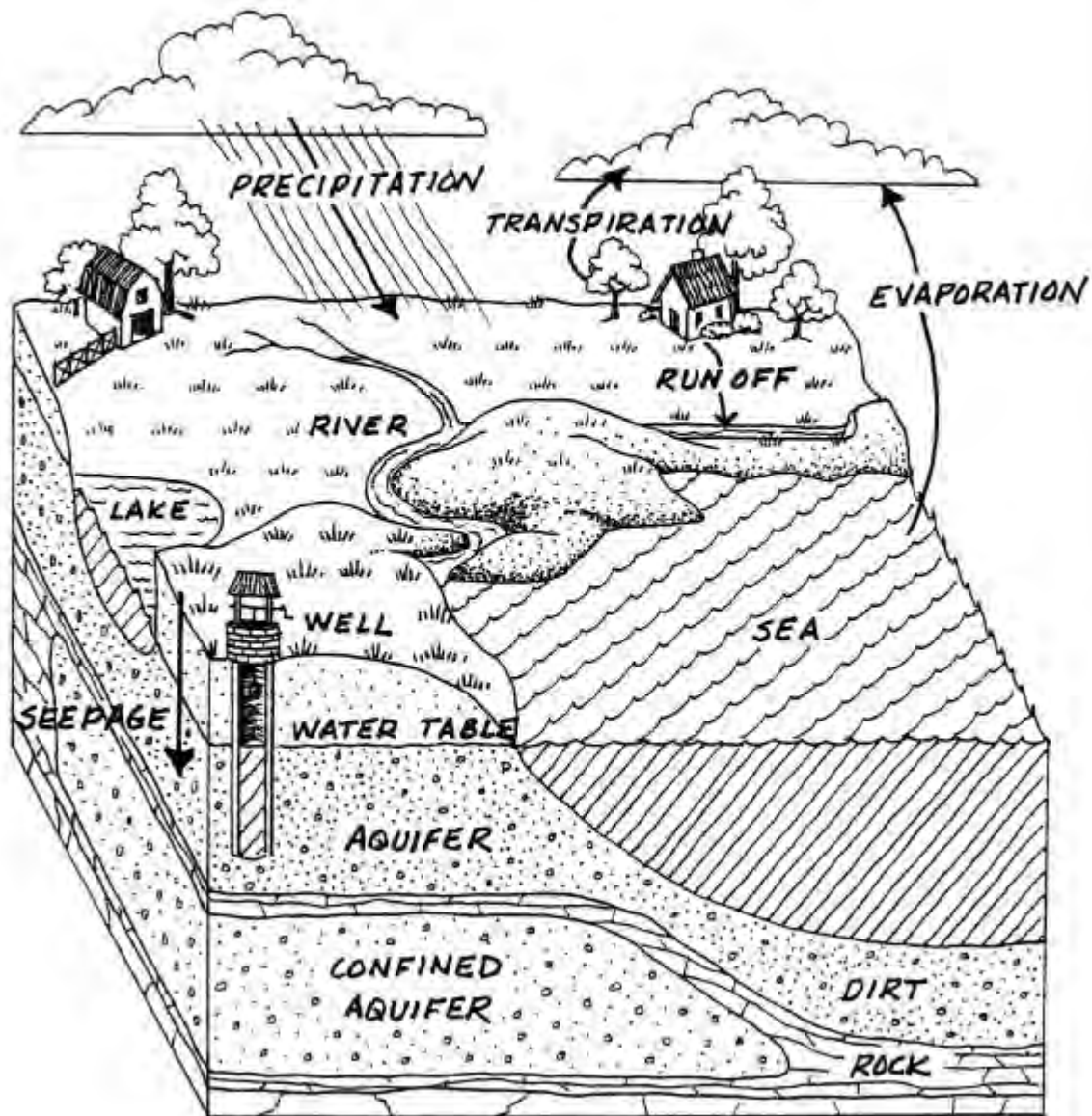
1. What part of this experiment demonstrated capillary action?
2. How could you tell that evaporation and transpiration were taking place?
3. What is the difference between evaporation and transpiration?
4. Another name for rain is_____.
5. What does the ice do in this experiment?
6. Do you think the water in the film can will contain impurities? Explain your answer.
7. What does the water in the bottom bottle represent?

THE HYDROLOGIC (WATER) CYCLE

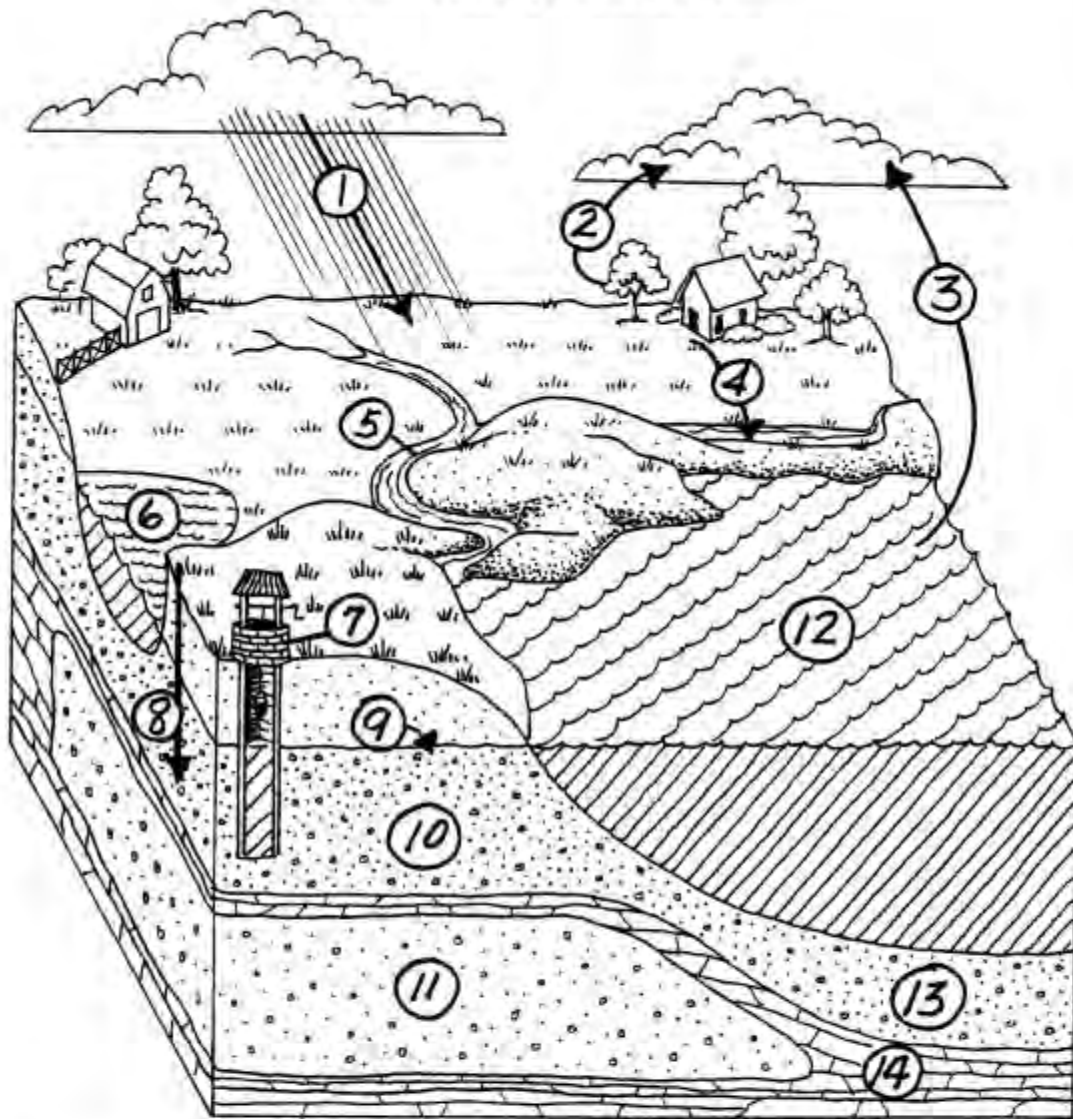
ANSWER KEY

1. What part of this experiment demonstrated capillary action?
(String)
2. How could you tell that evaporation and transpiration were taking place?
(condensation on bottle C and possibly bottle B)
3. What is the difference between evaporation and transpiration?
(Transpiration is the production of water vapor from a living organism. Evaporation is the formation of a vapor, in this case, water, from any source.)
4. Another name for rain is precipitation.
5. What does the ice do in this experiment?
(causes condensation due to a change in temperature)
6. Do you think the water in the film can will contain impurities? Explain your answer.
(Not really. When the water evaporates, it does not carry impurities with it. However, it may pick up impurities from the string.)
7. What does the water in the bottom bottle represent?
(Groundwater)

THE HYDROLOGIC CYCLE



THE HYDROLOGIC (WATER) CYCLE

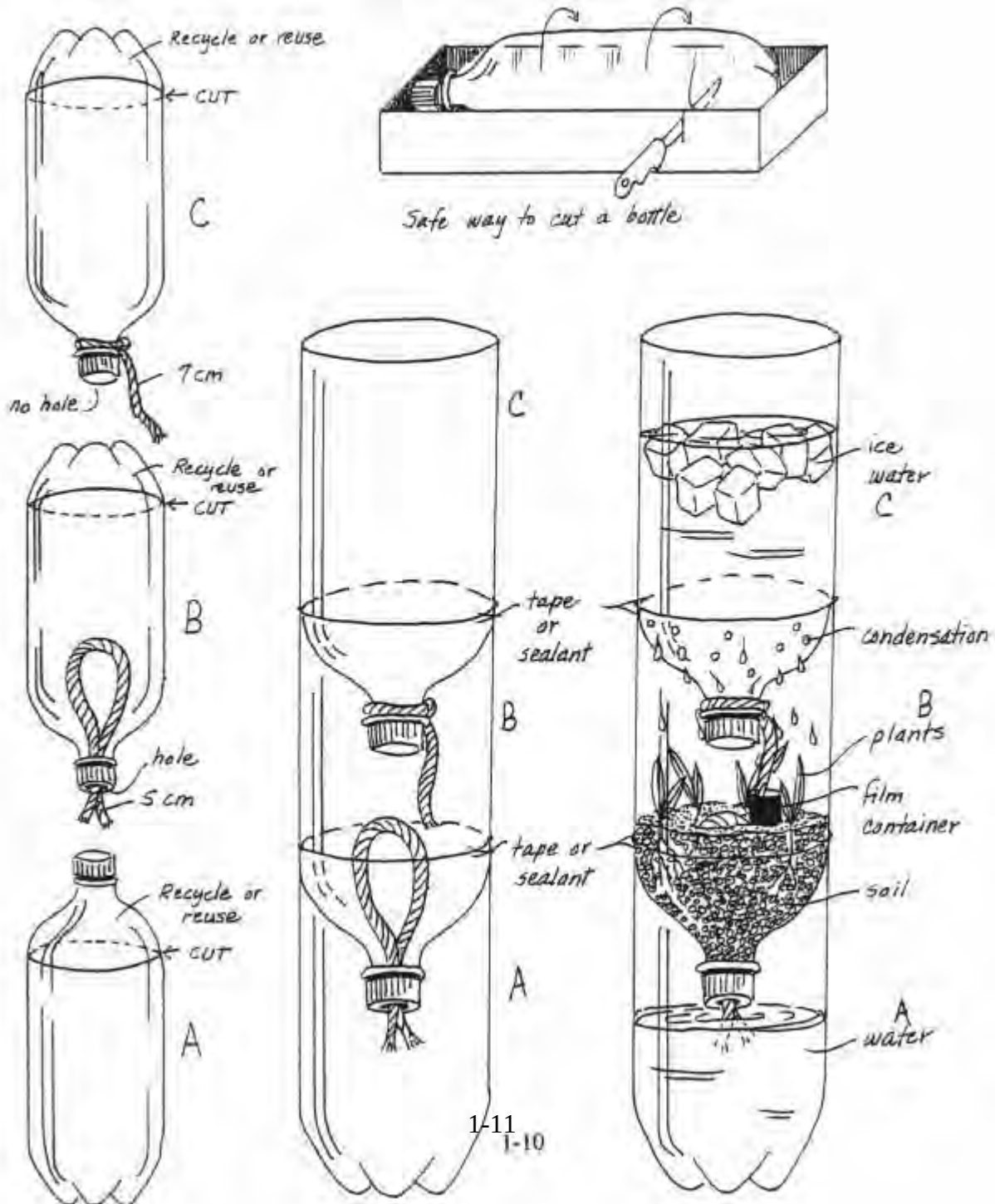


1. _____	8. _____
2. _____	9. _____
3. _____	10. _____
4. _____	11. _____
5. _____	12. _____
6. _____	13. _____
7. _____	14. _____

1-9

This is the 15. _____ cycle.

MODEL ASSEMBLY DIRECTIONS



SURVEYING THE PROPERTIES OF WATER

9-12

OBJECTIVES

The student will do the following:

1. Demonstrate the varied properties that make water unique.
2. List and define new terms.

BACKGROUND INFORMATION

The majority of the United States is blessed with an abundance of water. Seldom do the citizens of the U.S. experience a water shortage. These labs are designed to demonstrate to the student the unique properties of a natural resource that is often taken lightly because of its abundance.

Terms

colloid: a solid, liquid, or gaseous substance made up of very small, insoluble, nondiffusible particles that remain in suspension in a surrounding solid, liquid, or gaseous medium of different matter

density: the ratio of mass of an object to its volume

solution: a homogenous mixture of two substances, usually a gas or solid in a liquid

specific heat: the number of calories needed to raise the temperature of 1 gram of a given substance 1°C, relative to the number of calories (one calorie) needed to raise the temperature of 1 gram of water 1°C

surface tension: a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the formation of a meniscus. It is caused by unequal molecular cohesive forces near the surface.

SUBJECTS:

Science (Physical and Biology)

TIME:

1-2 class periods

MATERIALS:

plastic produce baskets
bowl
beaker
sand
vegetable oil
flashlight
3 x 5 index cards
thermometer
capillary tubes or straws
(assorted diameters)
Bunsen burner or hot plate
salt
balance
paper cup
hydrometer (or graduated cylinder and balance)

suspension: a mixture whose particles are temporarily dispersed through a fluid but not dissolved in it

Tyndall effect: the scattering and polarization of a light beam caused when light is reflected from colloidal particles in a system

universal solvent: water; a material that can dissolve almost any other substance

PROCEDURE

I. Setting the stage

- A. Review each of the characteristics to be demonstrated with the class.
- B. Provide materials as needed.

II. Activity

- A. The Universal Solvent: Water is said to be the “universal solvent” because a great many things can be dissolved in water. In this activity, we will investigate the mixtures formed with water.

- 1. Make predictions as to what will happen when small amounts of each of the following substances are added to water.
 - a. salt: _____
 - b. sand: _____
 - c. vegetable oil: _____
- 2. Add small amounts of these materials to three beakers of water and record the results.
- 3. Determine the type of mixture (solution, suspension, colloid) that was made when these materials were added to water. Record the data in Table 1.

B. Specific Heat:

In this activity, the teacher conducts a demonstration to illustrate the high specific heat of water. A quantity of water will be placed in a paper cup, and the cup will be held

directly in an open flame. Make a prediction as to what you think will happen.

Prediction _____

Observations _____

C. Surface Tension: The molecules of water are capable of maintaining a bond between each other. This bond can be quite strong and allows the water molecules to stay close together.

1. Determine the mass of a plastic produce basket and record the value in Table
2. Make a ball of modeling clay so that its mass is equal to that of the plastic basket.
3. Predict what will happen when each is placed on the surface of the water in a bowl.
 - a. clay ball _____
 - b. produce basket _____
4. Place each on the surface of the water and record your observations.
 - a. clay ball _____
 - b. produce basket _____
5. Determine the average mass of a 3 x 5 index card. Record the value in the Data Table.
6. Position the plastic basket so that it is resting on the surface of the water.
7. Carefully place one index card across the top of the basket.
8. Repeat this step by laying one card at a time on the basket. Observe what is happening to the water surface in between the holes on the bottom of the basket.
9. Stop when the basket sinks below the water surface.
10. Remove one card from the pile and count the total number of cards remaining. Calculate the total mass of cards and basket that was supported by the water

and record the information in the Data Table.

- 11 Repeat this experiment using cold water and warm water.

Prediction: _____

Why do you think this will happen? _____

- 12 Additional experiments could include testing a sugar solution, a water solution, and a salt water solution.

Predictions: _____

Why? _____

- D. Capillary action: a phenomenon related to surface tension is called capillary action. This characteristic causes water to “climb” in a narrow tube.

1. Use food coloring to make a colored water solution for this experiment.
2. Pour a small quantity of the colored water into a beaker or shallow bowl so that it is a few millimeters deep.
3. Make a prediction as to what will happen if one end of a straw is placed into the solution.

Prediction _____

4. Place one end of the straw into the water and record your observations.

5. Obtain an assortment of straws or capillary tubes. Measure the diameter of each tube or straw and record it on a label as well as on Table 3.
6. Record the temperature of the water in the Data Table.
7. Place each tube or straw into the water and record the height of the water in the column.
8. Repeat this experiment for water at higher and lower temperatures.

- E. Density: Water is unique in the way that its density changes with temperature.

Continued cooling will increase density to a certain point. Then water does something odd compared to other liquids.

1. Using a hydrometer, measure the density of a tap water sample.
2. Measure the water temperature and record both in Table 4.
3. If possible, continue to chill the cold water sample to 4°C. You may need to use a freezer.
4. Measure the density at 4°C and record.
5. Chill the sample further and record the density.

Guess what is happening? In a demonstration to the class, two beakers have been set up, each containing a clear liquid. Make predictions as to what will happen when an ice cube is placed in each beaker. (One is water and one is alcohol.)

a. beaker 1 _____

b. beaker 2 _____

III. Extensions

- A. Try the experiments using other kinds of liquids or solutions.
- B. Discuss or review how these characteristics of water help to:
 1. Support life.
 2. Create weather phenomena.
 3. Maintain ecosystems.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

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Organizing Data:**DATA****Table 1: Mixtures**

				Type of Mixture (check one)		
sample	color	setting	Tyndall effect?	solution	suspension	colloid

Table 2: Surface Tension

Mass of plastic produce basket _____ g

Mass of one 3x5 card _____ g

SolutionTotal mass supported (g)

Water (°C)

_____ g

Water (°C)

_____ g

Water (°C)

_____ g

Salt solution

_____ g

Sugar solution

_____ g

Table 3: Capillary Action

	height of water columns		
tube diameter	(°C)	(°C)	(°C)

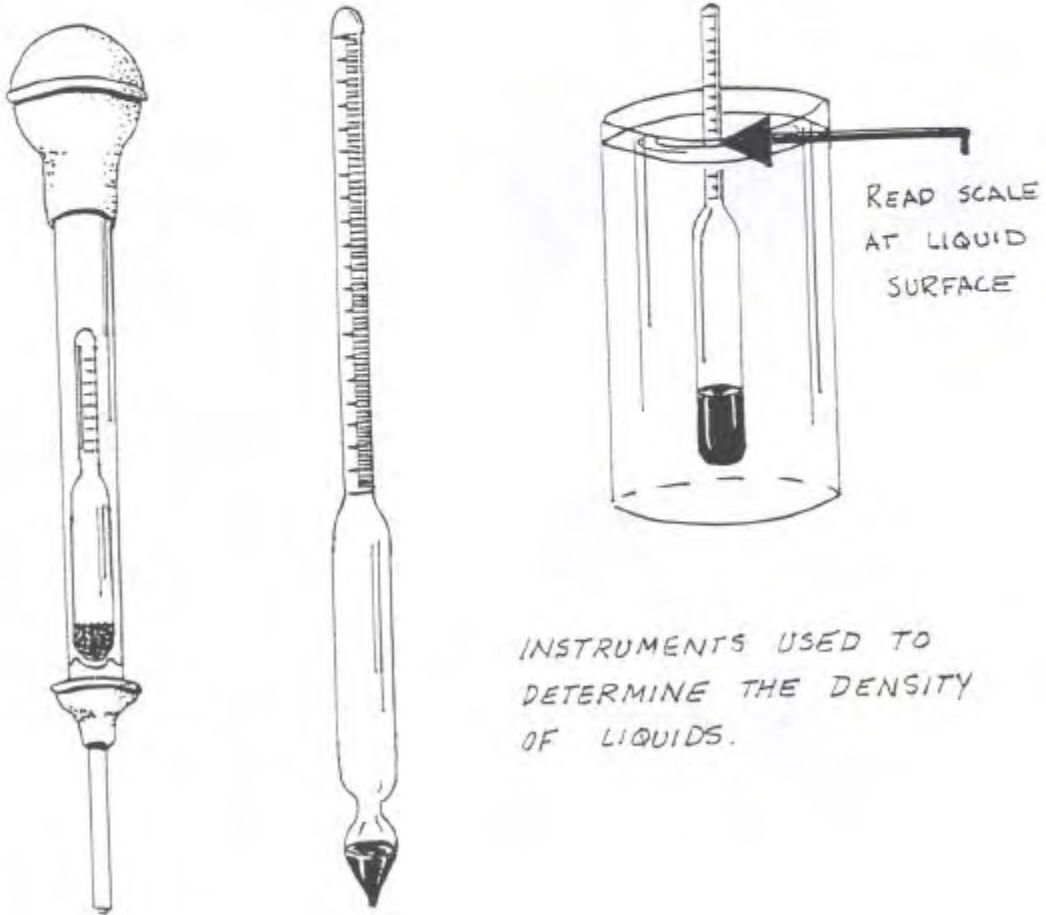
Table 4: Density of Water

water temperature (°C)	density of water (g/cm ³)

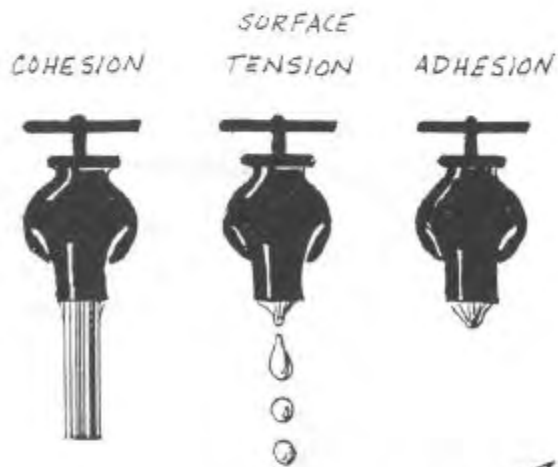
Analyzing Data:

1. Explain why the paper cup filled with water did not burn in terms of the specific heat of water.
2. Explain what your data tell you about the effect of temperature on surface tension.
3. How did the presence of solutes affect the surface tension of the water?
4. Explain what the capillary tube activity demonstrated about surface tension.
5. Explain what your data tell you about the effect of temperature on the density of water.
6. Explain why the ice cubes reacted the way they did in terms of density of the clear liquids in the beaker.

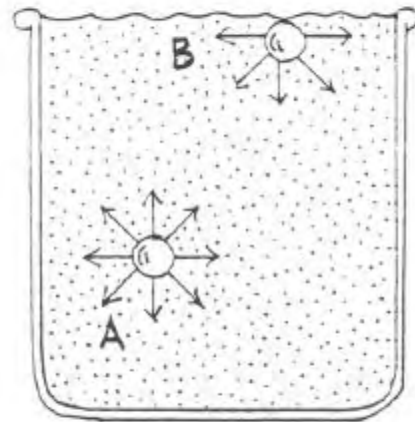
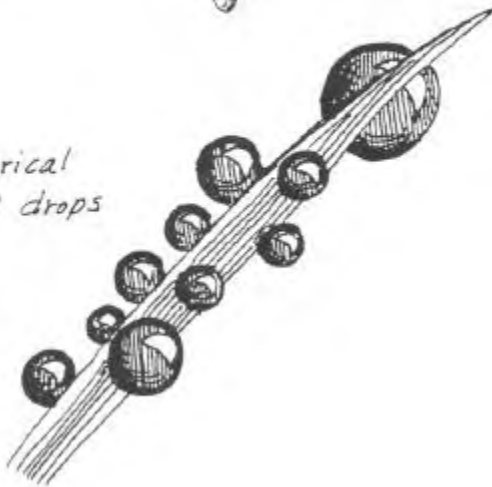
HYDROMETERS



SURFACE TENSION



Spherical
dew drops



- A - net forces = zero
surrounded by molecules
- B - net force downward
not surrounded

CLEARLY H₂O

9-12

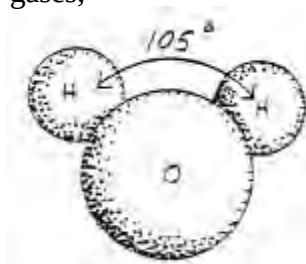
OBJECTIVES

The student will do the following:

1. Perform and read pH tests.
2. Observe with olfactory senses.
3. Determine boiling and freezing points.
4. Make a data chart to graph data.
5. Analyze the characteristics of water.

BACKGROUND INFORMATION

Water is abundant on, in, and around the Earth in liquid, gas (vapor), or solid (ice, snow) form. It has many unique properties that generally are the result of its unusual shape. Water molecules consist of two hydrogen atoms and one oxygen atom. Hydrogen and oxygen are gases; but when combined, they form a liquid chemical compound: The two hydrogen atoms form an angle of 105 degrees with the oxygen atom. (It looks like a mouse!)



form a
water.
form
with
Mick

SUBJECTS:

Science (Physical, Chemistry, Ecology)

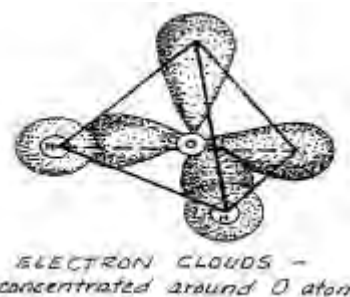
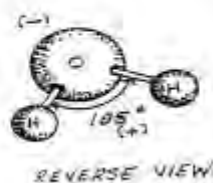
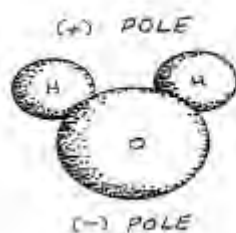
TIME:

1-2 class periods

MATERIALS:

10 - 100 ml beakers
10 thermometers
10 packs of pH paper
hot plate
10 trays
freezer
10 clear liquids
tap water
7-up®
vinegar
alcohol
distilled water
hydrogen peroxide
salt water
sugar water
dilute HCl
bottled water

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ecule and the hydrogen atoms dominating the other end. Because the oxygen atom has a larger positive nucleus than hydrogen, the electrons shared through covalent bonding between the oxygen and hydrogen atoms remain closer to the oxygen atom. This asymmetry causes the oxygen atom in a water molecule to have a slight negative charge and the hydrogen atoms to have a slight positive charge. A molecule that has (+) and (-) poles like this is called a polar molecule and it can act like a small magnet. Each (+) end of the water molecule repels a (+) end of another molecule or attracts another (-) molecule's end.

This weak attraction between the separate water molecules by way of the oxygen atom of one molecule and the hydrogen atom of an adjacent molecule is termed "hydrogen bonding" (each O-H bond is known as a hydrogen bond). Hydrogen bonds constantly form and break among the multitude of water molecules in liquid water; they hold water molecules together at normal temperatures and make it fluid. Evaporation of water occurs when individual water molecules at the air-water interface break free of all hydrogen bonds and enter the vapor phase.

Water can exist in any of three states: solid (crystal form), liquid, or vapor, depending primarily on temperature. Water molecules can be in constant, agitated motion, moving so fast that they are not connected to each other (vapor); or they can be slowed down so that each water molecule is touching other water molecules and the motion is not as fast (liquid); or the water molecules can be locked together in a

crystal form (ice). As the temperature of liquid water is decreased below the freezing point or raised above the boiling point, its state changes. Imagine a pot of boiling water on the stove, where millions of water molecules are moving, actually “jumping” up into the air (evaporation) because of their kinetic movement when close to the surface.

Just because a substance appears to be water doesn’t prove it is. Water, like any other substance, has its own specific properties: pH, boiling point, melting point, color, and odor. By using a few tests, students can determine if a substance is “clearly H₂O.”

Terms

acidity: (1) a characteristic of substances with a pH less than 7; (2) tending to form an acid

adhere: to stick fast; stay attached to another substance

alkalinity: (1) a characteristic of substances with a pH greater than 7; (2) the capacity of water to neutralize acids, imparted primarily by the water’s content of carbonates, bicarbonates, and hydroxides (expressed in mg/l of CaCO₃)

atom: any of the smallest particles of an element that combine with similar atomic particles of other elements to produce molecules; made up of electrons, neutrons, and protons

boiling point (BP): the temperature at which a liquid starts to bubble up and vaporize by being heated

cohere: to be united by molecular cohesion; to stick to the same substance

compound: a substance formed by the bonding of two or more atoms or ions that share electrons (covalent compounds) or transfer electrons (ionic compounds)

electron: any of the negatively charged particles that form a part of all atoms; exists outside the nucleus; involved in bond formation

element: natural substances that cannot be broken into anything simpler by ordinary chemical means

freezing point (FP): the temperature at which a liquid begins to precipitate crystals

kinetic movement: movement of electrons, atoms, and molecules as a result of their energy state

molecule: the smallest particle of a compound that can exist in the free state and still retain the characteristics of the compound

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

polar molecule: covalent molecule that has a partial (+) and partial (-) end

valence: a number representing the capacity of an atom or radical to combine with other atoms or radicals, as measured by the number of hydrogen or chlorine atoms which one radical or one atom of an element will combine with or replace (oxygen has a valence of two: one atom of oxygen combines with two hydrogen atoms to form the water molecule H_2O); the electric charge of an element or radical resulting from a change in oxidation state (that is, in the transfer or sharing of electrons)

ADVANCE PREPARATION

1. Ask students how they would determine that a glass of clear liquid was water.
2. Write down different ideas they have and discuss with class if these ideas would be accurate safe ways to determine whether or not the clear liquid was water.
3. Have students research to determine the pH boiling point and freezing point of water, or have them conduct experiments with one known sample being water.

PROCEDURE

- I. Setting the stage
 - A. Place 50 ml of 10 different clear substances in a 100 ml beaker. Number each beaker and keep a written record of each for a key. (For the teacher: see materials list.)
 - B. Place each beaker in a tray with a thermometer and a pack of pH paper.
 - C. Give each student a Data Sheet.
 - D. Students may work individually or in groups and exchange trays when data are

obtained from each one.

II. Activity

Data collection: Complete the Data Sheet from each of the following.

- A. Remove a strip of pH paper carefully from the container without touching the end used for testing. Dip the end of the strip in each substance and match the colorimeter for a numerical value. Record the value on the Data Sheet.
- B. To observe the odor, waft the top of the beaker with a hand towards the nose. Record if there is or is not a perceptible odor on the Data Sheet. If yes, record the odor (if you recognize it). If you do not recognize the odor, enter a ?(question mark).
- C. Have students place the beakers on hot plates with a thermometer in each beaker. Bring each to a boil while watching the thermometer. As soon as boiling begins, read temperature and record on the Data Sheet. Repeat this procedure for all remaining substances. (Wear goggles.)
- D. After boiling, let cool to room temperature. Then place all 10 substances in one tray in a freezer compartment. Keep thermometers in each of the beakers. Check every 30 minutes for signs of crystal formation. Remove substance from freezer as temperature

WARNING - DILUTE ACIDS USED

Use safety goggles.

DO NOT TASTE ANY SAMPLES!

Check for odors by gently wafting fumes from the liquids toward your face. (See illustration.)

Wash hands if they come in contact with the samples.

Carefully clean any spills.



is recorded on the Data Sheet when crystallization starts. Make temperature data

available to all students.

III. Follow-up

- A. Have students make three graphs of all 10 substances: one graph for pH, one for boiling point, and one for freezing point. (options: line or bar graph)
- B. Students should determine which sample(s) is(are) water using the known information on H₂O.

IV. Extensions

Ask students:

1. What would be the next step in determining if the water is potable? Design an experiment to determine if the water is potable.
2. How could it be guaranteed that the water is potable?
3. Which of the liquid unknowns is water? How do you know?
4. Do all clear liquids have the same BP? FP?
5. How can you use what you learned to find out if an unknown clear liquid is water?

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Data Sheet

1. Complete the data analysis:

Known information on H₂O: odor _____

pH _____

BP _____ °C

FP _____ °C

Give recorded data for each:

# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____
# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____	# _____ pH _____ odor _____ BP _____ FP _____

- A. Substances with recordings closest to known data for H₂O, #_____.
- B. Which sample(s) is(are) water?

C. Does this test determine if the water is potable?

WATER, WATER EVERYWHERE

9-12

OBJECTIVES

The student will do the following:

1. Determine how much water there is on the Earth.
2. Identify ways of conserving water.
3. Evaluate the future demand for water.
4. Reproduce the hydrologic cycle.
5. Determine what state or territorial agencies investigate, monitor, or regulate water resources in the state or territory.

SUBJECT:

Science (Physical)

TIME:

3 class periods
optional 1 field trip

MATERIALS:

The World's Water article
optional field trip and /or water analysis kit

BACKGROUND INFORMATION

With many rivers, lakes, and streams in the United States, you would think that there would never be a water shortage. Because we share our borders with Canada and Mexico, we also share water resources. Water from lakes and rivers, as well as groundwater, is shared. This creates a need for cooperation and planning between the United States and our bordering countries. With the increasing demand for fresh water, we can no longer take our water supply for granted. We now realize that our present water resources are limited. Today's students will be challenged to find technical and social solutions to meet future U.S. water demands.

Terms

atmospheric water: water found in vapor form in the atmosphere

condensation: (1) the process of changing from a vapor to a liquid; (2) a liquid obtained by the coming together of a gas or vapor

evaporation: the process of changing from a liquid to a vapor

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock

below the Earth's surface; water within the zone of saturation

hydrologic cycle: the cyclical process of water's movement from the atmosphere, its inflow and temporary storage on and in land, and its outflow to the oceans; cycle of water from the atmosphere, by condensation and precipitation, then its return to the atmosphere by evaporation and transpiration

salinity: the amount of salt dissolved in water

transpiration: process in which water absorbed by the root systems of plants, moves up through the plants, passes through pores (stomata) in their leaves or other parts, and then evaporates into the atmosphere as water vapor; the passage of water vapor from a living body through membrane or pores

vadose zone: the zone of aeration between the Earth's surface and the water table; area of the soil that contains both air and water; same as unsaturated zone--zones between land surface and the water table

water analysis: series of tests to determine various chemical or physical characteristics of a sample of water

zone of saturation: that region below the surface in which all voids are filled with liquid

ADVANCE PREPARATION

- A. Make copies and have students read "*The World's Water.*"
- B. The article is provided to explain the world water supply and nature's methods of replenishing fresh water. This inventory of the world's water and description of the water cycle provides the initial information for discussion.
- C. Class exercises may then expand on this information to learn what technology can do to provide sufficient water for the future.

PROCEDURE

- I. Activity

- A. Fill out Student Sheet on Hydrologic Cycle. (See activity on Hydrologic Cycle.)
 - B. Determine the source of water for your school and visit a local treatment plant.
 - C. From the total annual rainfall given in the article, calculate the average annual rainfall over the Earth.
 - D. Can glaciers and icecaps be used for fresh water? Are they limited, or are they being replenished?
 - E. Study past droughts in this century.
 - F. Evaluate the future demand for water in your city based on the patterns of population and industrial growth.
 - G. List short term and long term methods of conserving water.
 - H. If people in your city decided on a very austere use of water, how would it affect the community?
 - I. Discuss possible conflicts that could arise from the increased demand for water between countries and states.
- II. Follow-up
- A. Have students develop a water trivia sheet from “The World’s Water” article. Use these to develop quiz questions.
 - B. Name one state or territorial agency which regulates, monitors, or investigates water resources in your state or territory. (Contact state/territorial environmental management agency or geological survey.)
 - C. Write to research companies, such as Phillips Petroleum, who advertise that they can purify sea water for drinking water. Learn the way this is done and the potential for doing it in your area.
 - D. Investigate water’s role in providing the world’s energy (HINT: Hydropower - hydroelectric and tidal power).

III. Extensions

- A. In 1986, the Great Salt Lake in Utah was at its highest level in recorded history. The Great Lakes were also considered high and were eroding their shores. Can you determine why this occurred?
- B. Discuss this question: Do city officials encourage expanded use of water because it brings in revenue?
- C. Build a small, low-cost solar still. (This may require a little research.)

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Forrester, F. H., An Inventory for the World's Water, (ESO2), Weatherwise, Helen Dwight Reid Education Foundation, Heldref Publications, 1319 18th St. N.W., Washington, D . C . 20036-1802, April 1985.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

THE WORLD'S WATER

By Frank H. Forrester

Nobody really knows exactly how much water exists around the world. The sheer volume of our planet's water -- locked in glaciers, stored in lakes, detained in underground rocks, or moving in the atmosphere, river and seas -- almost defies the imagination. Even the hottest and driest parcels of air overlying the world's most arid regions contain at least traces of water vapor as part of the Earth's aerial canopy of gases. In the same arid regions, dry though the surfaces may be, abundant water often can be found in deep subsurface rock formations.

The waters of the world have been inventoried, roughly of course, but within generally accepted limits of hydrologic research. Like oil or gas inventories, estimates of water might be broken down into two major categories: known or identified reserves and unknown or inferred resources. Water contained in large glaciers, many rivers, lakes, and seas can be identified or estimated with reasonably high percentages of accuracy. Estimates of groundwater resources, however, often based on indirect evidence and measurements, are compiled with varying degrees of uncertainty. Even today, the United States is far from completing the task of probing suspected sources of groundwater and determining the amounts the hydrated rocks might yield.

Some research hydrologists of the U.S. Geological Survey have estimated that the world's water supply-- liquid, frozen, and vapor- - totals 326 million cubic miles (a cubic mile is equal to about 1.1 trillion gallons of water). If this total supply were in liquid form and poured upon the 50 United States, the land surface would be submerged to a depth of about 90 miles.

With "water, water everywhere," why are there shortages? To answer this question and others related to a variety of water problems, it is instructive --perhaps imperative -- to consider water on a planetary scale.

Most people are aware that water is unevenly distributed on the Earth's surface in oceans, rivers, and lakes, but few realize the disproportion of the distribution. Further, few realize the manner in which "hidden" water is distributed - underground, in glacial ice, and in the atmosphere. Finally, one of the most important concepts of hydrology, known as the hydrologic cycle, is often poorly perceived by the public. This endless cycle, a global natural distillation and pumping system, has been going on since the first clouds formed and the first rains fell, transferring water time and again from the surface of the land and water to the sky and back again, keeping our planet fed with the liquid of life. The waters of long geologic history are the waters of today; little has been added or lost.

An Inventory of the World's Water

Views of the Earth from space confirm one of the first lessons of geography in elementary schools--water covers about 70 percent of the Earth's surface. But this one-dimensional view, suggestive as it is, provides only a beginning hint in preparing a world water inventory. There are a host of surprises to be found in such an inventory; one is the realization that man gets by on an incredibly small amount of the total supply of 326 million cubic miles. Usable fresh water amounts to less than 1 percent of the total!

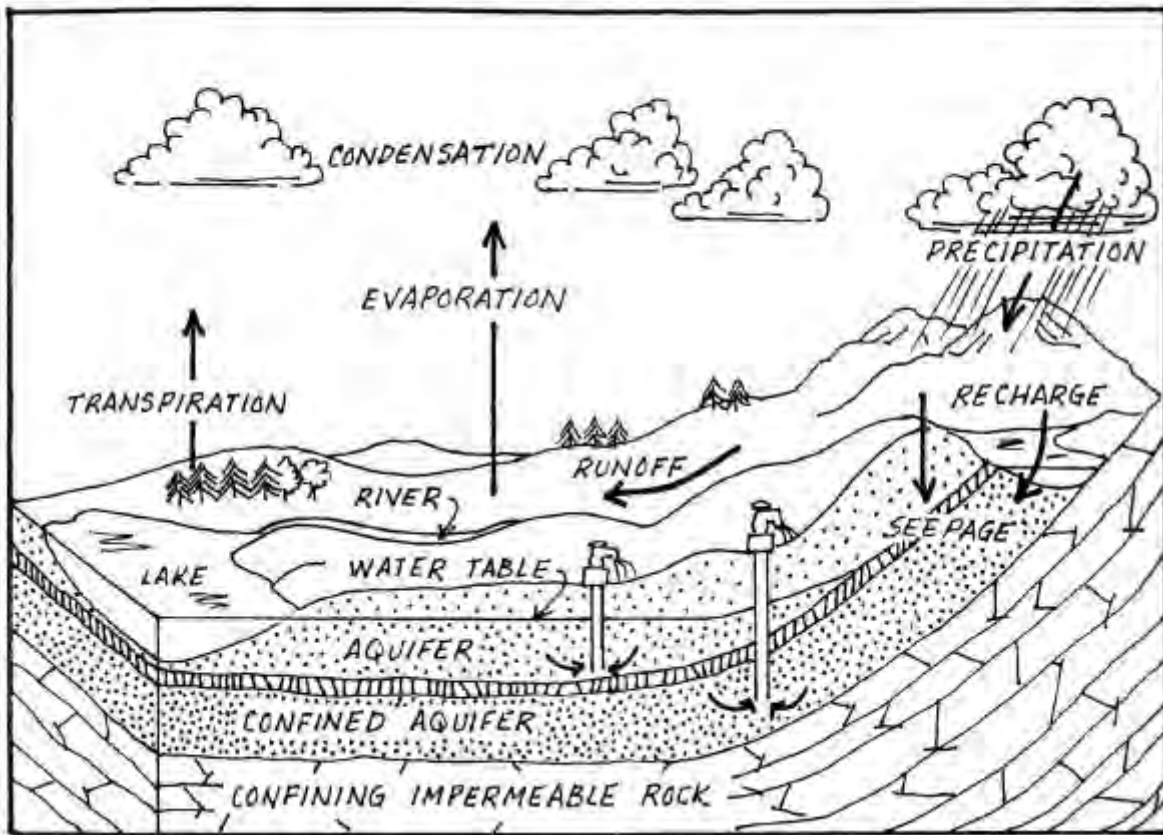
It should come as no surprise to find that the world's oceans -- covering 139.5 million square miles of the Earth's surface, with their basins averaging about 12,500 feet in depth -- comprise the bulk of the world's water. It may be an eye-opener, however, to learn that the approximately 320 million cubic miles of sea water constitute about 97.2 percent of the planet's total water supply. Every other source of water pales in statistical comparison to the oceans, but the importance to mankind of other, lesser sources is not revealed by sheer statistics.

The next items on the world water balance sheet are the planet's icecaps and glaciers. The amount of water stored in frozen form, though a far second to the oceans, nonetheless totals an impressive 7 million cubic miles, representing 2.15 percent of the world's water. Of the frozen water, mountain glaciers, such as those of the Alps in Europe, the Himalayas of Asia, the Cascades of North America, and small icecaps in the world, have a total volume of only about 50,000 cubic miles - an insignificant fraction of the world's water. But the Greenland and Antarctic icecaps are entirely different matters.

About 667,000 square miles in area, and averaging more than 5,000 feet in thickness, the Greenland icecap represents about 630,000 cubic miles of water. If melted, the Greenland icecap would yield enough water to maintain the flow of the Mississippi River for more than 4,700 years. Even so, this is less than 10 percent of the total volume of icecaps and glaciers.

The greatest single item in the water budget of the world, aside from the oceans, is the Antarctic ice sheet. The huge southern hemisphere icecap, 1000 feet thick in some places, and covering an area of about 6 million square miles, has a total volume of between 6 and 7 million cubic miles or about 85 percent of all existing ice and about 64 percent of all water outside the oceans. If the Antarctic icecap were to melt at a suitable uniform rate, it could feed the Mississippi River for more than 50,000 years; all rivers in the United States for about 17,000 years; the Amazon River for about 5,000 years; or all the rivers of the world for about 750 years.

THE HYDROLOGIC CYCLE



THE HYDROLOGIC CYCLE of the world's water budget. Water that has evaporated from the Earth's surface may fall as precipitation many thousands of miles from where it entered the atmosphere. (Adapted from Spiegel and Graber, From Weather Vanes to Satellites.)

Thus far, we have inventoried slightly over 99 percent of the world's water: that contained in the oceans, icecaps, and glaciers. Statistically, the next ranking source of water consists of subsurface water or groundwater. Estimates of such water are broken down into three categories: vadose water (which includes surface moisture); groundwater to a depth of a half mile; and deep-lying groundwater.

Vadose Water

The average amount of soil moisture at any given time is on the order of 6,000 cubic miles for the world as a whole, an extremely small percentage of the Earth's total water but profoundly important because of the key role played by plants in the food chain. On a global scale, relatively little vegetation receives artificial irrigation; most of it depends upon soil moisture. The world volume of vadose water -- water just below the belt of soil moisture -- probably is somewhat more than that of soil moisture, say 10,000 cubic miles. Again, this is not a significant amount on a world scale; and even though not extractable by man, it is important because it is potential groundwater recharge and groundwater is extractable.

Groundwater

Below the vadose water, our planet contains a water reservoir, groundwater, known to man for thousands of years. Scripture on the Noacniari Deluge states, "The fountains of the great deep (were) broken up ." Exodus, among its many references to water and to wells, refers to "water under the Earth." Many other chronicles show that man has known from ancient times that there is much water underground. Only recently, however, have we begun to appreciate how much groundwater exists and how important it is in meeting current and future water needs.

Beneath most land areas of the world, even under deserts, mountain peaks, and some sub-sea floors, there is a zone where the pores of rocks and sediment are saturated with water. The upper limit of the saturated zone is called the water table. It may be right at the land surface as in a marsh, or it may lie hundreds of thousands of feet below the land surface as in some arid regions.

Sometimes there are surprises in groundwater discoveries. In 1965 during a geologic probe of the Atlantic sea floor about 30 miles off northern Florida by an international team of scientists aboard a research vessel, drilling struck some sub-sea rocks that contained fresh water. Pumped to the ship's deck, the water was found to be potable -- a spinoff dividend from the expedition.

In 1975, U.S. Earth scientists tapped other water-bearing rock formations under the ocean about 30 to 60 miles off the Mid-Atlantic coast. When tested, the water was found to be of surprisingly low salinity, some of it directly potable and some requiring slight treatment to reach drinking water standards. These and other potential sub-ocean deposits of fresh water are not likely to be used in the reasonably near future. They do, however, reflect the watery nature of our planet, and they are of great research value. The findings off the Atlantic coast, for example, may yield insight into such problems as salt water invasion of aquifers (subsurface, water-bearing rock formations) that are tapped by many Atlantic coast communities.

Below the water table to a depth of about a half mile in land areas of the Earth's crust, there is an estimated 1 million cubic miles of groundwater. This is probably 3,000 times greater than the volume of water in all rivers at any one time. An equal, if not greater, amount of groundwater is present at

a greater depth down to some 10,000 to 15,000 feet. This deeper water, however, circulates sluggishly because its rocks are only slightly permeable. Much of the deep-lying water is not economically recoverable for human use at the present time, and a good deal of it is strongly mineralized.

Tallying all the subsurface waters of the planet, the total is a little over 2 million cubic miles or about two-thirds of one percent of the world's water. The balance is to be found in surface water (freshwater lakes, saline lakes, inland seas, and rivers) and in the atmosphere.

The Earth's land areas are dotted with hundreds of thousands of lakes. Wisconsin, Minnesota, and Finland each contain some tens of thousands. But these lakes, important though they may be locally, hold only a minor amount of the world supply of fresh water, most of which is contained in a relatively few large lakes on three continents - Africa, Asia, and North America.

Whether water is fresh or salty makes a considerable difference in its usefulness to man, and the Earth's greatest lakes fall in both categories, fresh and salt.

Lakes, Both Fresh and Salt

The volume of all the large freshwater lakes in the world aggregates nearly 30,000 cubic miles (their combined surface area is about 330,000 square miles). "Large" is a relative term for our inventory purposes. A lake is called large if its contents are 5 cubic miles or more. Thus, the listing includes the Dubawnt Lake, Canada (about 6 cubic miles), but excludes the Zurich Sea of Switzerland (about 1 cubic mile). The range of volume among the large lakes is enormous, from a lower limit of 5 cubic miles to an upper one of 6,300 cubic miles in Lake Baikal, Siberia. An appreciation of this volume may be gained from the realization that Lake Baikal alone contains nearly 300 cubic miles more water than the combined contents of the five North American Great Lakes. These Great Lakes loom large on a map, but their average depth is considerably less than that of Baikal.

For comparison purposes, here are some of the world's large freshwater lakes (in terms of water volume): Dubawnt, Canada; and Tutigting, China (about 6 cubic miles each); Leman, Switzerland (about 12 cubic miles); Vanern, Sweden (about 35 cubic miles); Nipigan, Canada (about 150 cubic miles); Great Bear, Canada (about 670 cubic miles); Superior, U.S. and Canada (about 3,000 cubic miles); Nyasa, Africa (about 3,200 cubic miles); Tanganyika, Africa (about 5,000 cubic miles); and Baikal, Siberia (about 6,300 cubic miles).

Saline lakes are roughly equivalent in magnitude to freshwater lakes. Their total area is about 270,000 square miles, and their total volume is about 25,000 cubic miles. The distribution, however, is quite different. About 19,240 cubic miles (75 percent of the total saline volume) is in the Caspian Sea, and most of the remainder is in Asia. North America's shallow Great Salt Lake is comparatively insignificant with about 7 cubic miles.

Rivers and Streams

Rivers and streams are next in the water budget calculations, and here we need to differentiate between the actual amount of water present at any given time in river channels and the amounts that are discharged by the rivers. It has been estimated that the total amount of water physically present in stream channels throughout the world at a given moment is about 500 cubic miles, a small fraction of the world's fresh surface water supply and only a little more than one thousandth of the world's total supply.

To get a better perspective of the relative importance of large and small rivers in maintaining continental water balance, consider some statistics on the amounts of water that flow or discharge out of rivers. The Mississippi, North America's largest river, has a drainage area of 1,243,000 square miles (about 40 percent of the total area of the 48 conterminous states) and discharges at an average rate of 620,000 cubic feet per second. This amounts to some 133 cubic miles per year and about 34 percent of the total discharge from all rivers of the United States. The Columbia, nearest competitor of the Mississippi, discharges less than 75 cubic miles per year. Relatively speaking, the great Colorado River is a watery dwarf, discharging only about 5 cubic miles annually.

On the other hand, the Amazon, the largest river in the world, is nearly 10 times the size of the Mississippi, discharging about 4 cubic miles each day or some 1,300 cubic miles per year -- about 3 times the flow of all U.S. rivers.

Africa's great Congo River, with a discharge of about 340 cubic miles per year, is the world's second largest. The estimated annual discharge of all African rivers is about 510 cubic miles.

Measurements of only the few principal streams on a continent afford a basis for reasonably accurate estimates of the total runoff item in a continental water balance. The small streams are important locally, but they contribute only minor amounts of the total water discharged. Thus, it is possible to estimate the total runoff of all the rivers of the world even though many of them have not been measured accurately. It is calculated that 97 principal rivers of the world discharge about 4,980 cubic miles of water yearly. The estimated total from all rivers, large and small, measured and unmeasured, is about 8,430 cubic miles yearly (about 23 cubic miles daily).

The figure of about 500 cubic miles --the amount estimated to be present in river channels throughout the world at any given moment--is, however, suitable for entry in the world water inventory.

The Atmosphere

The final item in the world's water budget is the atmosphere, the gaseous ocean that clings to the Earth's surface by gravity. In view of the total precipitation that falls on the surface of our planet in the course of a year, one of the most astonishing world water facts is the extremely small amount of water in the

atmosphere at any given time. Consider, for example, that the volume of the lower 7 miles or so of the atmosphere--the realm of weather phenomena--is roughly 4 times the volume of the world's oceans. But the atmosphere contains only about 3,100 cubic miles of water (about one-one hundredth of a percent of the world's total supply), chiefly in the form of invisible vapor. If all this vapor were suddenly condensed and then precipitated from the air onto the Earth's surface, it would form a layer only about 1 inch thick.

Powered by the sun's heat and energy, together with the force of gravity, the hydrologic cycle keeps the world's water moving; essentially there results a key balance--what goes up comes down. In the natural cycle, there occurs a three-way action that allows the total replenishment of water to the sky, sea, and Earth. It starts with a process whereby water vapor rises into the air from oceans, lakes, forests, fields, plants, and animals the world over (evaporation). This water vapor then develops, by cooling, into visible moisture in the form of clouds or fog (condensation). Finally, the cycle of replenishing is completed by the return of the water to the land and sea in liquid or solid form (precipitation).

As a cycle, the global water system has neither beginning nor end; but from man's point of view, the oceans are the major source, the atmosphere is the deliverer, and the land is the user. In the cycle, there is no water lost or gained; but the amount of water available to the user may fluctuate widely because of variations at the source or, more usually, in the delivering agent. In the geologic past, large alterations in the cycle roles of the atmosphere and the oceans have produced deserts and ice ages across entire continents. Even now, small fluctuations of the local patterns of the hydrologic cycle produce floods and droughts.

On the average--about once every 12 days or so--the water in the air falls and then is replaced. Once fallen, water may move swiftly to the sea in rivers or may be held in glaciers for several decades, in a lake for 100 years, or in the ground from a few years to thousands of years depending upon how deep the water goes. Or, the water may evaporate almost immediately. Regardless of how long the water is delayed, it is eventually released to enter the cycle once more.

About 102,000 cubic miles of water rise into the air annually. Of this amount, about 78,000 cubic miles fall directly back into the oceans. Streams and rivers collect and return to the oceans some 9,000 cubic miles of water including a large quantity that has percolated down into the ground and that, as groundwater, moves slowly to natural outlets in the banks and channels of rivers. This movement of groundwater into a river "feeds" the river, maintaining its flow even when precipitation is scarce throughout the basin drained by the river. The remaining 15,000 cubic miles of water soaked into the ground and, principally as soil moisture, maintain plant and animal life. The water ingested by living organisms ultimately is returned to the air again through evaporation, excreta, or perspiration. Once more there is a balance of water intake and outgo.

In the conterminous (48) United States, it has been estimated that about 1,420 cubic miles (about 1,560 trillion gallons of water or equivalent to about 30 inches of rain) fall annually as rain, sleet, and snow. Of this, about 995 cubic miles (about 1,100 trillion gallons) evaporate into the atmosphere. Another 380 cubic miles (420 trillion gallons) flow to the seas as surface runoff, and about 45 cubic

miles (about 50 trillion gallons) of groundwater are discharged directly to the seas. Recent rough estimates by federal hydrologists indicate that there is a total of about 53,400 cubic miles (58,740 trillion gallons) of groundwater in storage in the United States.

A Drumful of Water . . .

If we let a 55-gallon drum, filled to the brim, represent the world's total water supply, then . . .

- ' the oceans of the world would total 53 gallons, 1 quart, 1 pint, and 12 ounces;
- ' the icecaps and glaciers would total 1 gallon and 12 ounces;
- ' groundwater would add up to 1 quart and 11.4 ounces;
- ' the atmosphere would contribute 1 pint and 4.5 ounces;
- ' freshwater lakes would add up to half an ounce;
- ' saline lakes and inland seas would total slightly more than a third of an ounce;
- ' soil moisture and vadose water would total about one-fourth of an ounce;
- ' and the rivers of the world would measure only one one-hundredth of an ounce, less than one one-millionth of the waters on the planet.

Global Water: The Challenge

Water everywhere indeed! But while the water cycle balances what goes up with what comes down on a worldwide basis, no such reciprocity exists for individual areas -- a blessed circumstance for some regions and often a disastrous occurrence for others. Simply stated, nature does not always provide the amount of water needed everywhere, when needed, nor with the desired quality. And adding to the fickle ways by which water is distributed through the natural cycle are the complications posed by the spread of human population and activities. With about 97 percent of all water stored in the oceans, and with most of the remainder frozen on Antarctica and Greenland, man must get along with the less than 1 percent of the world's water that is directly available for freshwater use.

Thus, water is a global concern; the water cycle recognizes no national boundaries. Man's future success on this planet may well hinge on the degree to which nations join to cooperate effectively in the conservation and wise development and use of water.

A GLOBAL VIEW OF THE WET EARTH

9-12

OBJECTIVES

The student will do the following:

1. Locate and label the major bodies of water and the major rivers of Earth.
2. Locate and label the major centers of population in the world.
3. Locate and label countries that are “water scarce” at the present time and those projected to be in future years.
4. Differentiate among various types of water resources.
5. Know the impacts and stresses large centers of population exert on water resources.

SUBJECTS:

Science (Physical), Math, Art, Social Studies (Geography, Economics)

TIME: varies

several activities included, each requiring 1-2 class periods

MATERIALS:

outline maps
lists of water sources,
population centers
pencils (or colored pencils)
globe(s)
almanac(s)
world map(s)
worksheets

BACKGROUND INFORMATION

Earth is the water planet with 71% of its surface covered by water. Water features define continental, national, and state boundaries and influence climate, productivity, and accessibility for the land. Too often our knowledge of geography is hazy or limited and in need of expansion or review.

U.S. citizens use about 150 gallons of water per day per person for ordinary household use. Europeans use a third of this and citizens of other nations much less. It takes about one gallon per day per person just to sustain life.

Renewable water resources, such as groundwater or lakes, are becoming scarce for many countries experiencing population growth. World Resources Institute has identified 26 countries with less than 1000 cubic meters (m^3) of water available per person annually. The United States has about 10,000 m^3 /person annually. Most of the water-scarce places are located in Africa, the Middle East, or islands. (Note: 1 m^3 = 265 gal.)

Most citizens of developed countries consider water quality as a local environmental problem and have

focused efforts on local waterways. Many Americans do not understand the growing world-wide water crisis. Water, made unsafe by human waste, industrial wastewater, pesticides, and fertilizers, represents a major global health problem as well as contributes to water scarcity. If sources become too polluted, they are often abandoned rather than cleaned.

Over 12 million children die each year because of unsafe drinking water. The United Nations set a goal ensuring that all people would have safe drinking water by 1990. This goal has not yet been attained. Despite progress, many countries still lack sanitation facilities that would prevent organic wastes from polluting drinking water. In addition, affluent nations, such as the United States as well as these developing countries, need stronger measures to preserve groundwater from contamination. Many people rely on groundwater; and groundwater, once contaminated, cannot be decontaminated in the same ways that polluted lakes and rivers can.

Students should have a global conception of water resources and know where the resources lie. We, therefore, face the serious educational challenge of getting water quality and water scarcity to be perceived as central global environmental issues. These activities are steps toward that direction.

Terms

bay: a body of water partly enclosed by land but with a wide outlet to the sea

equator: a great circle of the Earth that is everywhere equally distant from the two poles and divides the Earth's surface into the northern and southern hemispheres

glacier: a large mass of ice formed on land by compacted snow

gulf: large area of a sea or ocean partially enclosed by land

harbor: a waterbody where wave action is reduced or dampened

lagoon: a shallow body of water, especially one separated from the sea by sandbars or coral reefs

lake: a standing body of water which undergoes thermal stratification and turnover by mixing

ocean: the entire body of salt water that covers about 71 percent of the Earth's surface

pond: a still body of water smaller than a lake where mixing of nutrients and water occurs primarily through the action of wind (as opposed to turnover)

river: a large body of flowing water that receives water from other streams and/or rivers

river mouth: where the river empties into a larger body of water

river source: where the river begins

sound: long, broad inlet of the ocean larger than a strait or channel, connecting larger bodies of water

strait: a narrow passage of water that connects two larger bodies of water

tributary: a stream that flows into a larger stream, river, or another waterbody

waterfall: a cascade of water, as over a dam

ADVANCE PREPARATION

- A. Prepare copies of world maps and lists for each student or group of students who will work together.
- B. Gather sufficient atlases, reference materials, maps, globes.
- C. Copy lists of waterways and population centers from an almanac.

PROCEDURE

- I. Setting the stage
 - A. Give Background Information and invite discussion about water uses and misuses, types of bodies of water, and problems from water shortages.
 - B. Distribute copies of maps and lists to students.
 - C. Explain the use of globes, almanacs, and other resources that have been provided.
- II Activity
 - A. Identify types of surface water sources in the vocabulary and locate examples on the maps provided.

B. Locate water-scarce countries and countries with large population centers on the maps provided.

C. Relate water scarcity to:

1. topography (runoff).
2. climate (little natural precipitation).
3. economic development (the cost of wells, water treatment).
4. population size or population growth rate (amount available per person).

IV. Follow-up

A. Watch for current events stories about world water supplies. Keep a current bulletin board of these items.

B. Have a geography bee to reinforce knowledge of types of surface waters and/or names of surface waters.

C. Discuss the relationship between population centers and fresh water sources.

IV. Extensions

A. Convert the amounts of water shown to gallons per person. Compare your own usage to that of an African nation.

B. Locate large industries, agricultural areas, economic centers, deserts. Note areas that have had recent water shortages.

C. Do a current events search for these bodies of water.

D. Assign each student a current event on which to do further research.

E. Add your state map with its rivers, lakes, bays, and dams to the assignment.

- F. List some possible environmental and cultural factors leading to water scarcity.
- G. Present and defend some possible solutions in terms of expense, time delay, cultural acceptability.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

State or Locally Adapted World History Book; World Almanac

Name_____ Date_____

FOR EACH TERM LISTED BELOW, DEFINE THE TERM AND LOCATE ONE OF THE EXAMPLES GIVEN ON A WORLD MAP. MARK THE LOCATION ON THE MAP WITH THE CORRESPONDING LETTER OF THE ALPHABET FOR EACH TERM.

A. Canal (Erie Canal, Panama Canal, Suez Canal)
Defined:_____

B. Gulf (Gulf of Mexico, Persian Gulf, Gulf of Carpentauria)
Defined:_____

C. River (Mississippi, Rio Grande, Nile, Amazon)
Defined:_____

D. Reservoir (Lake Mead, AZ or Lake Martin, AL)
Defined:_____

E. Port (New York, Los Angeles, Mobile)
Defined:_____

F. Harbor (San Diego, New Orleans, Hong Kong)
Defined:_____

G. Lake (Superior, Erie, Victoria)
Defined:_____

H. Coast (Gulf Coast, Pacific Coast, Atlantic Coast)
Defined:_____

I. Ocean (Atlantic, Pacific, Indian)
Defined:_____

J. Bay (Chesapeake Bay, Hudson Bay, Bay of Biscay)
Defined:_____

K. Strait (Bering Strait, Strait of Gibraltar, Magellan)
Defined:_____

L. Reef (Great Barrier Reef, Great Bahama Bank, Great Sand Barrier)

Defined: _____

Student Sheet (cont.)

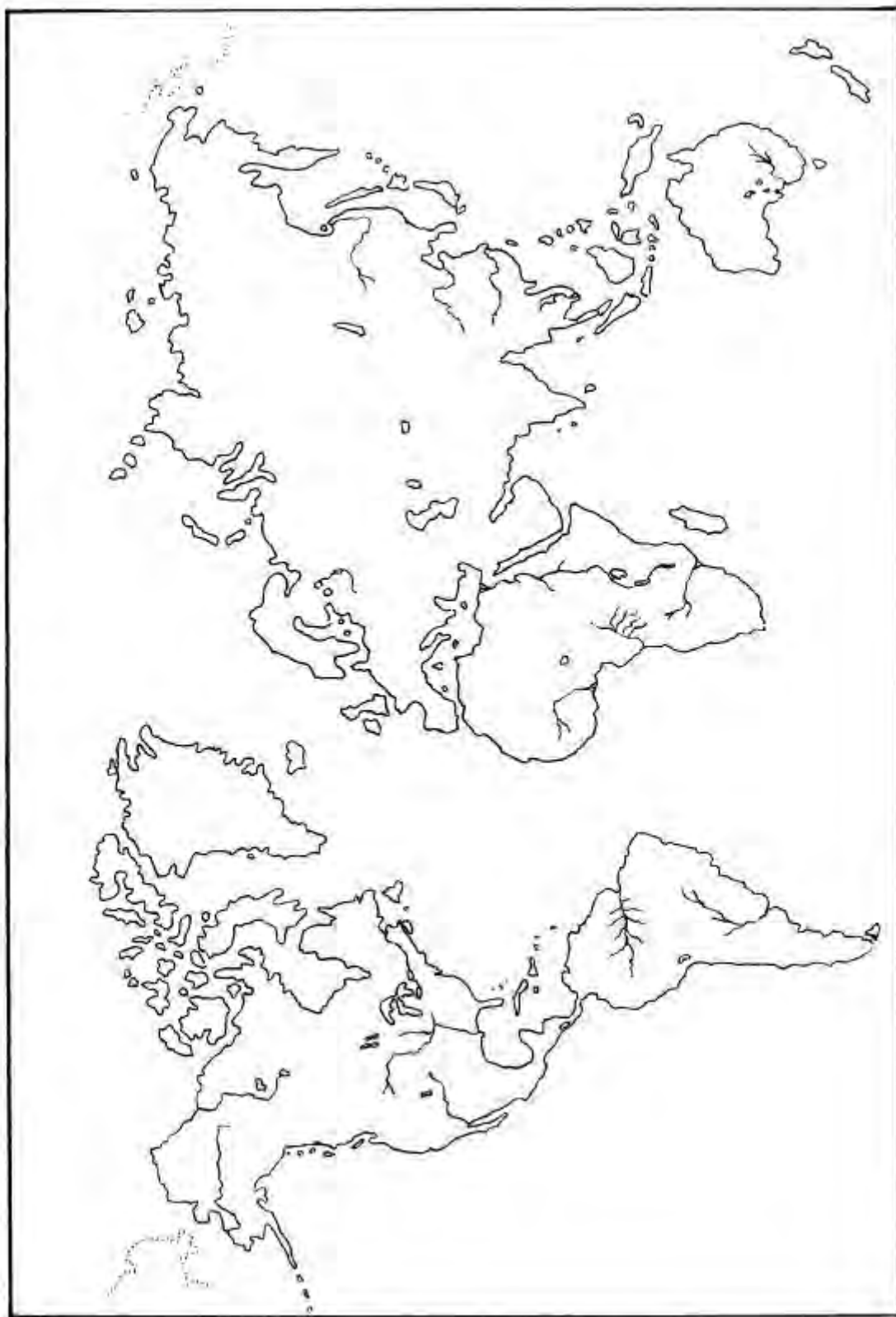
M. Sound (Puget Sound)

Defined: _____

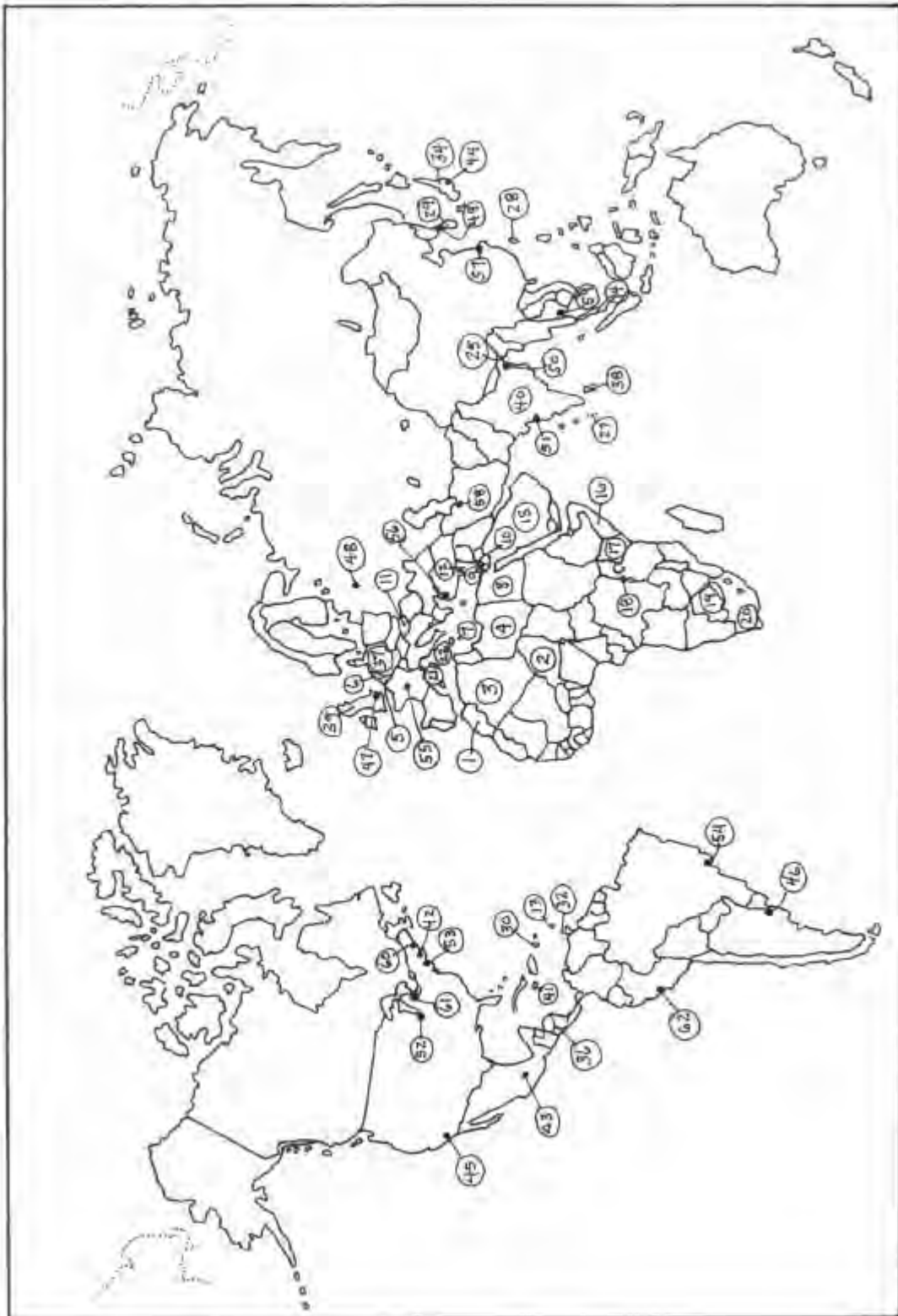
N. Swamp (Okefenokee)

Defined: _____

SURFACE WATERS OF THE WORLD



WORLD MAP - KEY



COUNTRIES OF THE WORLDSOME WATER-SCARCE COUNTRIES

Cubic meters of water/person/year

<u>Country</u>	<u>1992</u>	<u>2010</u>
1. Morocco	1150	830
2. Niger	1690	930
3. Algeria	730	500
4. Libya	160	100
5. Belgium	840	870*
6. Netherlands	660	600
7. Malta	80	80
8. Egypt	30	20
9. Israel	330	250
10. Lebanon	1410	980
11. Hungary	580	570
12. Syria	550	300
13. Barbados	170	170
14. Singapore	210	190
15. Saudi Arabia	140	70
16. Somalia	1390	830
17. Kenya	560	330
18. Rwanda	820	440
19. Botswana	710	420
20. South Africa	1200	600

* population decreasing

HIGH POPULATION DENSITIES

In descending order:

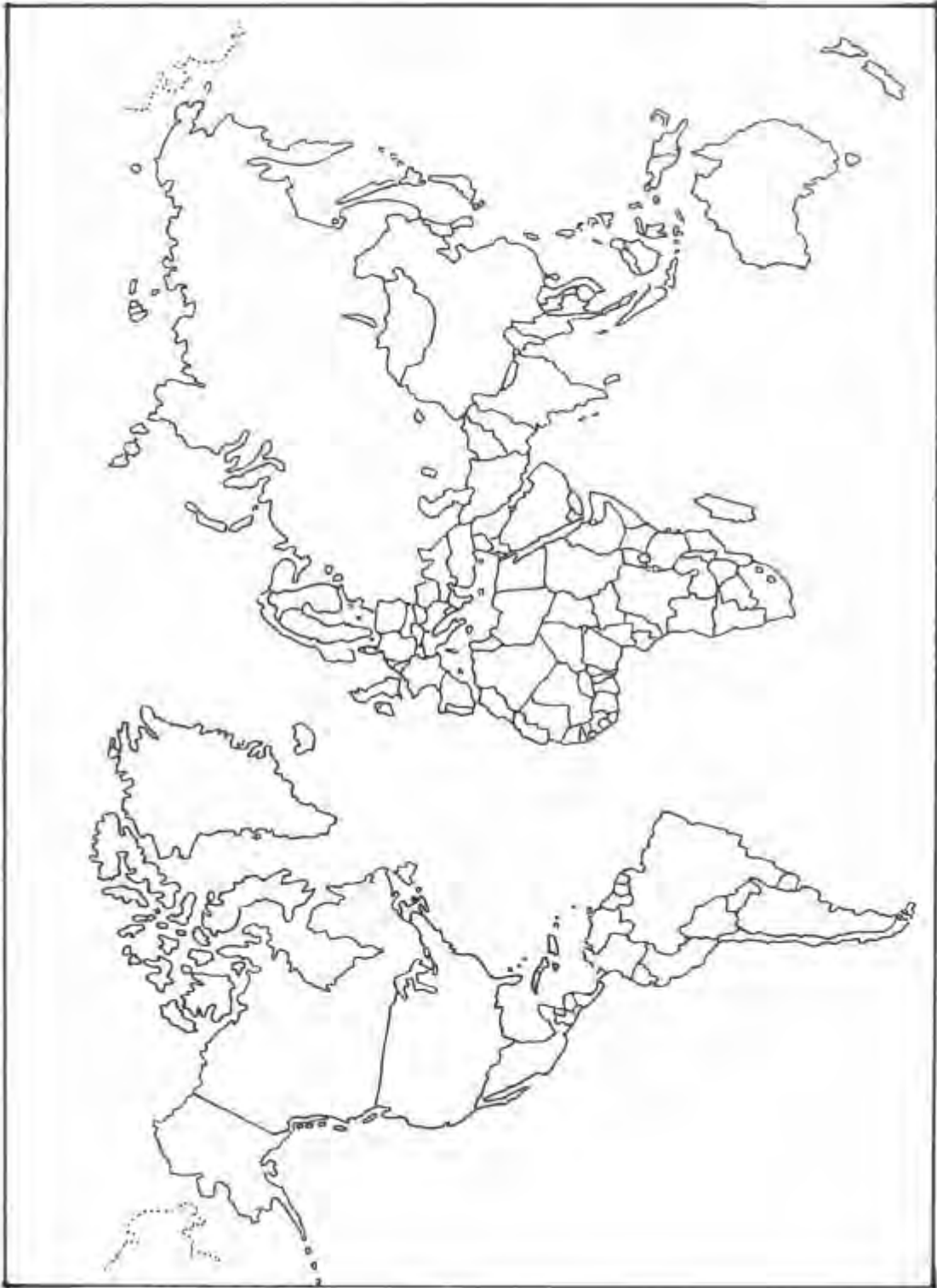
COUNTRIES/TERRITORIES

21. Monaco
22. Singapore (14)
23. Vatican City
24. Malta (7)
25. Bangladesh (13)
26. Barbados (13)
27. Maldives Islands
28. Taiwan
29. South Korea
30. Puerto Rico
31. Netherlands
32. Grenada
33. Belgium (5)
34. Japan
35. Lebanon (10)
36. El Salvador
37. Germany
38. Sri Lanka
39. England
40. India
41. Jamaica

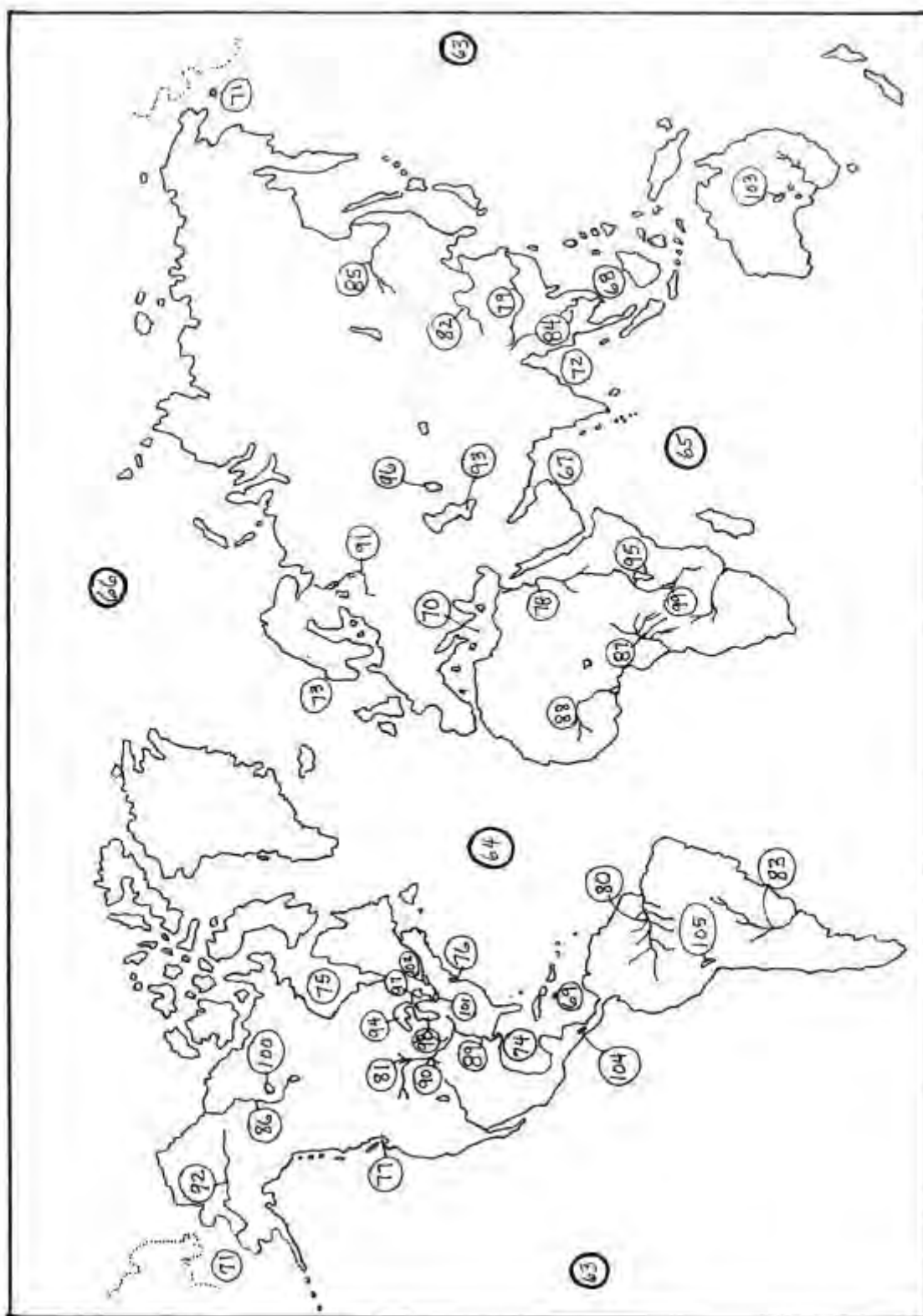
CITIES

42. New York, USA
43. Mexico City, Mex.
44. Tokyo, Japan
45. Los Angeles, USA
46. Buenos Aires, Arg.
47. London, Eng.
48. Moscow, Russia
49. Seoul, Kor.
50. Calcutta, India
51. Bombay, India
52. Chicago, USA
53. Philadelphia, USA
54. Rio de Janeiro, Brz.
55. Paris, France
56. Istanbul, Tur.
57. Shanghai, China
58. Tehran, Iran
59. Bangkok, Thai.
60. Boston, USA
61. Detroit, USA
62. Lima, Peru

WORLD MAP



SURFACE WATERS - KEY



SURFACE WATERS OF THE WORLD**PRINCIPAL OCEANS, SEAS, GULFS**

- 63. Pacific Ocean
- 64. Atlantic Ocean
- 65. Indian Ocean
- 66. Arctic Ocean
- 67. Arabian Sea
- 68. South China Sea
- 69. Caribbean Sea
- 70. Mediterranean Sea
- 71. Bering Sea
- 72. Bay of Bengal
- 73. Norwegian Sea
- 74. Gulf of Mexico
- 75. Hudson Bay
- 76. Chesapeake Bay
- 77. Puget Sound

PRINCIPAL RIVERS

- 78. Nile, Africa
- 79. Yangtze, China
- 80. Amazon, Brazil
- 81. MS-Missouri-Red Rock, USA
- 82. Yellow, China
- 83. Rio de la Plata-Parana, S. Amer.
- 84. Mekong, Asia
- 85. Amur, China
- 86. Mackenzie, Canada
- 87. Congo, Zaire
- 88. Niger, Africa
- 89. Mississippi, USA
- 90. Missouri, USA
- 91. Volga, Russia
- 92. Yukon, Canada-Alaska

PRINCIPAL LAKES

- 93. Caspian Sea, Iran
- 94. Lake Superior, USA-Canada
- 95. Lake Victoria, Africa
- 96. Aral Sea, Uzbekistan and Kazakhstan
- 97. Lake Huron, USA-Canada
- 98. Lake Michigan, USA-Canada
- 99. Lake Tanganyika, Africa
- 100. Great Bear Lake, Canada
- 101. Lake Erie, USA-Canada
- 102. Lake Ontario, USA-Canada
- 103. Lake Eyre, Australia
- 104. Lago de Nicaragua, Nic.
- 105. Lago de Titicaca, Bolivia

WATER WHIZ - A BOARD GAME

9-12

OBJECTIVES

The student will do the following:

1. Play a board game with three to five other students.
2. Compute the price of water that will be on the monthly water bill.
3. Identify the different activities in the game that affect the price of water.
4. Describe two ways that water usage is affected by each of the different aspects of community life.

SUBJECTS:

Science (Physical and Biology), Social Studies, Economics

TIME:

1-2 class periods

MATERIALS:

Water Whiz game board
game cards
dice
“water bills” for each student

BACKGROUND INFORMATION

Everyone of us in our daily lives is involved in activities that directly or indirectly affect the quality and price of the water made available to us by our water utility. This game can be used as an introductory activity for a water quality unit to be taught in any course. Its objective is to make students aware that the activities they engage in affect the quality of the water they will have for bathing and drinking.

ADVANCE PREPARATION

- A. Be certain that there are enough board games, game cards, blank water bills, and dice for the students.
- B. Suggestions:
 1. Print the game board on ledger paper. Color each “card” space a different color and

lamine the boards.

2. Print the cards for each category on colored paper to coordinate with the board. Lamine each sheet; then cut out the cards. (Hint: Cut bulletin board paper to 11"x17" and feed it into your copier!)
 3. Print water bills with game summaries on back. Use half sheets.
- C. Teach the students the rules of the game.
1. Each student will obtain a blank water bill and place \$1.00 as the initial price for each 1000 gallons of water used by him/her during the month.
 2. Predetermined by the roll of a die, the first player will roll a die and draw a card from the spot on the board as is indicated by the number on the die.
 - 1 is the agricultural space.
 - 2 is the business space.
 - 3 is the development space.
 - 4 is the industry space.
 - 5 is the recreation space.
 - 6 is the residential space.
 3. Pick up the card from the appropriate stack. Read this card so that everyone in the group may hear what affects the water and its price.
 4. Change the price of the water as you are instructed to do by the card. Then return the card to the bottom of the stack.
 5. The winner is the student who pays the least for water.
- D. Cut out the six different pages of station cards.

PROCEDURE

- I. Setting the stage
- A. After dividing the class into groups of four, tell the students to open up the game board and look at the community drawn on the board. The community reservoir provides roughly one-half of the community's drinking water; an artesian well and a river provide water for the other half. Have them study the game board to observe what

activities they see occurring in the community that might affect the quality and quantity of the water.

B. Tell the students to notice the six stations that are placed on the board. Each of these stations has a rectangular empty space next to it. Have the students place the shuffled and appropriately labeled cards upside down in these areas. The first station will have the agricultural cards, the second the business cards, and so on.

C. Have the students in each group select a person who will start the game, with the play moving to the right, until all persons in the group have had a chance to represent some sector of the community and have changed their water bill one time.

D. Remind the students that they must listen to the activity on the card because they will participate later in a summary activity from the information gained from the game.

E. The first player will roll the die, pick up the top card, and read it aloud. He/she will then alter the price of water on the bill as the card so instructs.

F. Each player in the group will follow the same procedure until all the students have taken part in a round. As many rounds will be completed as time permits (approximately 10).

G. Remember that the winner of the game is the person who pays the lowest rate for each 1000 gallons of water used.

II. Activity

A. Students will participate in the game.

B. Summary activity - The students will write down two activities carried out by each sector of the community that affect the quantity and quality of water, one activity that increases and one that decreases the bill. The information for this written activity will come from what they remember from playing the game.

III. Follow-up

Ask the students to discuss at home some ways their family can improve their community's water supply.

IV. Extensions

Ask students the following day to discuss, in their same groups, the reaction of their families. Have each

group make a short report to the class.

RESOURCES

The data for the amount of water lost in leaky faucets, garden watering with different size hoses, the shower, etc., came from a book entitled Water in Crisis by Peter H. Gleick, published by the Oxford University Press in 1993.

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Student Sheet

Game Cards

<u>Agricultural</u> A sod farmer uses simazine as a herbicide on his land. A weather front with severe thundershowers blows in very rapidly and the simazine is washed into the streams. <u>INCREASE</u>: \$.10/1000 gallons	<u>Agricultural</u> A farmer harvests his spring grain and then plows his soil to plant his corn. Harsh spring rains come and erode thousands of pounds of his topsoil into the streams and lakes. <u>INCREASE</u>: \$.10/1000 gallons
<u>Agricultural</u> Farmers allow cattle to graze too close to the streams and their banks. Fecal material winds up in the water. There is an increase in bacterial and viral contamination. More testing and treatment are required of the public water supply. <u>INCREASE</u>: \$.10/1000 gallons	<u>Agricultural</u> A farmer is extremely conscientious and gets support from the state to fence his cattle away from the streams and to build ponds to provide water for his livestock. The public water supply is free of microbial infection. <u>DECREASE</u>: \$.10/1000 gallons
<u>Agricultural</u> A farmer carefully uses no-till farming practices as he plants his spring corn crop. Heavy rains come, and the Milo stalks on the ground from his previous crop cut down on erosion. <u>DECREASE</u>: \$.10/1000 gallons	<u>Agricultural</u> A fisherman has been harvesting fish in lakes for 20 years to support his family. The insecticide chlordane is now building up in the sediment of the lake, and he has been prohibited from selling his catfish to the restaurants. <u>INCREASE</u>: \$.05/1000 gallons
<u>Agricultural</u> Straight row plowing practices have caused much topsoil to wash into the rivers and lakes. Deeper pool areas in the stream are filling. Recreational fishing and swimming have almost ceased. <u>INCREASE</u>: \$.05/1000 gallons	<u>Agricultural</u> Sunlight penetration into the river is decreased because of the turbidity caused by topsoil runoff. The natural inhabitants are moving out because the habitat is changing. <u>INCREASE</u>: \$.05/1000 gallons

<u>Residential</u> You neglect to fix a leaky faucet and lose 25 gallons of water each day. <u>INCREASE</u>: \$.10/1000 gallons	<u>Residential</u> You decide to replace your toilets with the new 1.6 gallon models. You will save approximately 60 gallons of water/day. <u>DECREASE</u>: \$.10/1000 gallons
<u>Residential</u> You change the size of the water hose you use in your yard from a $\frac{3}{4}$ inch to a $\frac{1}{2}$ inch diameter. You water your yard 5 hrs./wk. and save 1250 gallons in a week. <u>DECREASE</u>: \$.05/1000 gallons	<u>Residential</u> In summer months, you water your grass 2 hours each day. You use 100,000 gallons in a month. <u>INCREASE</u>: \$.10/1000 gallons
<u>Residential</u> Your cousins come to visit, and an additional 120 gallons of water are used each day in your home. <u>INCREASE</u>: \$.05/1000 gallons	<u>Residential</u> You change the oil in your car and take the old oil and pour it around your home's foundation to reduce pests. The hydrocarbons leach to the groundwater. It costs to clean it up. <u>INCREASE</u>: \$.05/1000 gallons
<u>Residential</u> It is spring. You plant your garden and then spray your lawn and garden for weeds. It rains the same day and washes the pesticide into the streams and lakes. <u>INCREASE</u>: \$.10/1000 gallons	<u>Residential</u> You change your shower head to a water-saving type and reduce the flow 50%. <u>DECREASE</u>: \$.05/1000 GALLONS

<u>Development</u> Your community is opening a new residential development next to the lake. They have graded new roads. This development created a turbidity problem in the lake. The fish are leaving the area because the food chain is being destroyed. <u>INCREASE</u>: \$.10/1000 gallons	<u>Development</u> The stream flowing into the river has a sediment problem, and the deeper fishing and swimming pools are filling with sediment. The value of the riverfront property has decreased. <u>INCREASE</u>: \$.05/1000 gallons
<u>Development</u> New housing development around the lakes and streams has increased the number of septic tanks. More nitrates and phosphates are going into the streams and lakes decreasing the oxygen supply for fish. New sewage pipes must be laid. <u>INCREASE</u>: \$.05/1000 gallons	<u>Development</u> You are maintaining your septic tank as you should. You have properly cleaned it of the sludge. <u>DECREASE</u>: \$.05/1000 gallons
<u>Development</u> A new golf course has been built around the lake. The caretaker has used simazine on the turf. Rain and stormwater discharge have carried the herbicide to the lake. <u>INCREASE</u>: \$.05/1000 gallons	<u>Development</u> The coliform count has increased with the addition of new septic tanks. More chlorination is needed to prepare the municipal drinking water. <u>INCREASE</u>: \$.05/1000 gallons
<u>Development</u> A request for permit to fill in a low-lying wetland bog to build more apartments has been denied. <u>DECREASE</u>: \$.10/1000 gallons	<u>Development</u> The new highway being built is coming into the north side of town. All the proper erosion protection practices are being used. The lake is not experiencing a sediment problem. <u>DECREASE</u>: \$.25/1000 gallons

<u>Business</u> The corner auto service station has a leak in its gasoline storage tank. Hydrocarbons leach down to the groundwater. <u>INCREASE</u>: \$.10/1000 gallons	<u>Business</u> Many old car batteries are taken to the old county landfill. There is no polyethylene or clay lining. Seepage of lead and acids occurs through the sandy soil. <u>INCREASE</u>: \$.10/1000 gallons
<u>Business</u> The county commissioners have been told that the present landfill is no longer environmentally safe. New monies must be found to construct a new landfill to protect our groundwater. <u>INCREASE</u>: \$.10/1000 gallons	<u>Business</u> Your dry cleaning business has permitted some of its chemicals to get into the ground and move toward the groundwater. Your treatment plant must install granular activated carbon to remove them. <u>INCREASE</u>: \$.10/1000 gallons
<u>Business</u> A furnace manufacturer improved its manufacturing process and now sells one of its recovered chemicals to claim a profit of over \$1000/year. They used to pour this waste chemical down the drain. <u>DECREASE</u>: \$.10/1000 gallons	<u>Business</u> The textile factory in town now has the technology to control its trichloroethylene release. <u>DECREASE</u>: \$.10/1000 gallons
<u>Business</u> Toluene from a gasoline spill leaks into the groundwater. <u>INCREASE</u>: \$.05/1000 gallons	<u>Business</u> A service station carefully recycles all its old oil drained out of cars and pays its “do it yourself” customers to bring in their oil. <u>DECREASE</u>: \$.10/1000 gallons

<u>Industry</u> Bad tilling practices in the agricultural and developmental sections of the town have caused the river to fill with sediment. The depth is no longer sufficient for the coal barge to take its load to the power plant. It must be dredged. <u>INCREASE</u>: \$.05/1000 gallons	<u>Industry</u> Detergent foaming agents were not completely removed by the industrial wastewater treatment plant. These have been released into the river and are causing concern among homeowners along the water's shorelines <u>INCREASE</u>: \$.05/1000 gallons
<u>Industry</u> The industrial sector has built its own wastewater treatment plant, relieving the municipal plant of such a heavy load. <u>DECREASE</u>: \$.05/1000 gallons	<u>Industry</u> Corrosive chemicals have been released into the surrounding watershed by older industry. These chemicals were not all removed by the treatment plant and have caused pipe corrosion in the city downstream. New pipes must be installed. <u>INCREASE</u>: \$.05/1000 gallons
<u>Industry</u> The town must drill a new well tapping the groundwater because an old hazardous waste underground storage tank has been found located too close to the wellhead. The tank has begun leaking and has contaminated the surrounding soil. <u>INCREASE</u>: \$.10/1000 gallons	<u>Industry</u> During the hot summer months, a coal- fired power plant is working at peak performance to provide electricity for air conditioning. SO₂ and NO₂ going into the air cause acid rain, and the pH of the lake is changing slightly. It must be adjusted. <u>INCREASE</u>: \$.05/1000 gallons
<u>Industry</u> The pulp and paper mill has a wonderful environmental engineering department. The mill is odorless, the water is returned at ambient temperatures, and the pH and dissolved oxygen (DO) of the river is normal. <u>DECREASE</u>: \$.10/1000 gallons	<u>Industry</u> In the hot summer months, the holding ponds of the mill do not cool the water as fast as in the winter months. Production is up, so the released water does not stay in the ponds long enough to cool down. It is causing fish kills in the river. <u>INCREASE</u>: \$.10/1000 gallons

<u>Recreation</u> Nutrients from a farm have caused hydrilla to grow around the shore of the lake. This must be removed for recreational activities. <u>INCREASE: \$.05/1000 gallons</u>	<u>Recreation</u> Boat fuel is being spilled into the lake because of improperly managed fueling stations at the marina. The water must be cleaned up. <u>INCREASE: \$.10/1000 gallons</u>
<u>Recreation</u> The marina has installed a pump-out station to dispose of human waste from the self-contained larger boats. <u>DECREASE: \$.10/1000 gallons</u>	<u>Recreation</u> Many boat owners will not take the time to return to the pump-out station at the marina and empty their holding tanks directly into the lake. <u>INCREASE: \$.10/1000 gallons</u>
<u>Recreation</u> The drainage ditches in the community have been converted into artificial wetlands that adjoin the lake. The natural wetlands in the low areas around the lake have been preserved. This helps to clean the storm water running into the lake. <u>DECREASE: \$.10/1000 gallons</u>	<u>Recreation</u> The creek and lake in town are filling up with sediment, and the community must pay the charge of dredging the lake out to restore its beauty and recreational value. <u>INCREASE: \$.05/1000 gallons</u>
<u>Recreation</u> Recreational fishing is at an all time high because the fishermen and volunteer lake quality monitors are preserving the natural habitats of the area. <u>DECREASE: \$.05/1000 gallons</u>	<u>Recreation</u> The schools in this community are very progressive and are teaching the students to care for their lakes' quality during their recreation. Their drinking water supply will stay uncontaminated. <u>DECREASE: \$.10/1000 gallons</u>

Name: _____

WATER BILL

Initial Cost 1000 gallons = \$1.00

Round 1 amount change: + or -
Altered Price \$ _____

Round 2 amount change: + or -
Altered Price \$ _____

Round 3 amount change: + or -
Altered Price \$ _____

Round 4 amount change: + or -
Altered Price \$ _____

Round 5 amount change: + or -
Altered Price \$ _____

Round 6 amount change: + or -
Altered Price \$ _____

Round 7 amount change: + or -
Altered Price \$ _____

Round 8 amount change: + or -
Altered Price \$ _____

Round 9 amount change: + or -
Altered Price \$ _____

Round 10 amount change: + or -
Final Price \$ _____

GAME SUMMARY

List several of the things you have learned that will affect your water bill.

AGRICULTURAL

Increase _____
Decrease _____

BUSINESS

Increase _____
Decrease _____

DEVELOPMENT

Increase _____
Decrease _____

INDUSTRY

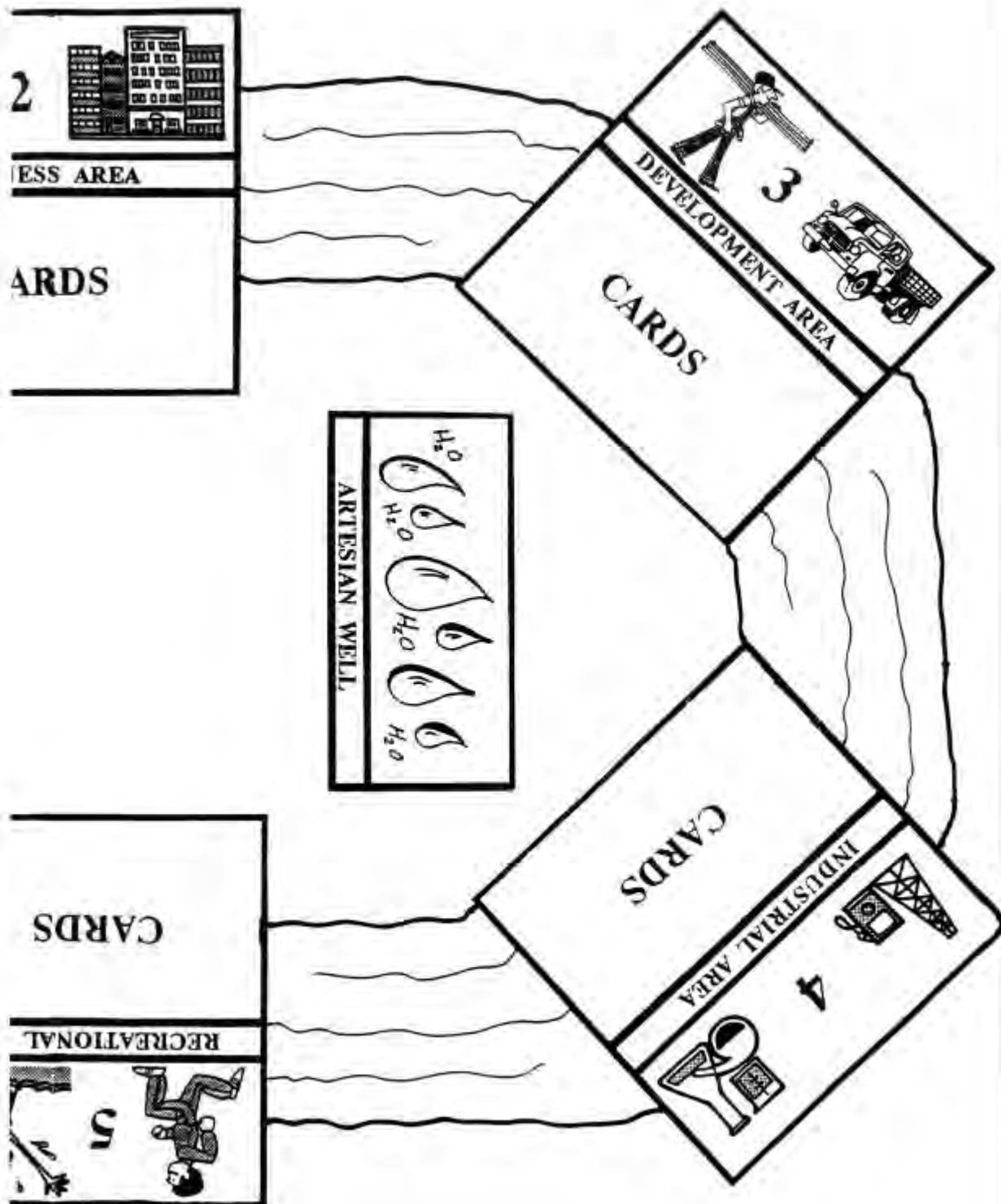
Increase _____
Decrease _____

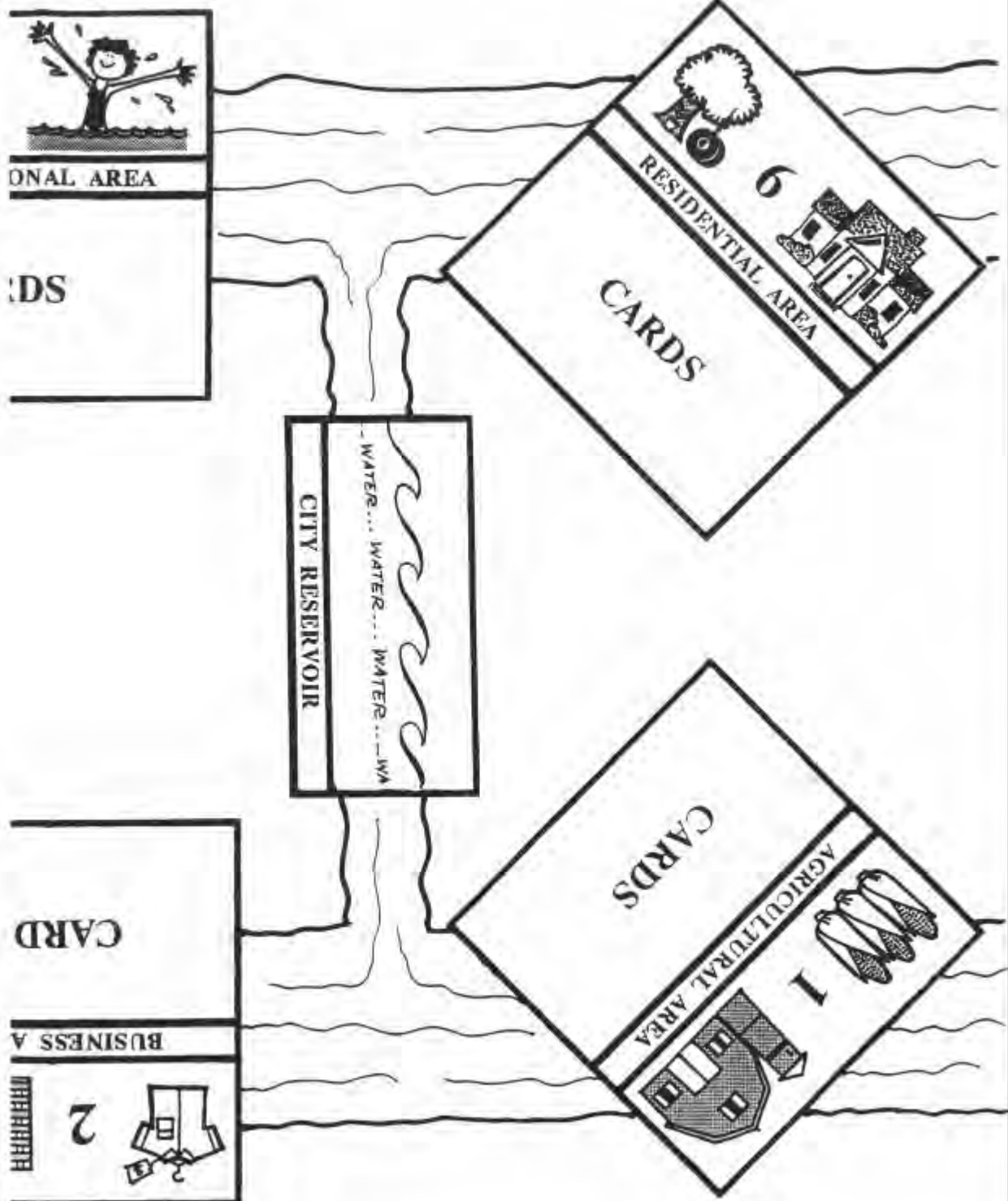
RECREATION

Increase _____
Decrease _____

RESIDENTIAL

Increase _____
Decrease _____





WATER: POETIC, PROSAIC, MOSAIC

9-12

OBJECTIVES

The student will do the following:

1. Watch film clips, slides, or look at pictures of water at its most beautiful in oceans, lakes, and rivers or take a field trip to a body of water (river, creek, lake).
2. Compose descriptive sentences of what is seen, using metaphors, similes, and alliteration.
3. Convert the sentences into a paragraph and then into a poem.
4. Explain various words, phrases, adages, and poems that refer to water.
5. Put the author's words into demonstrations.
6. Describe the aesthetic aspect of bodies of water.
7. Describe photographic composition.
8. Compile a photographic essay (8 photographs) of a local body of water.

SUBJECT:

Language Arts

TIME:

You will need three class periods if you are introducing metaphors, similes, and alliteration for the first time.

MATERIALS:

film clips
slides or pictures of large bodies of water--lakes, rivers, oceans

BACKGROUND INFORMATION

Almost all descriptive language uses metaphors, similes, and alliteration. These literary devices are the building blocks of poetry. Many students balk at a poetry writing assignment. But when they learn to use the building blocks of poetry as they write prose, they gain confidence to compose poetry. Describing such a beautiful natural setting as a lake, a river, or the ocean is a non-threatening assignment; and it also reminds students of the importance of keeping our natural settings beautiful and of the importance of clean water.

Water is not just a natural resource and a necessity for life. Humans always described it, used it in creation

stories, allegorized and anthropomorphized it, and put it in verse. Each of these usages says something about water and the way we view it.

Photography is a viable communication tool. The cliché, “A picture is worth a thousand words,” is a truism. How do we feel when we see a river, a creek, or a lake that has been littered or polluted? Conversely, how do we feel when we see beautiful, clean bodies of water? When students are forced to look through a lens to compose a photograph, they see things they would not otherwise see. By composing a photographic essay, they will take a close look at the aesthetic quality of a local body of water.

Terms

adage: an old saying; a phrase passed down through the years

allegory: a story in which symbols are used to present moral truths

alliteration: repetition of an initial sound, usually of a consonant or cluster, in two or more words of a phrase or line of poetry

anthropomorphize (personify): to take something inanimate or subhuman and give it human characteristics

haiku: 3-line poem. First line has 5 syllables, second line has 7 syllables, and third line has 5 syllables.

metaphor: a figure of speech containing an implied comparison in which a word or phrase ordinarily and primarily used for one thing is applied to another

model: using simple or familiar objects to explain or demonstrate a new, unfamiliar, or complicated concept

simile: a figure of speech in which one thing is likened to another dissimilar thing by the use of words such as *like* or *as*

ADVANCE PREPARATION

- A. Before starting this assignment, be sure students understand what metaphors, similes, and alliteration are. Provide them with examples of these literary devices from both prose and poetry.

- B. Gather pictures of beautiful water. Listed below are some possible sources.
1. Film clips
 - a. ANNE OF GREEN GABLES--film produced by Kevin Sullivan for Wonderworks (available for sale or rent in most video stores): lakes and rivers around Prince Edward Island, Canada.
 - b. A RIVER RUNS THROUGH IT--film directed by Robert Redford (available for rent in most video stores): river in Montana.
 2. Large photographs
Check with travel agencies. They will often let you borrow large posters.
 3. Slides
Obtain personal slides of lakes, rivers, oceans or slides in the social studies or science section of many school libraries.
 4. Copy the Water Quotes Student Sheet, adding to it as desired.
 5. Divide the students and/or phrases into groups.
 6. Copy the Hint Sheet (enclosed).
 7. Find several photographs in a National Geographic magazine that incorporate the hints given to the students.
 8. Collect some photographs that evoke strong feelings.
 9. Locate two water sites: one clean, one littered. Make arrangements for trips to both sites.

PROCEDURE

- I. Setting the stage
 - A. Explain to students that they are going to write a descriptive paragraph. They must use a metaphor, a simile, and at least one case of alliteration.

- B. Show students a film clip (slide or photo) and have them describe it.

II. Activity

- A. The students should first write a straightforward description; then they should create the metaphors, similes, and alliteration, putting their description in paragraph form.
- B. Students should read through their prose, looking for natural rhythms and breaking points for line arrangement. They may have to change some words, delete some words, or add words for the sake of rhythm.
- C. Students are now ready to make poems out of their descriptive paragraphs. Many of them will need help--or rather approval--to give them confidence to ~~finish~~ what they have started. An example of this process follows.

III. Follow-up

- A. Students may want to illustrate their poems and display them in the classroom.
- B. If the school has a literary magazine, submit some of these poems for publication.
- C. Evaluation - This assignment should be evaluated only on the use of metaphors, similes, and alliteration.
- D. Tell the students that water is like the weather -- everyone is always talking about it, but no one does much about it. They are going to see what people have said about water, figure out what they meant, and make a model or demonstration to explain their "water words."
- E. Show students the photographs that evoke strong emotion. Ask them to respond orally to these photographs. Emphasize that photography has the power to prompt action.
- F. Give students the Hint Sheet. Explain the sheet. Then show students some examples of well-composed photographs.
- G. Explain that the upcoming field trip is to give the students ideas about locations in which to film a

photographic essay that makes a statement about the aesthetic quality of water.

EXAMPLE

(photograph of rough surf on beach at sunset)

SIMPLE DESCRIPTION--

The waves are crashing on a deserted beach. The sky is a little cloudy so that the setting sun makes them and, consequently, the water look like they are on fire.

PARAGRAPH--

It is evening, and once again the sea claims the beach for its very own. The sun, like a defeated general, retreats behind the clouds that have become a screen of smoke and fire. Incessantly the waves, soldiers marching in forceful formation, crash upon the shore claiming new territory with salt and foam. Who sends these relentless soldiers? Who gives the orders to march? The sirens of the moon sing the marching tune as Neptune gives the orders.

POEM--

NEPTUNE'S ARMY

Behind a screen of smoke and fire
The Sun surrenders.
The waves, regimented soldiers,
March at Neptune's command.
The sirens of the moon sing his orders--
Rolling, rolling, relentlessly to the shore.

Like a defeated general,
The Sun retreats.
With salt and spray, the regimented waves
Claim new territory.
Day gives way to night
And land bows again to Neptune's sway.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Student Sheet

Water Quotes

1. "Sweetwater seas" - refers to the Great Lakes
2. Ben Franklin: "When the well's dry, we know the worth of water."
3. Romantic poet who called water a "sensitive chaos"
4. The cardinal law of California politics: "Water runs uphill to money."
5. "Water seeks its own level."
6. "That's all water under the bridge."
7. Coleridge: "Water, water everywhere and not a drop to drink."
8. Hermann Hesse: "Love this river, stay by it, learn from it." Yes, he wanted to learn from it, he wanted to listen to it. It seemed to him that whoever understood this river and its secrets would understand much more, many secrets, all secrets.
9. Kathleen Raines

"Because I see these mountains
they are brought low,
Because I drink these waters
they are bitter,

Because I tread these black rocks
 they are barren,
Because I found these islands
 they are lost;
Upon seal and seabird dreaming their
 innocent world,
My shadow has fallen.”

10. Ruskin Bond: “I never cease to wonder at the tenacity of water -- its ability to make its way through various strata of rock, zigzagging, backtracking, finding space, cunningly discovering faults and fissures in the mountains and sometimes traveling underground for great distances before emerging into the open. Of course, there’s no stopping water. For no matter how tiny that little trickle, it has to go somewhere.”

Student Sheet (cont.)

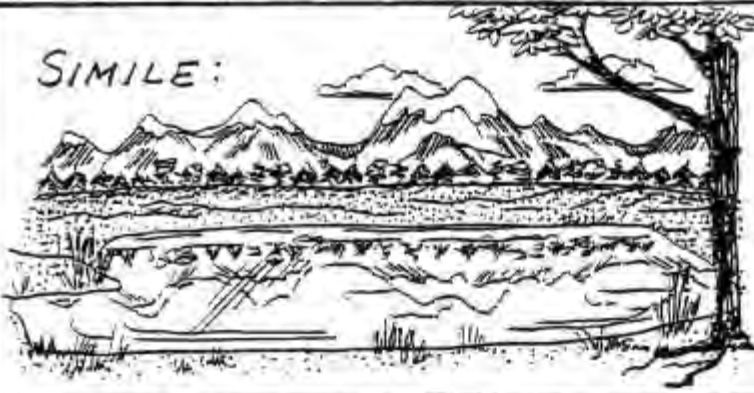
11. The 23rd Psalm: “My cup runneth over.”
12. “The Big Muddy” - refers to the Mississippi River
13. “Ol’ Man River” - refers to the Mississippi River
14. “Still waters run deep.”
15. That’s just “water off a duck’s back.”
16. “Oil and water don’t mix.”
17. “Up a creek without a paddle.”
18. “Blood is thicker than water.”
19. Don’t get “bogged down.”
20. He’d rather be a “big frog (fish) in a small pond.”
21. “Get your feet wet.”
22. “Don’t rock the boat.”
23. “Just a drop in the bucket.”

- 24. It's "raining cats and dogs."
- 25. He's a "fish out of water."
- 26. That's just the "tip of the iceberg."
- 27. Like the "parting of the waters."
- 28. "Everybody's downstream from someone."

Student Sheet

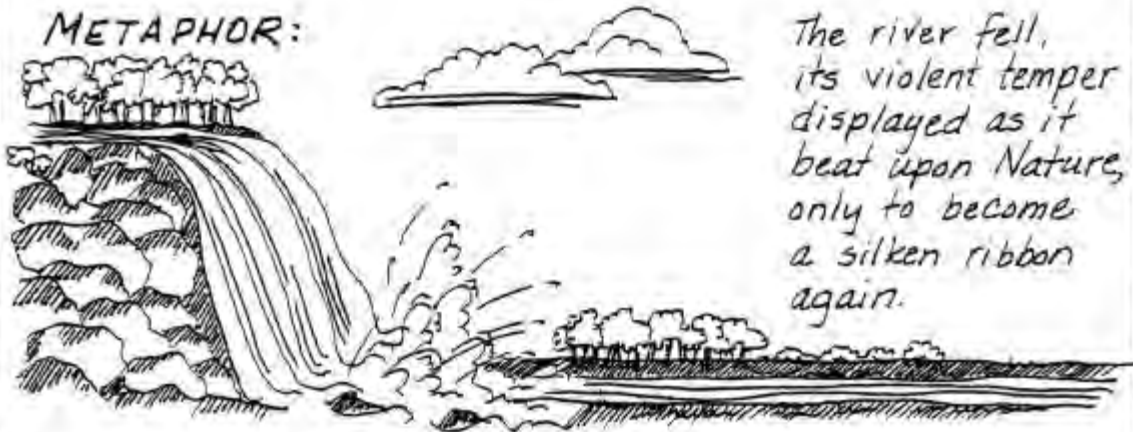
BUILDING BLOCKS OF POETRY

SIMILE:



The lake lay sparkling and quiet, like a huge mirror reflecting the distant fields and mountains.

METAPHOR:



The river fell, its violent temper displayed as it beat upon Nature, only to become a silken ribbon again.

ALLITERATION:



The bubbling brook bounced along across rocky ridges toward the bottomlands.

HOW WOULD WE SAY IT WITHOUT WATER?

9-12

OBJECTIVES

The student will do the following:

1. Participate in class discussion about the importance of water as a symbol in literature.
2. Work in a small group to explore thoroughly the importance of water in one particular work.
3. Prepare a group presentation to demonstrate the importance of water in his/her chosen work of literature.

SUBJECTS:

Language Arts, Social Studies (Geography)

TIME:

3 class periods,
1 week homework time

MATERIALS:

water poems
books
essays

BACKGROUND INFORMATION

As a natural resource and an ever-present force in our natural world, water has always been an important factor in one's imagination. In Homer's Odyssey, Odysseus meets many perils on his return--over water--to Ithaca. Beowulf journeys across the sea to assist Hrothgar and, at his death, embarks in the funeral ship upon the sea of the immortal unknown. Many poets from Matthew Arnold's "Dover Beach" to Alfred Lord Tennyson's "The Lady of Shalott" recognize both the physical and symbolic properties of water in verbal expression. Huckleberry Finn finds safety on the mighty Mississippi; Marlowe journeys into the Heart of Darkness on the Congo River. Great writers have used the aesthetic properties of water to make us think. They have used the familiar to ferry us into the unfamiliar.

ADVANCE PREPARATION

I. Reading Materials

- A. Check library for poems, books, essays, and stories whose central symbol is water or a body of water.
- B. Check the adopted literature book of your school (on your grade level) for poems and/or stories that use water as a central symbol.

- II. Copy Procedure Sheet for group project (one for each group).
- III. Copy Student Evaluation Sheets for each group.
- IV. Divide the class into groups of three or four (no more than four).

PROCEDURE

- I. Setting the stage
 - A. Secure an audio tape or CD that has sounds of the ocean or of rain (available at local and/or nature company stores). Have tape playing when students enter the room.
 - B. Have posters of oceans, rivers, or lakes around the room.
 - C. Have students write a paragraph about images or feelings that the tape and/or CD called to mind.
 - D. Have a few of the students read their paragraphs aloud. Then talk about what water symbolizes: relaxation, vacation, peace, soothing rainfall, freedom, no normal responsibilities on lake/river. Also discuss that what water symbolizes is dependent on its purity and accessibility.
 - E. Ask for discussion of the use of water as a significant symbol in works familiar to students. You may have to help them get started: Huckleberry Finn (river is freedom, safety) or “The Lady of Shallot” (river is the border between imagination and reality, ideal and/or real). List their selections on the board.
- II. Activity
 - A. Divide the class into small groups.
 - 1. Have each group select a leader/spokesperson.
 - 2. Have each group draw a number.
 - B. Each group should decide which work of literature it will research. The groups may announce their choices by the order of the numbers they draw.
 - C. Hand out Group Report Procedure Sheets and Group Evaluation Sheets. Explain

these to students.

1. Students should divide responsibilities among themselves.
 2. Students should set up out-of-class meeting times.
- D. Have one class day reserved for library work. After library day, give students one week to complete project.
- E. Students will give reports orally in the order of the numbers they draw and will hand in a written version. Students may display visual aids in classroom.
- F. Take up Student Evaluation Sheets. These should figure in the grading of the project.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

EVALUATION SHEET

NAME: _____

LITERARY WORK: _____

YOUR RESPONSIBILITY: _____

THREE THINGS YOU LEARNED WHILE WORKING ON THIS PROJECT:

1. _____

2. _____

3. _____

EVALUATE YOUR CONTRIBUTION TO THIS GROUP EFFORT 0-10

Explain: _____

EVALUATE OTHER GROUP MEMBERS (0-10)

#1 NAME: _____

SCORE: _____

WHY? _____

#2 NAME: _____

SCORE: _____

WHY? _____

#3 NAME: _____

SCORE: _____

WHY? _____

Student Sheet

PROCEDURE SHEET

GROUP #: _____

NAMES OF GROUP MEMBERS, RESPONSIBILITIES

1. _____ , _____
2. _____ , _____
3. _____ , _____
4. _____ , _____

LITERARY WORK: _____

AUTHOR: _____

BODY OF WATER USED AS A SYMBOL: _____

THE WATER SYMBOLIZES: _____

DUTIES OF GROUP MEMBERS:

I. SYMBOLISM DETECTIVE/REPORTER--This student should understand and explain how water is used as a symbol in this work. How is it used in the work, and what does it symbolize? His/her findings should be both written and oral.

II. CONTEXT DETECTIVE/REPORTER--This student researches the author or the time period to show why the author, in this place and time, chose this kind of water for this kind of symbol. His/her findings should be both written and oral.

III. HANDS ON MAN/WOMAN--This student should prepare a visual aid to demonstrate how the symbol is used in the book/poem/story (salt maps of rivers or oceans with significant locations noted; a representation of the Lady of Shallot's mirror showing everything she sees in the poem). This student should be ready to present

and explain the visual aid to the class.

IV. GOPHER AND TECHNICAL ASSISTANT--This student should help coordinate the work of the other three and should be available to help each of them.

Student Sheet (cont.)

HINT, HINT-- THE MORE YOU WORK TOGETHER, THE BETTER YOUR PROJECT WILL BE!

PROCEDURE

1. Choose a work of literature that uses water or a body of water in a symbolic way.
2. Each student prepares his/her report in a neatly written (or typed) format to be compiled with the other group members (by TECHNICAL ASSISTANT) and turned in.
3. Each student should be ready to give an oral presentation. The group will be introduced by the TECHNICAL ASSISTANT.
4. Each group should have:
 - a. Cover sheet (decorative with title and author of chosen work).
 - b. Table of Contents sheet (you'll have two reports--title both of them).
 - c. Reports one and two.
 - d. List of group members.
 - e. Group report in a plastic folder.

WATER CAREERS

9-12

OBJECTIVES

The student will do the following:

1. Describe the great variety in water-related careers.
2. Compare specific careers regarding education, training, salary, and job description.

SUBJECTS:

Science, Language Arts, Art, Social Studies, Math

TIME:

2 class periods
out-of-class time for research

MATERIALS:

list of careers (teacher sheet)
resource materials and people checklist
(student sheet)

BACKGROUND INFORMATION

Water-related careers abound in science, industry, agriculture, recreation, federal, state, and/or local government, research, transportation, engineering, and the military. With an increasing awareness of environmental concerns, these career options can be expected to multiply. Some require no more than a high school diploma and on-the-job training; some require a Ph.D. in a very specialized area. Too often students have no clear career goals. Many of these careers will be unfamiliar to the students; perhaps some will find their niche!

Terms

career: a chosen pursuit or life's work; job or profession one is trained to do

ADVANCE PREPARATION

- A. Put each career from Student Sheet on Water-Related Careers on slips of paper (one for each student). Cut them apart. Put them in a container so that students can draw them out.

- B. Have students contact any people in the area who are in these careers. If they are willing to be interviewed by the students, list their names and telephone numbers where they can be reached.

PROCEDURE

I. Setting the stage

- A. Ask students what their career goals are.

1. Are any water-related?
2. What does “water-related” mean?
3. Ask for examples.

- B. Tell students you have an expanded list and they are going to investigate these careers by randomly picking one. Students may exchange their careers as long as each student researches a different one.

II. Activity

- A. Research one or more water-related careers including all of the information on checklist (education or technical or on-the-job training, where education/training is available and what duration, degree, certification, or bonding is required, possible employers and geographical location of jobs, salary, job description).

- B. Locate and interview a person following this career including all the information on checklist (how long in profession, where trained, advancement or travel, favorite and least favorite aspects of job).

- C. Report to class (oral presentation). Turn in completed checklists.

III. Follow-up

- A. Invite persons who have the most interesting, in demand, or locally available jobs to speak to class.

- B. Send for information to some of the colleges, training institutes, or professional Organizations.
- C. Make a bulletin board with information and pictures of water-related careers.
- D. Make a file of all reports on the various careers so students can have access for future reference.

IV. Extensions

Have students impersonate a professional and demonstrate some of the activities involved in the job.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Current, Volume 12, Number 4, 1994, pp. 31-32.

Earth: The Water Planet, NSTA.

Grades 3-5 Water Sourcebook, pp. 1-88.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

WATER-RELATED CAREERS

Agricultural Engineer	Marine Salvage Engineer
Aquarium Director	Marine Geophysicist
Archaeologist	Marine Geologist
Aquatic Entomologist	Marine Conservationist
Biologist	Marine Explorer
Biosolids Specialist	Marine Technician
Boat Builder	Merchant Marine
Boater	Meteorologist
Botanist	Motor Sailboater
Bottled Water Company Employee	Navy
Builder	Oceanographer
Chemist	Olympic/Professional Swimmer
Chemical Engineer	Photographer
Civil Engineer	Physical Scientist
Coast Guard	Plant Physiologist
College/University Professor	Plumber
Commercial Fisherman	Potter
Computer Scientist	Professional Tournament Fisherman
Desalination Plant Director	Professional Skier (Water or Snow)
Diver	Rafting Guide
Docks Master	Ranger
Ecologist	Recreation Instructor
Environmental Attorney	Science Teacher
Environmental Chemist	Scuba Instructor
Environmental Engineer	Scuba Diver
Environmental Scientist	Ship Builder
Farmer	Seaman
Fire Fighter	Snow Hydrologist
Fisheries Biologist	Soil Scientist
Forester	Structural Engineer
Geographer	Submariner
Geologist	Sunken Treasure Hunter
Groundwater Contractor	Tugboat Biologist
Health Dept./Environmental Inspector	Underwater Photographer
Hydraulic Engineer	Wastewater Treatment Engineer
Hydrologist	Water Meter Reader
Ice Skater	Water Level Controller
Landscape Artist	Water Resources Engineer
Landscape Architect	Water Quality Control Officer
Limnologist	Well Driller
Malacologist	Yachtsman

Checklist

1. Job title:
2. Education required:
3. Where is this type of education available and how long does it take?
4. What kind of a degree, certification, or bonding is required?
5. Who employs this type of worker?
6. What is the most common geographical location for this type of job?
7. What is the average annual salary range?
8. What are the job prospects/stability of employment?
9. Describe the work that is done on this job.
10. If there is anything else you learned in your research of this job, include it below.
11. Would you be interested in this type of job? Why or why not?

WATER: MORE PRICELESS THAN GOLD

9-12

OBJECTIVES

The student will do the following:

1. Identify the source of the community's water that is used for residential housing.
2. Describe an actual case study of a water-rights issue in the western part of the United States.
3. Write water rights laws that are free of ambiguities.
4. Demonstrate skill of solving water-rights issues.
5. Outline the water rights laws of his/her state.
6. Compute the monetary value of the water being piped into homes in the community.
7. Demonstrate an appreciation for the importance of water.

SUBJECTS:

Science (Physical), Social Studies (History, Economics), Math

TIME:

2 class periods

MATERIALS:

a copy of the background material for each student

BACKGROUND INFORMATION

Water is indispensable! The possession of water rights with the ownership of real estate in the western half of the United States is prized as gold. Following this introductory paragraph is a summary of an actual water-rights dispute in a western state. Help settle the dispute as a class. In actuality, this has not yet been done. Role play the end of the story to get an understanding of the emotions of the people who are battling for their water.

For 75 years, Jack Wilson and his family have owned hundreds of acres of land backing up to a national forest. In 1955 the Wilson family formed a real estate agency and began the development of several canyons in the area. Gravel roads were graded and dug out of the side of the canyon hills to provide access to one-acre lots. Triple Canyon Real Estate then began the sale of these individual lots. The agency even provided the construction of a cabin shell on each purchased lot if the buyer did not want to construct his or her own. Triple Canyon Real Estate continued to sell lots and cabins in this area until 1991.

Water pipelines were laid connecting the cabins to a storage tank that was supplied with water from three different springs. Water usage and its misuse have been a problem there in dry years when less water flowed into the springs. Sometimes cabin owners had undetected leaks in their pipes when they were away from the area for long periods of time. These leaks often nearly drained the storage tank, thereby depleting the available water and also decreasing the water pressure. This pressure was necessary to carry the water to all the homes, especially during holidays when the area became alive with people on vacations.

Mountain winter freezes and thaws are destructive to underground pipelines laid close to the surface. Extreme water pressure during times that the storage tank was full also caused a fast deterioration of the water system's pipes. Jack Wilson was inundated with complaints about the system. The State Engineer's office sent a letter to Triple Canyon Real Estate advising them of the improvements that had to be made to the water system.

Concerned citizens of the area decided to form a water board and did so with the encouragement of Jack Wilson. Dues were charged, and the monies collected helped to pay for some of the improvements. Because all of the improvements suggested by the State Engineer's office were not carried out, this office sent another letter to Triple Canyon Real Estate. This time the recommendations were more stringent, and a deadline was given for their completion.

Jack Wilson was also advised to draw up a deed that would establish the springs of the area to be for residential usage, not agricultural. Wilson neglected to do so. One of the water laws of this state said that if the water from a spring had not been used as designated in a deed for the previous four consecutive years, the water may be used in another way. The water from the Meandering Slough Spring, which was the one in contention, had been used only for residential use since 1921.

In 1982 the newly formed water board elected a president (Harry Harrison) and a secretary (Nelda Ball). Their services were voluntary as were the services of the men who worked on the pipelines of Triple Canyon Estates. These men were retired petroleum engineers, oil-field workers, and plumbers.

In 1988 Nelda Ball and her husband Drew contracted to buy 15 acres of the Wilson Ranch to farm trees. The designated 15 acres were not part of the Triple Canyon Estates development but did contain one of the springs that was used to supply water to the residential area. Jack Wilson's lawyer, in drawing up the bill-of-sale, failed to include a retention of the water-rights for the area. This meant that Triple Canyon Real Estate's usage of water from Meandering Slough Spring was no longer legal.

Nelda and Drew Ball rerouted Meandering Slough Spring's water from the storage tank to another storage tank on their property. The property owners had approximately 1/3 less water to use for their subsistence. Jack Wilson convinced residential property owners that there was ample time for an appeal on the ruling. The board members, in their naivety and trust of Jack Wilson, let time pass without bringing suit against the Ball family.

The board from Triple Canyon Estates Water Association finally filed suit against Nelda and Drew Ball in 1989. The judge in the case, Martha Gregory, ruled in favor of Nelda and Drew Ball because of the water board's silence for a year after the legal decision. The Ball family did offer to sell water to the residents' Water Association at \$99/acre foot per annum. They would only agree to sell 15 acre feet, however. The association turned this down, feeling that the law was on their side because of the state's water laws. Six years later, the homeowners had not regained the

rights for usage of Meandering Slough Spring. There are 400+ homes and cabins using the water. They have had three lawyers at this time and have been to court twice. All the lawyers had told the homeowners' Water Association that it was certain to win its case.

The homeowners have been trying to find another source of water for their residential area. They have received permission from the Forest Service to drill on the land in the National Forest or to pipe in water from a nearby spring. They have not, however, been able to find a suitable source.

Terms

water rights: rights, sometimes limited, to use water from a stream, canal, etc. for general or specific purposes, such as irrigation

ADVANCE PREPARATION

- A. Answer the following by researching each topic.
 - 1. Determine how many gallons a family of four typically requires for subsistence each day.
 - 2. How many gallons of water must your water utility be able to supply daily in order to meet your community's demand? Yearly?
- B. Call your community's water supplier and investigate the source of your water supply. Ask them the price of your water when it comes into your treatment plant. Compare this to the amount that the Ball family was going to charge Triple Canyon Estates owners.
- C. Carefully read the Background Information and become familiar with the main players in the drama.
- D. Prepare copies of the Background Information for your students to read. Begin with the second paragraph.
- E. Obtain the name and address of your district's state congressperson.

PROCEDURE

- I. Setting the stage
 - A. Ask the students these questions.
 - 1. How would you feel if every time you wanted to flush your commode, you would have to pour two gallons of water into the tank before it would flush? This water would have to be water that you

had hauled into your home from an outside water source or would be “graywater” from other uses in your home.

2. How would you feel if you were limited to two 15-gallon baths a week? You dare not use any more water than this because if you did, you might not be able to take any baths the following week.

3. How would you feel if you turned on the tap, only a few drops of water flowed, and you were expecting company the following day?

B. Tell the students that these situations truly do happen in some parts of the United States. Water is a commodity to be grateful for and to conserve in all ways possible.

II. Activity

A. Have the students read and study the Background Information. While they are reading:

1. Have students think of themselves as the judge who will have to rule in this.

2. Have students write down reasons why the judge might rule in favor of the Ball family and reasons the judge might rule for the homeowners’ association.

B. Divide the class into two groups.

1. One group is in favor of the Ball family retaining the water rights.

2. The second group is in favor of the homeowners regaining their lost usage for Mending Slough Spring.

3. Collectively have each group prepare a list of arguments favoring its side.

C. Ask a willing teacher or an outside resource person to listen to the arguments presented in class and choose the group which best presents its arguments. Two students, perhaps absent the day before, can help the resource person make the decision.

D. Have each group choose a person to present its arguments and then let him/her do so. Have the Ball family presentation first. After both sides have had a turn, let each side ask questions of the other, or let any student speak who feels he or she has something extra to say.

III. Follow-up

As a homework assignment:

A. Have the students summarize the two class-period activities by having them write what they believe to be the

two best arguments, both pro and con, and the judge's decision.

B. Have the students write state water-rights laws that may have prevented this situation from occurring.

IV. Extensions

A. Have student(s) write the state congressperson from their district requesting to send the class the water-rights laws of their state.

B. Review these laws and see if you can find any gray areas that might be sources of future conflict.

C. Review federal water laws in fact sheet to see if the current laws can solve the problem.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

WATER YOU DOING ABOUT THIS?

9-12

OBJECTIVES

The student will do the following:

1. Demonstrate quantities of water that an average family uses on a daily basis.
2. Explain how water resources can be managed to meet human needs.
3. Explain how water can be conserved.

SUBJECTS:

Science (Physical, Earth Science), Related Arts, Math, Social Studies (Economics) Health

TIME:

1 class period and after-school time

MATERIALS:

data sheet
tables
writing materials
calculator

BACKGROUND INFORMATION

Water is too important to take for granted: without it, life would not exist on Earth. Our bodies need water to function properly. Tremendous amounts of water have been used all over the world. Water use in the United States is as follows:

8% for domestic use (washing, drinking, toilet)
10% for business/industry
33% for irrigation
49% for electric power plants

Although the world's total water supply is enormous, over 97% of it is salty ocean water. Salt water cannot be used

for drinking, irrigating crops, power plants, or other industries. All of these uses require fresh water supplies that only make up three percent of the world's total water; and 2/3 of that is frozen in Antarctica, Greenland, and alpine glaciers. Only 0.6% of the Earth's water supply is usable as liquid and fresh water. This water is unevenly distributed in lakes, rivers, and underground.

Since the water supply on Earth is fixed, the total amount stays the same. As the world's population grows, the demand for water also increases. We cannot increase the water supply; however, we can manage it more effectively. Scientists estimate that 30-50 percent of the water in the United States is wasted. One part of water management in which everyone can take part is water conservation--using only what is needed.

Since most of the water used in the United States is not used in our homes, it may seem we can do nothing about its use. We must keep in mind that industries use water to produce the products we purchase. If we do not demand a new car every two years, recycle as much as possible, and do not waste food and other materials, water will be saved!

We can also encourage conservation of water through industries by legislative action. Laws can be passed to require water conservation equipment and methods. Federal and state subsidies that encourage waste of water can be eliminated or reduced.

Reducing the amount of water used in flushing the toilet by only 10% would save enough water for doing the laundry and almost enough for drinking. Using a water-saving toilet can cut water usage almost 75 percent. Water pollution is a problem even in communities that have adequate water supplies. This makes clean fresh water more expensive. Our concern about water shortages should not just be for human consumption but also for the impact on the environment. When reservoirs are built, valleys are flooded and downstream rivers are changed. Channelizing of streams destroys riparian communities along their banks. Diverting water from one area to another using canals or pipes damages the environment from where the water was taken as well as from where the canals and pipes were laid. Conserving water just makes sense - environmentally, financially, and ETHICALLY!

Terms

conservation: act of using the resources only when needed for the purpose of protecting from waste or loss of resources

riparian communities: living organisms adjacent to or living on the bank of a river, lake, or pond

ADVANCE PREPARATION

Copy Data Chart and Water Use Student Sheets for each student.

PROCEDURE

I. Setting the stage

- A. Have the students list various ways that water is used in the home. Before students record how much water they use in a day and a week, have students record on their Data Sheet how much they THINK they use.
- B. Remind students that they will need to time showers and check for low flow equipment in their homes.

II. Activity

- A. Ask students to keep a Data Sheet of water use in their homes for two/three days. Students should record results on data table. They can add any appropriate activities that are not listed.
- B. Ask students to review the Student Sheet of average water volumes required for typical activities and then answer the following using the data from their two/three days.
 - 1. Estimate the total amount of water your family uses in a week. Give your answer in gallons and liters. (approximately 4.2 liters in a gallon)
 - 2. On average how much water did each family member use in a week? Give your answer in gallons and liters per person per week.
 - 3. On average how much water was used per family member each day? Give your answer in gallons and liters per person per day.
 - 4. Compare the daily volume of water used per person in your family to the average daily water volume used per person in the United States (100 gallons).
 - 5. What reasons can you offer to explain any differences?

6. Compare daily volume of water used per person in your family to the average daily volume used per person in several other countries. (Show a variety of water uses.)

III. Follow-up

- A. Have students list some other ways they could conserve water at home (turning off the hose when not in use, taking shorter showers, fixing leaky faucets, installing water conservative toilets and shower heads).
- B. Landscape with plants and grasses that are native to the area and thus require less watering.
- C. Have students find out what is done locally with wastewater. Is it discharged to a surface waterbody, injected underground, or sprayed onto land surfaces (e.g., dedicated sprayfields, agricultural areas, or public access areas, such as golf courses)? Have students determine additional “uses” for treated wastewater (e.g., aquifer recharge, etc.) and determine the level of treatment needed for each use and associated costs.
- D. Present any viable options as determined in C. above as recommendations to the community.

IV. Extensions

- A. Have students find out the cost of installing different water saving devices in the home.
- B. Have students estimate how long it would take for each item to pay for itself.

RESOURCE

“Water Quality and Pollution Control Handbook,” Alabama Cooperative Extension Service, Auburn University, Alabama, 36849.

WATER USE

TABLE A			
Gallons of water typically used to produce various products in the United States			
1 automobile	10,000	1 pound of grain fed beef	800
1 ton of brown paper bags	82,000	1 pound of rice	560
1 pound of cotton	2,000	1 pound of steel	25
1 pound of aluminum	1,000	1 gallon of gasoline	70

*Producing aluminum from raw materials “costs” much more in terms of water than it does when producing aluminum from recycled aluminum.

TABLE B			
Percentage of water consumed by various uses in the United States			
irrigation	60%	industry	13%
rural domestic use	59%	power plant cooling	2%
urban domestic and business	29%		

TABLE C			
Domestic use of water in the United States			
toilet flushing	40%	drinking	5%
washing and bathing	37%	household cleaning	3%
kitchen usage	7%	garden usage	3%
laundry	4%	cleaning car	1%

Student Sheet

DATA SHEET

I THINK I USE APPROXIMATELY _____ GALLONS PER DAY;
 I THINK I USE APPROXIMATELY _____ GALLONS PER WEEK

WATER USE	TIMES PER DAY	AMOUNT USED		TOTAL USED			
		average *estimated gallons	your estimated gallons	per day			per week
				1	2	3	
1. bathing		30					
2. showering		6 gals per min.					
3. flushing toilet		6					
4. washing face & hands		5					
5. getting a drink		.25					

6. brushing teeth		2					
7. cooking		10					
8. washing clothes		60					
9. washing dishes		30					
10 other							
			TOTALS				
TOTALS (should include things that don't happen every week)							

Student Sheet (cont.)

***estimates on Data Sheet are based on the following:**

1. This could vary depending on how full tub is for bathing.
2. 3 gallons/min with low-flow head
3. 1.5 gallons with water saver toilet
4. 2 gallons if water is turned off
5. Includes running water to reduce lead quantities from piping solder
6. 0.25 gallons if water is turned off
7. Per meal, includes rinsing
8. Large load
9. 10 gallons with dishwasher or using two 5-gallon pans

ENVIRONMENTAL CONTROVERSY: CLASS PROJECT

OBJECTIVES

The student will do the following:

1. Research one of two sides of an environmental issue dealing with industrial impacts on water.
2. Conduct a debate over that issue.
3. Summarize that debate and present, in written form, the strongest arguments on both sides.
4. Conclude with a decision over the debate.

SUBJECTS:

Any high school class

TIME:

1 hour in class

1 week homework preparation

MATERIALS:

none

BACKGROUND INFORMATION

Sometimes protecting the environment is not as straightforward as it seems. There are some hard choices that have to be made and different groups that have different ideas about what is best. It usually boils down to a debate about jobs versus the environment and the trade-offs needed to reach solutions.

In this exercise, students will learn and demonstrate negotiation. This is a role playing exercise.

SITUATION:

There is a medium-size town somewhere in the U.S. It has come upon hard economic times because several manufacturing operations have closed and the unemployment rate is up to 12 percent.

One of the positive things about this community is that it is a scenic part of the state and tourism business also comes in due to the pristine nature of a small, but scenic, river that flows close by. There is even a canoeing and fishing guide service that uses part of the river.

Because of the available work force, a new industry is interested in locating in the town. There are no other major industries in the town, and there is a regulated amount of wastewater that can be released into the local creek (Pretty Creek). The industry manufactures widgets. It will have a large discharge into Pretty Creek. It will create several hundred new jobs.

There is to be a public hearing on the proposed industry. Everyone will get to present his/her side, and the town people (class) must vote on whether or not they think the industry should be allowed to locate in the community.

PLAYERS:

Mayor Harried knows that the location of the industry will be controversial. The people need jobs, and the business owners need a transfusion of new customers. He is in favor of the new industry. But there are several groups opposed to the location of the industry.

Ms. Nature is a housewife who is involved in environmental issues and has started an environmental group called "Save Pretty Creek." She is adamantly opposed to the industry locating in the town. She is aware of a similar industry (but not the same company) that is located in a town close by that has a bad record with the environmental agency and a history of noncompliance.

Mr. Councilman represents the homeowners who will be primarily influenced by the discharge since they will be close to the industry. He is opposed because his constituents are opposed.

Mr. Consulting Engineer represents the industry. He knows that the Widget Company has a good environmental record. He also has designed a good treatment system that he is confident will treat the water to such an extent that it will not be harmful to Pretty Creek, but he also knows that the wastewater discharge is a large one for the size of the creek. Proper operation of the treatment system is going to be critical.

Mr. Company Owner wants to locate in the community because it is a nice area, and he knows that his core group of executives will not mind moving here. Also, there is a pool of well-trained labor available.

Mr. Retired Environmental Engineer now lives in the community. He has a home on the river. He is opposed because he knows that the system Mr. Consulting Engineer has designed will treat the wastewater to a point, but it will be critical as to how well the treatment system is run.

Ms. Business runs the canoeing and fishing guide service down the river from where the discharge is located. She has spent years and a lot of money building up her business and sees this discharge as a direct threat to its profitability. She is opposed to the project,

and she wants a large area of the creek zoned so that no business can go in any area that will affect her business.

Mr. Unemployed Worker has lost his job. He is having to get by on his wife's salary as a secretary for a lawyer in town. He very much wants the industry to locate in the town because he has the exact skills for which the industry is looking.

Terms

The terms below relate to the industry's impact or potential impact to a creek:

biochemical oxygen demand (BOD): a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material

eutrophication: the process in which a body of water becomes oxygen deficient, nutrient-rich and supports an abundant growth of surface aquatic plants and algae; natural aging cycle of lakes, normally taking centuries, but it can be rapidly accelerated when outside sources of nutrients are added, such as wastewater, fertilizer, or feed lot runoff.

phosphorus: an element considered the key nutrient in controlling eutrophication in lakes and ponds

total suspended solids (TSS): amount of solids in suspension in water or wastewater

ADVANCE PREPARATION

- A. Have some of the students in favor of the facility do some research on the effect of employment on other communities so that they can argue their side.
- B. Have the opposing students do research on the effect of BOD, TSS, phosphorus, and other pollutants from wastewater on streams.

PROCEDURE

- I. Setting the stage

The debate will be a town meeting with the mayor presiding.

- II. Activity

A. Students not involved will get to vote on whether they think that the industry will be allowed to come.

B. After hearing all cases, students not playing a part other than town citizen will vote on whether they think that the industry should be allowed to come.

III. Follow-up

The teacher will direct a discussion on the outcome and make the point that environmental debate is not always black and white and the decisions made have long-term consequences.

IV. Extensions

Students could interview different citizens in the community to get their opinions on allowing new industry with potential pollution problems into their community.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

“pH - THE FIRST CLUE TO WATER QUALITY”

9-12

OBJECTIVES

The student will do the following:

1. Define acidity and alkalinity.
2. Explain pH.
3. Perform pH tests to determine initial water quality.

BACKGROUND INFORMATION

Water is not simply water. The water around us is typically water and something else. (Renn) Water dissolves many of the materials that it touches and absorbs gases in the air. This ability of water to dissolve and hold so many other substances makes it important for us to know about water quality. The purest water is produced when water is vaporized into the atmosphere. This conversion of water from a liquid to a gas produces the purest form of water found in nature. Although this atmospheric water represents 3000 cubic meters of water, it constitutes less than 1/100 of one percent of the total water in the hydrologic cycle. Most water on Earth is not pure. When water vapor in the atmosphere condenses into rain or snow, it typically condenses around fine particles and absorbs some atmospheric gases and other impurities. These particles and impurities may be from the ocean or dust from prairies, forest fires, volcanoes, or smoke stacks. The newly formed droplets of water may contain nitrogen compounds, sulfur compounds, ammonia, salts, dust, argon, carbon dioxide, ozone, and other atmospheric gases. Rain is water and “something else.” The amount of materials that combine with water and the nature and types of these materials are of great importance to humankind.

When it comes to water quality, the compound carbon dioxide (CO₂) is the most important material that dissolves into water. CO₂ has a large effect on water. It causes water to be a weak acid. This increases water’s ability to dissolve materials, especially those which are slightly alkaline. This increased dissolving ability of water is responsible for most of the physical and chemical changes that have occurred on Earth (erosion, soil deposition, soil depletion, leaching, etc.). When weakly acidic rain falls on the Earth’s surface, it reacts with minerals and other materials in soils

SUBJECTS:

Science (Chemistry, Ecology, Earth Science)

TIME:

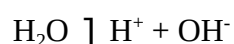
1-2 class periods

MATERIALS:

pH testing strips or pH meter
sand
salt
lime
vinegar
filter paper
funnels
200 ml beaker
jars for water samples

and rocks that dissolve in the weak acid. For instance, the mineral calcite (CaCO_3) that comprises most of limestone or marble, is readily dissolved in a weak acid. This results in water having a “mineral content.” The chemical process of water dissolving and carrying away elements and salts in the soil is called leaching. Water can also pick up CO_2 produced by biological processes such as respiration of plants and animals in the water and soil, and by the microbiological decomposition of dead organic materials. No matter what the source of CO_2 in water, it makes water behave like a weak acid and increases water’s ability to pick up other materials. The weak acid properties can cause corrosion, rusting, clogging, nutrient leaching, soil depletion, “smelly water,” off-colored water and a contamination of water resources. pH also affects soil quality. Shortage of rainfall in a desert makes the soil alkaline because very few minerals are washed away. Areas of high rainfall usually have acidic soil because many of the alkaline minerals are washed away. Different types of plants grow best in different pH soils.

Pure water is a very weak electrolyte and ionizes according to the equation:



The expression for the ionization constant is derived from this simplified equation:

$$K = [\text{H}^+][\text{OH}^-]/[\text{H}_2\text{O}]$$

Since the concentration of water is constant, we may combine $[\text{H}_2\text{O}]$ with K:

$$K[\text{H}_2\text{O}] = [\text{H}^+][\text{OH}^-]$$

The resulting constant $K[\text{H}_2\text{O}]$ is called the ion product of water, or the water dissociation constant, and is given the symbol, K_w . At 25°C ,

$$K_w = 1.0 \times 10^{-14} = [\text{H}^+][\text{OH}^-]$$

The concentration of $[\text{H}^+]$ in a solution can be expressed more simply in terms of the pH scale. The pH of any solution is the negative logarithm of the hydrogen ion concentration or

$$\text{pH} = \log 1/[\text{H}^+] = -\log[\text{H}^+].$$

Rules for the common logarithm of a number: $a = 10^n$ then, $\log a = n$

The following table represents the pH scale.

pH	$[H^+]$	$[OH^-]$
14	10^{-14}	10^0
13	10^{-13}	10^{-1}
12	10^{-12}	10^{-2}
11	10^{-11}	10^{-3}
10	10^{-10}	10^{-4}
9	10^{-9}	10^{-5}
8	10^{-8}	10^{-6}
7	10^{-7}	10^{-7}
6	10^{-6}	10^{-8}
5	10^{-5}	10^{-9}
4	10^{-4}	10^{-10}
3	10^{-3}	10^{-11}
2	10^{-2}	10^{-12}
1	10^{-1}	10^{-13}
0	10^0	10^{-14}

By examining the table above, it can be determined that when the pH is 2, the (H^+) concentration is much higher than the (OH^-) concentration. This is just the opposite of the pH of 12; more so, note a difference of 1 pH unit is equivalent to a ten-fold difference in concentration of H^+ and of OH^- .

Why would it be important in an aqueous environment to maintain a balance of ionic species? (osmosis)

Terms

acidic: having a pH value of less than 7; acidic liquids are corrosive and sour. (DO NOT TASTE!)

alkaline: having a pH greater than 7; alkaline liquids are caustic and bitter. (DO NOT TASTE!)

condensation: (1) the process of changing from a vapor to a liquid; (2) a liquid obtained by the coming together of a gas or vapor

conversion: a physical transformation from one material state to another

corrosion: a substance formed or an action of wearing away by chemicals; formed by deterioration

decomposition: the process of breaking down into constituent parts or elements

evaporation: the process of changing from a liquid to a vapor

fluid: a substance, as a liquid or gas, that is capable of flowing and that changes its shape at a steady rate when acted upon by a force

hard water: water high in mineral content; water containing an abundance of Ca^{+2} and Mg^{+2} ions

hydrologic cycle: the cyclical process of water's movement from the atmosphere, its inflow and temporary storage on and in land, and its outflow to the oceans; cycle of water from the atmosphere, by condensation and precipitation, then its return to the atmosphere by evaporation and transpiration.

ionization constant: a comparison of the strengths of acids or bases in a given solvent, such as water, expressed by the amount of H^+ ions compared to the OH^- ions

leaching: the removal of chemical constituents from rocks and soil by water;
(Leach = to leak)

liquid: fluid composed of molecules that move freely among themselves but do not tend to separate like those of gases; state of matter that has a definite volume but not a definite shape

microbiological: referring to microscopic or ultramicroscopic organisms such as algae, bacteria, protozoa

organic: of, pertaining to, or derived from living organisms

percolate: to drain or seep through a porous and permeable substance; to filter such as a liquid passing through a porous body (water through soil to the aquifer)

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow

respiration: the sum total of the process of oxygen being conveyed to the cells and tissues of living organisms and the process by which the products of this oxidation process, CO_2 and H_2O , are given off

soft water: water that is low in mineral content because it has flowed through soils and rocks containing minerals that react poorly. Soaps are very "sudsy" in soft waters.

solvent: a substance that dissolves another to form a solution

vapor: a substance in gaseous form

ADVANCE PREPARATION

- A. Obtain water samples from four different sites around the community or school.
 - 1. Be sure to collect enough water in each sample to give each student group/station samples.
 - 2. Use closeable jars or containers for the samples to ensure the integrity of the samples.
- B. Decide if you will use an electronic pH meter or pH paper.

PROCEDURE

- I. Setting the stage
 - A. Have four unidentified water samples prepared ahead for each group.
 - B. Have pH tests available for each group. You may use the simple pH test strips (papers) from a pH test kit or a pH meter. Show students how to use pH test strips or meter.
- II. Activity
 - A. Each group will test the pH of each of its water samples and record the results on the Data Sheet.
 - B. Each group will then filter, strain, or add one of the available chemicals to the water sample to see the effect on the water sample. They will describe the process on the Data Sheet. One group should not duplicate another group's work.
 - C. A new pH reading should be taken after the student process. Record on Data Sheet.
- III. Follow-up
 - A. Compare results and discuss implications to drinking water, to industry (corrosion, clogging), to soil quality.

- B. Discuss effects on water treatment and additives to water.
- C. Try to determine if each sample is surface water or groundwater. (Teacher will identify before end of activity.)
- D. Have groups explain how water acquired its properties through the hydrologic cycle.
- E. Graph the different results for different samples.

IV. Extensions

- A. Have students bring water samples from a location of their choice. Let groups determine the pH of the water, the source of the water, and the way it acquired observed properties.
- B. Test the “hardness” and “softness” of the water by ways, such as soap tests, and compare with your pH findings.
- C. Create graphs and/or charts of the results of tests before and after the student treatment” processes.
- D. Create a bulletin board to post the results and increase the awareness among students/teachers of water sources.
- E. Create a map of the locations of the samples and try to determine the causes of the pH of the different samples.

RESOURCES

Compton’s Encyclopedia, Water, Compton’s Learning Library, 1990.

EPA, Water Quality Management Bulletin, Water Planning Division, Washington D.C., March 1980.

Renn, Dr. Charles E, A Study Of Water Quality, Johns Hopkins University, Chestertown, MD, 1968.

Sumich, James L., Biology Of Marine Life, Wm. C. Brown Company, Dubuque, Iowa, 1982.

DATA SHEET

Group Number _____

Group Names _____

Water Sample Number _____

pH of Original Sample _____

Describe procedure done on water. (Include amounts.)

pH of altered sample _____

Try to determine where this original water sample was collected by reviewing the background information and discussing the characteristics of your local area.

WHERE COLLECTED _____

REASON(S) FOR DECISIONS _____

Did this sample get any of its pH properties from the Hydrologic Cycle? Explain.

WHAT'S IN A BOTTLE OF WATER?

9-12

OBJECTIVES

The student will do the following:

1. Examine the bottled water industry.
2. Distinguish between different kinds of bottled water.
3. Become more aware of the differences between bottled water and tap water.
4. Develop an individual perspective on bottled water controversy through a project.

SUBJECTS:

Social Science (Economics),
Language Arts, Science
(Physical, Ecology)

TIME:

1 class period for discussion.
homework/presentation

MATERIALS:

handout Bottled Water: "Quality
or Hype"

BACKGROUND INFORMATION

Bottled water is big business in the United States. It is a business that may anticipate considerable growth in the coming years, for consumers are often turning to bottled water as a replacement for tap water and as an alternative to alcoholic beverages and sodas.

Terms:

artesian well: a well that produces water without the need for pumping due to pressure exerted by confining layers of soil

bottled water: water that is sealed in food grade bottles and is intended for human consumption

club soda: same as soda water; water charged under pressure with carbon dioxide gas

mineral waters: sparkling (carbonated) waters generally used as an alternative to soft drinks or cocktails

natural water: water that comes from springs or streams and does not have any chemicals added to it

potable water: water suitable for drinking without harmful effects

seltzer water: natural mineral water that is effervescent

soda water: water charged under pressure with carbon dioxide gas

sparkling water: carbonated drinking water

spring: a surface flow of water originating from subsurface sources (groundwater); often a source of a stream or pond

well: a bored, drilled, or driven shaft or dug hole. Wells range from a few feet to more than 6 miles in depth but most water wells are between 100 and 2,000 feet in depth.

ADVANCE PREPARATION

- A. Have vocabulary words/definitions on board for discussion at beginning of class period.
- B. Copy Student Sheet “Bottled Water: Quality or Hype.”
- C. Copy Student Sheets for Word Find and Cryptogram (cover solution when copying) if teacher wants to include these.

PROCEDURE

- I. Setting the stage
 - A. Discuss the current popularity of bottled water.
 - B. Give copies of handouts.
 - C. Have individual students or groups research and read at least three articles dealing with bottled water.
- II. Activity
 - A. Write an article for the school newspaper in which you discuss the growth of the bottled water industry. Include information from the handout.
 - B. Construct poster/collage to show different labels of bottled water. Include name, source, distributor’s name, source of supply, and any other information unique to each label. Use U.S. or regional map to show point of origin of the water.

- C. Phone or visit a local supermarket. Talk to the manager about bottled water sales. Write a four-paragraph essay to report your findings. Be sure to develop a strong thesis in the introduction. Write two detailed body paragraphs to report your findings. Summarize and draw conclusions in the fourth paragraph.
- D. Develop your own questionnaire to poll opinions of ten students or adults about bottled water. Report your findings to the class using graphs and/or charts.
- E. Have a taste test of different kinds of bottled water.

III. Extensions

- A. Cryptogram
- B. Word Find
- C. Research the purity of your local tap water and compare it to state and federal contamination limits and guidelines. Check with the local water system for information.

RESOURCE

Marguardt, Sandra, "Bottled Water: Sparkling Hype at a Premium Price", Environmental Policy Institute. January, 1989.

Bottled Water Fact Sheet, EPA, May 1990. Call the Safe Drinking Water Hotline at 1-800-426-4791.

BOTTLED WATER: QUALITY OR HYPE

In this time of growing public concern over how safe is drinking water, Americans are buying bottled water to satisfy their needs and tastes. The bottled water industry has sales of \$1.9 billion a year. Concerns over the purity of bottled water are now stimulating research into the benefits/disadvantages of this water.

Americans are paying premium prices for bottled water with little assurance that the product is “purer” than their tap water. However, bottled water is tested for contaminants similarly to drinking water (or tap water) provided by a public water system. Sales of bottled water increased by almost 500 percent between 1977 and 1987. Bottled water costs 700 times the average cost of tap water and three times the cost of oil.

People have different reasons for buying bottled water products. Some buy it because of advertising that promotes the idea that bottled water is important to a fit lifestyle. For others, water in a bottle just tastes better. Then there are the people who are forced to buy bottled water because their private wells or public water supplies have become contaminated by pesticides, fertilizers, chemicals, or bacteria. Government reliance on bottled water as a response to water supply contamination, combined with advertising, appears to have encouraged the misconception that bottled water guarantees a product substantially safer and healthier than tap water.

The following is a quote from Sandra Marquardt who works for The Environmental Policy Institute (EPI). “After reviewing government documents, independent and government studies, as well as state and federal regulations governing bottled water, the Environmental Policy Institute has concluded that, despite the attractive packaging of bottled water, this product, in general, is not necessarily any safer or more healthful than the water which comes out of most faucets. In fact, the public water utilities supplying these same faucets are the source for more than one-third of all the bottled water in the U.S.”

EPI has found that numerous independent studies of bottled water have cast doubt on claims of bottled water purity. In reviewing these studies and assessing other available evidence, the Environmental Policy Institute has found that bottled water frequently contains low levels of contaminants such as heavy metals and solvents.

Activities for: DRINKING BOTTLED WATER

WORD FIND: DRINKING BOTTLED WATER

DRINKING WATER	D	W	P	O	T	A	B	L	E	A	S	H	L
MINERAL	E	R	E	M	U	S	N	O	C	P	H	T	L
NATURAL	S	T	I	L	L	W	A	T	E	R	E	S	E
STILL WATER	N	R	D	N	A	T	U	R	A	L	C	U	W
SPARKLING	O	G	E	O	K	R	M	G	E	S	I	S	N
PUBLIC	H	A	W	B	I	E	P	L	H	L	A	A	
FILTRATION	T	S	E	S	N	R	N	D	L	H	B	N	I
POTABLE	A	O	U	E	N	T	R	G	E	S	U	S	S
SODA	R	D	R	V	E	E	I	T	W	L	P	P	E
CLUB SODA	T	A	L	E	Z	A	S	L	A	A	R	B	T
SELTZER	L	P	A	T	A	E	M	A	R	I	T	E	R
WELL	I	X	L	Y	P	Z	X	K	N	R	Y	E	A
SPRING	F	E	M	A	R	L	L	G	Z	R	U	T	R
ARTESIAN WELL	S	T	N	A	N	I	I	M	A	T	N	O	C
TAP	X	Y	Z	N	N	C	L	U	B	S	O	D	A
CONSUMER	E	P	A	G	C	O	N	T	A	E	N	E	R
I B W A													
EPA													
PEST													

Activities for: DRINKING BOTTLED WATER

WORD FIND: DRINKING BOTTLED WATER

DRINKING WATER	D	W	P	O	T	A	B	L	E	A	S	H	L
MINERAL	E	R	E	M	U	S	N	O	C	P	H	T	L
NATURAL	S	T	I	L	L	W	A	T	E	R	E	S	E
STILL WATER	N	R	D	N	A	T	U	R	A	L	C	U	W
SPARKLING	O	G	E	O	K	R	M	G	E	S	I	S	N
PUBLIC	I	H	A	W	B	I	E	P	L	H	L	A	A
FILTRATION	T	S	E	S	N	R	N	D	L	H	B	N	I
POTABLE	A	O	U	E	N	T	R	G	E	S	U	S	S
SODA	R	D	R	V	E	E	I	T	W	L	P	P	E
CLUB SODA	T	A	L	E	Z	A	S	L	A	A	R	B	T
SELTZER	L	P	A	T	A	E	M	A	R	I	T	E	R
WELL	I	X	L	Y	P	Z	X	K	N	R	Y	E	A
SPRING	F	E	M	A	R	L	L	G	Z	R	U	T	R
ARTESIAN WELL	S	T	N	A	N	I	I	M	A	T	N	O	C
TAP	X	Y	Z	N	N	C	L	U	B	S	O	D	A
CONSUMER	E	P	A	G	C	O	N	T	A	E	N	E	R
I B W A													
EPA													
PEST													

CRYPTOQUOTE: Here's how it works: One letter stands for another letter. Single letters, double letters, word formations, and punctuation are all clues. E is the most frequently used letter of the alphabet; THE is the most frequently used three-letter word. Have fun!!

J S Q Q M B V O I Q B D K C J K H

J Z C K R B C C K R Q U B

Z R K Q B V C Q I Q B C.

SOLUTION:

Bottled water is big business in the United States.

KEEP OUR COMMUNITY BEAUTIFUL!

OBJECTIVES

The students will do the following:

1. Describe the severe trash dumping problem and its effects on surface water .
2. Organize a problem solving process.
3. Relate the pressure and confusion people often face when making decisions that affect the environment and health.

BACKGROUND INFORMATION

No discussion concerning water pollution is complete without the mention of trash dumping in and around our waterways. The magnitude of this problem continues to grow, and yet it is very simple to prevent. Despite millions of dollars spent by the federal government and private environmental groups to educate the public, trash dumping continues to plague both our land and water resources.

As students will discover through this activity, environmental professionals face difficult decisions when trying to affect change. Even at the community level, there are many factors to consider.

ADVANCE PREPARATION

Make copies of student sheets - Situation and Joe's Agenda.

SUBJECTS:

Science (Ecology, Physical), Social Studies (Economics), Language Arts, Math

TIME:

2 hours or 2 class periods

MATERIALS:

calculators (1 per group)
paper
pencils/pens
markers
staplers

PROCEDURE

I. Setting the stage

- A. Divide class into small groups of 3 or 4.
- B. Have students read student sheet - Situation.

II .Activity

- A. Tell student to follow the instructions in the student sheet and to reread carefully the “points to consider” in the reading.
- B. Allow time for group discussion of the possible solutions.
- C .Students may use student sheet “Joe’s Agenda” as a guide to producing their group report.

III. Follow-up

- A. Have groups present their report to the class. Tell them to do the presentation as if they were trying to “sell” their idea to a board of directors.
- B. Students should discuss each group’s proposal and choose one or a combination of ideas to solve the problem.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Hodge, Karen & Younger, Lids. K., 1991 International Coastal Cleanup Overview, Washington, DC, 1992.

Kuyendahl, Jim, Ph.D., personal interviews, Alpha Environmental Press Release, The Center for Marine Conservation, June 1995.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Student Sheet

Situation

You are a high school student who has been working weekends and summers at Lake Meramec. Your responsibilities include renting canoes, and water sports equipment, and heading the cleanup committee. You love working at the lake because you can utilize the facilities whenever you aren't working. You don't mind helping clean up the banks and sand bars because you like knowing that you can swim without the danger of stepping on broken glass or trash floating around in the water. Over the past two summers, you have befriended Mr. Smith, a boater who frequents the lake. This gentleman has discussed the cleanliness of the area with you and is impressed with your attitude and ideas.

It is May and after final exams, you will start your third summer at the lake. You have finally received a long deserved raise, so now you are making \$5.50 per hour. Mr. Smith approaches you and offers you a temporary job at twice what you are making - \$11.00 per hour. He says he needs some fresh ideas to complete an ongoing project. You decide not to quit the lake but try juggling both jobs and school. You are very excited as you ponder all the items that will now be affordable with your expanded budget.

For the first two weeks, you only have to spend a few hours on Mr. Smith's project. It turns out that he works for the Parks and Recreation Department in your state. He is in charge of an effort to rid the surface water of refuse in your area. He takes you on a tour of several streams, ponds, and lakes in the area. You are appalled at the severity of the problem. Part of the task will be to educate the community. The intention is to attack the source of the problem.

During the second week, you meet with Mr. Smith, and John and Joe who are also working on the project. One specific portion of the project is being finalized. This portion includes the plan for long- term community education and beautification for a 50-acre area surrounding the lake. At this meeting, Joe produces an Agenda (see Joe's Agenda).

At this meeting you begin to understand why Mr. Smith hired you. Although both John and Joe are qualified, they are both very negative toward the project and are not committed to its success. Mr. Smith knows that beyond your natural enthusiasm, you have a personal investment in the situation. While John and Joe live across the state, you live in the same region.

Under the heading WHAT DOESN'T WORK, Joe and John have filled the space allotted. They have only one idea under FRESH IDEAS. Together the four of you have a brainstorming session. Mr. Smith is very impressed with your ideas. Later, he informs you that with the completion of this project, he has other similar opportunities for you. You can't believe your good fortune.

At your next meeting, only you and John show up. Mr. Smith is overseeing another project, and Joe's wife had a baby prematurely. He will be gone for at least two weeks. The deadline to submit the final report is eight days away. John has brought a copy of the preliminary report for your perusal. John and Joe have amassed loads of information. However, on looking it over, you discover that it is unorganized and badly written. It even contains some erroneous statistics. John announces proudly that the cost sheet is correct but that his background is actually in accounting, and he has never had to submit a report of this nature. Even though you are just a high school student, you know that Mr. Smith will not be impressed. You convince John to scrap the report and start over.

The report must describe the problem, explain a plan of action, and justify a submitted budget. Joe and John have provided all the information you need. You suddenly wish you had paid more attention when writing term papers, but know that you can go to the library and check out a book on technical reports. It is Thursday afternoon, and the report is due next Friday. Unfortunately, you have final exams next week, Sunday is your grandmother's ninetieth birthday celebration, and Saturday afternoon you have to work at the lake. You decide to spend Friday evening at the library. John agrees to meet you on Saturday morning for an intense two hours in which the two of you will piece together the final report.

The following pages are examples of the information presented by Joe and John. Working in small groups of four or five, try to eliminate erroneous information and write a report that Mr. Smith will *be able* to pass on to the Parks and Recreation Department. Remember, the budget comes from taxes, and any use of those funds must be justified. As a bare skeleton your report should include these items:

Title Page	Table of Contents
Plan of Action	Outline of Community Campaign
Cost Sheet/Budget	Justification of Budget

Important points to consider:

- | Some of the points will simply be mentioned. Remember the aim is quality, not quantity. Those reading this report are busy; they want relevant information only. Utilize Joe's agenda to do some brainstorming of your own. Budget constraints and media resources can be changed if methods can be justified.
- | Allow at least an hour and a half to organize and write your report. Wise use of time can best be achieved when one person is named Project Coordinator or PC. The "PC" can then delegate specific tasks.
- | In the immediate area, there are nine schools, two libraries, and two community centers.

| This budget is for 36 months.

- | The acreage is five miles out of town, and the refuse pickup company wants to charge \$10 extra per pickup to cover time and fuel expenses.

JOE'S AGENDA

CAMPAIGNS

Enforcing through stakeouts and fines
Beautification - planting wildflowers
Education of community through pamphlets and videos

FRESH CAMPAIGN IDEAS

Adopt an Acre (publicity needed)

PLAN OF ACTION

ALTERNATE MEDIA RESOURCES

Mobilizing university, high-school, or local environmental groups (publicity needed)
Local newspaper reporter

BUDGET CONSTRAINTS

\$5,000

Fund raising activities possible but must be volunteered by civic-minded group

COST ESTIMATES

Community Awareness

Brochures/Pamphlets	
Black and White on colored paper 5,000	
Both sides Initial Setup (Text Only)	\$ 72.00
5,000 copies @13 cents each	\$ 650.00
Add additional cost per copy for Clip Art	

Color text including color photos	
Both sides Initial Setup	\$ 92.00
5,000 copies @79 cents per side	\$ 7,900.00
Distribution of pamphlets labor and gas	\$ 100.00
Video for presentations at schools (10 min.)	\$11,000.00
Labor for presentations - \$17.00 per hour/ per person. (Estimated need: 2 people)	

Circumventing Trash Dumping

Signs - law enforcement warning and/
or Keep This Area Beautiful

2 signs @ \$115.00 each \$ 230.00

Beautification - wildflowers

LONG TERM CONTRACT FOR WASTE DISPOSAL

Trash containers and refuse pickup (per month)

No picking up of grounds \$ 60.00

Labor for area pick-up twice a month

16 hours at \$5.00 per hour \$ 80.00

Mileage?

OTHER EXPENSES

Phone calls \$ 43.00

Newspaper Want Ad (Labor Pickup)

(\$56 weekly or \$21 weekend only) \$ 21.00

STATISTICS

Debris included in the 2,878,913 pounds of refuse collected by volunteers during the 1991 annual cleanup of lakes, rivers, streams, beaches, and underwater sites:

8,487 syringes	22,440 tampon applicators
7,143 condoms	13,162 diapers

967,873 cigarette butts

Information for subsequent years may be obtained by contacting the Center for Marine Conservation and requesting a copy of the latest edition of "International Coastal Cleanup Overview."

Last year, approximately 800 lbs. of litter were collected from Meramec park. This debris was collected by two volunteer groups: Boy Scout Troop 527 and Central High School's Green Group.

RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?

9-12

OBJECTIVES

The student will do the following:

1. Understand several ways of analyzing, prioritizing, and regulating risk.
2. Understand the concept of cost/benefit analysis as applied to regulating risk.
3. Examine his/her own attitudes about risk priorities.
4. Develop a personal rationale for assessing risk.

SUBJECTS:

Social Studies (Economics),
Language Arts, Math

TIME:

90 minutes, about 50
minutes in class

MATERIALS:

handouts of reading materials
handouts of attitude survey

BACKGROUND INFORMATION

Risk assessment is a term used for the process of describing or characterizing the nature and magnitude (that is, the effects and the size of those effects) of the potential hazard. Four activities are generally involved. The first is identifying the risk (such as benzene in relation to cancer). The second is drawing a dose/response curve (how much does it take to cause a reaction of some kind). This is usually done with animal testing. Next is estimating the amount of human exposure (how much and for how long might be probable). Finally, the result or effect must be categorized as high or low using all available data. An assessment should be both descriptive and mathematical. Even when the best available evidence is used, this is not an exact science. Once risks have been technically assessed, a more policy-oriented decision process, commonly called risk management is employed. This process involves weighing risk estimates with or against other key elements of public policy, such as equity, quality of life, individual preferences, cost effectiveness, and distribution of risks and benefits. Studies show a wide divergence between "expert" and public perceptions of risk. The public often makes a distinction between voluntary and involuntary risks and feels less fear of risks that provide personal enjoyment, benefit, or those over which they have a sense of personal control.

Over 50 federal agencies are responsible for various types of environmental regulation. In a given year, economists have estimated that environmental regulation costs the U.S. economy \$580 billion a year or \$6,000 per household. Comparisons of performance of risk protection agencies show that allocation of risk protection expenditures could be improved, even in environmental policy, if cost effectiveness were taken into account. One study estimated that shifting resources from less to more cost-effective programs could increase the number of life years saved in the U.S. by 600,000 per year at no increased cost to citizens. In a 1987 report titled Unfinished Business, little correlation was found between risks EPA judged most threatening and its program priorities. The report concluded that priorities appear more closely aligned with public opinion than with estimated risks.

Risk management is often hotly debated. For example, should the government spend more for AIDS research? Someone with AIDS would definitely say yes. Someone with cancer would argue against this because more people have cancer and cancer research would lose funding. Where is the greater risk? How would the money bring about the greatest benefits? Such questions are no easier to answer when they pertain to government spending and the environment.

Terms

assessment: a fact-based evaluation or judgement

benefit: help or reward; positive factors to consider

cost: price; practical factors to consider

management: to effect a plan of action; to solve a problem by direction, guidance, administration, or control

perception: one's belief, comprehension, or knowledge; may not be based on facts

risk: exposure to danger; negative factors to consider

ADVANCE PREPARATION

A.Run off Student Sheets.

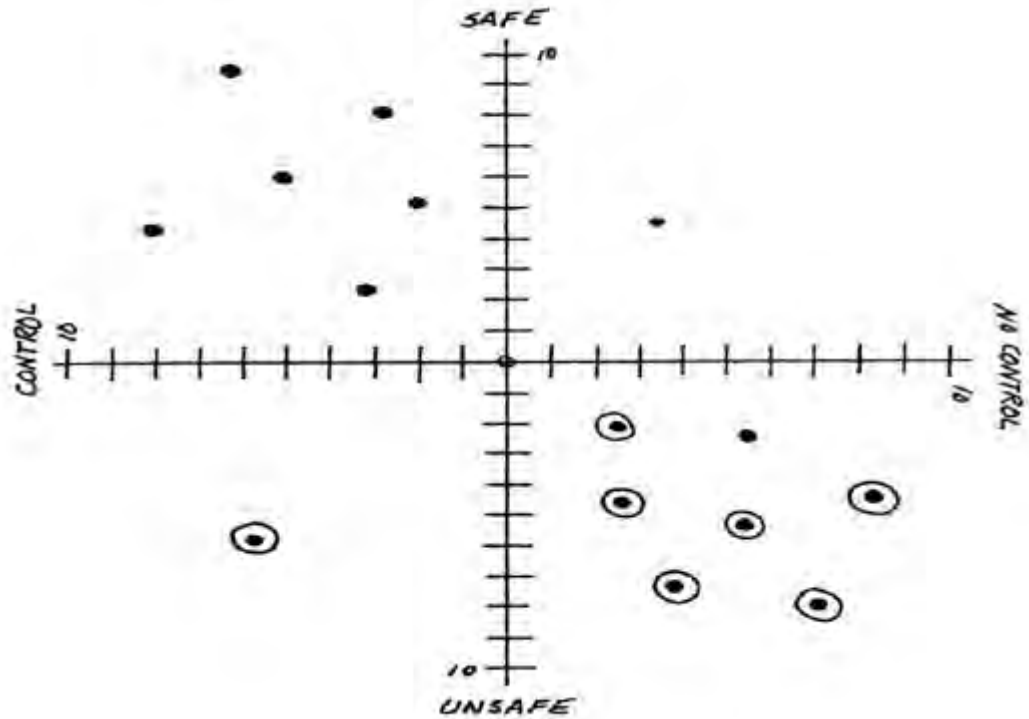
B.Put Teacher Sheet on the overhead.

PROCEDURE

I.Setting the stage

A. Give each student a copy of the Risk Perception Survey Student Sheet. Allow about 10 minutes to complete. Ask students to identify quadrants in which most points plotted.

NOTE:
MOST
STUDE
N T
RESPO
N S E S
W I L L
FOLLO
W THIS
PATTE
RN:



STUDENTS FEAR AND WANT CONTROL ON ITEMS OVER WHICH THEY FEEL THEY HAVE NO CONTROL!

B. After completing A, explain that experts rate the risk in reverse order. Show transparency and discuss the EPA's assessment of public concerns.

II. Activity

A. Divide class into four groups and choose two issues these materials or others that involve controversy over risk assessment or risk management. Two groups will work on each issue, identifying themselves with distinctly different interests or opinions on the given issue.

B. Allow the two groups to work together for about 15-20 minutes, utilizing the first set of questions below to develop their group identification. Then separate them, and use the second set of questions to establish what priorities or points of compromise exist for their interest groups. Be sure that each group has a recorder to write down the ideas that emerge.

1.State the issue.

a .Identify two "sides" to this issue.

b. Make a clear statement of the perceived risks related to this issue.

c .List at least four consumer groups, public interest groups, business groups, government agencies, or others that would identify themselves with each side.

2.For each group identified with your side in "a" above, write down a reason w it has a stake in the outcome of the issue.

a. List the outcomes you as a group of stakeholders most desire from a public hearing.

b. Write down any compromises you would be willing to make.

c. Think about what the other side is going to say and be prepared to counter their assertions.

C. Hold a mock public hearing on each issue with the teacher as facilitator. After each group is allowed 6-8 minutes to present its side, allow class discussion.

III. Follow-up

- A. Ask students to discuss the survey of risk perception. The list is in inverse order of the rankings made by experts.
- B. Over which of the listed risks do they have some control?
- C. From what kinds of risks do they feel the government should be most involved in protecting them? What sorts of risks should be left to individual choice: bike helmets, seat belts, personal health choices?
- D. Over what kinds of risks do they feel they have the least control? Why?

IV. Extensions

- A. Have students choose a specific risky activity .

- 1. Do a report on how many deaths are associated with this risk each year.
- 2. Explain how many might have been prevented and the cost associated with prevention.

- B. Have students do research for statistics used to estimate risk.

- 1. Tell them to look for different estimates of the same risk.
- 2. Have students do research looking for statistics on the numbers of cancers caused by different agents. Again, tell them to find several sources and estimates that are different.

RESOURCES

Graham, John D., "Risk Analysis," Environmental Engineer, Vol. 31, Apr. 1995, p. 22.

"Risk Based Decision Making at EPA ," hearings before Congress, Feb. 1994.

Unfinished Business, EPA report, 1987.

"Use of Risk Analysis and Cost Benefit Analysis in Setting Environmental Priorities," hearings before Congress, Nov. 1993.

SURVEY OF RISK PERCEPTION

Plot the numbers for each item on the graph, depending on how safe or dangerous you think it is to you and depending on how much personal control you have over it. Circle the numbers of the items that you feel should be regulated by the government. (See sample on graph.)

1. Skiing	16. Bicycles
2. Mountain climbing	17. Food preservatives
3. Power mowers	18. Large construction
4. Football	19. Private aviation
5. Spray cans	20. Contraceptives
6. Vaccinations	21. Swimming
7. Antibiotics	22. Electric power (non-nuclear)
8. Hunting	23. Pesticides
9. Home appliances	24. X-rays
10. Food coloring	25. Motorcycles
11. Nuclear power	26. Surgery
12. Railroads	27. Handguns
13. Fire fighting	28. Alcoholic beverages
14. Police work	29. Smoking
15. Commercial aviation	30. Motor vehicles

RISK ASSESSMENT

Comparison of public's perceived risk vs. non-cancer health risk. (1987)

Perceived Risk:

High

Chemical Waste Disposal
Water Pollution
Chemical Plant Accidents
Air Pollution

Medium

Oil Spills
Worker Exposure to Chemicals
Pesticides
Drinking Water

Low

Indoor Air Pollution
Consumer Products
Genetic Radiation (except nuclear power)
Global Warming

Non-Cancer Health Risk:

High

Air Pollution (hazardous/criteria pollutants)
Indoor Air Pollution (except Radon)
Drinking Water
Accidental Releases (toxics)
Pesticides (application & food residue)
@Consumer Product Exposure
Worker Exposure to Chemicals

Medium

Radon
Radiation (not radon)
UV Radiation/Ozone Depletion
Water Pollution (most point source & NPS)
Non-hazardous Waste Sites
Other Pesticide Risks

Low

Hazardous Waste Sites (active & inactive)
Industrial Discharges to Surface Water
Mining Waste
Storage Tank Releases
Contaminated Sludge

Not Ranked
Global Warming
Oil Spills

KEY:

@ Responsibility shared with other Federal Agencies

Unfinished Business: A Comparative Assessment of Environmental Problems,

EPA 230/2-87-025, February 1987, Overview Report, pp. xix-xx & Appendix II, p. 2-2.

The frequency of dramatic and sensational lethal events tends to be overestimated; the frequency of unspectacular events tends to be underestimated.

Most Overestimated

All accidents

Motor vehicle accidents

Pregnancy, childbirth, abortion

Tornadoes

Flood

Botulism

All cancer

Fire and flames

Venomous bite or sting

Homicide

Most Underestimated

Smallpox vaccinations

Diabetes

Stomach cancer

Lightning

Stroke

Tuberculosis

Asthma

Emphysema

Source: Fischhoff, Issues in Science and Technology, 1988, p. 8

The Big Cleanup - costs for several categories of polluted sites

Category	# of sites	Estimated cost (Billions of \$)
Superfund abandoned sites	4,000	\$ 80-120
Federally owned sites	5,000-10,000	\$ 75-250
Active private sites	2,000-5,000	\$ 12-100
Underground storage tanks	400,000	\$ 32
State law cleanups	6,000-12,000	\$ 3-120
Inactive uranium tailings	24	\$ 1.3
Abandoned mine lands	2,300	\$ 55

Source: New York Times, Sept. 1, 1991, p.28.

<u>Cause</u>		<u>Annual rate (deaths per 1 million)</u>
Asbestos		0.005-0.093
Whooping cough vaccinations (1970-80)		1-6
Aircraft accidents (1979)	10	
High school football		27
Drowning		32
Motor vehicle accidents, pedestrian (ages 5-14)		60
Home accidents (ages 1-14)		120
Long-term smoking		<1

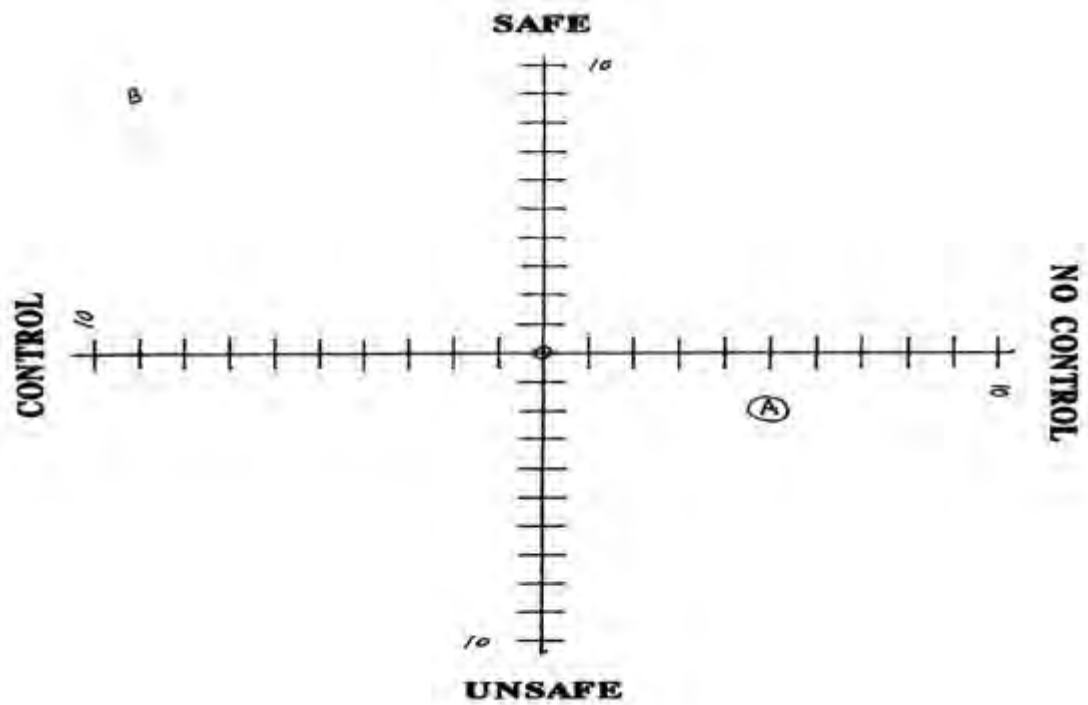
Source: Mossman, et. al., "Asbestos: Scientific Developments and Implication for Public Policy, 247 Science 297 (1990).

<u>Percent of all cancer deaths attributed to various factors</u>		
<u>Factor</u>	<u>Best estimate %</u>	<u>Acceptable range%</u>
Tobacco	30	25-40
Alcohol	3	2-4
Diet	35	10-70
Food additives	<1	0.5-2
Reproductive & sexual behavior	7	1-13
Occupation	4	2-8
Pollution	2	<1-5
Industrial products	<1	<1-2
Medicines and medical procedures	1	.05-3
Geophysical factors	3	2-4
Infection	10	1-?

Source: R. Doll and R. Peto, The Causes of Cancer, 1256, (1989).

Student
Sheet

**SURVEY OF
RISK PERCEPTION**



Plot each item on your survey list as directed, using your own personal perceptions.

See examples below. (Your personal perceptions may differ from the author's.)

EXAMPLE A - Drive-by shooting

Author's rationale: This is dangerous, but unlikely, thus it gets a "2" on the UNSAFE scale. I have no control over what others do, but I can avoid dangerous parts of town, thus it gets a "5" on the NO CONTROL scale. Laws are needed, thus the "A" is circled.

EXAMPLE B - Drag racing

Author's rationale: This is fun and safer than driving on highways. I've been doing it all of my life, thus it gets a "1" on the UNSAFE scale. I'm a good racer, so it gets a "9" on the CONTROL scale. There are many associations that set rules, so the government is not needed or wanted, thus the "B" is not circled.

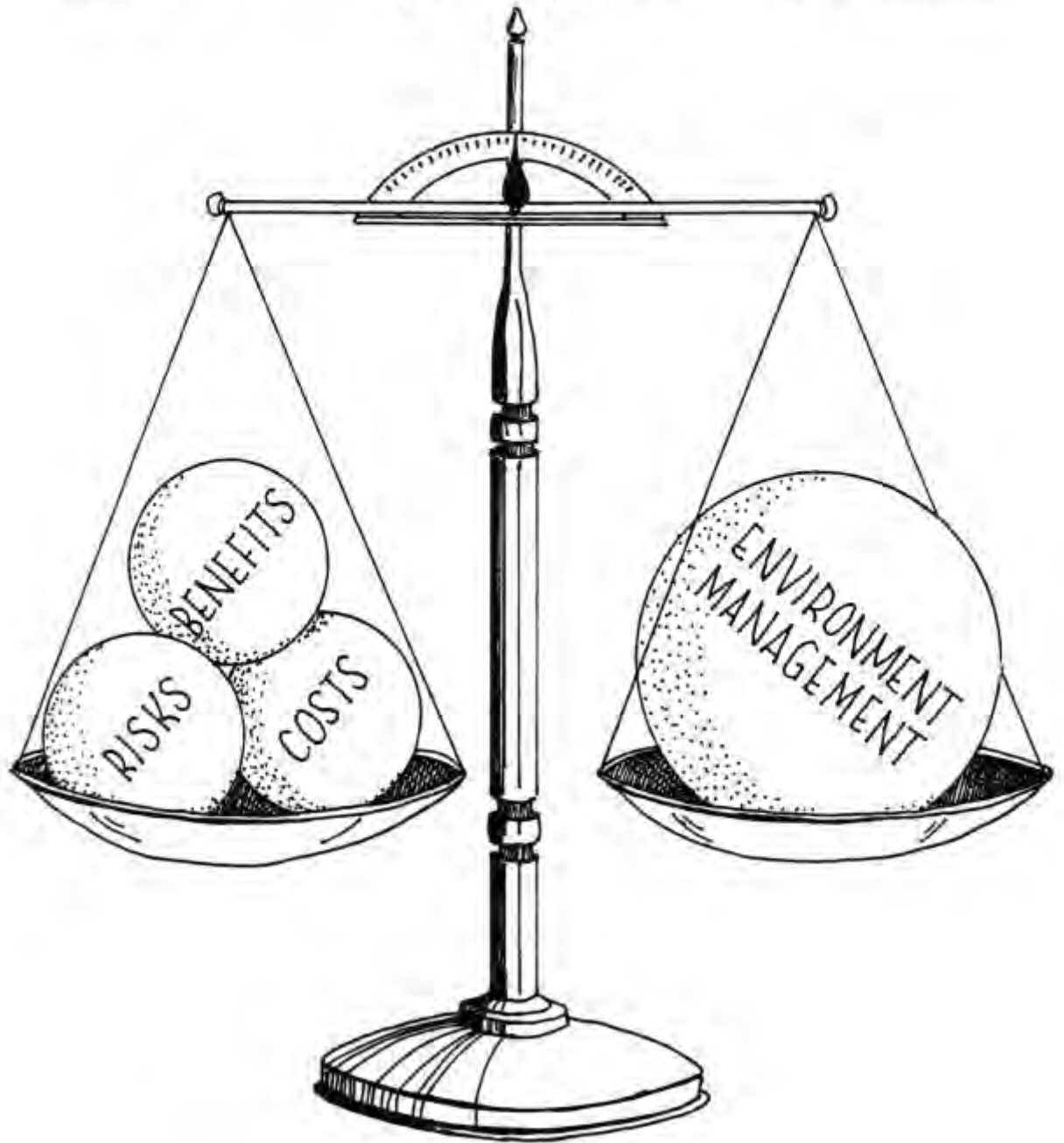
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Teacher Sheet

RISKS - exposure to danger; negative factors to consider.

BENEFITS - help or reward; positive factors to consider.

COSTS - price; practical factors to consider.



INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!

9-12

OBJECTIVES

The student will do the following:

1. Demonstrate researching skills.
2. Participate in a mock international water conflict.
3. Develop problem solving and negotiating skills.

SUBJECTS:

Science (Physical), Language Arts, Social Studies (Geography)

TIME:

2 weeks

MATERIALS:

student sheets

BACKGROUND INFORMATION

Many locations in the world experience ongoing disputes regarding plans in an upstream country or state to divert water for its use when that body of water travels through other countries or states downstream. In addition to limiting the amount of water to countries or states downstream, this can also seriously impact the quality of the remaining water. Conflicts between countries and states have been caused by problems related to both quantity and quality. Water rights issues have caused some very emotional and violent disputes.

Because water is essential to life, humans should learn to solve problems related to water. Water rights issues may be the major cause of wars between countries in the future. An understanding of the terms will be needed to complete the activity.

Terms

arid: lacking enough water for adequate growth; dry and barren

headwaters: the streams that are the sources of a river

hydrology: the study of water, its properties, distribution on Earth, and effects on the Earth's environment

negotiations: a conferring, discussing, or bargaining to reach an agreement

riparian: of, adjacent to, or living on the bank of a river or stream, or sometimes, of a lake or pond

riparian rights: water rights enjoyed by owners of land adjacent to a body of water

water rights: rights, sometimes limited, to use water from a stream, canal, etc., for general or specific purposes, such as irrigation

watershed: land area from which water drains to a particular surface waterbody

ADVANCE PREPARATION

1. Check library resources to see that articles about water disputes are available.
2. Photocopy Watershed Map, Helsinki Rules, and Assignment Sheet for each student.
3. Photocopy Article Summary Forms (two per student).
4. Prepare overhead transparency on which the watershed has been drawn. Prepare opening comments to "set the stage" for student research and negotiations.
5. Prepare cards for individual assignments within each group. (See list under vocabulary. Modify the list for the number of students in class.)

PROCEDURE

I. Setting the stage

A. Show students the local watershed so they have a clear understanding of what a watershed is.

B. Show overhead transparency and describe the situation to the class. Country A contains the headwaters of the river. The western part of the country has experienced drought for several years. Country B is very arid. The river is their main water source. Country C is arid except to the west of the river. Country C has the largest population and has more military power than countries A and B.

C. Explain the type of articles that students are to research. Have students study vocabulary terms. (Have students look for articles over water rights disputes between countries and states.)

D. Divide class into three groups--one group for each country. Have each student draw a card for his/her particular

role in the negotiation.

II. Activity

A. Have groups decide when they will meet outside of class or set up class time for meeting after they have finished their article research.

B. Make a pre-negotiation assignment. It will be due the day of the negotiations. This is assignment #3 on the Student Assignment Sheet.

C. Take students to the library to find pertinent articles.

D. Give students the following instructions:

1. Assign research articles. Make sure members of each team read about several different conflicts so they will have a broad base of information. As a group, discuss the articles.
2. Based on individual rules, write a proposal using guidelines from Assignment Sheet #3 telling what they have learned from articles.
3. Prepare a proposal for your country with all members having input. Again see guidelines, Assignment Sheet #3. Select a spokesperson.
4. Present your country's proposal. Follow "on negotiation day" steps.
5. Assign pact negotiation assignment.

E. On negotiation day:

1. Have each country's members present their opening positions.
2. Have open discussion time.
3. Facilitate discussion. Assist students in moving toward a consensus, if possible.
4. Make post-negotiation assignment. (See Student Assignment Sheet.)
5. Assign due date for the total project to include:

- a. Article summaries. (See Student Sheet.)
- b. Pre-negotiation opening position.
- c. Post-negotiation work.

III. Follow-up

- A. Discuss how students felt about the issues.
- B. Ask if they felt they came to the best solution for all three countries.

IV. Extensions

- A. Allow students who have developed an interest in a particular situation in the world to do further research and present a more extensive paper for extra credit.
- B. Research local water dispute issues and find out how water rights are determined in your state.
- C. Have a local water hydrologist or water-rights expert make a presentation to the class or send information.
- D. Conduct an Internet search on water disputes, if possible.

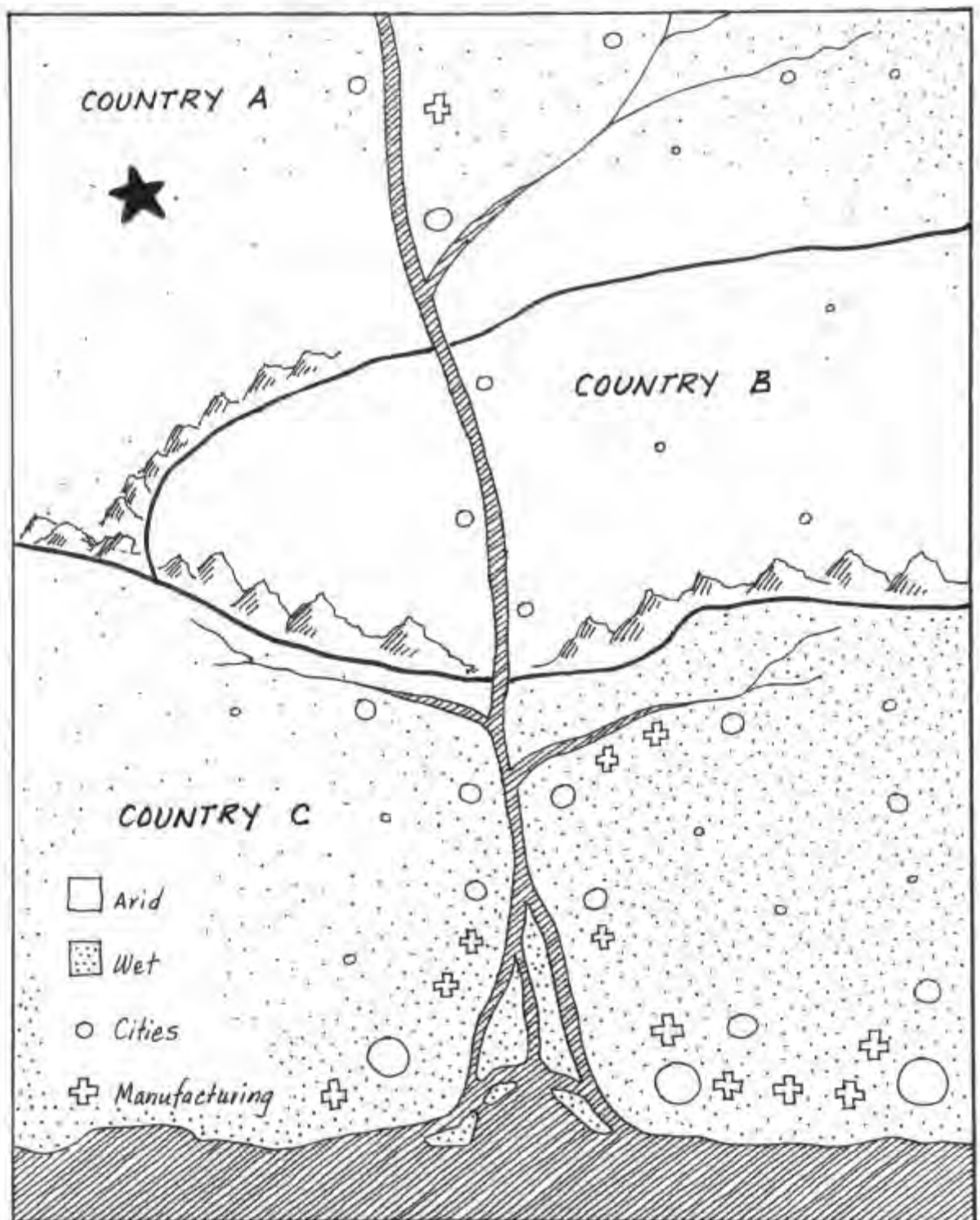
RESOURCES

High school government book.

High school political science book.

Wolf, Aaron, Ph. D., University of Alabama, Lecture and handout, Water Sourcebook Workshop, Camp McDowell, Alabama, June 1995.

WATER BASIN AREA



Vocabulary:

Define and learn the following terms:

1. watershed
2. hydrology
3. riparian rights
4. negotiations

INDIVIDUAL ASSIGNMENTS

FOR ALL THREE COUNTRIES:

1. minister of agriculture
2. president of local fishing association
3. farmer association representative
4. homeowner association representative
5. mayor of main city
6. group moderator

COUNTRY B ONLY

director of water management

COUNTRY C ONLY

coastline (salt water) fishing association representative

ASSIGNMENT SHEET

Water basin dispute situation:

An important river has its headwaters in Country A. It flows through Country B and flows into the ocean Country C. Country A has experienced a drought in the starred location on the map and wants to build a dam on the river to create a reservoir. Countries B and C are violently opposed to Country A's damming their main source of water.

RESEARCH:

This type of problem has occurred in the Middle East, the area of Egypt/Ethiopia, the southeastern United States in the Apalachicola-Chattahoochee-Flint River basin (as a conflict here between states in the United States), the Colorado River basin, and in other areas.

1. Find two articles about the same water conflict. Look for information in the articles on the cause of the conflict and the possible resolution to the problem. Fill in the Article Summary form.

2. Look at the map, read and think about the Helsinki Rules (which are suggestions and have been passed as international law), and consider the role you drew for the negotiations.

3. Pre-negotiations: Prepare a written opening position based on your research and your role. Describe what your position coming into the negotiations will be: what issues are important to you and to the people or group you are representing, what issues are negotiable, on what issues you are unwilling to compromise. Try to think of what you may be able to trade from your country to get the water you need. Be ready to turn in a typed pre-negotiation paper on the day of negotiations (two-page limit).

4. Take notes on the day of negotiations.

5. Post-negotiations: Add two pages to #4. What did you learn on negotiation day? Were the conclusions what you anticipated? Why or why not? What circumstances did you fail to consider in your pre-negotiation paper? How did you modify your opening position?

TURN IN THE COMPLETED PROJECT ON THE DAY ASSIGNED.

Student Sheet

NAME: _____ PERIOD: _____ DATE: _____

TOPIC: _____

ARTICLE SUMMARY FORM

1. Article Name: _____

2. Author: _____

3. Publication: _____ Date: _____

4. Page number(s): _____

5. What problem does this article address? _____

6. What groups are or were involved? _____

7. How is/was the resolution handled? _____

8. Remark on other important issues in the article. _____

I read the above named article. Date: _____

Signature: _____

HELSINKI RULES (1966)

ARTICLE IV:

Each basin state is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin.

ARTICLE V (REASONABLE AND EQUITABLE USE): (considerations during negotiations)

- A) The basin's geography and the extent of the drainage area in the territory of each basin state
- B) The basin's hydrology, including the contribution of water by each basin state
- C) The climate affecting the basin
- D) Past and existing utilizations of basin waters
- E) Economic and social needs of the basin states
- F) Population dependent on the waters of the basin within each basin state
- G) Comparative costs of alternative means of satisfying (E)
- H) Availability of other resources
- I) The avoidance of unnecessary waste in the use of the waters
- J) The practicability of compensation as a means of adjusting conflicts among users

K) The degree to which a state's needs may be satisfied, without causing substantial injury to a co-basin state

ENVIRONMENTAL INFRASTRUCTURE FINANCING

9-12

OBJECTIVES

The student will do the following:

1. Determine some of the economic considerations faced by communities in complying with the Clean Water Act.
2. Describe the value of two water treatment options.
3. Calculate the cost of financing two water treatment options.

SUBJECTS:

Science (Ecology), Math, Social Studies (Economics)

TIME:

1 hour

MATERIALS:

calculator
paper
pencil

BACKGROUND INFORMATION

All environmental concerns involve costs: either the cost of losing clean air, clean water, natural habitat, or living species, or the cost of retaining them through environmental management, education, and infrastructure expenses. By far, the most expensive are infrastructure costs that include construction or modification of buildings, equipment, roads, or waterways. These expenses are normally beyond what any individual can afford and are initially shouldered by business enterprises or government institutions. But eventually, through consumer purchases or taxation, the individual pays a portion of the overall cost. Therefore, each of us will benefit if infrastructure financing is accomplished using the best decision-making processes available.

Our federal government has decided that the cost of maintaining clean water is less expensive in the long run than the medical disasters that can result from unclean public water and the natural disasters from polluted rivers and streams. The Clean Water Act requires the establishment of water quality standards to protect existing or designated uses of state waters (e.g., navigation, irrigation, propagation of fish and aquatic life, recreation, drinking water supply, etc.) Municipalities with wastewater treatment plant discharges are issued NPDES permits, with some permit limitations based

on water quality standards. Meeting permit limitations can involve changing outdated methods of water treatment with all that entails in associated costs. Decisions made by city and county governments across the country can affect both your health and your pocketbook. Individual citizens can influence these decisions if they understand the various costs involved and what options are possible to achieve the best results at the least expense over the long run. Cost and benefits must be analyzed to determine the best financial and environmental decisions for the community. This lesson is designed to help students learn methods used to arrive at the most cost-effective decisions.

Terms

advanced treatment: any level of treatment beyond secondary treatment that includes secondary treatment plus nutrient removal. Advanced treatment generally removes greater than 85% of BOD and TSS; typically required when the waters receiving effluent from a treatment plant do not provide adequate dilution. It is generally very expensive to construct and maintain advanced treatment facilities.

biochemical oxygen demand (BOD): a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material

Clean Water Act (CWA): water pollution control law passed to restore and maintain the nation's waters; the nation's primary source of federal legislation that specifies the methods to be used in determining how much treatment is required for discharges (effluents) from publicly owned treatment works (POTWs)

effluent: treated wastewater flowing from a lagoon, tank, treatment process, or treatment plant

NPDES (National Pollutant Discharge Elimination System): a program created by the Clean Water Act to ensure that water quality is maintained by dischargers of wastewater. NPDES permits require the operator of wastewater treatment plants to test and report the quality of the effluent discharged to streams. The NPDES permit specifies pollutant limitations on the effluent that prevent damage to receiving waters.

primary treatment: the first stage of wastewater treatment that removes settleable or floating solids only; generally removes 40% of the suspended solids and 30-40% of the BOD in the wastewater.

secondary treatment: a type of wastewater treatment used to convert dissolved and suspended pollutants into a form that can be removed, producing a relatively highly treated effluent. Secondary treatment normally utilizes biological treatment processes (activated sludge, trickling filters, etc.) followed by settling tanks and will remove approximately 85% of the BOD and TSS in wastewater. Secondary treatment for municipal wastewater is the minimum level of

treatment required by the Clean Water Act.

total suspended solids (TSS): amount of solids in suspension in water or wastewater

ADVANCE PREPARATION

A. Go to the library and find articles about the cost of complying with various environmental regulations. See if the articles state the impact on the town/company due to the cost. Learn what the term “cost-benefit” means.

B. Learn about compound interest and how the interest on a loan is calculated. If you have a scientific or financial calculator, learn its features related to calculating loan payments.

PROCEDURE

I. Setting the stage:

A rural town of 2000 people (500 households) owns and operates a small wastewater treatment plant that was constructed about 30 years ago. Under the standards in place at that time, it was designed to produce primary effluent. The plant consists of a pump station and a concrete settling basin with an effluent discharge pipe to a small stream nearby. The town has been issued an NPDES permit by the state environmental agency that requires advanced treatment. According to monthly reports submitted to the state by the town, the POTW is not meeting the NPDES permit requirements. In particular, the town’s plant is producing effluent with BOD=100 mg/l and TSS=115 mg/l. This effluent has a very cloudy appearance and a definite odor of sewage. The state has determined that effluent of this quality has a negative effect on the small stream to which the plant discharges, causing fish to die. The stream also exhibits a high level of bacteria due to the POTW discharge and cannot support fish and wildlife. However, a study by the state suggests that the large river into which the stream flows is not affected negatively by the discharge because of its larger size (greater dilution).

Because the town violates its NPDES permit, the state environmental agency is required by federal law (Clean Water Act) to take action against the town. The agency issues an administrative order that fines the town \$5000 for polluting (noncompliance with its NPDES permit) and sets a schedule for the town to construct upgraded wastewater treatment facilities within three years. The town hires an environmental engineering firm to determine the most cost-effective way to comply with the requirements of the Clean Water Act.

The engineers prepare an engineering report that outlines two alternatives for the town.

1. Build a new advanced treatment plant on the site of the existing plant at a cost of \$600,000. It will take \$80,000/year to operate this plant including electricity, labor, and chemicals.

2. Build a new secondary treatment lagoon system downstream from the existing treatment facility that will discharge into a larger stream. This alternative will cost \$700,000 to build and \$50,000/year to operate.

Both treatment facilities will be designed to have a useful life of 20 years. In order to evaluate alternatives on the basis of cost, it is necessary to calculate the “present worth (PW) cost of each alternative. The present worth takes into consideration both the capital cost and the operations and maintenance cost (O&M). The capital cost (CC) is the cost of construction, engineering, and administration and occurs only once at the beginning of the project. However, the cost of operating and maintaining occurs every year that the plant is in operation and must be taken into consideration. Use the following formula to calculate the present worth (PW) cost of each alternative.

$$PW = CC + (P/A, i, n) \times O\&M$$

The factor (P/A, i, n) is a compound interest rate factor that may be found in accounting, finance, and engineering economics textbooks. The following table was generated for use in this exercise.

Present Worth Factors (P/A, i, n), given annual cost, interest rate, and # of periods

(P/A, i, n) Factors

Mathematically this factor can be calculated from the following formula.

$$(P/A, i, n) = \frac{(1 + I)^n - 1}{I * (1 + I)}$$

n (years)	Interest Rate	
	<u>4.00%</u>	<u>6.00%</u>
5	4.451 822	4.212 364
10	8.110 896	7.360 087
15	11.118 387	9.712 249
20	13.590 326	11.469 921

In order to use this table, read across the columns to the interest rate and then down the rows to the term of the loan (in years). The (P/A, i, n) factor is the number where these intersect. To determine the present worth of an annual cost, such as a loan payment, multiply by this factor. If you know the amount being borrowed and want to know the annual payment amount, divide by the (P/A, i, n) factor.

II. Activity

A. Determine which course of action is most cost effective for the town. Calculate the Present Worth” cost of the two alternatives.

B. After determining the best alternative, calculate the cost of financing the work with municipal bonds at 6% interest.

C. How much will the most cost-effective alternative cost each family? Discuss this cost relative to other household costs such as telephone and cable TV. Is the cost for providing advanced sewage treatment reasonable?

D. Recalculate the estimated household costs if the town is able to obtain a \$400,000 grant and financing for the remaining cost at 4%. Compare to the cost if no financial assistance is available from state/federal sources.

III. Follow-up

A. Present Worth Calculations:

1. For the Advanced Treatment alternative with CC= \$600,000 and O&M= \$80,000/yr:

$$PW = CC + (P/A, i, n) \times O\&M$$

From the interest rate tables for I=6% and n=20 years:

$$(P/A, i, n) = 11.469921$$

$$\text{Present Worth (PW)} = \$600,000 + (\$80,000) \times (11.469921)$$

$$\text{Present Worth (PW)} = \$1,517,594$$

2. For the Secondary Treatment alternative with CC= \$700,000 and O&M= \$50,000/yr:

$$PW = CC + (P/A, i, n) \times O\&M$$

from the interest rate tables for I=6% and n=20 years:

$$(P/A, i, n) = 11.469921$$

$$\text{Present Worth (PW)} = \$700,000 + (\$50,000) \times (11.469921)$$

$$\text{Present Worth (PW)} = \$1,273,496$$

Conclusion: The present worth cost difference between the two alternatives is \$244,098. Although moving the treatment system will cost more initially, the cost savings in O&M cost will, over time, more than make up for the difference.

B. Financing cost for the Selected Alternative:

Assuming that the town will be able to obtain financing at 6% interest, we can calculate the cost of borrowing \$700,000 (the project's capital cost; CC) for 20 years:

$$\text{Annual Loan Payment} = CC / (P/A, i, n)$$

$$\text{Annual Loan Payment} = \$700,000 / 11.469921$$

$$\text{Annual Loan Payment} = \$61,029/\text{year for 20 years}$$

$$\text{Total Annual Cost} = \$61,029 (\text{debt service}) + \$50,000 (\text{O\&M})$$

$$\text{Total Annual Cost} = \$111,029 / \text{year}$$

C. Expressed in terms of the monthly cost for each of the 500 families in the town:

$$\text{Average Monthly Household Cost} = \$111,029 / (12)(500)$$

$$\text{Average Monthly Household Cost} = \$18.50$$

D. If the town were able to obtain a \$400,000 grant and 4% financing:

From the interest rate tables for $I=4\%$ and $n=20$ years: $(P/A, i, n) = 13.590326$

$$\text{Annual Loan Payment} = CC / (P/A, i, n)$$

$$CC = \$700,000 - \$400,000 \text{ (grant)}$$

$$\text{Annual Loan Payment} = \$300,000 / 13.590326$$

$$\text{Annual Loan Payment} = \$22,075 / \text{year for 20 years}$$

$$\text{Total Annual Cost} = \$22,075 \text{ (debt service)} + \$50,000 \text{ (O\&M)}$$

$$\text{Total Annual Cost} = \$72,075 / \text{year}$$

Expressed in terms of the monthly cost for each of the 500 families in the town:

$$\text{Average Monthly Household Cost} = \$72,075 / (12)(500)$$

$$\text{Average Monthly Household Cost} = \$12.01$$

If no financial assistance were available from the state/federal government, the cost of the most cost-effective wastewater treatment system would be \$18.50 per month, which is \$6.49 per month more.

RESOURCES

For more information regarding wastewater treatment, consult the following sources:

National Small Flows Clearinghouse, West Virginia State University, Morgantown, WV 26506-6064.
1-800-624-8301.

Knopman, Debra S. and Richard A. Smith, "20 Years of the Clean Water Act," Environment, January/February 1993.

THERE “OUGHTA” BE A LAW

9-12

OBJECTIVES

The student will do the following:

1. Learn or understand existing law as it applies to water rights.
2. Apply various doctrines to case studies.
3. Evaluate different legal claims and remedies that apply to water rights.

BACKGROUND INFORMATION

U.S. citizens use more water than the citizens of any other country--about 150 gallons a day per person. In the U.S., irrigation consumes 33 percent of the available freshwater, power plants 49 percent, factories 10 percent, and households 8 percent a day. When water is plentiful and the usage is not polluting, there isn't a problem. But when water is scarce or the water quality is affected, questions of rights and priorities arise. We have no federal doctrine of water rights in our country.

Many of the basic rules of water use in the United States evolved as part of the *common law* of England during the period between the Norman Conquest and the American Revolution. Common law developed bit by bit as judges made decisions that were logical extensions from previous decisions. The common law was mainly concerned with private rights because a large proportion of the cases coming before judges in feudal England involved conflicts between private litigants over land rights. Generally, water came to be considered a part of the land. With ownership of the land went certain rights, riparian rights. Riparian rights address issues dealing with streams flowing across the land's known and defined channels. Under common law, the riparian land owner had absolute right to use a stream for domestic purposes or livestock defined as ordinary or primary use. For extraordinary or secondary use like irrigation or power, so long as these were incidental to the use of the land, the land owner also had rights; but they were more limited. Owners had no right to export the water or to use it for purposes unconnected with the land. The riparian owner, under common law, had the right to the water of the stream in its natural state. An owner could bring action against those responsible for changing its quality even though he sustained no actual damages.

SUBJECTS:

Science (Physical Science, Ecology),
Social Studies (Geography, Government,
Political Science)

TIME:

1 or several class periods for preparation
and presentation of simulations

MATERIALS:

optional props or visual displays of major
rivers
literature on applicable water-rights
disputes
information on rates of water use, per
facility, for various purposes

Most of the 26 states east of the Mississippi River follow Riparian Water Policy that has the shortcoming of not recognizing the interrelationship of surface water and groundwater. Under this policy, state legislatures must define virtually all the parameters of water use management.

Although riparian rights are not recognized in some western states, they remain an important part of the law relating to water in most parts of the United States. They are often modified in various ways to better meet local or regional needs. Riparian doctrine cannot be successfully applied, however, in arid western states where large quantities of water are needed for mining and irrigation. From the few streams having adequate flow, it is sometimes necessary to transfer water great distances for use at other locations.

The Prior Appropriations Water Rights Doctrine is embraced by the western states due to the perennial shortage of water in these states. Simply stated, this doctrine says that one who “is first in time is first in right,” or whoever was there first receives water that he/she wants or needs before the next user receives any allocation. Under appropriative doctrine, the traditional concepts of priority have generally been applied when applications have competed for appropriation from a limited supply: domestic and municipal uses have been given first priority and irrigation second. Appropriative rights have typically not been given for the use of water for waste disposal. The administration of appropriative rights is pursuant to state laws. Administration of these principles, therefore, is under state law rather than federal law. Modern courts have ruled, however, that under neither principle can a state totally prohibit export or diversion of water to another state without a conflict with interstate commerce provisions. Today in water-scarce areas, low flow equipment and water-saving toilets may be required in new construction, and high rates may discourage water waste. Various types of water conservation may reduce some of the problems involving water disputes.

Terms

common law: the law of a country or state based on custom, usage, and the decisions and opinions of law courts

NIMBY: NOT IN MY BACK YARD

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (e.g., outlet or pipe) because it comes from many individual sources or a widespread area (typically, urban, rural, and agricultural runoff)

point source pollution: pollution that can be traced to a single point source such as a pipe or culvert (e.g., industrial, wastewater treatment plant, and certain storm water discharges)

Prior Appropriations Water Rights: doctrine of western states that says that “one who is first in time is first in right,” or whoever occupies a location first receives the water that he/she wants or needs

riparian rights: water rights enjoyed by owners of land adjacent to a body of water

ADVANCE PREPARATION

A. Depending on your geographical location, research current water right conflicts.

(Suggestions: 1. Colorado River usage in the SW for irrigation and water shortages in California and Arizona, 2. the Chattahoochee River diversion in Georgia/

Alabama/Florida, or 3. pollution cases like the Peridido River in Alabama/Florida.) Discuss the situation with your students.

B. Prepare or have students research information concerning recent court decisions about water rights and the roles of federal and state governments in managing water rights questions.

C. Have vocabulary words on board at the beginning of the class period. Guide students to discover their meanings as they read Background Information and discuss dilemmas.

PROCEDURE

I. Setting the stage

Discuss current law or policy regarding water rights in the U.S. Divide the class into groups and have several water dilemma scenarios, one for each group. Give each member of the group a different perspective or role. Let groups meet to discuss their problems in terms of law, need, morality, expense, and technical feasibility. Stress to students that solutions are workable compromises. Discuss that the goal is not identifying the bad guy or the right/wrong “side.” Real life is often found in shades of gray!

II. Activity

Each group will make an oral presentation to the class. The group may choose to have a presenter or to allow each student to present his/her own viewpoint in the form of an organized debate.

Dilemmas:

1. Strict water rationing must occur in the community because of the drought year. Consider those with water usage roles: municipal “water police,” “water court” judge, swimming pool owner, plant nursery owner, farmer with Best Management Practices (BMPs), a farmer who uses no till farming and drip irrigation, mayor, hotel owner, hydroponics farmer, school principal, hospital employee, landscape architect, and steam plant manager.

2.The border of your state is a river, and the neighboring state has decided to construct a nuclear power plant on the river. Roles: power company officials, state officials, environmentalists, NIMBY anti-nuclear activists, local fish hatchery owner, and/or recreational area employees.

3.You're in a state near the mouth of a river that runs through several states. Not only has the volume of water been reduced but point and nonpoint source pollution have severely impacted upon water quality. Roles: politicians of affected states, environmental activists.

4.Your family has owned a large parcel of land since before World War II. The land is no longer used for timber; but you've managed to keep the land holdings by making it an environmental camp available for schools, scouts, church groups. Beavers have dammed up a creek providing a terrific scenic and educational highlight for the camp. Property owners below you are complaining that their boats are high and dry, the mud stinks, and the fishing is not good. Roles: family members, camp owners, camp attendees, and property owners below camp.

5.You're a biology teacher whose Environmental Club has been monitoring a stream. You are finding lower dissolved oxygen values and some fish kills. Upstream is a rendering plant that employs about 10 of your students' fathers and mothers. Roles: teachers, students, parents, plant officials and/or state environmental officials.

6.You're part of an aquaculture co-op that is involved in growing oysters on racks. Last week two customers became ill, and E. coli and vibrios were detected in the water. The Health Department wants to shut you down. Roles: health department workers, customers, co-op workers.

III. Follow-up

A .Offer extra credit or some incentive to keep this issue simmering. Follow a continuing real-life conflict, looking for current events relating to this subject.

B. Each student's written assignment is to design a win/win compromise and an agreement that will avoid similar future conflicts.

IV. Extensions

A. Create a game with "choices" for several communities along a waterway. Offer "incentives" of money, market profit, cleaner environment, cheaper energy and "penalties" of fines, legal hassles, shutdowns, and bad publici

B. Write a bill for your state legislature defining water rights for your state.

C. Invite different sides of a legal dispute on water to sit on a panel for the class with student moderation, interviewers, timers.

RESOURCES

Parfit, Michael, “Water,” National Geographic: Special Edition, November, 1993.

UNCLE SAM SAYS, "KEEP IT CLEAN!"

9-12

OBJECTIVES

The student will do the following:

1. Describe the Clean Water Act.
2. Explain the legalities of the Clean Water Act.
3. Infer the local benefits and responsibilities of the Act.

SUBJECTS:

Social Studies (Economics, Government, Political Science),
Language Arts

TIME:

2 class periods, longer if necessary

MATERIALS:

student sheets

BACKGROUND INFORMATION

The Federal Water Pollution Control Act (Clean Water Act), passed in 1972 with major amendments in 1977, 1981, and 1987, provides the basis for water quality standards today.

In 1992, President George Bush, the U.S. Congress, and 35 governors proclaimed 1992 as the "Year of Clean Water" and October as "Clean Water Month." The Clean Water Act was originally created in response to public demands that the government do something to clean up and protect the nation's waterways.

Today there are more than 18 federal laws and regulations governing water quality. In 1994, approximately 63 percent of the nation's surveyed waters fully supported their water quality designated uses. This number has steadily increased over the years due to the efforts of state and federal regulators, local governments, industries, citizens, and environmental organizations.

Terms

biodegradable: capable of being decomposed (broken down) by natural biological processes

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (e.g., outlet or pipe) because it comes from many individual sources or a widespread area (typically, urban, rural, and agricultural runoff)

point source pollution: pollution that can be traced to a single point source such as a pipe or culvert (e.g., industrial, wastewater treatment plant, and certain storm water discharges)

toxic chemical: a chemical with the potential of causing death or damage to humans, animals, or protists; poison

water quality criteria: levels of water quality needed to support a designated use for a body of water, usually expressed as concentration values for specific chemicals

ADVANCE PREPARATION

Have vocabulary words on board at the beginning of class period. Have students enter vocabulary words and definitions in class journals; allow time for brainstorming.

PROCEDURE

I. Setting the stage

A. After using vocabulary words as introduction, allow time for independent reading of "America's Clean Water Act."

B. Discuss the article according to the 5 W's of a newspaper article: Who, What, When, Where, and Why.

C. Discuss political comic on handout page. Discuss the pun and its effect on readers. Discuss trivia statements on handout page.

D. Ask for student opinion to the idea of federal laws controlling water pollution.

II. Activity

As a homework assignment, ask students to select one of the following activities:

A. Write a letter to the editor of your local newspaper in which you cite an obvious infraction of some requirement of the "Clean Water Act" as you understand the Act.

B. Draw a political cartoon in which you stress one of the principles of the "Clean Water Act."

C. Create on paper a conversation between two people who have owned lakefront property for several years. In the dialogue, both are concerned about federal regulations of lake water.

D. Work with one other student to create a skit involving a federal compliance officer and a person who has violated one requirement of the "Clean Water Act." Have the officer explain the violation; have the other person accept responsibility for the violation and agree to "clean up his/her act."

E. As each presentation is made to the class, a copy of the "America's Clean Water Foundation Personal Proclamation" may be presented to students (year may be changed from 1992 to the present).

III. Follow-up

Have each student write up one good question concerning the "Clean Water Act." Compile the best questions into a quiz for students.

IV. Extensions

A. Have students present activities to entire class on assigned day. Assignments may be further developed according to student interests and response

B. Have students solve Cryptoquote and Word Find. (See Student Sheets.)

C. Have students do research on water quality criteria and learn why they are set at certain levels for different parameters.

RESOURCES

1992: THE YEAR OF THE CLEAN WATER CALENDAR; America's Clean Water Foundation; 750 First Street NE, Suite 911, Washington, D.C. 20002.

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Student Sheet

Extensions:

Cryptoquote: Here's how it works: One letter stands for another letter. Single letters, punctuation, and the length and formation of the words are all hints. E is the most frequently used letter, and THE is the most frequently used word. Have fun!

M H M L O T V M L M T P Q M L N B P Q V N G R X A

C M P S Q O ; E M M J N Q Z Y M P G , J Y M P B M !

O X S L S G Z Y M B P U

Solution: Everywhere water is a thing of beauty; keep it clean, please! - Your Uncle Sam

WORD FIND

CLEAN WATER ACT

CLEAN WATER	P	S	E	W	A	G	E	H	U	N
POLLUTION	E	O	H	U	N	T	S	V	T	R
QUALITY	N	I	L	L	E	G	A	L	N	U
STANDARD	V	N	I	L	Q	L	L	E	I	N
PRES BUSH	I	T	A	L	U	S	A	C	O	O
CONGRESS	R	E	B	A	A	T	M	I	P	F
WATERWAYS	O	R	A	G	L	A	I	X	N	F
TOXIC	N	S	P	O	I	N	T	O	O	E
POINT	M	T	O	O	T	D	R	T	N	G
NONPOINT	E	A	I	S	Y	A	E	C	T	P
POISON	N	T	S	Y	S	R	H	R	R	R
CULVERT	T	E	O	A	E	D	P	I	E	E
CRITERIA	S	H	N	W	E	R	D	T	V	S
INTERSTATE	S	M	A	R	R	I	A	E	L	B
ENVIRONMENT	E	L	Y	E	N	W	E	R	U	U
ILLEGAL	R	J	A	T	N	E	G	I	C	S
ECOSYSTEM	G	N	E	A	S	P	A	A	U	H
SEWAGE	N	S	E	W	A	A	W	N	M	A
RUNOFF	O	L	R	W	A	T	E	R	G	A
	C	M	E	T	S	Y	S	O	C	E

WORD FIND

CLEAN WATER ACT

CLEAN WATER

POLLUTION

QUALITY

STANDARD

PRES BUSH

CONGRESS

WATERWAYS

TOXIC

POINT

NONPOINT

POISON

CULVERT

CRITERIA

INTERSTATE

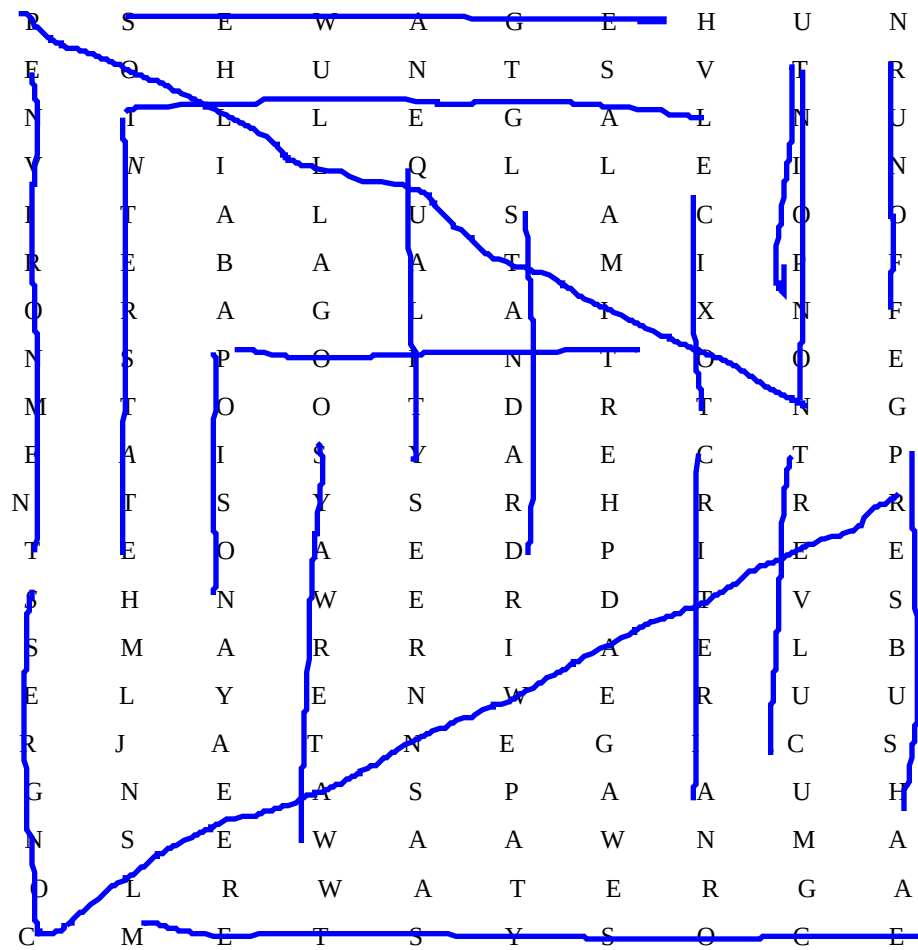
ENVIRONMENT

ILLEGAL

ECOSYSTEM

SEWAGE

RUNOFF



WATER QUALITY LEGISLATION

Laws involving water quality date back as far as 1914. The first Federal law dealing exclusively with water quality was the Water Pollution Control Act, passed in 1948. Under this law, the states retained primary responsibility for water quality standards and maintenance. The Federal government supplied money primarily for research. There were no water quality standards established, and the law provided only weak punishments for offenders. During the 1960s, amendments provided for water quality standards for interstate waterways, Federally approved state standards, and increased funding for research. However, as water pollution increased in many areas of the country, public concern resulted in passage of two more very important environmental laws.

The National Environmental Policy Act of 1969 (NEPA) required federal agencies to consider the environmental impacts of their actions. All federal agencies must prepare environmental impact statements to assess the impacts of major federal actions, such as large building or industrial projects. Because of NEPA, federal undertakings have been conducted in a manner to ensure protection of all natural resources, including water.

The Federal Water Pollution Control Act (Clean Water Act) which was passed in 1972 and amended in 1977, 1981, and 1987, provides the basis for water quality standards today. The Clean Water Act allowed the Federal government to assume a lead role in cleaning up the nation's waterways. National goals for pollution elimination were set, and the National Pollutant Discharge Elimination System (NPDES) was established. The NPDES permitting system made pollution discharge without a permit illegal. Generators of pollution to surface waters (sources) must apply for NPDES permits, which are issued by EPA or EPA - approved state agencies. The limits on what the generators may release vary from small amounts (for suspended biodegradable organic material and solids) to none allowed (for some toxics). The stringency of the requirement is greatest for the most dangerous water pollutants. The public is invited to participate in the permit issuance process through public notice of proposed permits, and opportunity to comment or request a public hearing.

The Clean Water Act also established four national policies for water quality:

1. Prohibit the discharge of toxic pollutants in toxic amounts
2. Assist publicly owned treatment works with Federal grants and loans
3. Support area-wide waste treatment planning at Federal expense

4. Create a major research and development program for treatment technology.

In 1994, 63 percent of surveyed surface waters met water quality standards. In 1973, only 36 percent of streams were of high enough quality to meet standards. Future amendments to the Clean Water Act are likely to make ecosystem protection as important as providing potable water for human use. Amendments are also likely to establish water quality standards for lakes and to focus more specifically on preventing storm water nonpoint source pollution.

Other federal laws that deal with water quality are the Safe Drinking Water Act and Amendments of 1986 and 1996, the Toxic Substances Control Act of 1976, the Resource Conservation and Recovery Act of 1976, the Surface Mining Control and Reclamation Act of 1977, and the Rivers and Harbors Act of 1899.

America's Clean Water Act

In response to citizens' demands that the government do something to clean up and protect our water resources, Congress passed the Federal Water Pollution Control Act amendments of 1972, known as the Clean Water Act. Its message was simple - there shall be no unlawful discharge of pollution to U. S. waters. The goals of the law called for water to be clean enough for swimming, fishing, and other recreational uses.

In the first decade after the Clean Water Act was passed, when the nation's population grew by 11 percent and water use by industry and recreation increased, significant progress was made. It is estimated that:

- , 47,000 stream miles improved in quality. That's a distance of about twice around the world.
- , 390,000 acres of lakes (an area twice the size of New York City) improved in quality.
- , 142 million people received secondary or more advanced levels of sewage treatment - a 67 percent increase.

Congress revised and expanded the Clean Water Act in 1977, 1981, and 1987. Today the Clean Water Act addresses:

- C Point-source pollution (direct pollution from pipes or other conveyances)
- C nonpoint-source pollution (diffuse pollution from sources such as urban, rural, and agricultural runoff)
- C Marine ecology, including oceans, estuaries, and wetlands
- C Toxic pollutant controls
- C Groundwater protection.

America's water quality continues to improve. Federal, state, and local laws have been strengthened; and public and private institutions have invested many billions of dollars to restore the physical, chemical, and biological quality of water.

While advances in technology have helped clean up our waters, societal demands continually increase pollution. To ensure clean water for ourselves and for future generations, we must strengthen our clean water programs and provide the necessary funds to protect our precious water resources.

President George Bush, the United States Congress, and 35 Governors have proclaimed 1992 as the Year of Clean Water and October as Clean Water Month to commemorate the Twentieth Anniversary of the passage of the Clean Water Act.

In 1972 Congress passed the Federal Water Pollution Amendments (Public Law 92-500) (The Clean Water Act). The Clean Water Act as designed to respond to public demands that the government do something to clean up and protect our nation's waterways. The Act stated that there shall be no unlawful discharge of pollution to U. S. waters. The goals called for waters to be "fishable" and swimmable" by 1983 and the elimination of pollution discharges to navigable waters by 1985.

With the passage of time, the public attention to these goals has waned, even though Americans consistently cite clean water as among their highest priorities. In an effort to rekindle support for the mission of the Clean Water Act, America's Clean Water foundation was created to coordinate the Twentieth Anniversary of the Clean Water Act. The goals of this nonprofit foundation are to:

1. Increase public awareness.
2. Educate our nation's youth.
3. Promote personal stewardship.
4. Generate national support for protecting our precious water resources.

Water: The Source of Life America's Clean Water Foundation ©1992

To accomplish these goals, the Foundation has enlisted the support and involvement of a host of public and political figures, known throughout the world as active supporters of environmental protection. For example, Senator Edmund Muskie, Senator Howard Baker, and Representative William Harsha (the original authors of the Clean Water Act) jointly chair the Foundation's Board of Governors. The Board is comprised of such leaders as President Jimmy Carter, 16 members of Congress, 5 state governors, and a host of prominent environmental leaders. Some 70 national organizations serve on America's Clean Water Foundation Steering Committee and a Celebrity Advisory Council assists the Foundation with public outreach.

For ideas on how you can get involved and help us make a difference, call or write:
America's Clean Water Foundation
Roberta Haley Savage, President

This booklet was adapted from the 1992 The Year of Clean Water Calendar. A special thanks to Kathryn Sevebeck, George Wills, and T. W. Johnson of the Virginia Water Research Center, and to Charles Evans of America's Clean Water Foundation for their dedication to citizen awareness of clean water.

Backyard mechanics that change their own oil generate over 324 million gallons of used oil and dispose of more than 90 percent of it improperly.

CCCCCCCCCCCCCCCCCCCCCCCCCCCC

Nearly 1.3 billion gallons of used oil are produced each year, but only about 770 million gallons are reprocessed by recyclers.

CCCCCCCCCCCCCCCCCCCCCCCCCCCC

Since 1950 fertilizer use has increased from 20 million tons annually to 50 million tons. Nearly 1.1 billion pounds of pesticides are applied each year in the United States.

CCCCCCCCCCCCCCCCCCCCCCCCCCCC

The average household generates 20 pounds of hazardous waste each year from household cleaners and chemicals.

CCCCCCCCCCCCCCCCCCCCCCCCCCCC

An estimated 60 percent of the 23 million septic systems in the United States are not operating properly.

CCCCCCCCCCCCCCCCCCCCCCCCCCCC

About 10 percent of the 1.4 million underground storage tanks for gasoline and other hazardous substances are leaking.

CCCCCCCCCCCCCCCCCCCCCCCCCCCC

KEEPING IT CLEAN

President George Bush and the Congress have proclaimed October as Clean Water Month. During the month there will be many opportunities to participate in activities that will broaden your understanding of today's critical water quality issues.

- < Organize a stream cleanup program and monitor the stream on a regular basis for evidence of pollution incidents. Report the results to your state water control agency.
- < Participate in comprehensive plan development and zoning for your city or county and take a position on how your community can best protect its water.
- < Encourage civic associations and other community groups to get involved in programs and efforts to maintain clean water.
- < Tell your elected representatives about your concern for the quality of life and the need for protection of our natural environment for drinking water, wildlife habitat, and human activities.
- < Become a steward of our natural resources.

AMERICA'S CLEAN WATER FOUNDATION PERSONAL PROCLAMATION

WHEREAS: clean water is a natural resource of tremendous value and importance to every American citizen;

WHEREAS: there is resounding public support for protecting and enhancing the quality of this Nation's rivers, lakes, wetlands, coastal waters and groundwater;

WHEREAS: maintaining and improving water quality is essential to protect public health, to protect fisheries and wildlife, and to assure abundant opportunities for public recreation;

WHEREAS: substantial progress has been made to improve water quality since the passage of the Clean Water Act in 1972 due to the concerted efforts by Federal, State and Local governments, the private sector and the American public;

WHEREAS: further development of water pollution control programs, advancement of water pollution control research, technology and education are necessary and desirable;

WHEREAS: 1992 is the 20th anniversary of the enactment into law of the Clean Water Act;

NOW THEREFORE, be it resolved that I, the undersigned, do hereby proclaim, in support of America's Clean water Foundation to make the calendar year 1992 my personal YEAR OF CLEAN WATER, and be it further resolved that I will do all I can to assure the integrity of our vital water resources for my generation and for the generations to follow.

Signatory of Proclamation

Roberta Haley Savage

ONE HUNDRED FIRST CONGRESS OF THE UNITED STATES OF AMERICA

AT THE SECOND SESSION

Begun and held at the City of Washington on Tuesday, the twenty-third day of January
one thousand nine hundred and ninety

JOINT RESOLUTION

To establish calendar year 1992 as the ~~A~~Year of Clean Water~~g~~.

Where as, clean water is a natural resource of tremendous value and importance to the Nation;
Where as, thee is resounding public support for protection and enhancing the quality of the Nation's rivers,
streams, wetlands, and marine waters;
Where as, maintaining and improving water quality is essential to protect public health, to protect
fisheries and wildlife, and to assure abundant opportunities for public recreation;
Where as, it is a national responsibility to provide clean water as a legacy for future generations;
Where as, substantial progress has been made in protecting and enhancing water quality since passage of the
1972 Federal Water Pollution Control Act (Clean Water Act) due to concerted efforts by Federal, State, and
local governments, the private sector, and the public;
Where as, serious water pollution problems persist throughout the Nation and significant challenges lie ahead
in the effort to protect water resources from point and nonpoint sources of conventional and toxic pollution;
Where as, further development of water pollution control programs and advancement of water pollution control
research, technology, and education are necessary and desirable; and
Where as, October of 1992 is the 20th anniversary of the enactment into law of the Clean Water Act:
Now, therefore, be it

*Resolved by the Senate and House of Representatives of the United States of America in congress
assembled, That, the Congress of the United States hereby designates calendar year 1992 as the ~~A~~Year of
Clean Water~~g~~ and the month of October 1992 as ~~A~~Clean Water Month: in celebration of the Nation's
accomplishments under the Clean Water Act, and the firm commitment of the Nation to the goals of that Act.*

APPROVED

October 12, 1990

Speaker of the House of Representatives

President of the Senate

WATER CHEMISTRY CHECKUP

9-12

OBJECTIVES

The student will do the following:

- 1 Conduct a number of water quality tests.
2. Determine the quality of a sample of water.

BACKGROUND INFORMATION

Water quality standards are often based on seven criteria - pH, temperature, dissolved oxygen, toxic pollutants, bacteria, radioactivity, and turbidity.

To profile a healthy stream, pH must be within an acceptable range (6.0-8.5). Temperature must not exceed 90° F (86° F in certain rivers) nor have rapid increases or decreases in temperature. Dissolved oxygen must not go below 5.0 mg/l except due to natural conditions. Toxic pollutants and radionuclides must not be present at harmful levels or levels which may cause bioaccumulation or biomagnification throughout the food chain. Bacteria must not be present at levels harmful to human health when stream water is ingested or absorbed. Turbidity (cloudiness) must not be at such levels that sunlight penetration is significantly diminished and sedimentation damages benthic habitat.

Terms

acidic: having a pH value of less than 7; acidic liquids are corrosive and sour (DO NOT TASTE!)

alkalinity: (1) a characteristic of substances with a pH greater than 7; (2) the capacity of water to neutralize acids, imparted primarily by the water's content of carbonates, bicarbonates, and hydroxides (expressed in mg/l of CaCO_3).

benthic: living on the bottom of a lake or sea; pertaining to the ocean bottom

bioaccumulate: to accumulate larger and larger amounts of a toxin within the tissues of organisms at each successive trophic level

SUBJECTS:

Science (Chemistry, Physical)

TIME:

one 50-minute class period
field trip (optional)

MATERIALS:

a fresh sample of water for testing
water analysis kit
student sheet
thermometers

biological magnification (biomagnification): bioaccumulation occurring through several levels of a food chain; process by which certain substances (such as pesticides or heavy metals) are deposited into waterway, eaten by aquatic organisms which are in turn eaten by large birds, animals, or humans, and become concentrated in tissues or internal organs as they move up the food chain.

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water

hardness: a measure of all the multivalent (primarily calcium and magnesium) ions expressed in mg/l of calcium carbonate ($CaCO_3$)

hydrogen sulfide: gas emitted during organic decomposition by anaerobic bacteria which smells like rotten eggs and can cause illness in heavy concentrations (chemical formula, H_2S)

ingestion: the process of taking into the body, as by swallowing

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

plankton: microscopic plants and animals in water which are influenced in mobility by the movement of water (i.e., as opposed to nekton (fish) which can swim)

radionuclides: types of atoms which spontaneously undergo radioactive decay; usually naturally occurring and can contaminate water or indoor air (e.g., radon)

toxic: harmful to living organisms

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

ADVANCE PREPARATION

A. Obtain water testing kits from one of the companies listed on page F-69, Water Testing Fact Sheet.

B. Copy and distribute Student Sheets.

C. Have students collect water samples. Explain that bottles should be filled to the top and sealed.

PROCEDURE

I. Setting the stage

- A. Have students carefully read and go over each of the water tests that they will be doing.
- B. Answer any questions about these tests before beginning the experiment.
- C. Explain to students that they will only be testing for the presence of a few of the many contaminants that may occur in water.

II. Activity

- A. Students will use an assortment of test kits to determine the quality of water from a local stream. If a field trip is possible, take students to a local stream to collect water samples.
- B. If a field trip is possible, take students to a local stream to collect water samples. If a field trip is not possible, samples can be brought to the classroom and tested for some parameters. The samples must be fresh and sealed tightly, or the DO will be incorrect. Temperature needs to be taken at time of collection, and no air bubbles should be present in the top of the jars. Jars should be capped while they are completely submerged.

Parameter		Limitations on Sample Storage
1.	Temperature	Must be recorded in the field at the time of sample collection.
2.	Dissolved Oxygen	First two steps of reaction must be done in field to yield iodide solution that will be titrated. Treated solution must be kept cool in sealed sample container. This can be kept up to six hours before titration.

3. pH **Y** Fill containers to top and keep sample cool.
Measure within two hours.
4. Alkalinity **Y** Should be done in field to get valid data.
5. CO₂ **Y** Must be done in field to get valid data.

C. Students will work in teams to complete tests on alkalinity, hardness, DO, ammonia, phosphate, turbidity, silica, pH, carbon dioxide (CO₂), nitrate, and hydrogen sulfide (H₂ S).

III. Follow-up

- A. Teams should compare results to those found in standards.
- B. Alkalinity, hardness, and carbon dioxide are not regulated parameters but are important
to water quality.

IV. Extensions

- A. Ask students to try to identify the source of their sample, if unknown, by looking at data
(groundwater or surface water: lake, river, pond). Discuss how this might be done. (e.g.,
groundwater would have comparatively low turbidity).
- B. Discuss what students think could be done to improve water quality in the body of water from
which this sample was taken.

RESOURCES

Water Analysis Kit, page F-69, Water Testing Fact Sheet

Team Member Names _____

WATER TEST KITS DATA SHEET

We have all heard reports about water being contaminated by many different types of substances. You are aware that water can be crystal clear and still have substances dissolved in it. How does anyone determine if water contains dissolved materials and whether they are harmless or dangerous? In this activity, you will have the opportunity to conduct a number of tests to determine if a sample of water contains certain substances.

Materials:

sample of water to be tested
 assortment of test kits

Gathering Data:

1. When you have been assigned a series of tests to perform, read the instructions completely before actually going through the procedures.
2. When you have completed a test, record the value in Table 1.
3. When all groups have finished, combine all the data on the master data sheet.

Organizing Data:

Table 1: Water Chemistry Data

Source:

Your Name:

Date:

Water Temperature:

Parameter	Results (mg/l)	Typical Discharge Limitations
* Alkalinity		
* Hardness		
Dissolved Oxygen		not below 5.0 mg/l
Ammonia		
Phosphate		
Turbidity		
pH		6.0 - 8.5
* Carbon dioxide		
Nitrate		

pH		6.0 - 8.5
Sulfide		

* not regulated parameters but important to note

Student Sheet

Testing will be done on five basic water quality parameters.

1. Temperature
2. Turbidity
3. pH
4. Dissolved oxygen
5. Total alkalinity

Most tests are colorimetric; that is, they are based on adding chemical reagent to the water sample until a color change is produced. The amount of reagent used to produce the color change is then directly related to a quantitative measure of the parameter being tested.

Temperature

Temperature affects the physical and chemical properties of water and greatly influences aquatic organisms by affecting feeding, reproduction, and metabolic rate. Most species have optimal temperatures for normal growth with corresponding upper and lower lethal limits. Temperature determines the density of water, the amount of oxygen it can hold, and how quickly nutrients will be recycled through the process of decomposition.

Turbidity

Turbidity, exhibited as cloudiness in water, is caused by suspended matter that scatters light passing through the water. The suspended particles range in size from colloidal (small) to coarse (large) dispersion.

There are many sources of turbidity. Although sediment from disturbed or eroded soil is often thought of as the source of cloudy water, turbidity can also be caused by dissolved organic matter from an abundance of microscopic plankton. Apparent water color, microscopic examination, and streamwalk observations can help determine the sources of turbidity.

Measuring Turbidity

Turbidity can be measured by using the clear plastic tubes in a water analysis kit. This method involves a

clear plastic tube with a turbidity “target” at the bottom. The sample turbidity causes a “fuzziness” of the target that can be matched in a second tube containing clear water by adding a standard turbidity reagent [calibrated in Nephelometric Turbidity Units (NTUs)] dropwise until the fuzziness of both targets are equal.

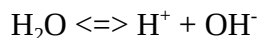
Student Sheet (cont.)

Assuring Accuracy

Turbidity is best measured in the field. The turbidity of a bottled sample will change due to biological activity, settling, clumping, and absorption of particles onto surfaces of the sample container. If time elapses between sampling and measurement, be sure to shake the sample well to suspend particles before measuring turbidity.

pH

Water is an effective ionizing solvent. Water ionizes into hydrogen (H^+) and hydroxyl (OH^-) ions as demonstrated by the equation below:



Even perfectly pure water contains some hydrogen and hydroxyl ions. The equilibrium condition for the two ions depends upon temperature.

The pH, a term coined in 1909 meaning the power of hydrogen, is a quantitative indicator of concentration of hydrogen ions. The pH is defined as the negative logarithm of the hydrogen ion activity [$pH = -\log (H^+)$].

If the hydrogen ion concentration is greater than that of the hydroxyl ions, the solution is said to be acidic. When the reverse situation exists and there are more hydroxyl ions, the solution is said to be basic. When the concentrations of the two ions are equal, the solution is neutral.

Values for pH are usually between 0 and 14.0 with the neutral point at (25°C) at 7.0. Solutions with pH values less than 7.0 are considered acidic; those between 7.0 and 14.0 are designated as basic. Most natural waters have pH values between 5.0 and 10.0 with the greatest frequency of values found between 6.5 and 9.0. Since the pH scale is logarithmic, every one-unit change represents a tenfold change in acidity (a pH value of 6.0 indicates 10 times more acidity than a value of 7.0; a value of 5.0 represents 100 times more acidity than the neutral condition). pH is affected by carbon dioxide concentrations (CO_2) because CO_2 in water forms a weak organic acid (carbonic acid). Both plants and animals continuously release carbon dioxide through the process of respiration. During daylight, aquatic plants use carbon dioxide during photosynthesis. Since CO_2 is acidic, and if plants remove more than is being produced through respiration,

the pH will increase during periods of high photosynthetic activity, decreasing at night when photosynthesis stops. Daily fluctuations in pH are less when water is buffered (has higher alkalinity).

Measuring pH

The pH is measured using liquid indicator kits or electronic pH meters.

Student Sheet (cont.)

Significant Levels

The following figure and table represent pH values for common substances and natural water supplies, and the effect on the aquatic community of varying pH values, respectively.

What measured levels may indicate

Routine monitoring of a waterbody should provide baseline information about normal pH values. Unanticipated decreases in pH could be indications of acid rain, runoff from acidic soils, or contamination by agricultural or livestock chemicals or by-products. pH values outside the expected range of 5.0 to 10.0 could be considered as an indication of industrial pollution.

Assuring accuracy

When using test kits, accuracy is a function of the sensitivity of the kit. Many groups use kits with a test range of pH 3.0 to 10.0 with a sensitivity of 1.0 units. This can be complemented with a test range of 6.8 to 8.2 with a sensitivity of 0.2 pH units.

When using pH meters, these should be calibrated frequently. Temperature affects the function of the electrode, and the meter must calibrate for temperature to provide correct pH values.

pH should be measured in the field since the pH of bottled samples will rapidly change due to biological and chemical activity in the sample container.

Effects of pH on aquatic life	
AT pH	EFFECT ON AQUATIC LIFE
3.0 - 3.5	Unlikely fish can survive for more than a few hours in this range although some plants and invertebrates can be found at pH levels this low.
3.4 - 4.0	Known to be lethal to salmonids.
4.0 - 4.5	All fish, most frogs, and insects absent.
5.0 - 5.5	Bottom-dwelling bacteria (decomposers) begin to die. Leaf litter and detritus begin to accumulate, locking up essential nutrients and interrupting chemical cycling. Plankton begin to disappear. Snails and clams absent. Mats of fungi begin to replace bacteria in the substrate.
5.5 - 6.0	Metals (aluminum, lead) normally trapped in sediments are released into the acidified water in forms toxic to aquatic life.
6.0 - 6.5	Freshwater shrimp absent. Unlikely to be directly harmful to fish unless free carbon dioxide is high (in excess of 100 ppm).
6.5 - 8.2	Optimal for most organisms.
8.2 - 9.0	Unlikely to be directly harmful to fish, but indirect effects occur at this level due to chemical changes in the water.
9.0 - 10.5	Likely to be harmful to salmonids and perch if present for long periods.

10.5 - 11.0 Rapidly lethal to salmonids. Prolonged exposure may be lethal to carp and perch.

11.0 - 11.5 Rapidly lethal to all species of fish.

In addition to direct effects on aquatic systems, pH affects many chemical processes. The toxicity of ammonia increases as the pH increases. Low pH can reduce the amount of dissolved inorganic phosphorus and carbon dioxide available to plankton. Low pH can also increase the risk of hydrogen sulfide toxicity.

9-12

HOW HARD IS HARD WATER?

OBJECTIVES

The student will do the following:

1. Perform chemical analyses for hardness on water samples.
2. Collect data and prepare Data Sheets.
3. Analyze data using various graphing techniques.
4. Determine the importance of water hardness in natural habitats and for human use.

BACKGROUND INFORMATION

Hard water is the result of the presence of primarily two elements in their ionic form in water. The two elements mainly responsible for hardness are calcium (Ca^{+2}) and magnesium (Mg^{+2}). Iron, aluminum, manganese, and other minerals may also cause hardness, but large amounts of these minerals are not usually found in natural waters. Water hardness is often correlated with the “lathering” capacity of soap in certain water sources by the general public--the harder the water, the less the lather!

The geological makeup of an area usually determines the natural source of hardness. Limestone rock that has been dissolved by slightly acidic water (carbonic acid) is the usual source. Granite isn't easily dissolved by carbonic acid; therefore, areas rich in limestone usually have very hard water whereas those that are

SUBJECTS:

Science (Chemistry, Physical, Biology, Ecology), Math

TIME:

1-2 class periods

MATERIALS:

bottled drinking water
distilled water
milk
soft drink
Epsom salts
fabric softener
deionized salt
lotion
water analysis kit

mostly granite do not.

Acidic water is formed when water absorbs carbon dioxide. Carbon dioxide (CO₂) makes up 0.03% of air and is a waste product of plant and animal respiration. The decomposition process, in soil and water, also contributes CO₂ to the atmosphere.

When carbon dioxide combines with water, it forms a weak solution of carbonic acid, which is found in carbonated beverages. Carbonic acid reacts with limestone to produce calcium carbonate (CaCO₃)--a white compound that leaves a scaly deposit, especially in teakettles.

There's an important relationship between the amount of carbonates in water and the amount of "bicarbonates" that are similar compounds. Bicarbonates function like Alka-Seltzer to buffer water against acids. If a waterway has a high carbonate content (total alkalinity), it also has a good buffering ability and is less likely to be hurt by acid rain and acid wastes. Some common hardness values are shown in the following chart.

TOTAL HARDNESS (mg/L CaCO ₃)	DESCRIPTION
0 to 60	Soft water
61 to 120	Moderately hard water
121 to 180	Hard water
181 and up	Very hard water

In the baking industry, very soft water produces sticky bread dough and soggy bread. On the other hand, hard water used for cooking toughens many vegetables and slows fermentation----the process by which cheese, yogurt, and beer are made. Recommended hardness values for industrial use are summarized in the table below.

INDUSTRY	TOTAL HARDNESS (mg/L CaCO ₃)
Brewing beer	200 to 300
Carbonated beverages	200 to 250
Washing clothes	0 to 50
Steel manufacturing	50

Heavy metals, such as mercury, copper, and lead, and nonmetals, such as ammonia, phenols, and certain acids, are much more toxic to fish in soft water than in hard water because soft water has fewer binding sites for the toxic substances. Research studies have appeared to indicate that drinking soft water over long periods of time may increase one's chances of having a heart attack. To avoid the potential problems, faucets providing drinking water can be disconnected from a water softener.

There are two different testing procedures for hardness. The total hardness test is performed frequently in the water industry. It measures the total amount of calcium and magnesium in water, and the results are expressed in metric units as milligrams per liter (mg/l) of calcium carbonate (CaCO_3). The second procedure determines calcium content only.

Both hardness tests, total and calcium only, use EDTA, ethylenediaminetetraacetic acid. It chelates, or wraps around, any ions in solutions that have multiple positive (multivalent) charges. Calcium and magnesium are the most common multivalent ions in natural waters that contribute to hardness.

Terms

acid rain: rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels or from volcanic activity; may cause damage to buildings, monuments, car finishes, crops, forests, wildlife habitats, and aquatic life.

bicarbonate: an acid salt of carbonic acid containing the radical HCO_3^-

calcium carbonate: one of the most stable, common, and widely dispersed materials on Earth; occurs naturally in oyster shells, calcite, limestone, marble, chalk, and other forms; used to express hardness and alkalinity (mg/l of CaCO_3)

carbon dioxide: colorless, odorless gas made of carbon and oxygen (CO_2); exhaled by animals and humans, utilized by plants in photosynthesis and contained in automobile exhaust

carbonic acid: substance formed by combining water (H_2O) and carbon dioxide (CO_2); chemical formula H_2CO_3 .

hard water: water high in mineral content; water containing an abundance of Ca^{+2} and Mg^{+2} ions

hardness: a measure of all the multivalent (primarily calcium and magnesium) ions expressed in mg/l calcium carbonate (CaCO_3)

ion: an atom or molecule that has lost or gained one or more electrons

multivalent (ion): ion that has lost or gained more than one electron (also called a “polyvalent” ion)

toxic: harmful to living organisms

ADVANCE PREPARATION

- A. Copy Data Sheets.
- B. Discuss Background Information and/or copy and hand out to students.
- C. Divide students into small groups.

PROCEDURE

I. Setting the stage

Have the students engage in directed discussion, or have them make a list of places they have lived or visited where they have noticed differences in the water when used for certain activities --- drinking, brushing teeth, shampooing, washing clothes, bathing, etc.

II. Activity

- A. Have students bring in samples of water from various sources.
 - 1. bottled water from various geographic areas
 - 2. tap water
 - 3. well or spring water
 - 4. river or creek water
 - 5. lake or pond water
- B. Other substances can also be used to test for hardness.
 - 1. carbonated beverages

2. milk
3. solution of Epsom salts
4. liquid fabric softeners diluted with distilled water
5. lotions, creams diluted with distilled water

C. Using a water analysis kit, test each item for hardness. (Directions for using each test kit are included in the kit.)

D. Follow the directions for each testing procedure.

E. Record the data on the Data Sheet.

F. Graph the data from each sample using a bar graph.

G. Write an analysis comparing the test results of each.

III. Follow-up

Explain why groundwater is generally harder than surface water.

IV. Extensions

1. Have students research the geologic areas of the world on the bottled water samples to determine the rock formations. Report on how this correlates with the hardness results.

2. Analyze the hardness results of flowing waters (rivers, creeks) compared to that of standing waters (wells, ponds, swamps, rain barrels). Use bar graphing on poster board, perhaps computer generated, to present results.

3. Obtain hardness data from water quality testing in different states and/or countries and compare to your area. Use a computer to locate databases with this information if there is access to the Internet or a commercial communications network. Hardness data may be obtained from the state Geological Survey and from the U.S. Geological Survey. (See fact sheet pages J-1 to J-6 in the back of this book.)

4. Locate other schools or organizations that do water testing and compare the data collected to that of your area.

RESOURCES

Jacobson, Cliff, Water, Water Everywhere (Student Reading Unit About Water Quality), Hack Company, Loveland, CO, Catalog Number 21975-00. 1-800-227-HACH.

TVA Teacher - Student Water Quality Monitoring Network, March, 1992, Tennessee Valley Authority.

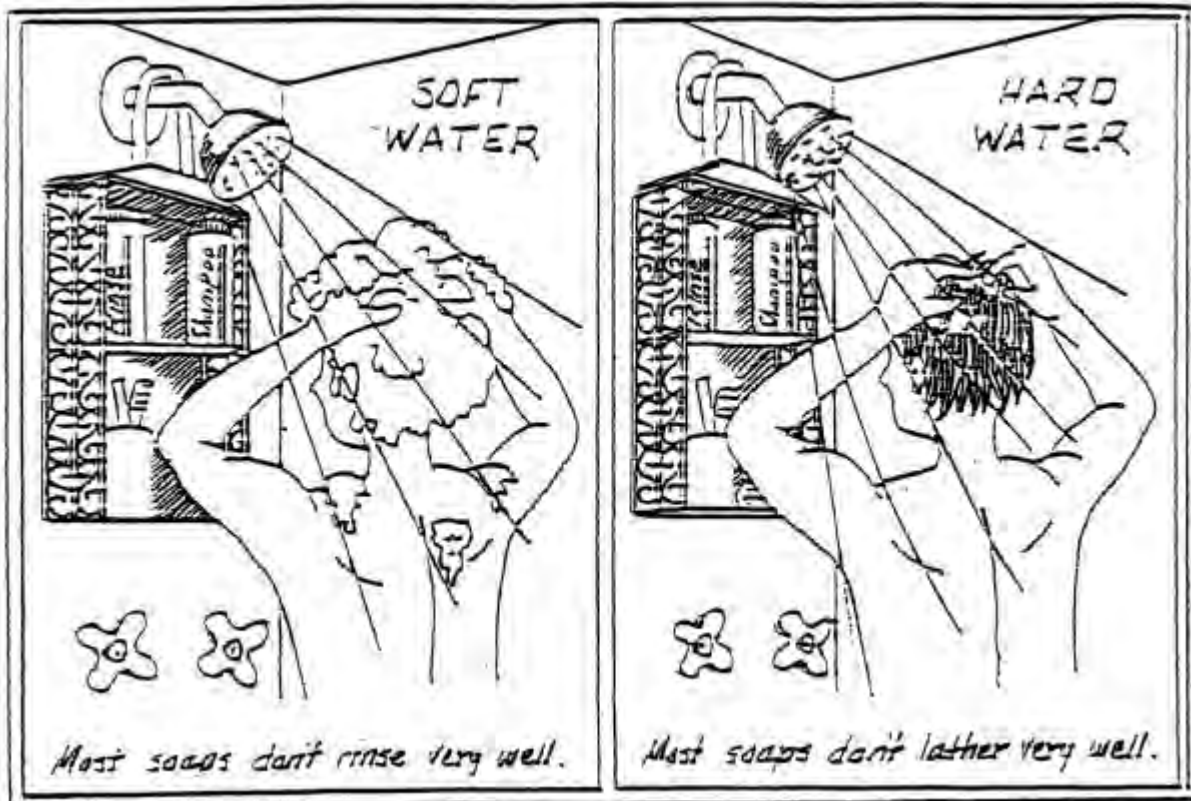
Water Analysis Kit, page F-69, Water Testing Fact Sheet

Water Hardness

Data Sheet

Substance Tested

Hardness (CaCO_3 , mg/L)



IS YOUR WATER WELL FOR DRINKING?

9-12

OBJECTIVES

The student will do the following:

1. List the types of tests that are done on drinking water.
2. Outline a wellhead protection program.
3. Learn and report on some aspect of water quality and/or water testing.

BACKGROUND INFORMATION

Americans have traditionally had the safest drinking water supplies in the world. However, in a country as industrialized as ours, there is nothing natural or simple about the need to keep our water supplies safe. It takes a tremendous amount of work to ensure this. At all levels of government and industry, there are people who work full-time to protect our drinking water supplies by passing laws, setting regulatory standards, making improvements in treating water, and delivering it to our homes.

Terms

contaminant: an impurity that causes air, soil, or water to be harmful to human health or the environment; something that makes a substance impure, infected, corrupted, or polluted

drinking water standard: maximum contaminant level or treatment technique requirement

Environmental Protection Agency (EPA): the U.S. agency responsible for efforts to control air, land, and water pollution, radiation, and pesticide hazards, and to promote ecological research, pollution prevention, and proper solid waste disposal

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock

SUBJECTS:

Science (Chemistry, Ecology, Social Studies, Language Arts)

TIME:

1 class period; longer if necessary

MATERIALS:

handouts: "Groundwater Protection and "Home Water Testing"
transparencies: "Possible Drinking Water Contaminants" and "Activities Which Contribute to Well Water Contamination"

below the Earth's surface; water within the zone of saturation

maximum contaminant level (MCL): maximum permissible level of a contaminant in water which is delivered to any user of a public water system; drinking water standard.

Safe Drinking Water Act: a law passed by the U.S. Congress in 1974 and amended in 1986 and 1996 to help ensure safe drinking water in the United States. The Act requires that regulations be enacted to set maximum contaminant levels (MCLs) or treatment technique requirements for a variety of chemicals, metals, and pathogens in public water supplies; also requires protection of surface source waters and underground sources of drinking water.

treatment technique: drinking water treatment requirement in lieu of a maximum contaminant level (MCL); typically used when establishing an MCL is too difficult or when compliance with an MCL would be too costly; drinking water standard.

wellhead: the physical structure or device at the land surface from or through which groundwater flows or is pumped

ADVANCE PREPARATION

- A. Have vocabulary words on board to be used as a springboard for an introduction to the lesson theme.
- B. Have students write terms and definitions in their class journals. These words will later be used in a unit vocabulary study.
- C. Prepare copies of "Ground Water Protection: A Citizen's Action Checklist" and "Home Water Testing."

PROCEDURE

I. Setting the stage

A. After a brief discussion of the topic of the lesson, give students copies of handouts and guide students through independent study of handouts. Call special attention to the ~~section titled~~ "Should You Have Your Water Tested?".

B. Show the Possible Drinking Water Contaminants transparency. Discuss the sources and effects with the class.

II. Activity

A. Show the Activities Which Contribute to Well Water Contamination transparency. Have the class list five ways to protect the wellhead area for each category shown. Students may reply based on municipal or individual well supplies.

B. Invite an employee of your municipal water works or local water supplier to talk to the class about ongoing water testing and water supply protection in the area. If an employee cannot come to the class, schedule a telephone or personal interview (perhaps, combined with a water treatment plant tour). Ask about the type of contaminants in the water, MCLs typically exceeded, and source water protection activities conducted.

C. Write a newspaper article stressing the importance of testing drinking water using information from the handouts.

D. Write an article for the school paper discussing the current fad of buying bottled drinking water. Survey students to find out why they purchase bottled water and the distrust their local water supply.

E. Create a collage/poster in which you illustrate rules and regulations related to safe drinking water.

F. Have students look up the Public Notification regulations for MCL exceedences and treatment technique requirements. Have them research to see if their water system has ever exceeded an MCL or other requirement which necessitates Public Notification. Have them find the Public Notices in the newspaper and report on their content.

FOR MORE INFORMATION, CALL SAFE DRINKING WATER HOTLINE 1-800-426-4791.

III. Follow-up

On a designated class day, have students present findings/projects to the entire class. Work the cryptoquote for fun or bonus points.

IV. Extensions

Do more intense research of local drinking water treatment plants; possibly take field trips individually or as a class. Have students write individual reports.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Public Education Fact Sheets, United States Environmental Protection Agency, Office of Water, "Home Water Testing," June 1991, EPA 570/9-91-500 and "Groundwater Protection," June 1992, EPA 810-F-92-002.

Cryptoquote:

Here's how it works: One letter stands for another letter. Single letters, double letters, one-letter words, and punctuation are all clues. E is the most frequently used letter; THE is the most frequently used word. Have fun!!

NEXCI,NEXCI C RCIUNACIC

EBZ EHH XAC QKEIZP ZMZ PAIMBY;

NEXCI,NEXCI C RCIUNACIC

BKI EBU ZIKO XK ZIMBY.

-JKHCIMZVC:XAC EBJMCBX

WEIMBCI

solution:

Water, water everywhere
And all the boards did shrink;
Water, water everywhere

Nor any drop to drink.
-Coleridge: The Ancient Mariner

Student Sheet

United States
Environmental Protection
Agency

Office of Water
WH550A

EPA 570/9-91-500
June 1991



EPA Home Water Testing

Should You Have Your Water Tested?

The question of whether or not to have your wastewater tested is a serious one. In addition to illness, a variety of less serious problems, such as taste, color, odor, and staining of clothes or fixtures, are symptoms of water quality problems.

Not everyone needs to test his/her water. This fact sheet provides a few guidelines for deciding whether or not to have your water tested; and, if so, what tests would be appropriate for your situation.

Public Versus Individual Water Supplies

If you obtain drinking water from your own well, you alone are responsible for assuring that it is safe. Routine testing for a few of the most common contaminants is highly recommended, and regular testing can be valuable to establishing a record of water quality.

If your water comes from a public or municipal water system, your water is regularly tested for contaminants regulated by federal and state standards. However, some water supply districts do not have enough money to hire trained specialists or to comply immediately with expanding government requirements. In addition, bacteria may grow in your plumbing, or corrosive water or deteriorating pipes in the house may add contaminants to your drinking water.

Individual Water Supplies

Routine Tests. The testing frequencies in this fact sheet are general guidelines. Test more often if you suspect there is a problem. If any tests give positive results, contact either the state health department or call the Safe Drinking Water Hotline for more information.

< Once each year test for coliform bacteria, nitrate, pH, and total dissolved solids (TDS). Test for these contaminants during the spring or summer following a rainy period or after repairing or replacing pipes and after installing a new well or pump.

Every three years, test for sulfate, chloride, iron, manganese, hardness, and corrosion index.

- < If your home plumbing contains lead materials, brass fittings, or lead solder, test your water as soon as possible. Congress has banned the use of lead in new or replacement plumbing materials.
- < If a new baby is expected in the household, test for nitrate in the early months of a pregnancy, before bringing an infant home, and again during the first six months of the baby's life.

Special Situations. If someone in your family becomes ill or the taste, odor, or color of your water changes, your water supply may be contaminated. Table 1 lists other situations that deserve attention.

Municipal Water Supplies

Municipal water supply systems perform a variety of tests and will provide water quality reports upon request. You should have your water tested when any of the situations in Table 1 arise.

If you are considering buying a home treatment device for protection against any contaminants, first have your water tested by an independent certified laboratory. Also, if you are buying a home and wish to assess the safety and quality of the existing water supply, test for coliform bacteria, nitrate, lead, radon, iron, hardness, pH, sulfate, total dissolved solids (TDS), corrosion index, and other parameters depending on proximity to potential sources of contamination.

How Should You Collect Test Samples?

Most testing laboratories or services supply their own sample containers. Use the containers provided and carefully follow the instructions given for collecting, preserving, and handling water samples. Laboratories may sometimes send a trained technician to collect the sample or to analyze the sample directly in your home. Keep a record of all your water test results as a reference for future testing. By comparing recent test results with original results, you may discover that a change in treatment is needed or that a treatment device is not working as it should.

Where Can You Have Your Water Tested?

- , Private testing laboratories (listed in the telephone book)
- , The Safe Drinking Water Hotline(to find state certified labs)
- , County and state health laboratories, departments of health, and local hospital and university laboratories
- , Water treatment companies and plumbing supply stores may offer certain tests in your home for free.

, Local engineering firms.

TABLE 1.

Conditions or nearby activities	Recommended Test
Recurrent gastrointestinal illness	coliform bacteria (total, if possible, then fecal)
Household plumbing contains lead	pH, lead, copper
Radon in indoor air or region is radon rich	radon
Scaly residues, soaps don't lather	hardness
Water softener needed to treat hardness	calcium, magnesium
Stained plumbing fixtures, laundry	iron, copper, manganese
Objectionable taste or smell	hydrogen sulfide, corrosivity, metals, algae
Water appears cloudy, frothy, or colored	color, detergents
Corrosion of pipes, plumbing	corrosivity, pH, lead
Rapid wear of water treatment equipment	pH, corrosivity
Nearby areas of intensive agriculture	nitrate, pesticides, coliform bacteria
Coal or other mining operation nearby	iron, manganese, pH, corrosivity
Gas drilling operation nearby	chloride, sodium, barium, strontium
Odor of gasoline or fuel oil, near gas station or buried fuel tanks	volatile organic compounds (VOCs), oil and grease analysis
Dump, junkyard, landfill, factory, or dry cleaning operation nearby	VOCs, TDS, pH, sulfate, chloride, metals
Salty taste, seawater, or a heavily salted roadway nearby	chloride, TDS, sodium

United States
Environmental Protection
Agency

Office of Water
WH550A

EPA 81 0-F-92-002
June 1992

Ground Water Protection:

EPA

A Citizen's Action Checklist

What is being done to protect our drinking water

Americans have the safest drinking water supplies in the world. In a country as industrialized as ours, though, there is nothing natural or simple about our safe water. At all levels of government, there are people who work full time to protect our drinking water supplies through passing laws, setting regulatory standards, and making improvements in treating water and delivering it to you.

However, these people make up a relatively small group compared to the size of their task, and there are always limited government resources to protect drinking water.

There is much that individual citizens can do to pitch in and help. This fact sheet describes actions that you can take to help protect your drinking water supply.

What you should know about potential threats to ground water supplies

Until recently ground water was thought to be protected from contamination by the natural filtering action of soil and rock. We now know that chemicals can pass through these soil layers. Some types of activity around your water source can affect your water quality, whether your water comes from a public supply or a private well. The most important of these are listed here.

- < Expanding or building new industrial, residential or commercial areas.
- < Routine road maintenance such as repaving or deicing during winter months.
- < Using pesticides or fertilizers on any commercial or residential areas.
- < Disposal of household waste at landfills or in your backyard.
- < Use of underground storage tanks or drains such as at gasoline stations or on farms for farm equipment.

What you should do to help protect your water

1. Begin by finding out where your drinking water comes from
If it comes from a private or household well:

- ! Determine the type of well you have - is it shallow dug or a deep, drilled well? If you are not sure, call your well drilling contractor or the drinking water office in your state department of public health, natural resources or environmental protection.
- ! Shallow wells or poorly constructed deeper wells tend to be more vulnerable to contamination. If your well is likely to be vulnerable, conduct a survey of the area around your well:
 - C Is there livestock nearby?
 - C Are pesticides being used on nearby agricultural croplands or nurseries?
 - C Do you use lawn fertilizers near the well?
 - C Is your well "downstream" from your's or a neighbor's septic system?
 - C Is your well located near a road that is frequently salted or sprayed with deicers during the winter months?
 - C Do you or your neighbors dispose of household wastes or used motor oil in the backyard, even in small amounts?
- ! If any of these items apply, it may be best to have your water tested, and ask your local public health department or agricultural extension agent for preventive measures.

If your water comes from a public supply:

- < Look for a phone number on your monthly water bill. Call about the operation of the water system plant.
- < Ask a plant operator about the source of your drinking water. Is it surface water or a ground water source?
- C If the source is ground water from a well, does the state have a wellhead protection program that manages the land around the well and around the original source of the ground water?
- C If the source is surface water from a lake, river, or spring, does the water system have a watershed protection program in place around the supply?
- < If there are such programs in your area, ask the supplier to send you any public information he or she may have on the program. A citizen's advisory group may help guide the program.
- < If the supplier does not have this information, contact the drinking water office in your state department of public health, natural resources, or environmental

protection.

Student Sheet (cont.)

2. Get involved in long-term protection of your water supply.
 - < Be aware of your surroundings. Take note of new construction and new development of industry.
 - < Check the paper or call your local planning or zoning commission for hearings or zoning appeals on development or industrial projects that could possibly affect your water.
 - < Attend these hearings. Ask questions like, "If you build this landfill, what will you do to ensure that my water will be protected?"
 - < Support plans to improve your community's water system, sewage system, or waste disposal landfills.
 - < Enlist in local citizen's advisory groups that serve planning or utility commissions.
3. Learn how to use the right tools for protecting your water supply.

Communities actually have quite a bit of power over land use, construction, and health standards. There are several management tools your community can use to influence these decisions.

- < Zoning Ordinances can specify the appropriate regulations that can be used to prevent activities that could affect ground water quality.
- < Subdivision Ordinances can set limits on population density, require open space set aside and regulate the timing of development.
- < Site Plan Reviews can determine if proposed projects and existing facilities are compatible with planned land use.
- < Design Standards can ensure that structures will not affect water quality. Underground tanks may be required to be double-walled.
- < Operating Standards can ensure that best management practices are used for some activities. Pesticide applications or feedlot operations may be limited.
- < Source Prohibitions may forbid or restrict the use of some materials within a defined area, perhaps around a wellhead.

- < Purchase of Property or Development Rights of lands that feed water supplies can guarantee control over activities there.
- < Special Programs, such as public education campaigns, volunteer ground water monitors, or household hazardous waste collection programs, can be organized.

For More Information
Call the Safe Drinking Water
Hotline at:

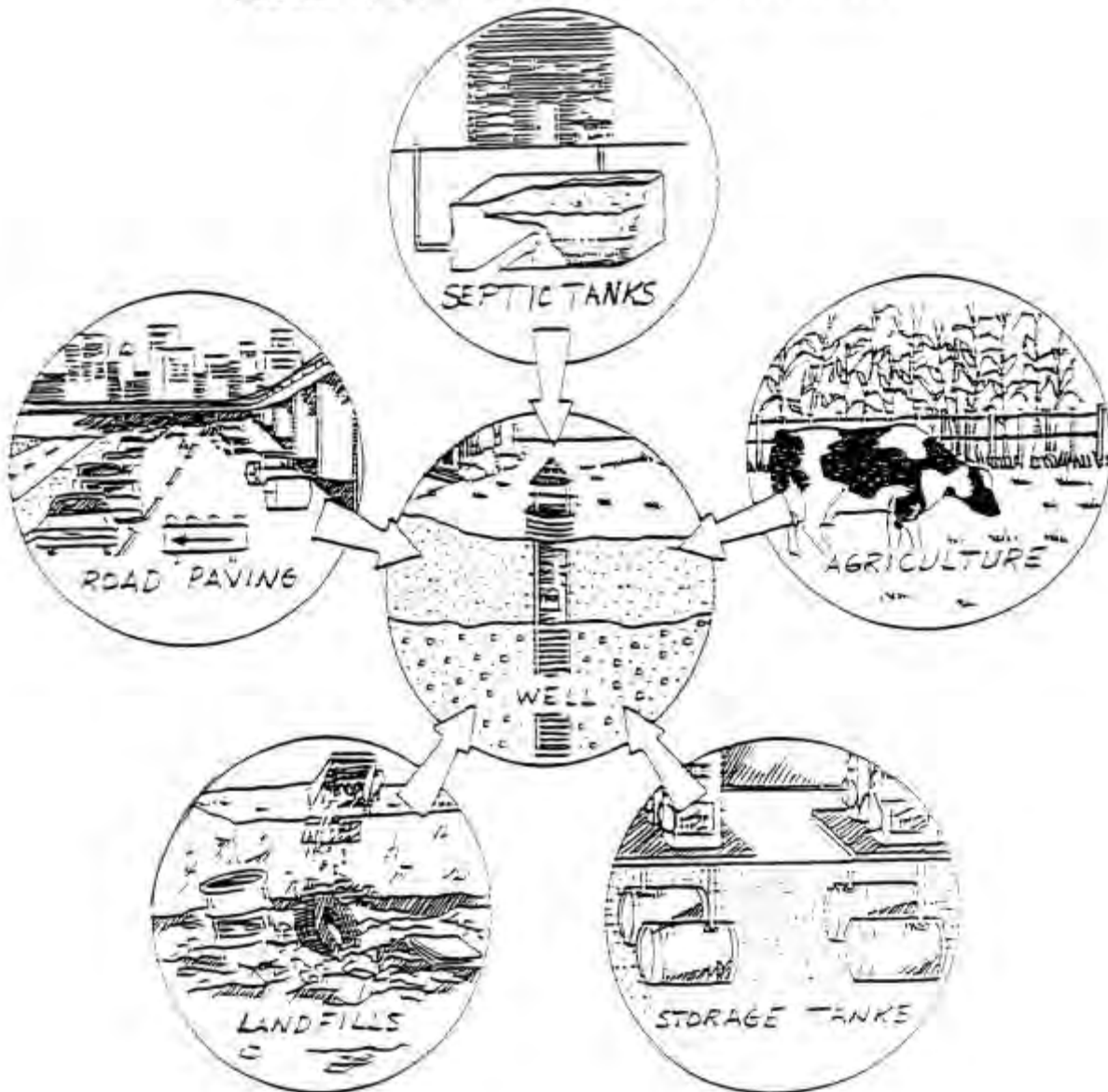
POSSIBLE DRINKING WATER CONTAMINANTS		
Most of these are only of concern at levels above those set by the EPA.		
SUBSTANCE	SOURCES	EFFECTS
SOLIDS/SOILS Sediment Sewage Total dissolved solids (TDS)	Erosion: agriculture, forests, mines, construction Toilets, drains, sewers; human wastes, soaps, detergents	Reduced light penetration (turbidity), reduced volumes Enrichment of surface water (eutrophication), carries germs
ORGANISMS Cholera bacteria	Variety: industry, agriculture, urban activities	Varied, depending on solutes
Dysentery	Infected person(s)	Diarrhea, vomiting, dehydration, death
bacteria/amoeba	Infected person(s)	Colon infection, diarrhea, blood in stools, abdominal pain
E. coli bacteria	Sewage	Kidney and pelvic inflammation; infantile diarrhea
Hepatitis A	Infected person(s); contaminated food; hypodermic needles	Inflammation of liver, jaundice, fever
viruses	Infected person(s)	
Hookworms	Infected person(s); contaminated food or water	Severe anemia, diarrhea, abdominal pain
Typhoid bacteria		Typhoid fever (high fever, fatigue, headache, rash, pneumonia, intestinal hemorrhage, death)
INORGANICS		
Copper	Plumbing, algae control	Stomach and intestinal distress, liver and kidney damage, anemia
Lead	Old ceramics, paints, gasoline, plumbing, batteries, pesticides	Neurotoxin, tremors, learning disabilities
Mercury	Batteries, thermometers, gold mines, industry	Neurotoxin, Minimata Disease in shellfish, bottom feeders
Metals	Varied: industry, mines	Varied: toxins or carcinogens
Nitrates	Fertilizers, industry, car exhaust, combustion	Anemia, especially in infants; toxin, carcinogen
Radon	Radioactive gas from the crust	Increased risk of lung cancer
Salts	Industry, deicing	Inhibit plants and aquatic life
Sulfates		
ORGANICS	Coal combustion, car exhaust, industry	Toxic, contribute to acid rain
Dioxins	Industry, white paper mills	Carcinogens, birth defects
Organic pesticides	Agriculture, industry	Toxins, carcinogens, inhibit wildlife
Polychlorinated biphenyls	Industry, electrical transformers	Attack liver and kidneys
Vinyl chlorides	Plastics, during manufacturing or combustion	Carcinogens
Volatile organic compounds (VOCs)	Fuel gases, phenols, benzene, chlorofluorocarbons (CFCs)	Varied, may be toxins, may be carcinogens

POSSIBLE DRINKING WATER CONTAMINANTS

Most of these are only of concern at levels above those set by the EPA.

Teacher/Student Sheet

ACTIVITIES WHICH CONTRIBUTE TO WELL WATER CONTAMINATION



WATER WORKS

OBJECTIVES

The student will do the following:

1. Describe the process that water treatment plants use to purify water for drinking.
2. Demonstrate how a water treatment plant works.

BACKGROUND INFORMATION

Our drinking water comes from both surface water and groundwater. Water in lakes, rivers, and swamps contains impurities that may make it look and smell bad. Water that looks clean may contain harmful chemicals or bacteria and other organisms that can cause disease.

Waterborne diseases have been and continue to be a major public health concern. Waterborne disease outbreaks, such as occurred in Milwaukee, WI in 1993 with 400,000 sick and over 100 deaths, give cause for continued vigilance in drinking water protection and treatment.

It takes the efforts of federal, state, and local governments, as well as local water suppliers, to keep our drinking water safe. The Safe Drinking Water Act and its amendments set the standards for public drinking water supplies. The Environmental Protection Agency is charged with ensuring that these standards are met. Technicians working in drinking water facility laboratories conduct thousands of tests each year to ensure that our drinking water supply is free of disease-causing bacteria and other pathogens. These test results are reported to state and local governments.

Drinking water treatment plants clean and maintain the quality of our water supplies through the following processes: (1) aeration, (2) coagulation/flocculation, (3) sedimentation, (4) filtration, and (5) disinfection. (See definitions in “Terms.”)

Terms

SUBJECTS:

Science (Physical, Earth, & Biology)

TIME:

2 class periods

MATERIALS:

student sheets
2-gallon (8 L) jug of water
5 cups (600 ml) soil or mud
acetate sheet
many 2-liter plastic bottles
funnels, scissors, stirring rods
alum, bleach, fine sand
coarse sand, fine gravel
coarse gravel
activated charcoal
cotton for plugs, tap water
tablespoons, clock
small piece of cheese cloth,
rubber band

aeration: exposing to circulating air; addition of oxygen to wastewater or water, as in first step of both activated sludge wastewater treatment process and drinking water treatment.

alum: aluminum salt (typically, aluminum sulfate) used as a flocculant

coagulant: a substance added to a mixture that will cause precipitates (flocs) to form; also called “flocculant”

coagulation: the process by which dirt and other small suspended solid particles are chemically bound, forming flocs using a coagulant (flocculant) so they can be removed from the water (the second step in drinking water treatment)

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in the water (the fifth step in drinking water treatment)

filtration: the process of passing a liquid or gas through a porous article or mass (e.g., paper, membrane sand) to separate out matter in suspension (the fourth step in drinking watertreatment)

flocculant: a substance added to a mixture that will cause precipitates (flocs) to form; also called “coagulant”

flocs: lumpy or fluffy masses of particles agglomerated by a flocculant or coagulant

flocculation: physical process of growing of flocs from smaller flocs or particles

microbe: microorganism (microbiological organism)

microbiology: study of microorganisms, a large and diverse group of organisms that exists as single cells or cell clusters

sedimentation: the drinking water process of letting heavy particles in raw water settle out into holding ponds or basins before filtration

sludge: any solid, semisolid, or liquid waste that settles to the bottom of sedimentation tanks (in wastewater treatment plants or drinking water treatment plants) or septic tanks

waterborne diseases: diseases spread by contaminated water

water treatment: a method of cleaning water for a specific purpose such as drinking

ADVANCE PREPARATION

- A. Make a copy of the diagram of a water treatment plant or use as a transparency.
- B. Gather materials for students to demonstrate the drinking water treatment process.
- C. Prepare “dirty water”; add approximately 5 cups (600 ml) of soil or mud to 2 gallons(8 L) of water.
- D. Alum (flocculant) can be found at the grocery store in the spices section. It is commonly used for making pickles.

PROCEDURE

- I. Setting the stage
 - A. Discuss the water treatment plant and what it does.
 - B. Hand out the diagram of a Water Treatment Plant and Data Form.
 - C. Discuss each step of water treatment. (An overhead transparency of the Student Sheet may be helpful.) Use the definitions given to explain each step.
- II. Activity
 - A. Divide the students into working groups. Have each group perform the following steps and answer the following questions on the Student Sheet - Data Form:
 - 1. Pour about 1.5 quarts (1.4 L) of “dirty water” into the uncut 2-liter bottle with the cap. (Use a funnel.) Describe the water.
 - 2. Put the cap on the bottle and shake for 30 seconds. Continue the process by pouring the water back and forth between two bottles 10 times. What part of the treatment process does this represent?
 - 3. Pour the aerated water into the 2-liter bottle with top cut off. Add 2 tablespoons (30 ml) of alum to the water. Stir the mixture slowly for 5 minutes. What process is occurring?
 - 4. Allow the water to stand undisturbed for 20 minutes. Ask the students to observe the water at 5-minute intervals and record their observations. What process is

occurring? (Note: some members of the group could be constructing the filter during this time according to the diagram on page 2-8 - see #5 below)

5. Cut the bottom from another 2-liter or 3-liter bottle. Construct the filter. Turn the bottle upside down. Loosely put a cotton plug in the neck of the bottle, then cover the neck of the bottle with a piece of cheese cloth secured with a rubber band. Pour the fine sand over the cotton plug followed by activated charcoal, coarse sand, fine gravel, and coarse gravel. Clean the filter by slowly and carefully pouring through 1-2 gallons (4-8L) of clean tap water. Place the filter over the bottom part of the bottle. Without disturbing the sediment in the container with the alum, pour the top two-thirds of the water through the filter. What process is occurring?

6. After waiting until more than half of the water poured through the filter has been collected, add 2 tablespoons (30 ml) of bleach to the filtered water. What part of the treatment process does the addition of bleach represent?

B. Compare the treated and untreated water.

1. Record differences in appearance and odor.

2. Examine water with a microscope (both treated and untreated). Record observations.

C. Have students find out if there is any special treatment that is done to “smelly” water. (Note: Activated charcoal is often used.)

III. Follow-up

A. Have students write a report on how a water treatment plant purifies water. They must include all the steps.

B. Visit the local water treatment plant. If this is not possible, ask a representative from the water utility to visit the class.

RESOURCES

“Science Demonstration Projects in Drinking Water: Grades K-12,” U.S. Environmental Protection Agency, Washington, D.C., 1990.

“The Official Captain Hydro Water Conservation Workbook,” East Bay Municipal Utility District, Oakland, California, 1982.

“The Story of Drinking Water” (student booklet), American Water Works Association, Denver, Colorado, 1984.

“The Story of Drinking Water: Teachers Guide, Intermediate Level, Grades 4, 5, 6,” 2nd Edition, American Water Works Association, Denver, Colorado, 1988.

Student Sheet

Data Form

II. Activity

A. 2. Answer to question:

3. Answer to question:

4. Observations -----

Answer to question:

6. Answer to question:

B. 1. Differences in appearance and odor.

Treated Water

Untreated Water

2. Microscope Observations

Treated Water

Untreated Water

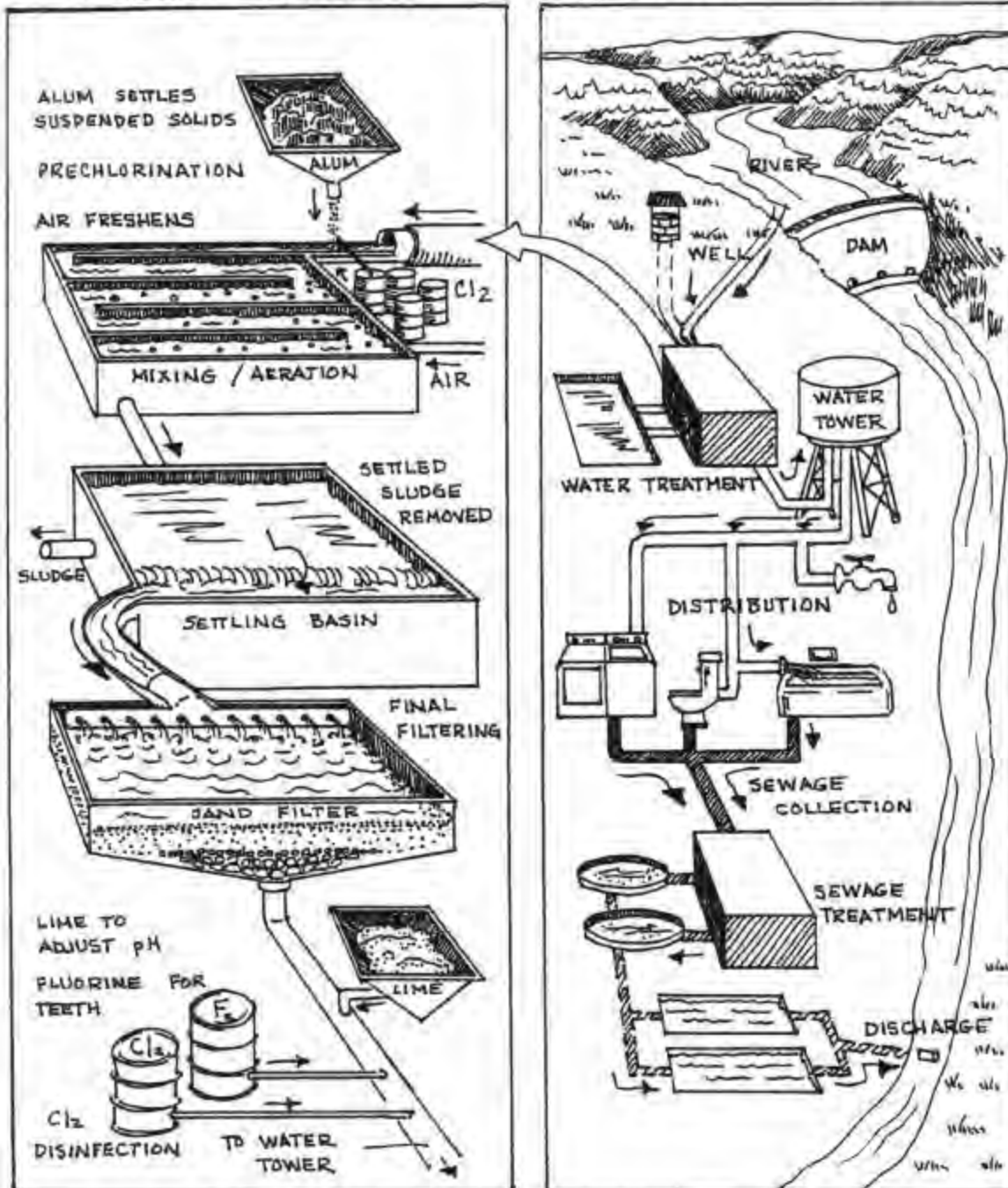
III. Follow-up

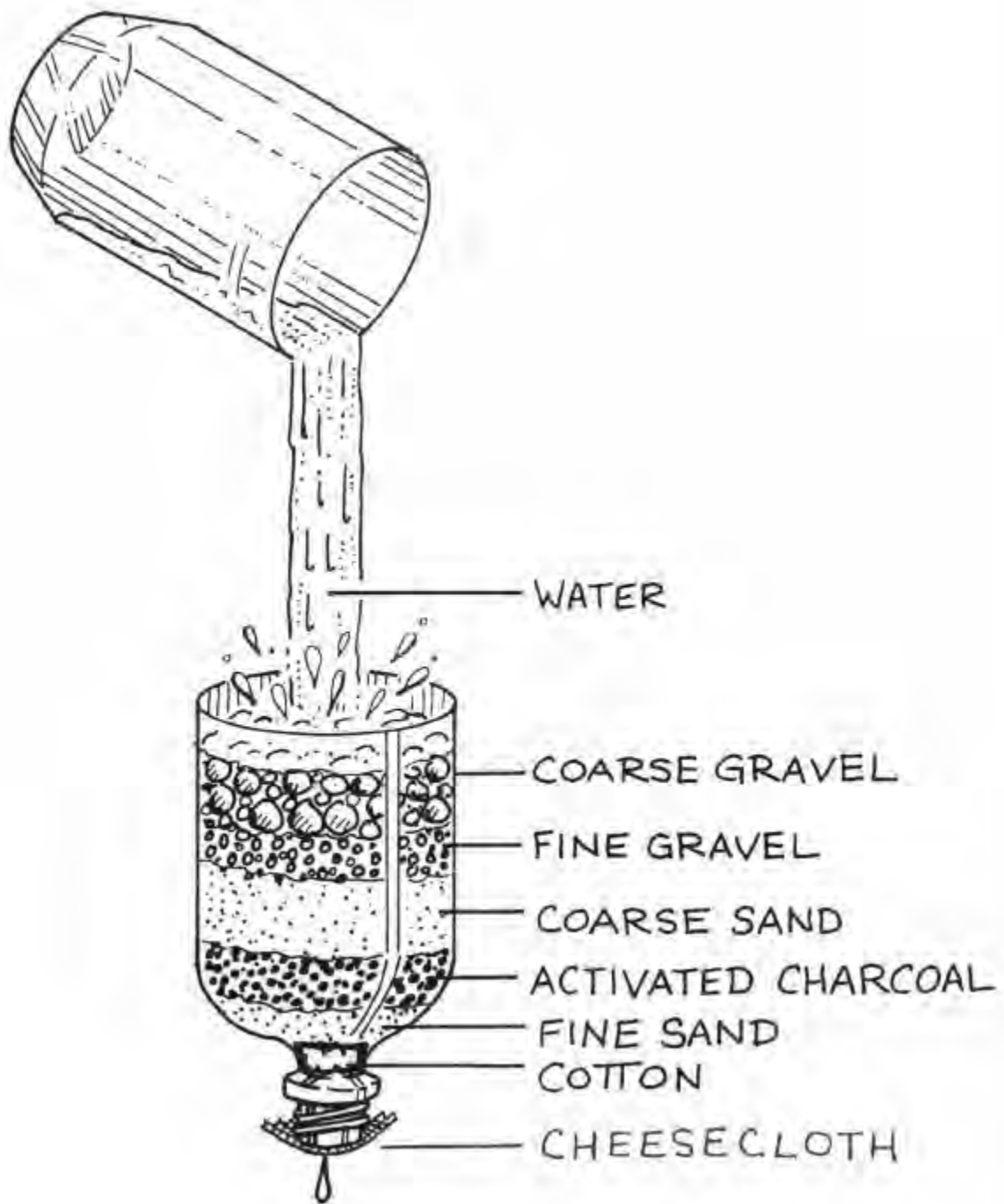
Write a one-page report on how a water treatment plant purifies water for drinking.

TYPICAL MUNICIPAL WATER TREATMENT PLANT

STANDARD TREATMENT

MUNICIPAL SYSTEM





CARBON TREATMENT FOR WATER POLLUTION CONTROL

9-12

OBJECTIVES

The student will do the following:

1. Describe different types of carbon.
2. Determine which type of carbon is most effective for removing organic pollutants.
3. Explain how carbon removes organic pollutants from water.

SUBJECTS:

Science (Chemistry, Ecology)

TIME:

1 class period

MATERIALS:

pulverized coal
activated charcoal(carbon)
charcoal (ground)
food coloring
16 capped containers
color pencils

BACKGROUND INFORMATION

Granular activated carbon selectively removes soluble organics from water or wastewater by adsorption of these molecules to the carbon particle surfaces. Granulated carbon has an extremely large surface area per unit weight (approximately 1000 m²/gram) due to the many pores within the carbon particles and the vast areas of the walls within these pores.

In aqueous environments, carbon has a preference for large molecules and for substances nonpolar in nature. The forces of attraction between the carbon and adsorbed organic molecules are greater the closer the molecules are to the size of the pores in the carbon.

Carbon is used in multimedia filters in drinking water treatment plants to remove organics, in carbon columns for treatment or advanced treatment of wastewater, and in the powder form (powdered activated carbon or PAC) in biological treatment plants to remove the organics where treatment organisms may be slow or unable to remove them.

Carbon treatment has advantages and disadvantages. It is very effective for pollutants of a large or complex molecular structure (pesticides, color, ringed organics, branched organics). It is ineffective for most simple organics (formaldehyde, simple alcohols). However, it requires regeneration (usually by burning off adsorbed organics), which is very expensive, is sophisticated to operate, and may have unforeseen side results as production of sulfides or odorous chemicals. Carbon beds may also become plugged. With its positives and negatives, however, carbon adsorption is often the treatment of choice if

treatment needs and surrounding circumstances are appropriate.

Terms

activated carbon (charcoal): material made from coal by driving off hydrocarbons under intense heat without oxygen, leaving a tremendous surface area on which many chemicals can be adsorbed

adsorption: phenomenon by which molecules in a fluid phase are attracted to a solid surface (e.g., activated carbon) and are held there by physical or weak chemical bonds

aqueous: of, pertaining to, or dissolved in water

biological treatment: treatment of wastewater using microorganisms to decompose undesirable organic compounds in an aqueous waste stream

carbon column: compressed activated carbon in a tube; used for adsorption processes

filtration: the process of passing a liquid or gas through a porous article or mass (e.g., paper, sand, gravel, membrane) to separate out matter in suspension; used in both wastewater and drinking water treatment

multimedia filters: filters that contain more than one type of filtering material

nonpolar molecule: covalent molecule that does not exhibit any partial (+) or (-) charges or fields

organic molecule: any molecule that contains carbon and hydrogen

polar molecule: covalent molecule that has a partial (+) and partial (-) end

regeneration: the process of being renewed or reconstituted

PROCEDURE

I. Setting the stage

- A. Have three types of carbon in class - pulverized coal, ground up activated charcoal (sold with aquarium supplies), and ground charcoal.
- B. Mix different solutions of different food coloring (red, yellow, green, and blue). Record what colors were used for each mixture on Data Sheet. (If 4 mixtures are

made, 16 capped containers will be needed.)

II. Activity

- A. Add equal amounts of each color to three capped containers with equal amounts of carbon in each (each color mixture having one of each carbon source).
- B. Shake each of the containers thoroughly mixing the carbon sources and food coloring.
- C. Observe, record, and compare the color of each solution after settling or filtering to the color of the original food coloring solution in the containers without carbon. Use coloring pencils to indicate the results.

III. Follow-up

- A. What happened to the food coloring? This same thing happens to some types of pollutants in an actual application.
- B. Were certain colors removed better than others? Why?
- C. Determine the clarity of each of the food colors. What does this tell you about the chemistry of each of the food colorings?
- D. What does this tell you about matching carbon pore size to the molecular pollutant to be removed?
- E. Find out how many acres (approximately 1000 m²/gram) of surface area one pound of activated charcoal has.

IV. Extensions

- A. Call the local water and wastewater treatment facilities to see if they use activated carbon in their plants. Find out what pollutants they are removing.
- B. Locate the source (sources) of organic pollutants in water in the area. Discuss means of reducing these pollutants.
- C. Try the same process with non-organic dyes.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Culp, R.L. and G.L. Culp, Advanced Wastewater Treatment, Van Nostrand Reinhold Company, 1971, pp.133-140.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

EPA Facts About Activated Carbon Treatment, June 1992.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Data Sheet

Colors Used

Mixture 1 -

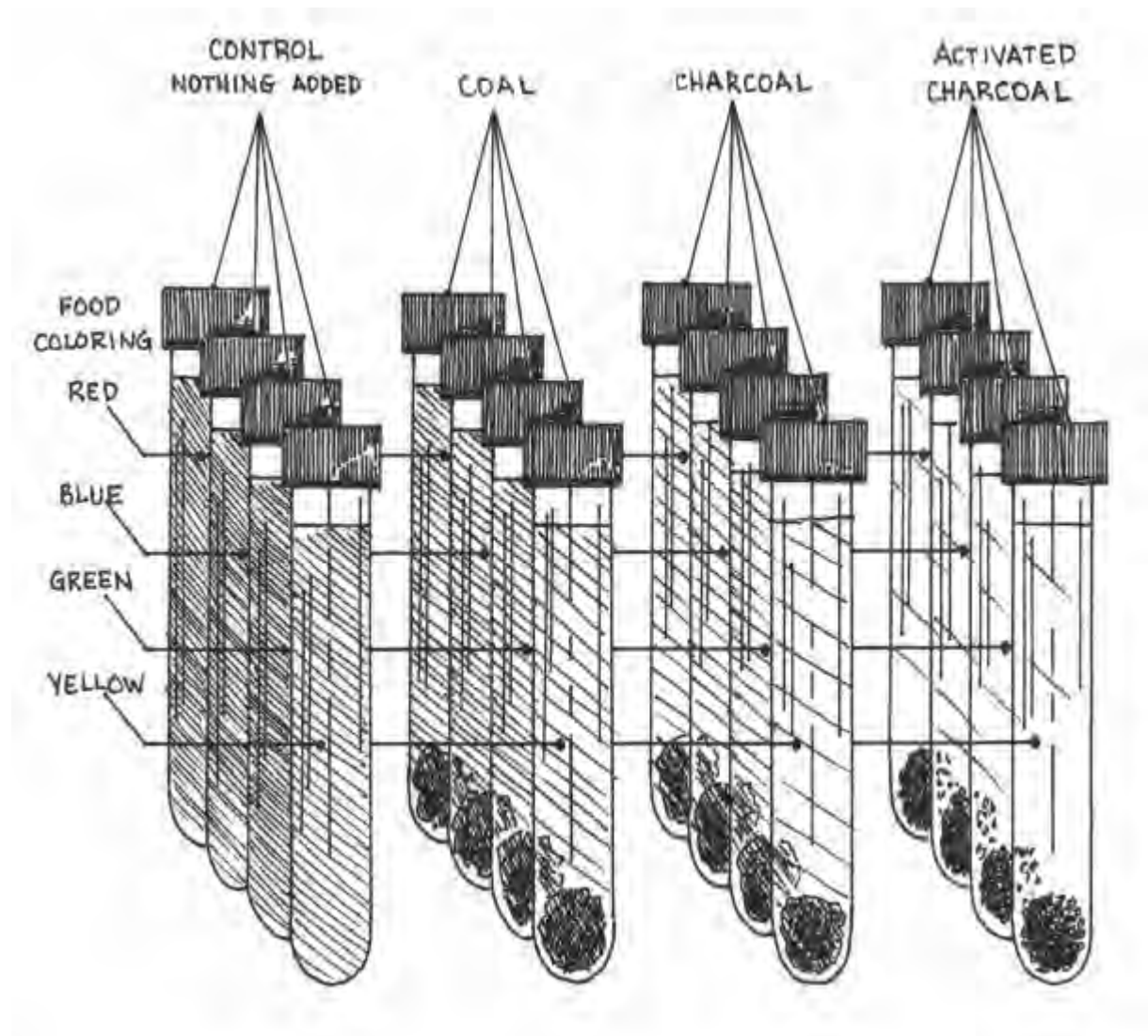
Mixture 2 -

Mixture 3 -

Mixture 4 -

Change in Color

	Pulverized Coal	Activated Charcoal	Ground Charcoal
Mixture 1			
Mixture 2			
Mixture 3			
Mixture 4			



CHLORINATION FOR DISINFECTION

9-12

OBJECTIVES

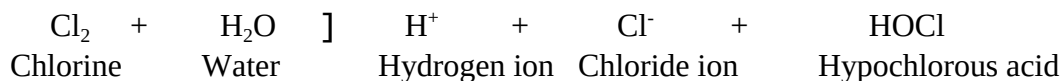
The student will do the following:

1. Explain how chlorine works.
2. Describe what it is used for and why.
3. Show effects on pond or wastewater.
4. Discuss the consequences of its use.

BACKGROUND INFORMATION

Chlorine belongs to the class of elements termed the halogens. Each halogen has one less electron than the noble gas that follows it in the periodic table. Since there is only one electron missing from the $3p$ shell, chlorine's outermost electron shell, there is a very large tendency for chlorine to form a single covalent bond or a (Cl^-) ion. Under ordinary conditions, chlorine exists as a diatomic molecule that is written as Cl_2 . Of the groups in the periodic table, the halogen group is the most reactive nonmetal.

Chlorine is used in, both drinking water and wastewater treatment, as a disinfectant. Its germicidal action is due to the hypochlorous acid ($HOCl$) that forms when chlorine is added to water. Exactly how this acid exerts its killing power is not yet fully known. It possibly releases a reactive form of oxygen that combines with the protoplasm of the microbial cell and, therefore, destroys it. The hypochlorite ion OCl^- also has some killing potential. The following equations describe the chemical action when chlorine is added to water.



SUBJECTS:

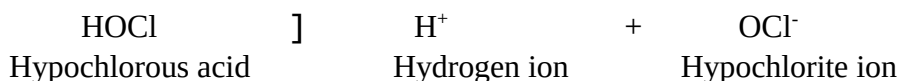
Science (Chemistry, Biology, Environmental Science)

TIME:

1 class period

MATERIALS:

four 2-L bottles
pond water
bleach ($NaOCl$)
microscopes
slides
stain (crystal violet)
eye droppers
stirring rods



A liquid form of compressed chlorine gas is widely used in wastewater treatment plants, drinking water treatment facilities, and swimming pools. Other compounds containing chlorine also are widely used for disinfection. Calcium hypochlorite, $\text{Ca}(\text{OCl})_2$, is used for disinfection of dairies and barns, slaughter houses, and restaurants' eating utensils. Sodium hypochlorite, NaOCl , known commonly as bleach, is also used in dairies as well as food processors and hemodialysis systems. When the quality of drinking water is in question, household bleach can achieve a rough equivalent of municipal chlorination. For purification of water in emergency situations, add 2 drops of NaOCl (bleach) to a liter of water (4 drops if it is cloudy). Let the water sit for 30 minutes before drinking. THIS IS ONLY FOR EMERGENCY SITUATIONS.

Chloramine compounds consisting of chlorine and ammonia are also widely used disinfectants. They also are used as antiseptics and sanitizing agents. Chloramines are very stable compounds that release chlorine over long periods of time. They are used when a long residual time is necessary.

Terms

covalent bond: bond formed between two atoms when they share pairs of electrons

diatomic molecule: molecule made of two atoms

residual: the quantity left over at the end of a process; remainder

ADVANCE PREPARATION

Acquire some pond water or wastewater in four 2L bottles that have been thoroughly washed.

PROCEDURE

I. Setting the stage

A. Discuss Background Information with students. Ask students these questions.

1. When is chlorine added to drinking water during the treatment process?

2. What are some household products that might contain chlorine? What is the purpose of having chlorine in these products?
- B. Write the chemical equation for the breakdown of chlorine in water on the board and have students copy it.
- C. Define terms on board and have students record.

II. Activity

- A. Use the first gallon bottle of collected water as a control.
- B. To the second bottle add 1 drop of NaOCl (bleach).
- C. To the third bottle add 2 drops of NaOCl.
- D. To the fourth bottle add 4 drops. Let them sit for 30 minutes.
- E. Make up some microscope slides with water from each bottle and observe.
- F. Record observations on Data Sheet. (Optional: prepare some slides for bacterial observation by using a stain such as crystal violet.)

III. Follow-up

- A. Based on student observations, what was the most effective concentration of chlorine for “killing” organisms in water?
- B. Why is it important to keep a residual concentration of chlorine in drinking water?
- C. What effect do students think the chlorine in drinking water has on them? Do the benefits outweigh the problems?

IV. Extensions

- A. Have students research diseases caused by microorganisms found in water. What effect has chlorinating water had on the reduction of these diseases?

- B. Discover what other types of treatment can be used to disinfect water. Why are these not used as often as chlorine?
- C. Have students research human health concerns related to chlorine (the chemical itself and its disinfection by-products). How do the relatively low chlorine levels used in drinking water disinfection (below 2 mg/l) relate to the students' findings?
- D. Have students research human health concerns related to alternative drinking water disinfectants such as chloramines, chlorine dioxide, and ozone. Also note the disinfection by-products associated with each of these alternative disinfectants. Compare this information to the concerns related to chlorine in item C. above.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

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Data Sheet

1. Observation of bottle 1. Describe and/or draw all types of organisms found under microscope.

2. Observation of bottle 2. Describe and/or draw all types of organisms found under microscope.

3. Observation of bottle 3. Describe and/or draw all types of organisms found under microscope.

4. Observation of bottle 4. Describe and/or draw all types of organisms found under microscope.

DRINKING WATER JEOPARDY

9-12

OBJECTIVES

The student will do the following:

1. List the characteristics of contaminated water.
2. List the characteristics of clean (non-contaminated) water.
3. Discuss what makes water contaminated.
4. List ways to prevent water contamination.

SUBJECTS:

Science (Biology, Chemistry)

TIME:

2 class periods

MATERIALS:

sets of questions
rules
index cards

BACKGROUND INFORMATION

Most Americans believe that their drinking water is the best in the world. Many U.S. citizens who travel abroad know the familiar problems of unsafe drinking water. At home, most of us seldom give it a thought. We believe that the purity of our water can be depended upon, and usually we are right.

Yet, every year, some Americans get sick from their drinking water. The Centers for Disease Control and Prevention reports that there were almost 7,400 yearly cases (on average) of illness in the U. S. linked to drinking water from 1971 to 1985. And a devastating 1993 waterborne cryptosporidiosis outbreak in Milwaukee, WI, sickened 400,000 and caused over 100 deaths.

Terms

acute (toxic) effects: adverse health effects which are observed rather quickly after exposure to a toxin; illness with rapid onset caused by a toxin.

agriculture: science of cultivating the soil, producing crops, and raising livestock; farming

blackwater: domestic wastewater containing human or animal waste or other sources of pathogens

“blue baby” syndrome (methemoglobinemia): pathological condition where the skin of infants (or other sensitive groups) turns blue due to nitrates bonding with red blood cells, which prevent the transport of oxygen throughout the body; can be caused by nitrate contamination in drinking water

chemical water pollution: introduction of chemicals into a waterbody

chlorine: a chemical compound used as disinfectant in wastewater treatment and drinking water treatment processes; symbol Cl_2

chronic (toxic) effects: adverse health effects that are either the result of long-term (chronic) exposure or those that are permanent or long-lasting (e.g., cancer)

Clean Water Act (CWA): water pollution control law passed to restore and maintain the nation’s waters; the nation’s primary source of federal legislation that specifies the methods to be used in determining how much treatment is required for discharges (effluents) from publicly owned treatment works (POTWs)

cryptosporidiosis: acute, highly infectious disease caused by the protozoan *Cryptosporidium parvum* that can be transmitted by contaminated food or water

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in water (the fifth step in drinking water treatment)

Environmental Protection Agency (EPA): the U.S. agency responsible for efforts to control air, land, and water pollution, radiation, and pesticide hazards, and to promote ecological research, pollution prevention, and proper solid waste disposal

epidemic diseases: diseases that spread rapidly by infection among many individuals in an area

fecal coliform bacteria: a type of coliform bacteria found in the intestines of humans and warm-blooded animals that aids in the digestion process and is used as an indicator of fecal contamination and/or possible presence of pathogens

feed lots: confined areas where livestock is kept

fertilizer: natural and synthetic materials including manure, nitrogen, phosphorus and treated sewage sludge that are worked into the soil to provide nutrients and increase its fertility

fluoride: a binary compound of fluorine added to drinking water to help prevent tooth decay

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

leachate: a liquid that results from water collecting contaminants as it trickles through wastes, or soil containing agricultural pesticides or fertilizers

leaking underground storage tank: underground storage tank which has spilled, leaked, emitted, discharged, leached, disposed, or otherwise allowed an escape of its contents into groundwater, surface water, or subsurface soils

microbiology: study of microorganisms, a large and diverse group of organisms that exists as single cells or cell clusters

microorganisms: microscopic or ultramicroscopic organisms (e.g., bacteria, protozoa, viruses)

nitrates: compounds containing nitrogen as nitrates (NO_3^-). In the environment, these compounds are found in animal wastes, fertilizers, and in septic tanks and untreated municipal sewage. Their primary public health hazard is the cause of methemoglobinemia or "blue baby" syndrome.

pathogens: disease-causing agents, especially disease-producing microorganisms

percolate: to drain or seep through a porous and permeable substance; to filter such as a liquid passing through a porous body (water through soil to the aquifer)

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

pollution: an unwanted change in air, water, or soil (usually through the introduction of pollutants or contaminants) that can affect the health and survival of humans and other organisms

privy: an outhouse; a latrine

radionuclides: types of atoms which spontaneously undergo radioactive decay; usually naturally occurring, and can contaminate water or indoor air (e.g., radon)

radon: colorless, odorless, tasteless, naturally occurring radioactive gas formed from natural deposits of uranium that can cause lung cancer. It can enter the home around plumbing pipes and/or through cracks and openings in the foundation.

sewage contamination: the introduction of untreated or improperly treated sewage into a water body

sulfuric acid: (chemical formula, H_2SO_4) the most widely used industrial chemical; a major component of acid rain that is formed by sulfur oxides combining with atmospheric moisture

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

toxic chemical: a chemical with the potential of causing death or damage to humans, animals, plants, or protists; poison

typhoid fever: acute, highly infectious disease caused by *Salmonella typhosa* bacteria that can be transmitted by contaminated food or water

underground storage tank (UST): any tank, including underground piping connected to the tank, that has at least 10% of its volume underground and contains petroleum products or hazardous substances (except heating oil tanks and some motor fuel tanks used for farming or residential purposes)

waterborne diseases: diseases spread by contaminated water

water quality: the condition of water with respect to its content of contaminants, natural or anthropogenic

ADVANCE PREPARATION

- A. Put the questions and answers on the index cards and put the categories on the board. (See Teacher Sheets.)

Ex.

Level: 3

Q: What is the chemical formula for water?

A: H₂O

- B. Give students a list of the terms and definitions to study the day before the game.

PROCEDURE

I. Setting the stage

A. Duties

1. Moderator: reads the questions
2. Scorekeeper: records each team's scores on the board
3. Timekeeper: allows only the specified amount of time for each question
4. Judge: makes the final decision about answers and rules (teacher)

- B. Divide the class into 2 groups (teams). Decide which team will go first. Select a captain for each team.

C. Rules

1. Ahead of time, place the categories on the board.

Ex.	Level 4*	40, 40, 40, 40, 40, 40, 40, 40, 40, 40
	Level 3*	30, 30, 30, 30, 30, 30, 30, 30, 30, 30
	Level 2*	20, 20, 20, 20, 20, 20, 20, 20, 20, 20
	Level 1*	10, 10, 10, 10, 10, 10, 10, 10, 10, 10

2. Each time a team chooses a level, the scorekeeper needs to eliminate that item (ex. Level 2-- , 20, 20) by marking over or erasing it. If a team correctly answers the question on any chosen level, those points are awarded to that team.

Allow 5 seconds for each question to be answered. If the question is correctly answered [the answer must come from the person who raised his/her hand first], the moderator will read a bonus question. The team will have 15 seconds to discuss the bonus question. The bonus answer must be given by the captain. Bonus questions are worth the same amount as the original question.

3. If one team misses the answer, the opposite team may have a choice to answer the question. If a team member answers incorrectly, the amount of points are subtracted from the team's total points. If both teams answer incorrectly, the moderator answers the question. At the end of a certain amount of time (20 minutes) or the end of the questions, the team with the most points wins the game.

II. Activity - Play the game.

RESOURCES

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

National Drinking Water Clearinghouse, West Virginia University, Morgantown, WV, 26506-6064, 800-624-8301.

Safe Drinking Water Hotline: 800-426-4791.

Questions & Answers

Level 1 Questions and Answers

1. Immediate illnesses which can come from a virus or poison. **acute illnesses**
2. Define waterborne diseases. **diseases spread by contaminated water**
3. Long-term illnesses that are developed over many years. **chronic illnesses**
4. Sources of water supply are being endangered by chemicals. **True**/False
5. Contaminated water may increase cancer and heart disease rates. **True**/False
6. What does CDC stand for? **Centers for Disease Control and Prevention**
7. Who is responsible for making laws to ensure that our drinking water is safe? **U.S. Congress**
8. What can cause typhoid fever? **drinking contaminated water**
9. The Safe Drinking Water Act of 1986 banned all future use of what kind of pipes in public drinking water systems? **lead**
10. What does EPA stand for? **Environmental Protection Agency**
11. Why should water system owner/operators disinfect the drinking water supplies? **to help kill harmful microorganisms**
12. If a public water system is contaminated and its water causes acute illnesses, the owner/operator of the water system must notify the water users within 72 hours by way of radio and television. **True**/False

(cont.)

Level 2 Questions and Answers

1. What is the name of the bacteria that comes from human and animal waste that can contaminate drinking water? **Coliform bacteria**
2. Boiling water will eliminate nitrate contamination. True/**False**
3. What is the chemical formula for water? **H₂O**
4. Clear water is always clean and safe to use. True/**False**
5. What is the suggested pH level range of drinking water? **6.5 to 8.5**
6. Too much fluoride causes a brownish discoloration of teeth. **True**/False
7. Where is the main office of the Centers for Disease Control and Prevention located? **Atlanta, GA**
8. What are microorganisms? **microscopic or ultramicroscopic organisms too small to be seen with the unaided eye**
9. Pesticides can contaminate drinking water sources. **True**/False
10. Owners/operators of water plants must check water samples regularly for contaminants. **True**/False
11. Is drinking water from private household wells subject to regulation by federal drinking water standards? **No**

Level 3 Questions and Answers

1. Nitrates present in large amounts can reduce the amounts of oxygen in an infant's blood. What is the chemical symbol for nitrates? **NO₃⁻**
2. What can the ingestion of radon in water cause? **cancer**

3. Excessive levels of copper in drinking water cause a metallic taste. True/False

Teacher Sheet (cont.)

4. What are pathogens? disease - causing agents, especially microorganisms
5. What type of microorganism is a virus? a parasite
6. What is surface water? precipitation that does not soak into the ground. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.
7. What is groundwater? water that is stored below the Earth's surface
8. Is radon more of a problem in groundwater or surface water? Explain. groundwater - because radon in surface water usually escapes to outside air
9. Is there more exposure to radon in the bedroom or the bathroom of your house? Explain. could be bathroom if water use is from a well and the radon in water levels are high
10. How does radon from the soil enter into a home? through cracks and openings in the foundations, floors, or walls that are in contact with the soil or through plumbing
11. Define microbiology. the study of microorganisms, a large and diverse group of organisms that exist as single cells or cell clusters.

Level 4 Questions and Answers

1. Define water quality. the condition of water with respect to the amount of pollutants in it
2. Define underground storage tanks. tanks such as gasoline tanks that are buried underground
3. Define toxic chemicals. chemicals with the potential of causing death or damage to humans, animals, plants, or protists

4. Define sulfuric acid. **a product that forms when sulfur oxides combine with atmospheric moisture; a component of acid rain**

Teacher Sheet (cont.)

5. Define septic tank. **a tank, commonly buried, to which all of the wastewaters from the home should flow; the main part of a septic system where scum and sludge accumulate**
6. Define percolate. **to drain or seep through a porous and permeable substance**
7. Define sewage contamination. **the introduction of untreated or improperly treated sewage into a waterbody**
8. Define agriculture. **the science of cultivating the soil, producing crops, and raising livestock**
9. Define epidemic disease. **disease that spreads rapidly by infection among many individuals in an area**
10. Define Clean Water Act. **a water pollution control law intended to restore and maintain the nation's waters**
11. Show the chemical formula for sulfuric acid. **H_2SO_4**

Bonus

1. Name 3 reasons why the body needs water.

Examples:

To dilute harmful substances (all may not be poisonous)

To have healthier skin

To regulate body temperature

To deliver oxygen and other nutrients to organs

2. Water has a nutritional value. True/**False**
3. What is the function of CDC? **to study and monitor disease control and health issues and to facilitate disease prevention**
4. Why was the Safe Drinking Water Act established? **to ensure safe public water supplies primarily through the establishment of drinking water standards and source water protection**

Teacher Sheet (cont.)

5. Name 3 types of waterborne diseases. **Examples: typhoid fever, cholera, infectious hepatitis, dysentery, cryptosporidiosis**
6. What is the “blue baby” syndrome? **pathological condition where blood is incapable of carrying oxygen resulting in the skin turning blue in infants; can be caused by nitrate contamination of drinking water**
7. Why is fluoride added to drinking water? **to help prevent tooth decay**
8. Why is chlorine added to drinking water? **to help kill microorganisms**
9. What are pesticides? **chemicals that kill plant or animal pests** (usually insects)
10. Name 2 ways that farming practices could cause drinking water contamination. **Examples: excess fertilizers, oil and gas leakage from storage tanks, livestock waste, improper or excessive use of pesticides**
11. What is the source of radon? **naturally occurring uranium found in soil and rock**
12. Name 3 groups of microorganisms. **Examples: bacteria, protozoa, viruses, some algae**
13. Hepatitis is caused by the smallest and simplest common form of microorganism that is known as a _____. **Virus**
14. How do you recognize radon as a problem in your home? **Test**

15. Name 2 sources of surface water. **Examples: streams, rivers, lakes, ponds, wetlands oceans, and reservoirs**
16. Name 2 sources of groundwater. **Examples: wells and springs**
17. What is hydrology? **the study of water, its properties, distribution, and circulation on Earth**
18. Name 3 activities or land uses that can threaten and contaminate water supplies. **Examples: septic tanks, landfills, agricultural activities, lawn and crop fertilizer, transporting chemicals or waste by road, wastewater discharges, abandoned wells**

Teacher Sheet (cont.)

19. Why is radon from well water more of a problem and more present in the bathroom, kitchen, and laundry rooms? **It escapes to the air (comes out of solution) when faucets, toilets, showers, washing machines, etc. are used.**
20. Define chemical pollution of water. **introduction of harmful chemicals into a waterbody**
21. How could a leaking underground storage tank cause groundwater contamination? **The contents in the tank or the associated piping could leak into the soil and groundwater.**
22. What is blackwater? **domestic wastewater containing human or animal waste or other sources of pathogens**
23. How does the privy (outdoor toilet) contribute to groundwater contamination? **The bacteria in human waste percolate through the soil to the groundwater.**
24. Describe the purpose of the Resource Conservation & Recovery Act with respect to water protection. **a law intended to protect waterways and groundwater from hazardous waste contamination**
25. Explain why Congress decided to pass the Clean Water Act. **to protect the nation's waters**

26. What agency is responsible for enforcing federal water-related regulations? **EPA**
27. What should you do if you suspect contamination in a public water supply? **Don't use it and notify your water supplier immediately.**
28. Boiling water kills all microorganisms. True/**False**
29. How can oil spills contribute to groundwater contamination? **The chemicals could seep into the ground and release contaminants into the water.**
30. What is the chemical symbol for chlorine gas? **Cl₂**

SOURCE WATER PROTECTION: Surface Water Sources

9-12

OBJECTIVES

The student will do the following:

1. Identify sources of contamination to water.
2. Describe management methods to protect water supply sources.
3. Develop a plan to improve watershed management.

BACKGROUND INFORMATION

Many towns and cities obtain their drinking water from a nearby river, lake or reservoir. The quality of this source water is influenced by the quality of streams flowing into it, the land uses and activities conducted near it, and any air deposition that might occur.

SUBJECTS:

Science (Ecology, Physical Science), Social Studies (Economics, Government)

TIME:

2 class periods
field trips

MATERIALS:

student sheets
bus for field trip
writing materials

EPA's Source Water Protection (SWP) Program was established to help states and communities protect their drinking water supply sources. Surface source water protection is a 3-step process involving: delineating areas contributing water to a surface water intake, identifying potential contaminant sources that may threaten the water supply, and protecting the supply using a combination of watershed management strategies for specific communities or watersheds. (Since water does not flow only within politically-established boundaries, some strategies may extend beyond these boundaries and address the entire watershed.)

Watershed management strategies incorporate broad concepts such as land use control and/or management, best management practices, and pollution prevention. They emphasize prevention of both point source and nonpoint source contamination. Specific watershed management strategies may include the following or others: protection of inland wetlands that serve as filters for pollutants, appropriate forestry management practices, erosion controls, control of adjacent zoning and urbanization, creation of buffer zones along reservoir edges, reservoir access and activity control, and community education. Homeowners, businesses, farmers, and industries may also be encouraged to use pollution prevention and best management practices to prevent surface water contamination.

Terms

best management practices (BMPs): techniques that are determined to be currently effective, practical means of preventing or reducing pollutants from point or nonpoint sources, in order to protect water quality. BMPs include, but are not limited to structural and nonstructural controls, operation and maintenance procedures, and other practices. Usually, BMPs are applied as a system of practices rather than as a single practice.

buffer zone: an area between the water supply source and the possible contamination sources where no contamination activities are likely to occur

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation or increased efficiency in the use of energy, water, or other materials

Source Water Protection: process that involves delineating areas contributing water to a water well or surface water intake; identifying potential contaminant sources that threaten the water supply; and using management strategies to protect the source water from contamination. Source water protection is applied to both surface water and groundwater supply sources.

watershed: land area from which water drains to a particular surface waterbody

zoning: to divide into areas determined by specific restrictions; any section or district in a city restricted by law for a particular use

ADVANCE PREPARATION

1. Copy Student Sheets.
2. Arrange for field trips.

PROCEDURE

- I. Setting the stage
 - A. Discuss Background Information with students.
 - B. Contact the local drinking water treatment plant and find out the water source in the community.
- II. Activity
 - A. Schedule a visit to the water supply reservoir with a water system representative and ask about source water protection methods that are used, including upstream management methods in the watershed. If a field trip is not possible, have a water system representative visit the class.
 - B. From local, state, or other sources, define the water supply watershed on a topographic or other map and locate potential pollutant sources. (Use Student Sheet to determine potential pollution problems.)
 - C. Visit each pollutant source, or a location downstream of each one, to determine the type and extent of pollutants to the reservoir. (Students could be assigned this as an out-of-class assignment and report to the class.)

D. Note any pollution prevention or best management practices in place or, where none exist, make notes of recommendations (not just what is needed but how to do what is needed).

E. Make a compilation of all notes from the class into a report on protection of the water supply watershed. Include recommendations as to the location and type of pollution prevention or best management practices used or needed, and other water quality management steps which should be taken.

III. Follow-up

Share compiled information or reports with local watershed managers and ask them to comment on the class ideas.

IV. Extensions

Have students construct a solar evaporator using the materials you have provided or some they may want to bring to class. They can follow the directions on the Student Sheet or try their own design. Students should wash hands and dip a finger in salt solution and taste. Place solar evaporators in a warm, sunny place for 24 hours. Taste water in beaker (glass) using finger method after washing, and answer questions on Activity Student Sheet. Finally discuss the findings.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Roberts, Susan A. and S. K. Krishnaswaini, "Protecting the Source," Water Engineering and Management, Scranton Gillette Communication Inc., March 1982, p. 28.

Activities Harmful to Water Supply Reservoir

1. Unauthorized disposal of sludge, solid, septic and hazardous waste, dredge spoil
2. Erosion/sedimentation
3. Uncontrolled/illegal access
4. Atmospheric transfer of contaminants
5. Unauthorized/illegal impounding of upstream watercourses
6. Unauthorized use of pesticides
7. Accidental loss of hazardous materials from surface storage or transport
8. Discharges of animal wastes/agricultural runoff
9. Urban drainage
10. Point source discharges

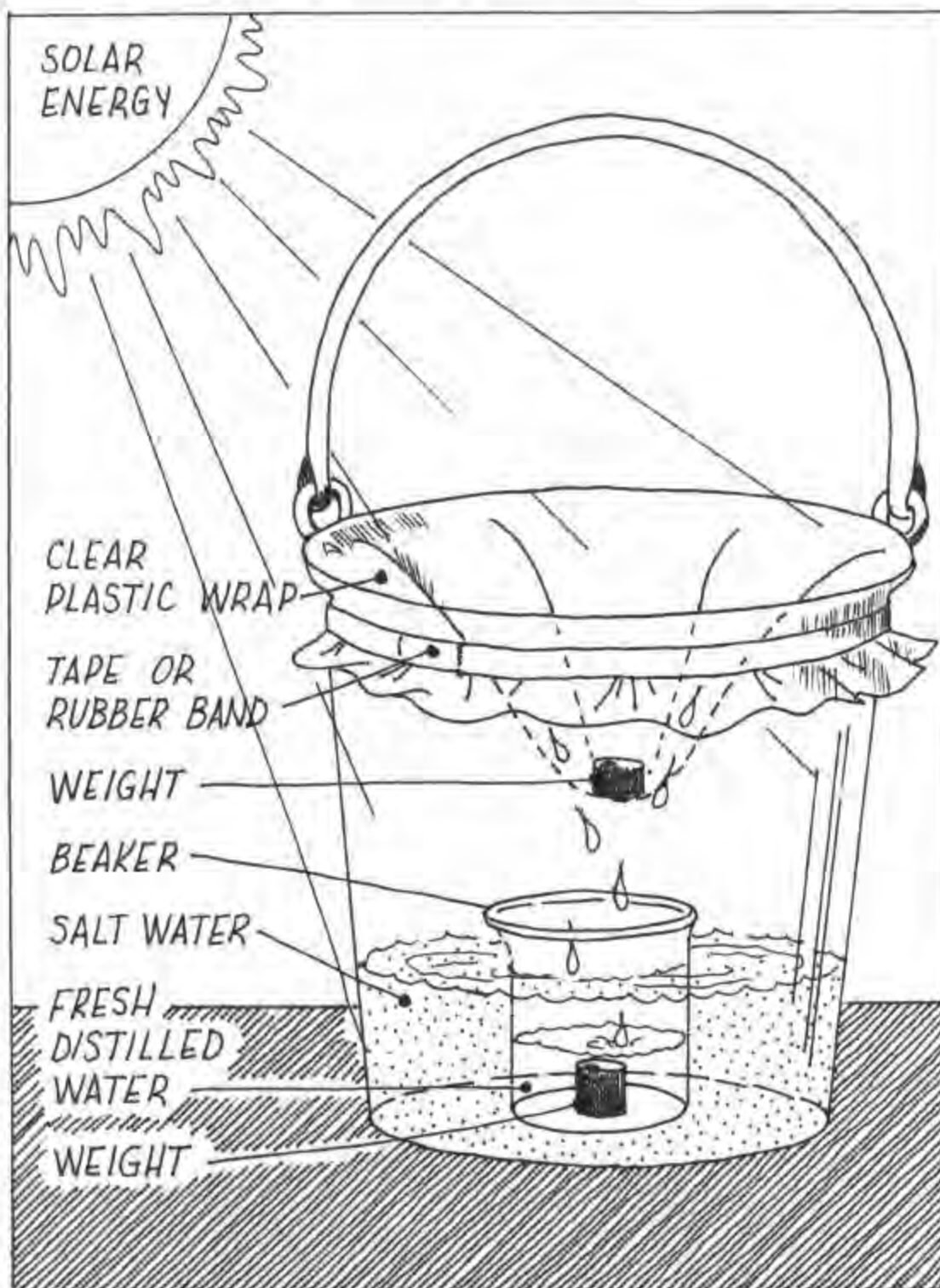
Constructing a Solar Evaporator or Solar Still

1. Follow the illustration to set up your lab materials. The water level should be at least an inch below the top of the beaker.
2. Be sure that your plastic completely covers the top bucket. The plastic should sag enough when the weight is placed on it so that a cone shape is formed that points down to the open beaker. Make sure that the plastic does not touch the mouth of the beaker.
3. Place your apparatus in the heat of the sun and leave it there for a few hours.
4. During class the next day, remove the plastic covering and taste the water in the beaker.

Results

1. How does it taste? _____ Is it fresh or salty? _____
2. What was the energy source that caused the water to change states? _____

3. What are the three states of water? _____



Potential sources of surface water/groundwater contamination (based upon lists compiled by U.S. EPA and ADEM)

1. Gas stations/service stations
2. Truck terminals
3. Fuel oil distributors/storage
4. Oil pipelines
5. Auto repair shops
6. Body shops
7. Rustproofers
8. Auto chemical suppliers/wholesalers/retailers
9. Pesticide/herbicide/insecticide wholesalers/retailers
10. Small engine repair shops
11. Dry cleaners
12. Furniture strippers
13. Painters/finishers
14. Photographic processors
15. Printers
16. Automobile washers
17. Laundromats
18. Beauty salons
19. Medical/dental/veterinarian offices
20. Research laboratories
21. Food processors
22. Meat packers/slaughter houses
23. Concrete/asphalt/tar/coal companies
24. Treatment plant lagoons
25. On-site sewage
26. Railroad yards
27. Storm water impoundment
28. Cemeteries
29. Airport maintenance shops
30. Airport fueling areas
31. Airport firefighter training areas
32. Industrial manufacturers
33. Machine shops
34. Metal platers
35. Heat treaters/smelters/descalers
36. Wood preservers
37. Chemical reclamation sites

(cont.)

- 38. Boat builders/refinishers
- 39. Industrial waste disposal sites
- 40. Wastewater impoundment areas
- 41. Municipal wastewater treatment plants and land application areas
- 42. Landfills/dumps/transfer stations
- 43. Junk/salvage yards
- 44. Subdivisions
- 45. Individual residences
- 46. Heating oil storage (consumptive use) sites
- 47. Golf courses/parks/nurseries
- 48. Sand and gravel mining/other mining
- 49. Abandoned wells
- 50. Manure piles/other animal waste
- 51. Feed lots
- 52. Agricultural chemical spreading/spraying
- 53. Agricultural chemical storage sites
- 54. Construction sites
- 55. Transportation corridors
- 56. Fertilized fields/agricultural areas
- 57. Petroleum tank farms
- 58. Existing wells
- 59. Nonagricultural applicator sites
- 60. Sinkholes
- 61. Recharge areas of shallow and highly permeable aquifers
- 62. Injection wells
- 63. Drainage wells
- 64. Waste piles
- 65. Materials stockpiles
- 66. Animal burial
- 67. Open burning sites
- 68. Radioactive disposal sites
- 69. Saltwater intrusion
- 70. Mines and mine tailings
- 71. Other

SOURCE WATER PROTECTION:

Groundwater Sources

9-12

OBJECTIVES

The student will do the following:

1. Define a Wellhead Protection Program.
2. List 25 common groundwater pollutants.
3. List 25 potential sources of groundwater pollution.
4. Identify problems involved in starting a Wellhead Protection Program in a developed area.

SUBJECTS:

Social Studies (Economics, Government), Science (Physical, Ecology, Earth, Chemistry), Ethics

TIME:

1-2 class periods

MATERIALS:

copies of student sheets

BACKGROUND INFORMATION

It is important to be aware of the source of your drinking water. If the water is pumped from a well, the source is groundwater from an aquifer. Just like rivers and lakes, aquifers need to be protected from contamination. Chemicals spilled on or applied to the ground can move down and eventually contaminate an aquifer, sometimes making groundwater unsafe to drink. It is especially important to protect areas immediately around wells from releases of harmful chemicals, because it is from within these sensitive areas that chemicals can most quickly and profoundly affect the quality of water pumped from a well.

EPA's Source Water Protection (SWP) Program was established to help states and communities protect their drinking water supply sources. Wellhead Protection Programs may serve as Source Water Protection Programs for communities relying on groundwater as their source of drinking water. Wellhead protection is a 5-step process involving: (1) forming a community planning team; (2) delineating the area contributing groundwater to a water supply well; (3) identifying potential contaminant sources within the delineated area that pose threats to the well; (4) using a combination of management strategies to ensure that identified sources don't impact the well; and (5) developing a contingency plans in case there is a release of contaminants within the delineated area.

Wellhead protection management strategies incorporate broad concepts such as land use control and/or management, best management practices, and pollution prevention. Specific strategies may include the following: zoning controls, local ordinances governing pesticide/herbicide use, enforcement of septic tank regulations, and community education. Homeowners, businesses, farmers, and industries may also be encouraged to use pollution prevention and best management practices to prevent contamination in the delineated areas. For example, waste oil collection centers may be set up in convenient locations so that oil can be brought in for proper disposal or recycling (rather than citizens dumping it illegally onto the ground).

The illustration in Figure 4 shows a wellhead protection area with the zone of influence (Zone I), a 10-year time-of-travel (Zone II), and the rest of the recharge area for the well (Zone III). Potential pollutants and potential pollutant sources are listed in Student Sheets, Figures 2 and 3 respectively. Various activities in the recharge area are illustrated in Figure 4.

Terms

Source Water Protection: process that involves delineating areas contributing water to a water well or surface water intake; identifying potential contaminant sources that may threaten the water supply; and using management strategies to protect the source water from contamination. Source water protection is applied to both surface water and groundwater supply sources.

time-of-travel: the time required for groundwater to move from a specific point beneath the surface to a well

Wellhead Protection Area: the surface and subsurface area surrounding a public water supply well through which contaminants are reasonably likely to move toward and reach such well

Wellhead Protection Program (WHPP): a groundwater-based source water protection program

zone of influence: area surrounding a pumping well within which the potentiometric surface has been changed due to groundwater withdrawal

zoning: to divide into areas determined by specific restrictions; any section or district in a city restricted by law for a particular use

ADVANCE PREPARATION

- A. Copy Student Sheets for each group or individual.
- B. Make overhead transparency of Student Sheets.

PROCEDURE

- I. Setting the stage
 - A. Discuss the concept of Wellhead Protection and go over terms.
 - B. Put up overhead transparencies of Figure 1 and Figure 4.
 - 1. Discuss land use zones and time-of-travel.
 - 2. Discuss groundwater pollutants and potential sources. (Students may wish to read over Student Sheets - Figures 2 & 3.)
 - C. Break into study/discussion groups to complete activities.
- II. Activity
 - A. Assume you are a mayor considering a WHPP. List the considerations (pros and cons) of establishing such a program.
 - B. If you are a farmer or businessperson in the same town, what concerns would you have if this program were instituted?
 - C. As a citizen drinking the water produced by the well, what concerns would you have? What form would you prefer the WHPP take? Why?
 - D. You are an employee of the state environmental agency and would like to see a WHPP put into place by all small towns. What position would you take relative to this town after learning the above positions?
 - E. Is a WHPP a good groundwater protection approach? Why or why not?
- III. Follow-up
 - A. Each group should have a spokesperson report its conclusions to the class. Allow some discussion and debate over the “best” policies.

- B. Give quiz over groundwater pollutants and potential sources of pollution to groundwater.
- C. Have students write a short essay about what they think they could do to protect groundwater in the area.

IV. Extensions

- A. Students should find out if their state or city has a WHPP and what is or is not being done in its implementation.
- B. Locate a city well and visit it. Have students identify pollutants and potential pollution sources in the wellhead protection area.
- C. Learn about Environmental Ethics. Read “Jay’s Situation” and “Ethics”. Respond to the questions. Students should look for ethical, win-win compromise solutions.

RESOURCES

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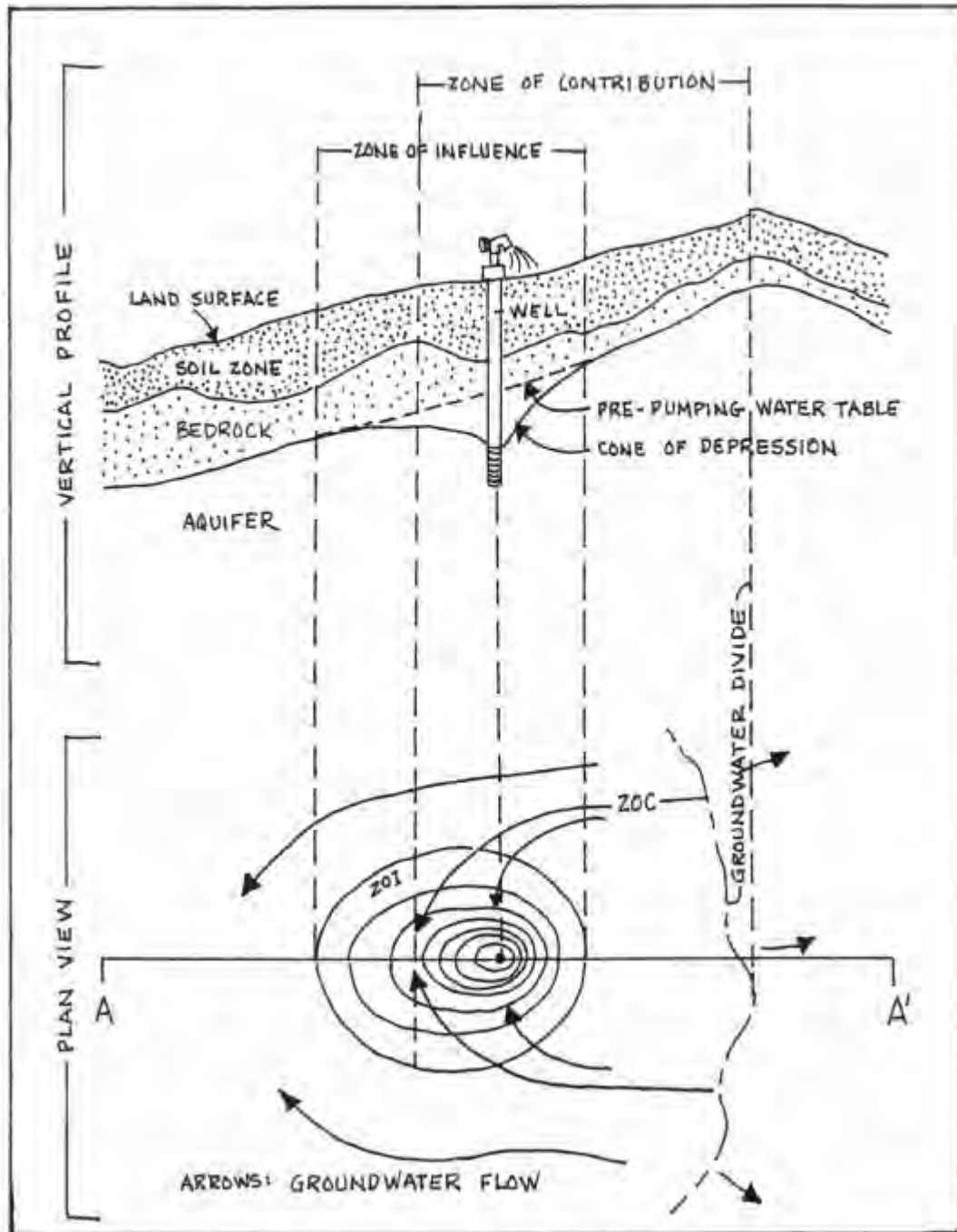
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DETERMINING A WELLHEAD AREA



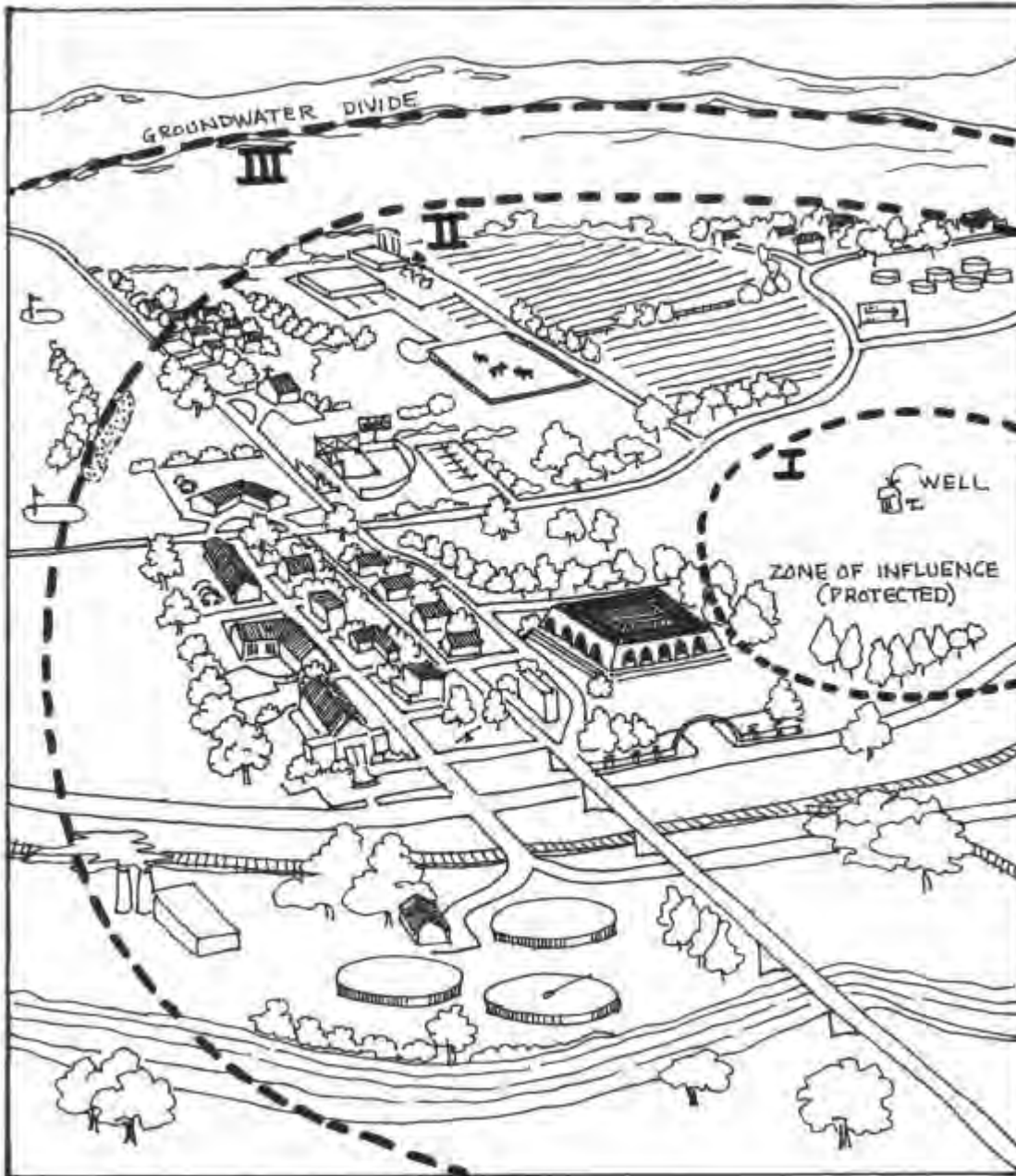
COMMON GROUNDWATER POLLUTANTS**FIGURE 2**

1. Antifreeze (for gasoline coolant system)	21. Refrigerants
2. Automatic transmission fluid	22. Pesticides (insecticides, herbicides, rodenticides)
3. Engine and radiator flushes	23. Photochemicals/ Printing ink
4. Hydraulic fluid (including brake fluid)	24. Wood preservative (creosote)
5. Motor oils/waste fuels/grease lubricants	25. Swimming pool chlorine or bromine compounds
6. Gasoline, jet fuel	26. Lye or caustic soda
7. Diesel fuel, kerosene, #2 heating oil	27. Jewelry cleaners
8. Degreasers for driveways and garages	28. Leather dyes
9. Battery acid (electrolyte)	29. Fertilizers (if stored outdoors)
10. Rust proofers	30. PCBs
11. Car wash detergents, waxes, and polishes	31. Other chlorinated hydrocarbons, including carbon tetrachloride)
12. Asphalt and roofing tar	32. Any other product with "Poison" labels (including chloroform, formaldehyde, hydrochloric acid, and other acids)
13. Paints, lacquer thinners, and brush cleaners	33. Other products not listed that you feel may be toxic or hazardous (please list):
14. Floor and furniture strippers	
15. Metal polishes	
16. Laundry soil and stain removers (including bleach)	
17. Spot removers, cleaning solvents	
18. Disinfectants	
19. Household cleaners (oven, drain, toilet)	
20. Cesspool cleaners	
21. Road salt (Halite)	

POTENTIAL SOURCES OF GROUNDWATER POLLUTION**FIGURE 3**

1. Truck terminals and service stations	21. Heat treaters, smelters, annealers, descalers
2. Petroleum pipelines, stores, and tank farms	22. Wood preservers
3. Auto repair, body shop, and auto supplies	23. Chemical reclamation
4. Rust proofers	24. Industrial waste disposal
5. Pesticide, herbicide wholesalers and	25. Municipal and private waste retailers
6. Dry cleaner	wastewater treatment plants, lagoons
7. Painters, finishers, furniture strippers	26. Landfills, dumps, and transfer stations
8. Printers, photo processor	27. Junk, salvage yards, recycle centers
9. Auto washes, laundromat	28. Subdivisions, individual residences
10. Beauty salons	29. Heating oil storage (consumptive use)
11. Medical, dental, and vet offices	30. Golf courses, parks, nurseries
12. Food processors, meat packers, and slaughter houses	31. Sand, gravel, other mining
13. Concrete, asphalt, tar, and coal companies	32. Abandoned wells, existing wells, sinkholes
14. On-site sewage disposal	33. Feed lots, manure piles
15. Railroad yards, industrial sites	34. Agricultural chemical storage, handling, spreading, spraying
16. Storm water impoundment	35. Construction sites
17. Cemeteries	
18. Airport maintenance, fueling	
19. Machine shops	36. Transportation corridors
20. Metal platers	37. Fertilized fields, agricultural area

WELLHEAD PROTECTION



JAY'S SITUATION

Jay Barlow is sitting with his elbows on his desk. His face is pressed into his hands. He feels a small hand pull his hand away from his face. "Daddy?" Jay looks down into his daughter's sparkling brown eyes. He is still her hero, and that trusting smile just increases the pressure he already felt.

Last week Jay was on top of the world. He was hired onto an environmental project as a consultant. The state of Florida had finally passed a regulation that would require a zone of protection around wellheads. The state's minimum requirement is a 500-ft. radius around the well. The suburb he lives in has adopted more stringent measures. He was given a map showing several public wells from which drinking water is pumped. His task is to recommend a viable zone of protection and report any potential contamination hazards.

Interestingly, the very area in which he lives is included on the map. He is familiar with a large land development that has been in construction for two years. His neighbor has told him many details as he is the construction foreman. The massive construction effort has provided 200 jobs. Jay decides to meet with a company representative. They discuss the scope of the project. To his dismay, he discovers that the final two years of the company's project involve developing land directly over the aquifer within the state's minimum protection zone from the well.

The land developers purchased the land at high cost before the state laws were passed. The company has invested millions in pre-development and will not respond positively to any attempt to block the contract. They have plenty of resources to fight a legal battle against the state.

Jay's uncle calls him for advice on a leaking UST (underground storage tank). He thought to call Jay because Jay knows about environmental issues. His uncle cannot afford to have the tank dug up and replaced; it would bankrupt his small business. Jay has no idea what to tell his uncle except that the leaking gasoline is a serious threat to groundwater. Jay's uncle laments that he has owned the station for 30 years and would have no income without it. As if Jay didn't have enough to think about, he realizes that his uncle's gas station is also located above the aquifer.

1. What do you think is Jay's primary responsibility as an environmental professional?
2. Does Jay have a responsibility to his uncle?
3. Are the construction workers Jay's problem?
4. Should he be worrying about the drinking water in his own region?
5. Should the above concerns affect Jay's recommendations to the state about the wellhead protection for that particular aquifer? If so, in what way?

ETHICS

As part of this lesson, the instructor may wish to include a brief discussion on ethics. The environmental industry is dependent on ethical decision making. For an intensive treatment of this issue, Michael Josephson's *Making Ethical Decisions* (1993) is perfect. In *Making Ethical Decisions*, Josephson describes "The Six Pillars of Character: (1) Trustworthiness, (2) Respect, (3) Responsibility, (4) Justice and Fairness, (5) Caring, (6) Civic Virtue and Citizenship."¹

Most students of this age will be surprised to learn that acting with "Caring" (being sensitive to human suffering such as job loss and family distress) is an integral part of the decision-making process at the professional level. The teacher will most likely find that the majority of the class will choose extreme action in one direction or the other. The middle road seems a taboo place to choose; yet, in reality, it is often the only reasonable one. With the added responsibility of ethics, students will find achieving that "balance" between the economy and environment a less bitter pill to swallow.

It may be most effective for the ethics treatment to follow the exercise. Since the "balance" method gives them a standard to shoot for, students should then have the opportunity to reconsider their answers.

Here is a closure to share with students after they have completed the activity.

Reality will be frustrating for the generation who has grown up learning to accept environmental responsibility. The following recount is simplified, but factual, and is a real life example of the middle road. It should not be discouraging but enlightening. Sometimes when it is impossible to kill the dragon, be satisfied with knocking a chink out of its armor.... progress is progress is progress!

¹ Josephson, Michael, “*Making Ethical Decisions in Environmental Practice*,” Environmental Manager, Vol. 1, July 1993.

CONCLUSION

There are many different options that Jay might choose. He always has the option of consulting with other professionals if he has run into an ethical snag. Generally, they will be objective and a good source for ideas.

In dealing with land development, companies have to comply with many regulations today and often have a representative or department that handles that aspect. Jay may opt to call a meeting with this individual or group of individuals and call attention to the aquifer’s vulnerability. Accomplished in a non-accusing diplomatic way, he may be able to convince the developers to choose double-walled, lined, or anodized septic tanks in order to head off future liability. While the threat to the aquifer is still apparent, it can be greatly reduced. The state may even be able to buy back a portion of the land. However, it is doubtful that the company would relent their construction. In fact, Jay may have to recommend a compromise or advise the department that they will probably be sued.

Jay’s uncle may have some help in dealing with his gasoline leaks. If he is in compliance with other state and federal regulations for underground storage tanks, he may be eligible to receive assistance from Florida’s leaking UST trust fund. Available in most states, these funds allow small business owners of USTs to receive assistance in cleaning up leaks. The money for these funds usually comes from a tax on gasoline. The sites chosen to receive cleanup funds are based upon how large the risk is to human health or the environment. Since Jay’s uncle’s tank is located in an area above a drinking water aquifer, there is a good chance that his cleanup will be funded.

In Florida, as previously discussed, there is a tremendous need for wellhead protection. In 1980, the Florida Department of Environmental Protection (FDEP) began fighting for wellhead protection. FDEP was promptly sued by large industrial corporations that had almost unlimited legal resources. The suit was in court for almost 15 years. FDEP was forced to accept a compromise, a middle-of-the-road decision, by the judge. They achieved the stipulation of a circular buffer zone 500 feet in diameter.

Of course, this circular zone has no basis either geologically or hydrologically. Most aquifers are oddly shaped and miles in length or width. FDEP officials wanted to model individual aquifers and tailor the needed buffer zones. What good does it do to have a 500-foot circle of protective zone and a five-mile long cigar-shaped aquifer? It seems nonsensical, but the FDEP rejoiced. They now have buffer zones. Before May 1994, they had none. Perhaps they should have agreed to a compromise years earlier and started gathering data for the next fight.

Even state environmental agencies understand that they cannot unduly restrict the state's or nation's economy. An unhealthy economy often creates an inadequate tax base, which can ultimately result in underfunded state agencies.

HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?

9-12

OBJECTIVES

The student will do the following:

1. Explain the methods used to calculate detection limits.
2. Calculate detection limits on a set of data.
3. Demonstrate how reporting data close to detection limits must be qualified with an accuracy statistic.
4. Explain what happens to accuracy and precision as detection limits are set to increasingly lower levels.

SUBJECTS:

Math, Science (Environmental Science, Physics)

TIME:

1 class period

MATERIALS:

stop watch
small toy racing car
inclined surface
meter stick with cm divisions
metric ruler with mm divisions
scientific calculator (per class)

BACKGROUND INFORMATION

Government agencies, such as EPA, set water quality criteria for pollutant discharges and issue permits to facilities that discharge treated wastewater into receiving waters. Monitoring agencies and facilities run tests on discharges and must be able to document the amount of specific pollutants that are present in the discharges. Very specific tests are used to analyze water for pollutants, and each test has a limit of detection. Everyone's ideal would be that all discharges would contain zero pollutants. Advancements in technology have made it possible to measure smaller and smaller amounts of pollutants. The desire of the public in recent years for increased environmental protection has encouraged the trend toward requiring monitoring laboratories to measure and report these smaller amounts and to push down the amounts permitted to be discharged. There are several trade-offs

involved in establishing more stringent regulations and requiring monitoring agencies to measure and report down to very low levels. In exchange for the greater protection of the environment that is provided, there is greater cost incurred by industries and taxpayers for the technology. Another trade-off that must be considered is greater uncertainty in the measurement. Statistical measures and expressions of the variance or random error may be used to express that uncertainty. The lower the level of detection and reporting, the more important it becomes to use some expression that qualifies the reported value with an accuracy statistic.

Terms

accuracy: the closeness of a measurement to the true or accepted value

Method Detection Limit (MDL): the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero

precision: the agreement among the numerical values of a set of measurements of the same quantity made in the same way

standard deviation: a statistical value that is equal to the square root of the arithmetic average of the squares of the deviations from the mean in a frequency distribution

uncertainty: lack of certainty; doubt

variance or random error: degree of change or difference; divergence; discrepancy

ADVANCE PREPARATION

- A. Choose two objects to measure. One should be close to the length of a meter stick, with a length that is unambiguously close to a cm mark. The other object should be less than 1 cm; students will be estimating it to 0.1mm. This number inevitably will be ambiguous for students and is meant to be so.
- B. Experiment and choose an incline and carefully mark a starting distance from the bottom that will allow a toy car to move to the endpoint in less than one second. Students will have trouble measuring this, but problem in measuring is the point.
- C. Divide students into ten groups of 2-3 students, number the groups, and give them a sequence of measurements: large object, small object, timed car. You will assist with the car.

PROCEDURE

I. Setting the stage

- A. Explain to students that they will be making measurements in their groups and writing these down without discussing them with other groups. This is to preserve their unbiased scientific openness to the true value of the measurement. Measurements will be compared and used.
- B. Explain to students that they will be using a statistical method published by the EPA to be used by environmental laboratories to set detection limits. Instruct them to estimate and roundoff measurements as follows: large object - nearest cm; small object - nearest 0.1 mm; car time - nearest 0.1 or 0.01 second if possible.

II. Activity

- A. Take measurements of objects and time.
- B. List on board ten group measurements.
- C. Use a scientific calculator to analyze the three sets of data for mean and standard deviation.
- D. Utilize the following procedure to calculate the detection limits of the meter stick, the metric ruler, and the stop watch.
 - 1. Method Detection Limit = standard deviation $\times t$
(where t value is a statistical value used in the student's t test for testing the validity of data, a standard statistical method)
 - 2. The t value to be used here is 2.821 for ten replicates at the 99% confidence level.

III. Follow-up

- A. Ask students to explain what happened to the certainty of their data when they attempted to measure smaller things.
- B. Ask students to suggest ways the certainty of their data could be improved.
(Technology)

- C. Involve students in a discussion about the factors involved in applications of new technology. One thing that may apply is the idea that because the technology exists, we have to use it to detect lower levels and require all monitoring facilities to report these. Whom do they think are the greatest advocates of this? (Often they are the companies that develop the technology.) Ask them to think about some analogies where the safety provided by a regulation may not be worth the cost of it. An example may be something like a broken stair in their home, on which people can trip and bump their knees, but which might cost several hundred dollars to be fixed properly by a good carpenter. People make those kinds of decisions every day about various aspects of their lives.

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METALS POLLUTION REDUCTION

OBJECTIVES

The student will do the following:

1. Explain how metallic pollutants are removed from wastewater.
2. Determine the optimum pH level for different types of metal removal. Explain how to read the graph.
3. Describe problems that metallic pollutants cause.
4. Devise a method of disposal for metal-containing "sludge."

SUBJECT:

Science (Environmental Science, Biology, Earth Science, Chemistry), Math

TIME:

1 class period

MATERIALS:

(per lab station)
 beaker
 glass rod
 pH paper or meter
 water test kit for metal detection
 sodium hydroxide (diluted in water)
 metal salts
 copies of student sheets

BACKGROUND INFORMATION

Metals in wastewater are harmful in excessive quantities to wastewater treatment plants, to receiving waters, and to those creatures living in or affected by the receiving waters.

Most metal pollutants (Pb, Cu, Zn, Cd, and Fe) are present in household sewage in small amounts. When combined with metals from industrial operations (Cr, Ni, Ag, as well as those mentioned above), these metals have enhanced combined (synergistic) effects and may: (1) be toxic to treatment plant microorganisms; (2) bioaccumulate in the microorganisms (which eventually become sludge or biosolids); (3) pass through the treatment plant to the receiving waters and exhibit toxicity to stream biota; (4) accumulate in and contaminate sediments; and (5) bioaccumulate in the food chain to fish, other wildlife, and people.

Metals can be removed from wastewater using hydroxide precipitation at an optimum pH level, depending on the metal or mix of metals present. Industries may use either hydroxide precipitation or other means to remove high concentrations of metals in their wastewaters.

Terms

bioaccumulate: to accumulate larger and larger amounts of a toxin within the tissues of organisms at each successive trophic level

biota: the plant and animal life of a region

flocculant: a substance added to a mixture that will cause precipitates (flocs) to form; also called "coagulant"

hydroxide precipitation: using the hydroxide ion (OH^-) to cause a material to come out of solution

optimum pH: the pH condition that will produce the best results for a given purpose

ADVANCE PREPARATION

- A. Prepare a solution of "polluted wastewater" using known quantities of metal salts of Fe, Pb, Ni, Zn, Cu, and Cd mixed in water (distilled water if available).
- B. Measure the metal pollutant concentration using a water analysis kit from a Volunteer Monitoring Program (or see page F-69, Water Testing Fact Sheet) to determine a before-treatment pollutant content. (Note - it may simplify the procedure to introduce only one "pollutant" initially.)
- C. Copy the Student Sheet.

PROCEDURE

A simulation of metal(s) removal will be done using a common technique of industry.

I. Setting the stage

This exercise requires a beaker, glass rod, pH paper or meter, and use of a monitoring kit equipped to test for the metal pollutant(s) of interest. A treatment solution of sodium hydroxide (diluted in water) is also necessary.

II. Activity

- A. Into a beaker containing the polluted water, add a solution of sodium hydroxide (NaOH), controlling to the optimum pH in the figure on the student sheet and stir with a glass rod until a cloudy appearance occurs. This cloudiness is called floc and is the formation of metal hydroxides, which will eventually settle as a precipitate.

- B. The majority of the "pollutants" have been removed; in a real-world application, the treated wastewater would be decanted or removed, leaving this precipitate, or sludge, behind.
- C. Using an eyedropper, remove enough clear water and test again using the monitoring test kit. How do these results compare with the original ones?

III. Follow-up

- A. Removal of the metal from wastewater is only an initial step. What happens to the "sludge"? Determine how it must be further treated and disposed of.
- B. What must industry do to place these treatment steps (from A) into effect?
- C. How do you determine (from the figure) the optimum pH to use if there is only Cd present and you want to remove to 1.0 mg/l? What if Cd, Ni, Cu, and Zn are present? Which metal is easiest to remove to 1.0 mg/l at a neutral pH? What must be done to pH before discharge if the optimum treatment pH is 10 to 11? How might this be done?

IV. Extensions

- A. Contact a local wastewater treatment plant, consulting engineer, engineering professor, or state environmental agency and ask about experiences in metals treatment.
- B. Why is there some amount of metal(s) left after treatment? What is the chemical basis for this?

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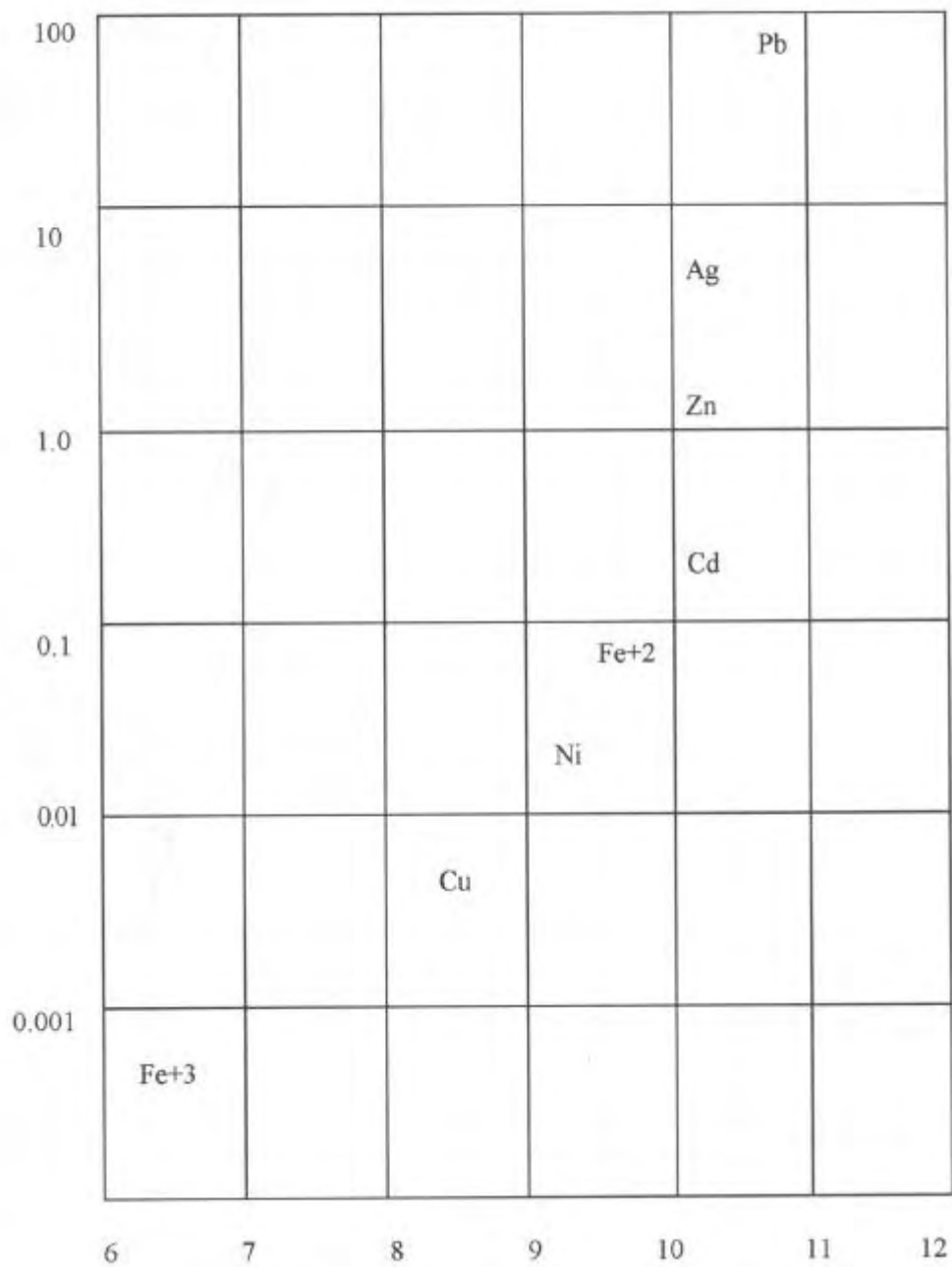
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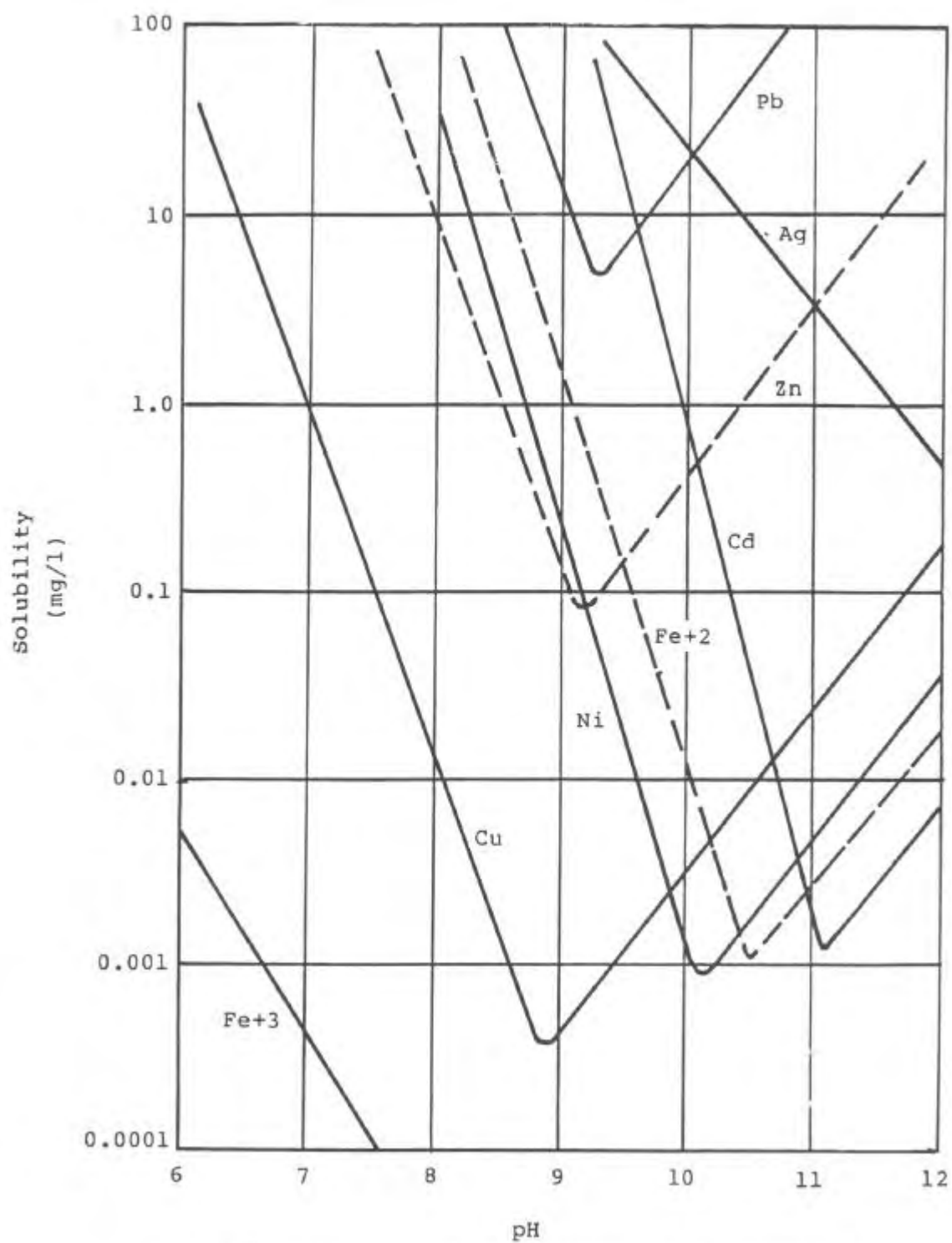
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Water Analysis Kit, page F-69, Water Testing Fact Sheet



SOLUBILITIES OF METAL HYDROXIDES AS A FUNCTION OF pH



SOLUBILITIES OF METAL HYDROXIDES AS A FUNCTION OF pH

WHAT IS IN SOURCE WATER?

9-12

OBJECTIVES

The student will do the following:

1. Observe pond and stream water samples for microorganisms and macroinvertebrates present in those aquatic ecosystems.
2. Categorize and compare the types of microorganisms in pond samples and stream samples (compare pond water samples with stream samples).
3. Distinguish between harmless macro- and micro-invertebrates and disease-causing organisms, if any.
4. Decide which pond appears to have better water samples.

BACKGROUND INFORMATION

Freshwater biomes include lakes, ponds, wetlands, and rivers. Most aquatic organisms live near the surface where nutrients and oxygen are plentiful.

Different types of communities of organisms dwell successfully in bodies of freshwater, depending on temperature, humidity, and amount of light. Some freshwater invertebrates are protists, green algae, and monerans (bacteria and blue-green algae). Other invertebrates, such as mayflies, stoneflies, snails, riffle beetles, crayfish, and caddisflies, may also be abundant.

Bioassessment is a technique used to monitor water quality. Groups of students can conduct bioassessments. This type of testing is a supplement to chemical testing. Usually different species are found in differing proportions and can be used as indicators of water quality. Some tolerant species

SUBJECTS:

Science (Biology, Ecology)

TIME:

1 to 2 class periods

1 week extension

MATERIALS:

jars

sample of "pond water"

sample of "stream water"

labels

medicine dropper (per group)

microscope (per group)

slides with cover slips

kick nets or D-ring nets

distilled water

jars and labels

rice

book on aquatic microorganisms (if available)

wallpaper paste

paper & writing implements

student sheets

can survive drastic changes in conditions. Other intolerant species are affected even by small amounts of pollution. Populations change when water quality changes.

Terms

algae: any various, primitive, chiefly aquatic, one-celled or multicellular plants that lack true stems, roots, and leaves, but usually contain chlorophyll. Algae are divided into three groups: chlorophyta (green), phaeophyta (brown), and rhodophyta (red), typically grow in sunlit waters in proportion to the amount of nutrients available, and serve as food for fish and small aquatic animals.

bacteria: typically one-celled, non-photosynthetic microorganisms that multiply by simple division. They occur in three main forms; spherical (cocci), rod-shaped (bacilli), and spiral (spirilla).

bioassessment: an evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters

biomes: area or groups of ecosystems with similar climates, soils, and communities

community: assemblage of populations of species living together and interacting with each other within a certain area

population: group of organisms of a single species living in a certain area and interbreeding (or interacting)

tolerance: the natural or developed ability to endure or resist the harmful effects of a substance

ADVANCE PREPARATION

- A. Collect samples of pond water in jars and label them with a unique name or location for each pond.
- B. If possible, take students to the nearest stream and utilize kick nets or D-ring nets to collect macroinvertebrates. Place organism-containing water in sorting pans by group. Place organisms in jars with alcohol if preservation is desired, otherwise return organisms to stream.
- C. Copy Student Sheets. (one set for each student)

- D. If testing five-day-old pond water samples, add a few rice grains to each jar to feed organisms.

PROCEDURE

I. Setting the stage

- A. Go over Microorganism and Macroinvertebrate Student Sheets.
- B. Go over the different zones in a pond that support life.
- C. Explain how to use wallpaper paste to slow down microorganisms (not needed for macroinvertebrates).

II. Activity Part 1- Observations

- A. Prepare microscope slides of pond and stream water using medicine droppers and cover slips.
- B. Ask students to make observations, draw, and identify the organisms present in the samples, using the Student Sheets as the key.
- C. Let each student observe a variety of slides.
- D. Compare and contrast the pond water organisms from different ponds.

Part 2 - Bioassessment

- A. Have students identify the macroinvertebrates of the three groups according to their key for macroinvertebrate samples.
- B. Have students record names and numbers of different macroinvertebrates found in each group for each stream macroinvertebrate sample.
- C. Compare and contrast the results for different samples; determine the water quality.

III. Follow-up

- A. Repeat the same procedure after 5-10 days. (Keep jars warm and in indirect sunlight.)
- B. Record the changes in size, number, and species in the new samples and the 5-10 day samples.
- C. Discuss possible reasons for any differences that are observed in the samples.

IV. Extensions

- A. Is water quality different in the streams? Which is best? Why?
- B. Collect more information about pond life and freshwater flora and fauna. (library research)

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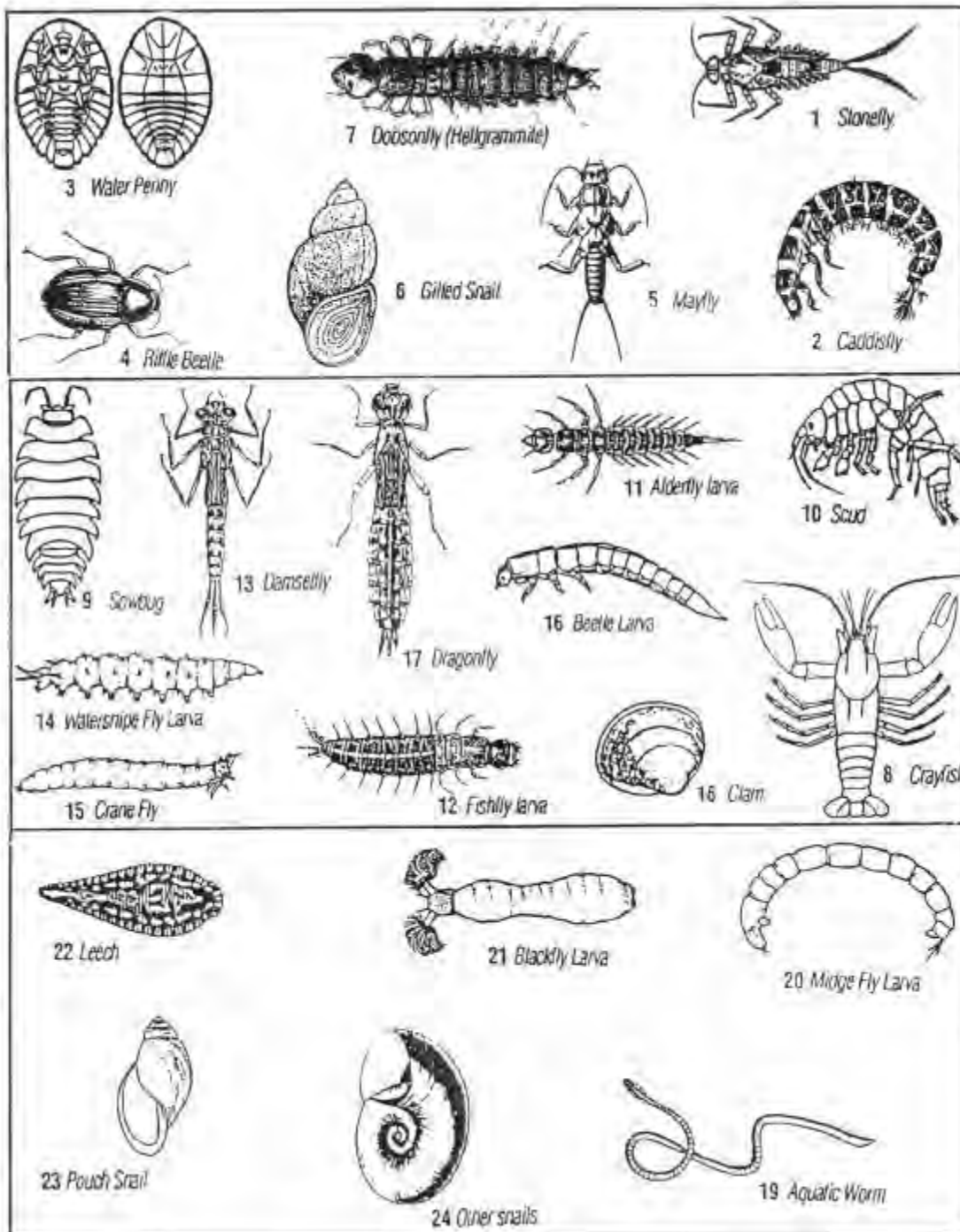
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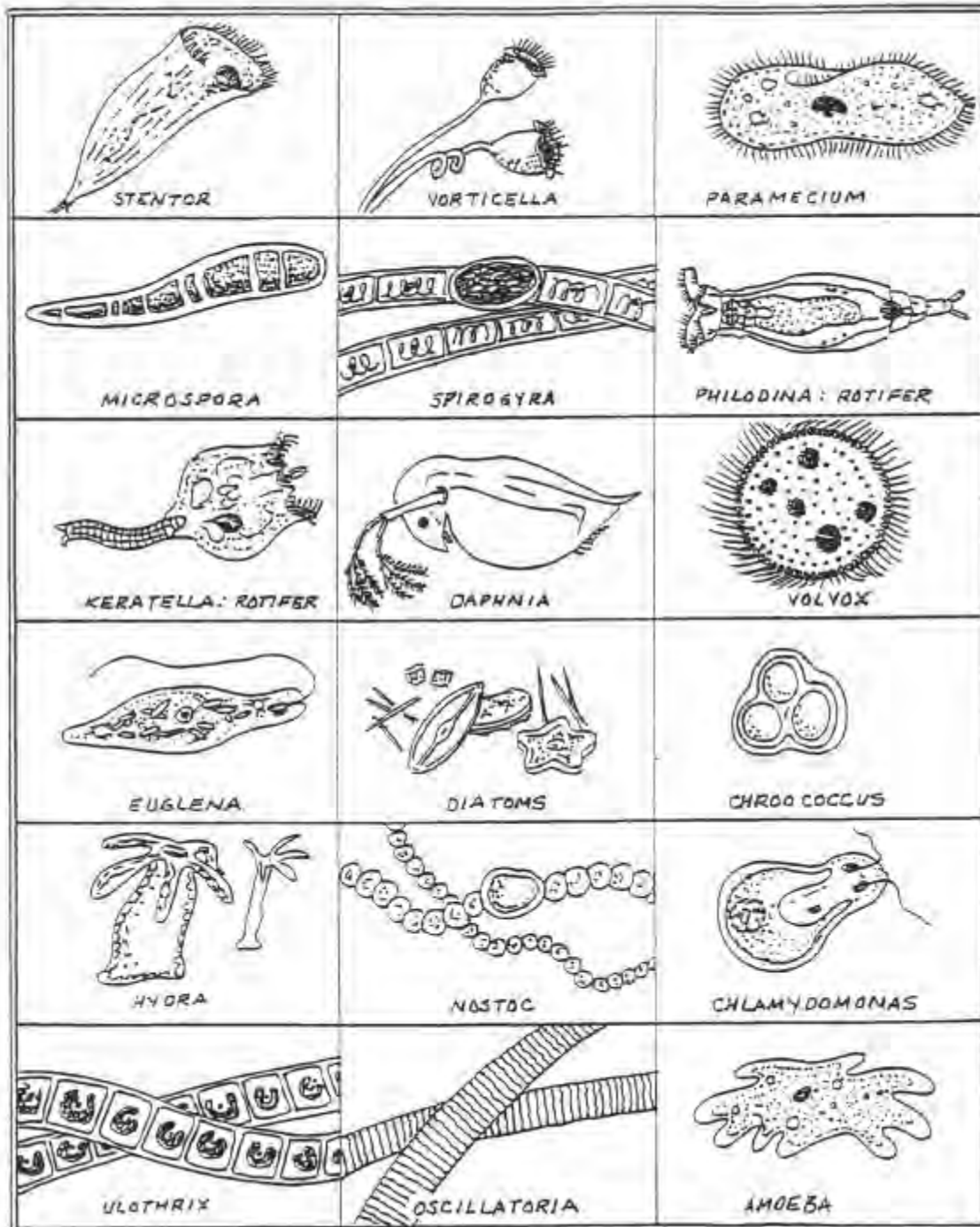
MACROINVERTEBRATE GROUPS

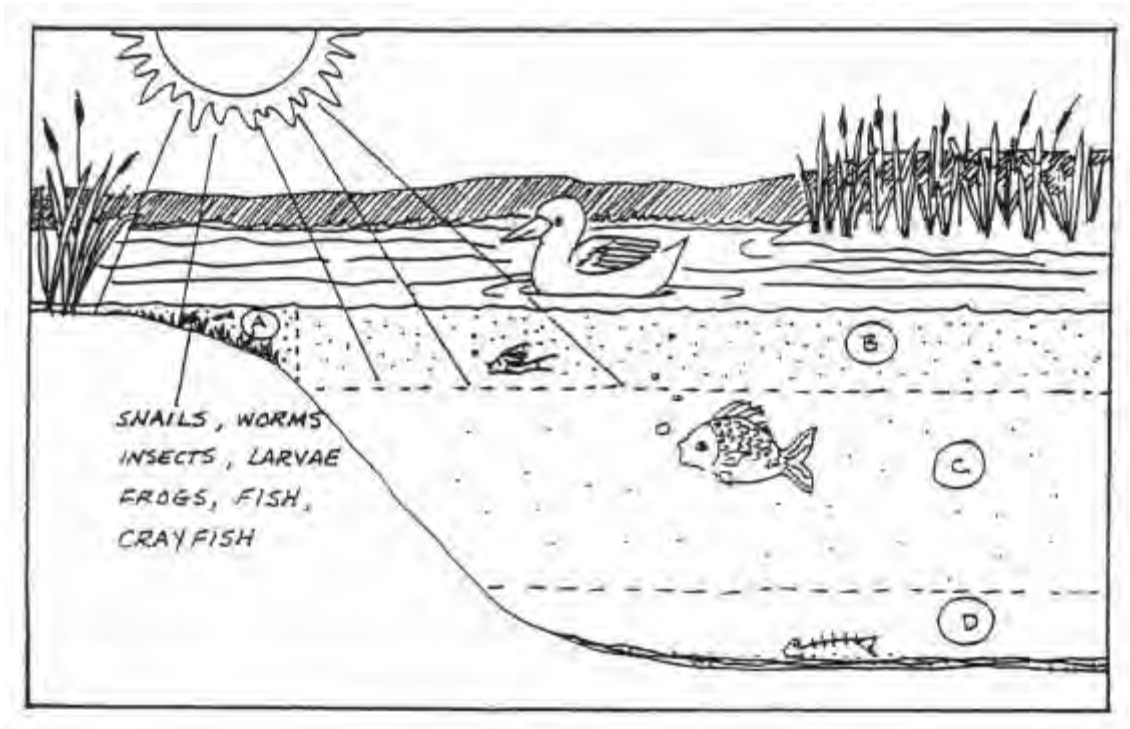
Beginner's Protocol PICTURE KEY

GROUP 1		GROUP 2		GROUP 3	
1.	STONEFLY	8.	CRAYFISH	19.	AQUATIC WORM
2.	CADDISFLY	9.	SOWBUG	20.	MIDGE FLY LARVA
3.	WATER PENNY	10.	SCUD	21.	BLACKFLY LARVA
4.	RIFFLE BEETLE	11.	ALDERFLY LARVA	22.	LEECH
5.	MAYFLY	12.	FISHFLY LARVA	23.	POUCH SNAIL
6.	GILLED SNAIL	13.	DAMSELFY	24.	OTHER SNAILS
7.	DOBSONFLY	14.	WATERSNIPE FLY LARVA		
		15.	CRANE FLY		
		16.	BEETLE LARVA		
		17.	DRAGONFLY		
		18.	CLAM		



COMMON FRESHWATER ORGANISMS





A pond or lake ecosystem is structured according to how much light is available.

- A. Shallow water at shore line; sunlight reaches bottom; life abundant and varied.
- B. Near surface; light penetrates for photosynthesis; phytoplankton, zooplankton abundant.
- C. Cooler, darker; bacteria and fish that feed in Zone B.
- D. Very dark and very cold, few bottom feeders, many decomposers.

WASTEWATER TREATMENT

OBJECTIVES

The student will do the following:

1. Define wastewater and list components of wastewater.
2. Describe the function of a wastewater treatment plant.
3. Create a wastewater treatment model and use it to clean wastewater.
4. Describe some primary and secondary wastewater treatment methods.

SUBJECT:

Science (Physical Science, Physics)

TIME:

2-3 class periods

MATERIALS:

student sheets
writing materials

BACKGROUND INFORMATION

Wastewater is not just sewage. All the water used in the home that goes down the drains or into the sewage collection system is wastewater. This includes water from baths, showers, sinks, dishwashers, washing machines, and toilets. Small businesses and industries often contribute large amounts of wastewater to sewage collection systems; others operate their own wastewater treatment systems. In combined municipal sewage systems, water from storm drains is also added to the municipal wastewater stream. The average American contributes 265-568 liters (66 to 192 gallons) of wastewater each day. Wastewater is about 99 percent water by weight and is generally referred to as influent as it enters the wastewater treatment facility. “Domestic wastewater” is wastewater that comes primarily from individuals, and does not generally include industrial or agricultural wastewater.

At wastewater treatment plants, this flow is treated before it is allowed to be returned to the environment, lakes, or streams. There are no holidays for wastewater treatment, and most plants operate 24 hours per day every day of the week. Wastewater treatment plants operate at a critical point of the water cycle, helping nature defend water from excessive pollution. Most treatment plants have primary treatment (physical removal of floatable and settleable solids) and secondary treatment (the biological removal of dissolved solids).

Primary treatment involves:

1. screening- to remove large objects, such as stones or sticks, that could plug lines or tank inlets.
2. grit chamber- slows down the flow to allow grit to fall out
3. sedimentation tank (settling tank or clarifier)- settleable solids settle out and are pumped away, while oils float to the top and are skimmed off

Secondary treatment typically utilizes biological treatment processes, in which microorganisms convert nonsettleable solids to settleable solids. Sedimentation typically follows, allowing the settleable solids to settle out. Three options include:

1. Activated Sludge- The most common option uses microorganisms in the treatment process to break down organic material with aeration and agitation, then allows solids to settle out. Bacteria-containing “activated sludge” is continually recirculated back to the aeration basin to increase the rate of organic decomposition.
2. Trickling Filters- These are beds of coarse media (often stones or plastic) 3-10 ft. deep. Wastewater is sprayed into the air (aeration), then allowed to trickle through the media. Microorganisms, attached to and growing on the media, break down organic material in the wastewater. Trickling filters drain at the bottom; the wastewater is collected and then undergoes sedimentation.
3. Lagoons- These are slow, cheap, and relatively inefficient, but can be used for various types of wastewater. They rely on the interaction of sunlight, algae, microorganisms, and oxygen (sometimes aerated).

After primary and secondary treatment, municipal wastewater is usually disinfected using chlorine (or other disinfecting compounds, or occasionally ozone or ultraviolet light). An increasing number of wastewater facilities also employ tertiary treatment, often using advanced treatment methods. Tertiary treatment may include processes to remove nutrients such as nitrogen and phosphorus, and carbon adsorption to remove chemicals. These processes can be physical, biological, or chemical.

Settled solids (sludge) from primary treatment and secondary treatment settling tanks are given further treatment and undergo several options for disposal. (See Sludge Treatment and Disposal Methods on page 2-87 & 2-114 thru 2-115.)

Terms

activated sludge: sludge particles produced by the growth of microorganisms in aerated tanks as a part of the activated sludge process to treat wastewater

aeration: exposing to circulating air; adds oxygen to the wastewater and allows other gases trapped in the wastewater to escape (the first step in secondary treatment via activated sludge process)

biochemical oxygen demand (BOD): a laboratory measurement of wastewater that is one of the main indicators of the quantity of pollutants present; a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material

biosolids: sludge that is intended for beneficial use. Biosolids must meet certain government-specified criteria depending on its use (e.g., fertilizer or soil amendment).

decomposition: the process of breaking down into constituent parts or elements

domestic wastewater: wastewater that comes primarily from individuals, and does not generally include industrial or agricultural wastewater

effluent: treated wastewater, flowing from a lagoon, tank, treatment process, or treatment plant

grit chamber: a chamber or tank used in primary treatment where wastewater slows down and heavy, large solids (grit) settle out and are removed

influent: wastewater flowing into a treatment plant

lagoons (oxidation ponds or stabilization ponds): a wastewater treatment method that uses ponds to treat wastewater. Algae grow within the lagoons and utilize sunlight to produce oxygen, which is in turn used by microorganisms in the lagoon to break down organic material in the wastewater. Wastewater solids settle in the lagoon, resulting in effluent that is relatively well treated, although it does contain algae.

municipal: of or relating to a municipality (city, town, etc.). Municipal wastewater is primarily domestic wastewater.

primary treatment: the first stage of wastewater treatment that removes settleable or floating solids only; generally removes 40% of the suspended solids and 30-40% of the BOD in the wastewater

secondary treatment: a type of wastewater treatment used to convert dissolved and suspended pollutants into a form that can be removed, producing a relatively highly treated effluent. Secondary treatment normally utilizes biological treatment processes (activated sludge, trickling filters, etc.) followed by settling tanks and will remove approximately 85% of the BOD and TSS in wastewater. Secondary treatment for municipal wastewater is the minimum level of treatment required by the Clean Water Act.

sedimentation: the process used in both primary and secondary wastewater treatment, that takes place when gravity pulls particles to the bottom of a tank (also called settling).

settling tank (sedimentation tank or clarifier): a vessel in which solids settle out of water by gravity during wastewater or drinking water treatment processes.

sludge: any solid, semisolid, or liquid waste that settles to the bottom of sedimentation tanks (in wastewater treatment plants or drinking water treatment plants) or septic tanks

tertiary treatment: any level of treatment beyond secondary treatment, which could include filtration, nutrient removal (removal of nitrogen and phosphorus) and removal of toxic chemicals or metals; also called “advanced treatment” when nutrient removal is included

total suspended solids (TSS): a laboratory measurement of the quantity of suspended solids present in wastewater that is one of the main indicators of the quantity of pollutants present

trickling filter process: a biological treatment process that uses coarse media (usually rock or plastic) contained in a tank that serves as a surface on which microbiological growth occurs. Wastewater trickles over the media and microorganisms remove the pollutants (BOD and TSS). Trickling filters are followed by settling tanks to remove microorganisms that wash off or pass through the trickling filter media.

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

wastewater: water that has been used for domestic or industrial purposes

PROCEDURE

I. Setting the Stage

- A. Make transparencies of Teacher Sheets. Copy Student Sheets.
- B. Discuss the processes involved at a typical municipal wastewater treatment facility.
- C. Discuss typical municipal wastewater collection systems.
- D. Relate discussion to any relevant local or national wastewater issues.

II. Activity

- A. Have students complete Student Sheet.
- B. (Optional): Have students research pertinent local or national wastewater issues and write a paper on their issue of choice.

III. Follow-up

- A. Have students determine which types of treatment (primary, secondary, tertiary) and specific processes are used at the local municipal wastewater treatment facility.
- B. Have students discuss the plant's efficiency (with respect to various contaminants) with a plant operator. Learn about any "pretreatment" operations conducted for industrial wastewater.

IV. Extensions

- A. Visit the local municipal wastewater treatment plant, or invite a speaker from the plant to talk to the class.
- B. View a video or slides of various types of wastewater treatment processes.
- C. Determine which types of municipal treatment processes are used in industrial wastewater treatment processes. Discuss which processes are used for particular industries and why.

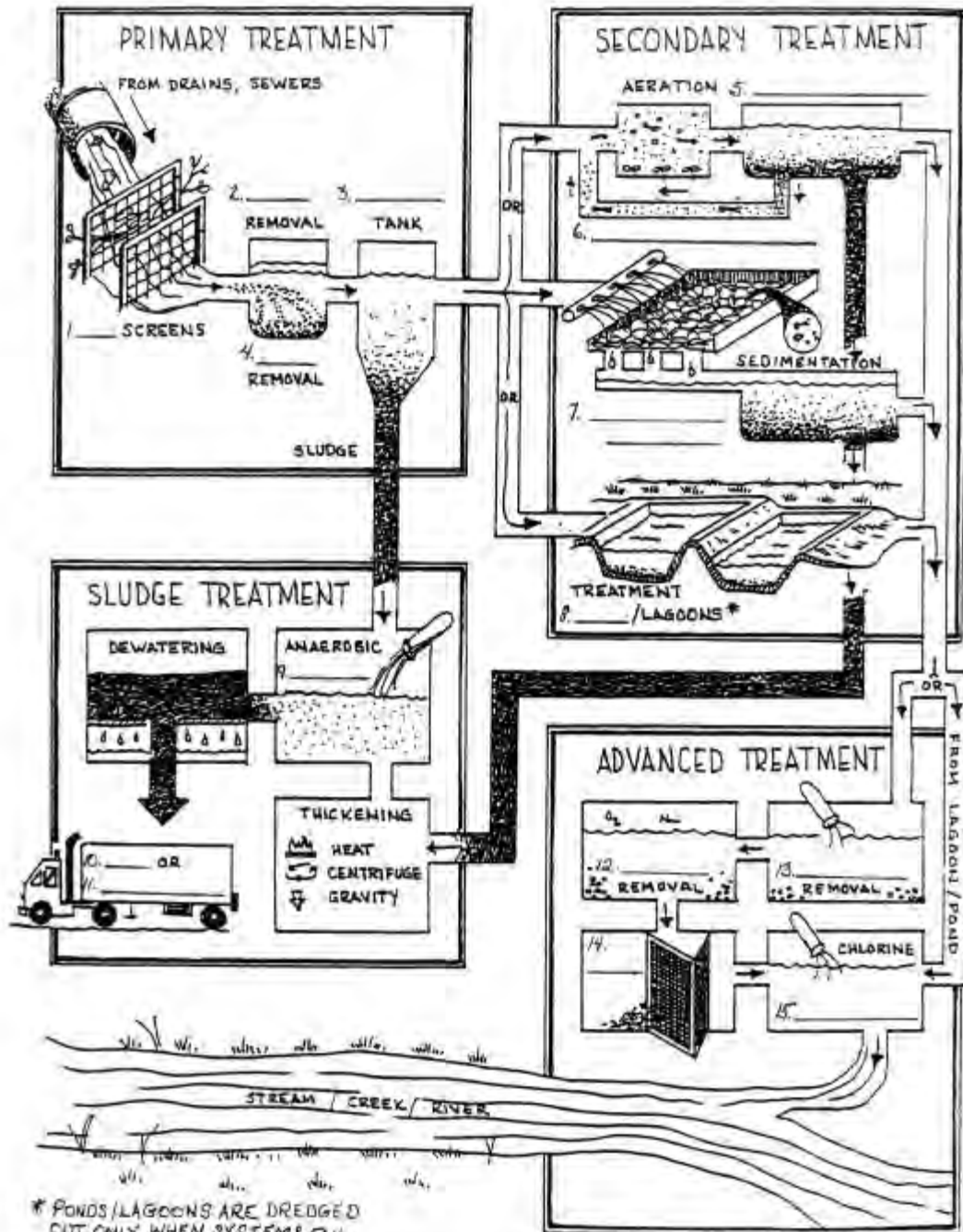
RESOURCES

National Geographic Society Teachers Handbook, Geography: Reflections on Water", Nov. '92.

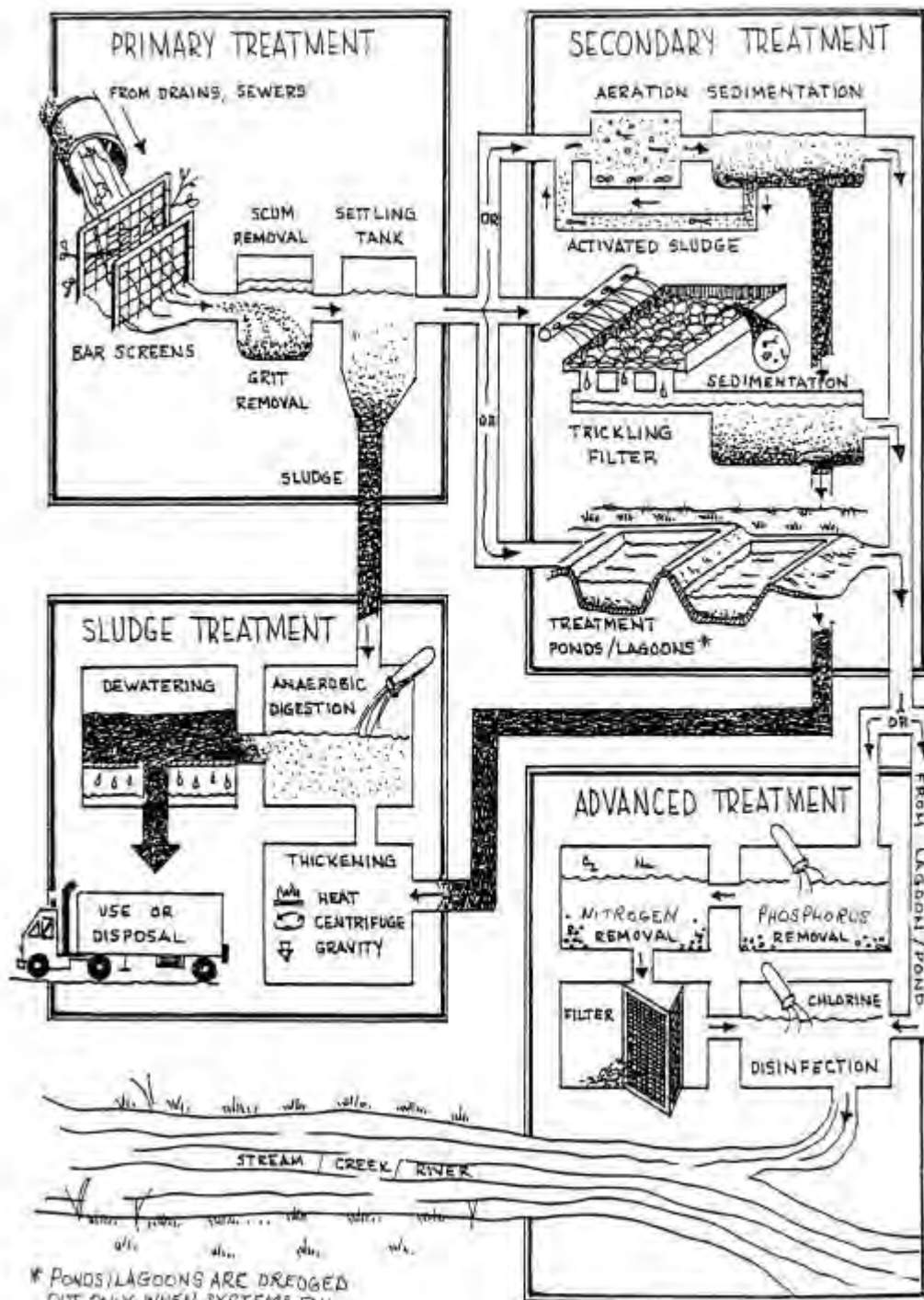
Nature Projects on File, "Cleaning Dirty Water," 6.008, The Diagram Group.

Water Environment Federation, "Clean Water for Today: What is Wastewater Treatment?"¹
800-444-2933 (Fax Reply Service)

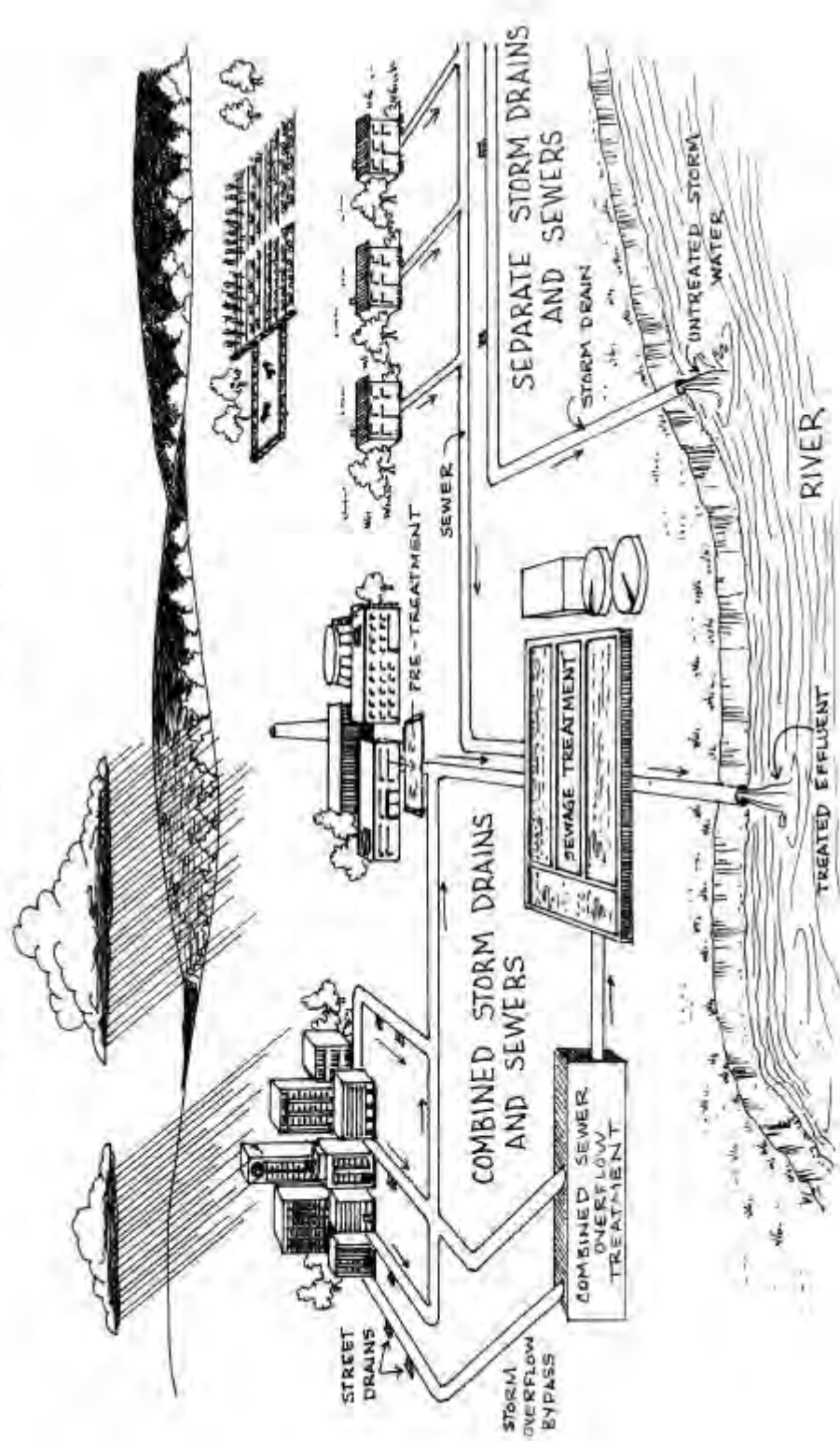
TYPICAL WASTEWATER TREATMENT FACILITY



TYPICAL WASTEWATER TREATMENT FACILITY



MUNICIPAL SEWER SYSTEMS



THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT

9-12

OBJECTIVES

The student will do the following:

1. Balance equations involving common household products found in domestic wastewater.
2. Describe different types of biological wastewater treatment and sludge treatment.
3. Identify microorganisms in wastewater and determine sludge quality.

SUBJECT:

Science (Chemistry, Biology, Physical Science). Social Studies (Economics).
Language Arts

TIME:

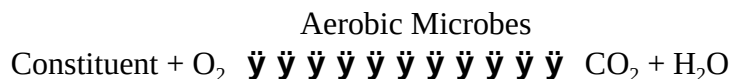
2-3 class periods

MATERIALS:

students sheets

BACKGROUND INFORMATION

In biological wastewater treatment processes, microorganisms metabolize or break down organic constituents (or pollutants) in household wastewater to carbon dioxide and water. While breakdown is commonly not 100% complete, for purposes of demonstrating the chemical changes in wastewater treatment, it can be assumed that reactions are complete as summarized by:



These are called “oxidation” reactions, because oxygen is required for the reactions to occur. Oxygen in the above equation is supplied by aeration in activated sludge treatment plants or trickling filters and by photosynthesis and surface wind action in ponds and lagoons.

Biological treatment of municipal and industrial wastewater has evolved almost in its entirety since the beginning of the 20th century. Many methods and techniques of biological treatment have been adapted to meet many waste-specific, site-specific, or other needs such as economic constraints, reliability, energy efficiency, space constraints, variability of wastewater, organic characteristics, operational simplicity, ease of maintenance, removal of specific pollutants, and many other criteria that may affect a given application.

Biological organisms that provide treatment may be either suspended growth organisms (activated sludge, ponds, or lagoons) or attached growth organisms (trickling filters, rotating biological contactors, or biological towers). These microorganisms use most of the suspended and dissolved material found in the wastewater as their food source. The microorganisms depicted on the Student Sheet are aerobic and, therefore, require a supply of oxygen to function. Their need for food and oxygen is similar to the needs of humans and other animals.

The biological treatment process provides the environment to keep these microorganisms under controlled conditions so that they can remove most of the solids from wastewater as it passes through the treatment facility.

The purpose of a biological treatment process is to decompose as much organic matter from the wastewater as possible and produce a high quality effluent. The process thereby assists in protecting the receiving stream from organic loads that could lower dissolved oxygen enough to kill fish or otherwise adversely affect the receiving stream.

Terms

effluent: treated wastewater, flowing from a lagoon, tank, treatment process, or treatment plant

refractory wastewater: wastewater containing an organic or nutrient content that will not oxidize in normal treatment processes

variable wastewater: wastewater that comes from different sources (regular sewage, storm water, or industrial wastewater)

ADVANCE PREPARATION

- A. Copy all Students Sheets.
- B. Review or instruct students on how to balance equations.
- C. Put students into work groups.
- D. Copy sources of wastewater (from PROCEDURE, II. Activity. B), and cut the different ones into individual strips. Give 1 or 2 to each group.
- E. Obtain from a treatment plant a sample of activated sludge or other material that would contain microorganisms. (Note: Students should not handle activated sludge, as it may contain pathogens. Teachers should receive handling instructions from a certified wastewater treatment operator.)

PROCEDURE

- I. Setting the stage
 - A. Explain the purpose of organic constituent breakdown with oxygen in wastewater treatment.
 - B. Explain that there are many variations on the most commonly known biological treatment processes and sludge treatment processes.
- II. Activity
 - A. Contact the local water and sewer authority, a consulting engineer, state or federal environmental agency, or another source and find out the most common wastewater treatment systems used in the area and why they are used. What are commonly used sludge treatment processes and what is typically done with the sludge.
 - B. Assuming joint treatment with domestic wastewater, use the Student Sheet information and contact one of the following external sources to find out its wastewater characteristics. Match the source with the treatment technique most applicable to that source. Be sure you can explain why you chose that method of treatment.

< domestic wastewater (small town)	< petroleum refining
< domestic wastewater (larger city)	< fruit/vegetable processing
< pulp and paper mill	< bakery
< chemical plant	< fertilizer manufacture
< textile dyeing operation	< soft drink bottling
< poultry or meat processing	< iron and steel manufacture
 - C. Visit the local municipal wastewater treatment plant (or talk to a plant operator) and determine its type. Why are those particular wastewater and sludge treatment processes used for your town or city?
 - D. Balance the equations on Biodegradable Balancing Student Sheet.

E. Look at a drop of activated sludge under a microscope. Each group should prepare 3 slides. Record the different types and numbers of organisms present on the Student Sheet for each slide. Draw pictures of what you see. Determine the sludge quality using the Student Sheet on quality.

III. Follow-up

- A. Do you think your local municipal wastewater treatment plant is using the best treatment methods for your area and circumstances? Explain your answer.
- B. What are some common organic constituents you would find in local wastewater. What is the source of most of them?
- C. Do you think the treatment plant that the activated sludge was taken from is operating effectively? Explain your answer.

IV. Extensions

Have students research one household pollutant common in wastewater, searching for healthier environmental substitutes.

RESOURCES

Metcalf and Eddy, Wastewater Engineering: Collection and Pumping of Wastewater, McGraw-Hill, New York, 1981.

Water Environment Federation, "MOP for Treatment Plant Operation & Design," 1-800-444-2933.

Water Environment Federation, "Nature's Way" Video & Brochure, 1-800-444-2933.

METHODS OF WASTEWATER TREATMENT & DISPOSAL

1. EXTENDED-AERATION ACTIVATED SLUDGE

ADVANTAGES

Key advantages of the extended-aeration process include:

- C Lowest solids production of any activated-sludge process
- C High-quality effluent achievable
- C Preengineered package plants quickly installed with minimal site preparation
- C Favorable reliability with sufficient operator attention
- C Nitrification likely at wastewater temperatures >15°C
- C Relatively minimal land requirements
- C Relatively low initial cost
- C Can handle moderate-shock hydraulic loadings with minimal problems

DISADVANTAGES

Key disadvantages of this type of system include:

- C High power consumption and energy cost compared to land-based or natural systems
- C High O&M requirements compared to land-based or natural systems; skilled operator necessary
- C Susceptible to excursions in effluent SS and associated BOD due to high flow variations and operator inattention
- C Potential freezing problems in cold climates
- C Possibility of poor settleability of mixed liquor suspended solids (MLSS) due to formation of "pinpoint" floc
- C Potential for rising solids due to denitrification in final clarifier in warmer months
- C Blower noise and odor potential
- C Preengineered plants may require additional components or modification to meet specified effluent limitations

2. OXIDATION DITCH

ADVANTAGES

Key advantages of the oxidation ditch process include:

- C Low solids production
- C Excellent performance. High reliability
- C Nitrogen removal likely
- C Relatively low initial cost
- C Can be designed for biological phosphorus and nitrogen removal

DISADVANTAGES

Key disadvantages to this process include:

- C Protection from aerator freezing problems necessary in cold climates
- C Relatively high maintenance requirements for aerators
- C Potential for rising solids due to denitrification in final clarifier
- C Requires good operator skills and routine monitoring

3. SEQUENCING BATCH REACTORS

ADVANTAGES

Key advantages of the SBR process include:

- C Simple, reliable
- C Ideally suited for wide flow variations

DISADVANTAGES

The disadvantages of this process include:

- C Capable of very high and consistent effluent quality due to sequiescent batch shifting
- C Requires less operator attention than most other mechanical systems
- C High operational flexibility allowing capability for nutrient removal, filamentous growth control
- C Some problems reported with decant systems
- C Improvements to hardware continue to be made as the technology develops.
- C Requires skilled operator and regulator inspection and maintenance

4. TRICKLING FILTRATION (TF) AND ROTATING BIOLOGICAL CONTACTORS (RBC)

ADVANTAGES

Key advantages of TF and RBC processes include:

- C Simplicity of operation. Low energy requirements
- C Dependability
- C The relatively small amount of solids produced is more easily dewatered than activated sludge.

DISADVANTAGES

Key disadvantages of these processes include:

- C High land requirements
- C High capital cost
- C Lower degree of process control
- C The conventional TF process is limited with respect to performance.

5. TRICKLING FILTER SOLIDS CONTACT (TFSC) PROCESS

ADVANTAGES

Advantages of the TFSC process include:

- C Applicable for new facilities or upgrading existing trickling filter plants
- C Capable of consistently achieving very high-quality effluent (<20 mg/L BOD & SS)
- C Relatively simple process
- C Low cost and reliable upgrading technique for trickling filters
- C Can be designed to provide nitrification

DISADVANTAGES

Key disadvantages of this process include:

- C Primary clarification required
- C Pumping required to douse trickling filter
- C Potential for nuisance odors from primary clarifiers, trickling filter, solids handling
- C Moderate O&M requirements; skilled operator necessary

6. CONSTRUCTED WETLANDS

ADVANTAGES

Constructed wetlands offer the following advantages for wastewater management:

- C Low construction cost
- C Passive system easily managed by small community with O&M personnel
- C Excellent removal of biochemical oxygen demand (esp. BOD5) and suspended solids (SS) from primary or septic tank effluents
- C Generally attractive systems with secondary ecological benefits in terms of wildlife habitat enhancement

DISADVANTAGES

The following disadvantages should be taken in account when considering a constructed wetland system:

- C Lack of generally agreed-upon design factors, resulting in several unproven approaches to design of land-intensive systems, especially FWS types where up to 4 ha/Us (450 ac/mgd) have been required
- C SF systems remain unproven for other than BOD5 and SS removal.

7. OVERLAND FLOW

ADVANTAGES

Overland flow is well suited for wastewater treatment by rural communities and seasonal industries with organic wastes. It provides secondary or advanced secondary treatment, yet is relatively simple and inexpensive to operate. If the vegetation cover can be harvested and sold (e.g., as forage), overland flow can provide an economic return from the reuse of water and nutrients. Of the land application methods of wastewater treatment, overland flow is the approach least restricted by soil characteristics; however, this method does require a relatively impermeable soil for conventional operation.

DISADVANTAGES

Overland flow is primarily limited by climate, crop water tolerances, and land slope. Application is restricted during wet weather and can be limited when temperatures remain below freezing. Application rates may be restricted by the type of crop grown. Steeply sloping or flat terrain is not well suited for this method of treatment. Disinfection is required in order to meet effluent permit requirements prior to discharge (unique to land application processes).

8. SLOW RATE LAND APPLICATION

ADVANTAGES

Slow rate land application is well suited for treatment of wastewater from rural communities and seasonal industries such as vegetable canning. It can provide an economic return from the reuse of water and nutrients for irrigation of landscaped areas or production of marketable, commercially processed crops. It also provides groundwater recharge. Of the various land treatment methods, slow rate land application is the least limited by surface slopes.

DISADVANTAGES

Because of the vegetation component, slow rate land application is limited by climate and nutrient requirements of the vegetation. Climate affects the growing season and will dictate the period of wastewater application and storage requirements. Crop water tolerances, nutrient requirements, and nitrogen removal capacity of the vegetation-soil complex limit the hydraulic loading rate. Application must be suspended during wet periods or frozen soil conditions. Because of the limits on the hydraulic loading rate, the area of land necessary is significantly larger than for other land application methods.

9. RAPID INFILTRATION

ADVANTAGES

Rapid infiltration is a method of land application providing very favorable removal of the conventional wastewater parameters-including ammonia-that is simple to operate and requires only a minimum of operator intervention. Moreover, it requires less land area than other land application methods and may be operated year round. It is a "zero discharge" method that provides groundwater recharge rather than requiring an outfall for direct discharge to surface water. Frequently, renovated wastewater is recovered via wells for reuse in irrigation.

DISADVANTAGES

Use of rapid infiltration is limited by site and soil characteristics that affect the capability of the soil to accept and treat the applied wastewater. Potential groundwater impacts from nitrate nitrogen are a serious concern and may also limit its application.

SLUDGE TREATMENT AND DISPOSAL METHODS

1. AEROBIC DIGESTION

ADVANTAGES

Key advantages of the aerobic digestion include:

- C Minimal operator attention
- C Low odor potential
- C Simple process
- C Resistant to upset
- C No chemicals required

DISADVANTAGES

The disadvantages of this process include:

- C Very high power consumption
- C Aeration system requires high maintenance
- C Larger volume tank required for cold climate application
- C Foaming potential

2. ANAEROBIC DIGESTION

ADVANTAGES

The recovery and use of this gas (primarily methane) as well as the reduction in solids volume are considered the most attractive features of anaerobic digesters.

DISADVANTAGES

The complexity of the recovery and use process makes their feasibility marginal for wastewater systems with capacities in the range of 100,000 to 1 million gpd and unlikely in smaller systems.

3. LAND APPLICATION OF BIOSOLIDS

ADVANTAGES

Key advantages of land application include:

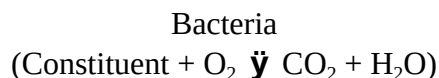
- C Recycling as soil conditioner, source of organic matter and nutrients
- C Simple
- C Low cost

DISADVANTAGES

The disadvantages of this process include:

- C Storage requirements may be considerable to accommodate generation during wet, frozen soil conditions
- C Odor potential
- C Local opposition possible
- C Close monitoring required

Organic Constituents



Substituting the chemical formula for common household constituents, the equation may be balanced to show complete reactions. Some examples of common household constituents of wastewater are listed below. Common household constituents and their formulas are below.

1. Acetic Acid (vinegar) CH_3COOH
2. Acetone (nail polish remover) CH_3COCH_3
3. Citric Acid (orange juice) $\text{C}_6\text{H}_8\text{O}_7$
4. Sucrose (sugar) $\text{C}_{12}\text{H}_{22}\text{O}_{11}$
5. Benzene (a component of gasoline) C_6H_6
6. Phenol (present in mouthwash) $\text{C}_6\text{H}_5\text{OH}$
7. Naphthalene (mothballs) C_{10}H_8
8. Uric Acid $\text{C}_5\text{H}_4\text{N}_4\text{O}_3$
9. Caffeine $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$
10. Acetylsalicylic Acid (aspirin) $\text{CH}_3\text{COOC}_6\text{H}_4\text{COOH}$
11. Vitamin A $\text{C}_{20}\text{H}_{30}\text{O}$
12. Thiamine (Vitamin B₁) $\text{C}_{12}\text{H}_{17}\text{N}_4\text{SOCl}$
13. Ascorbic Acid (Vitamin C) $\text{C}_6\text{H}_8\text{O}_6$
14. Vitamin D₂ $\text{C}_{28}\text{H}_{44}\text{O}$
15. Tocopherol (Vitamin E) $\text{C}_{29}\text{H}_{50}\text{O}_2$
16. Riboflavin (Vitamin B₂) $\text{C}_{17}\text{H}_{20}\text{N}_4\text{O}_6$
17. Alanine (a constituent of most proteins) $\text{C}_3\text{H}_4\text{NH}_2\text{O}_2\text{H}$
18. Stearic Acid (soap) $\text{C}_{17}\text{H}_{35}\text{COOH}$
19. Ethanol (the alcohol contained in beer, wine, etc.) $\text{C}_2\text{H}_5\text{OH}$
20. Starch $(\text{C}_6\text{H}_{10}\text{O}_5)_n$

where n = a whole number

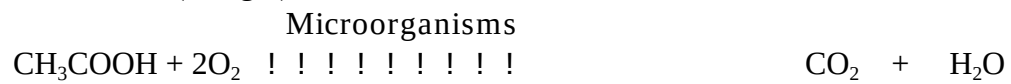
BIODEGRADABLE BALANCING

Name _____

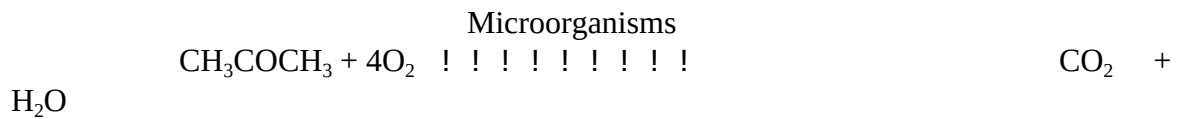
Date _____

Procedure: Balance the following equations that use common household constituents found in wastewater treatment plants.

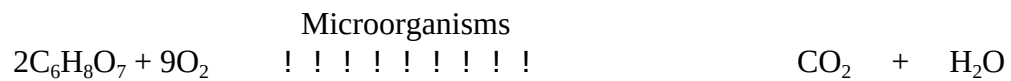
1. Acetic Acid (vinegar)



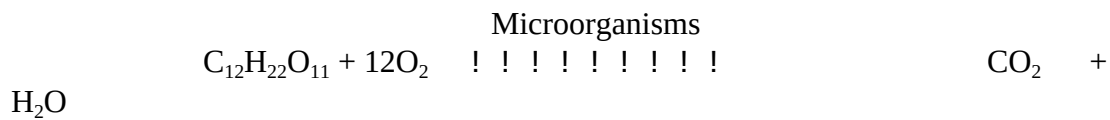
2. Acetone (nail polish remover, will not stay in solution - very volatile)



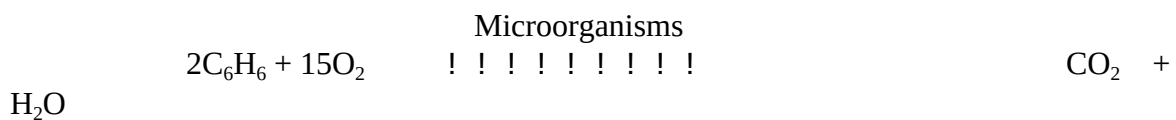
3. Citric Acid (orange juice)



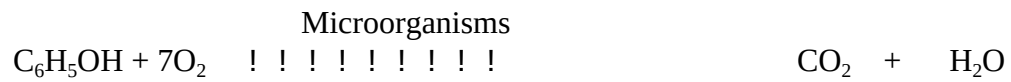
4. Sucrose (sugar)



5. Benzene (a component of gasoline)



6. Phenol (present in mouthwash, toxic to microorganisms at low concentrations)



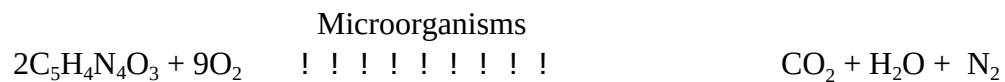
Student Sheet

BIODEGRADABLE BALANCING (cont.)

7. Naphthalene (mothballs, will sublime rather than dissolve)

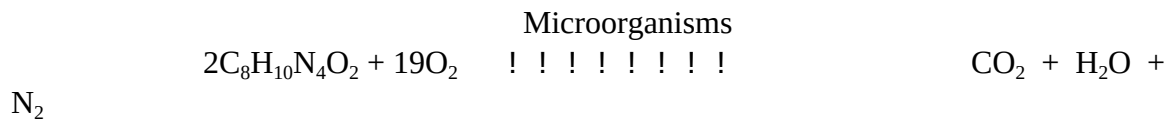


8. Uric Acid

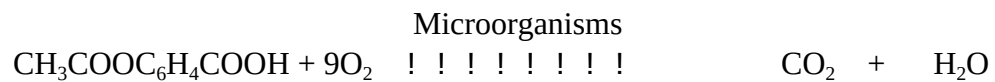


Some of these compounds will not be effectively treated with biological stabilization.

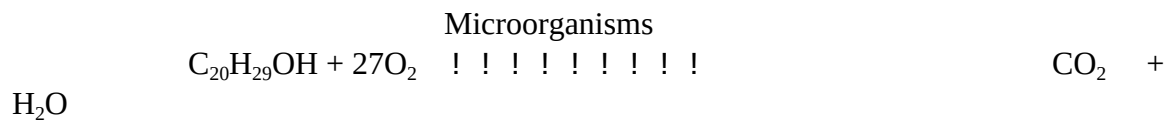
9. Caffeine

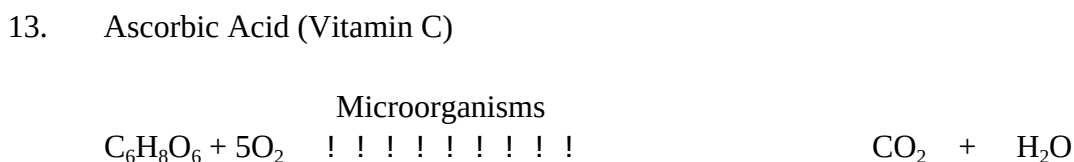
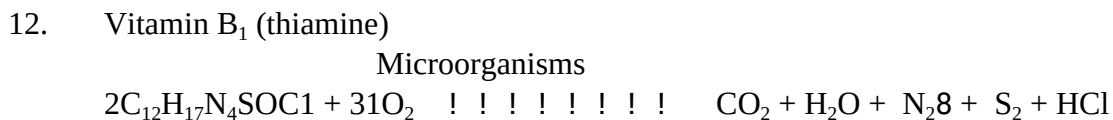


10. Acetylsalicylic Acid (aspirin)



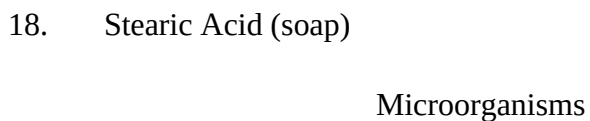
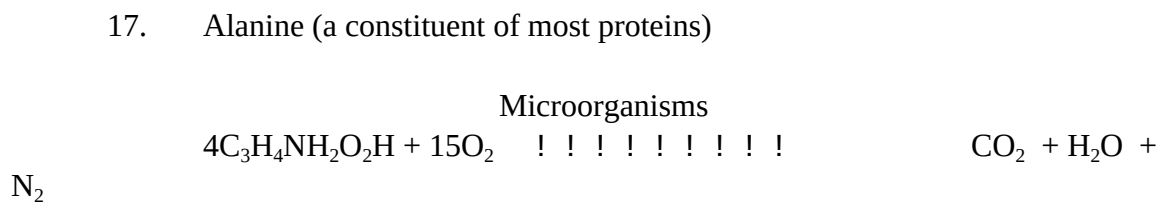
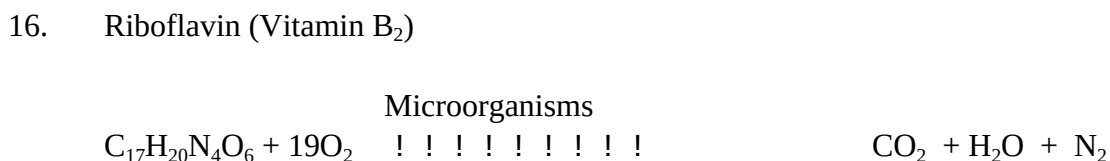
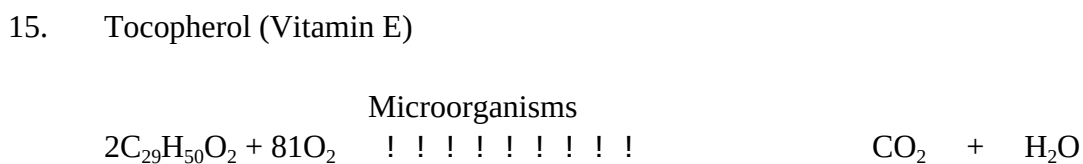
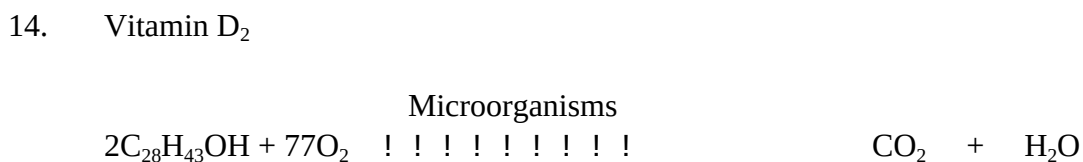
11. Vitamin A

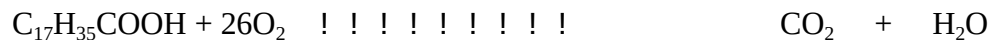




Student Sheet

BIODEGRADABLE BALANCING (cont.)

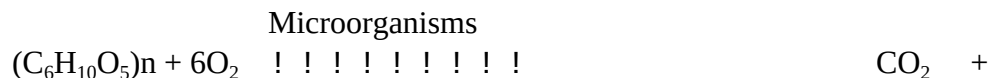




19. Ethanol (the alcohol contained in beer, wine, etc.)



20. Starch



H₂O

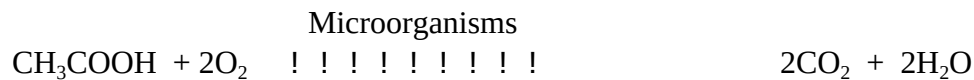
where n = 1

Teacher Sheet

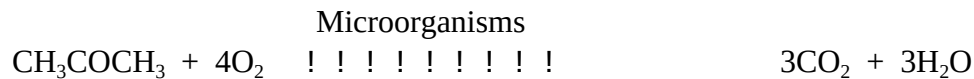
BIODEGRADABLE BALANCING

Teacher Answer Key

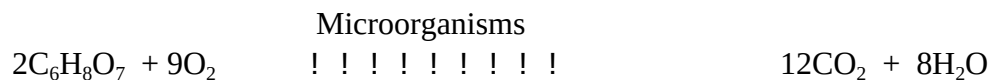
1. Acetic Acid (vinegar)



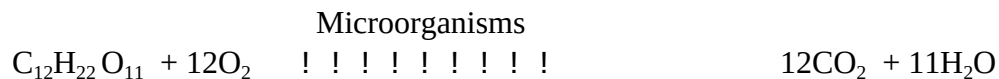
2. Acetone (nail polish remover)



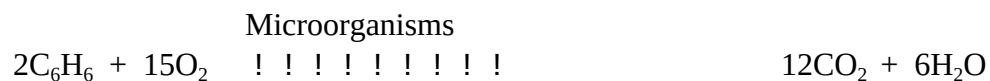
3. Citric Acid (orange juice)



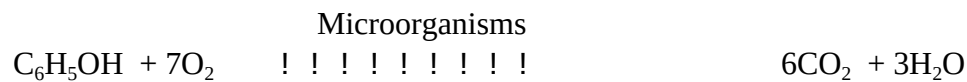
4. Sucrose (sugar)



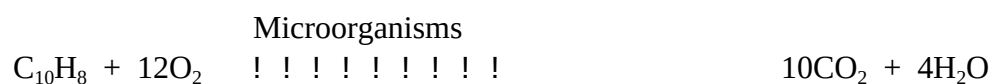
5. Benzene (a component of gasoline)



6. Phenol (present in mouthwash)



7. Naphthalene (mothballs)

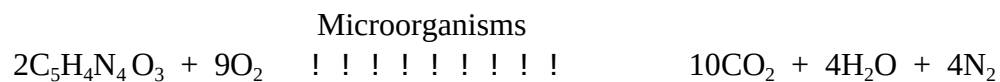


Teacher Sheet

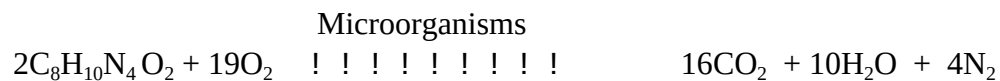
BIODEGRADABLE BALANCING (cont.)

Teacher Answer Key

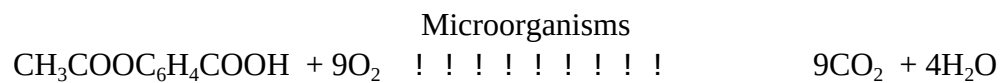
8. Uric Acid



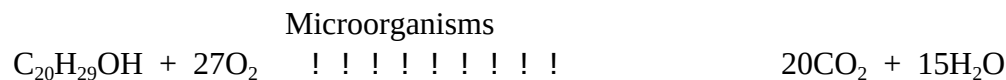
9. Caffeine



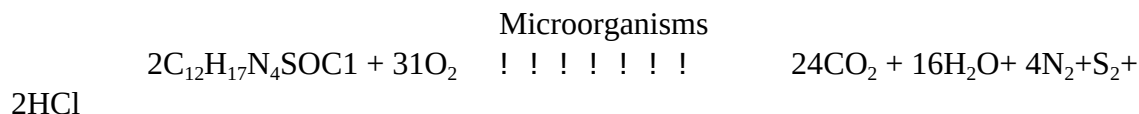
10. Acetylsalicylic Acid (aspirin)



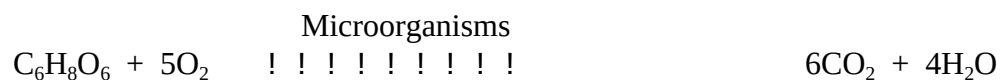
11. Vitamin A



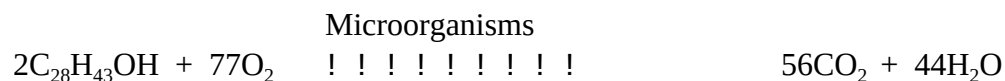
12. Vitamin B₁ (thiamine)



13. Ascorbic Acid (Vitamin C)



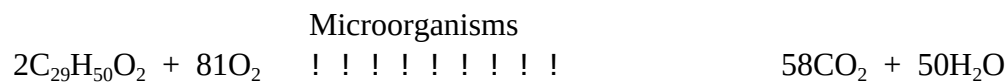
14. Vitamin D₂



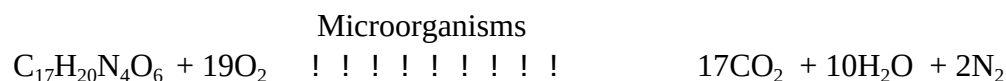
Teacher Sheet

BIODEGRADABLE BALANCING (cont.) Teacher Answer Key

15. Tocopherol (Vitamin E)

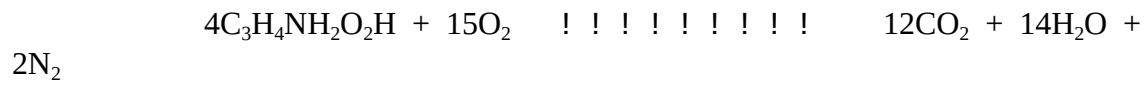


16. Riboflavin (Vitamin B₂)

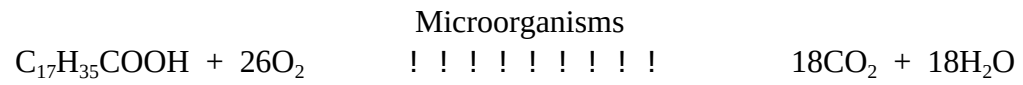


17. Alanine (a constituent of most proteins)

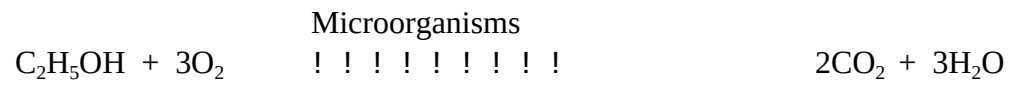
Microorganisms



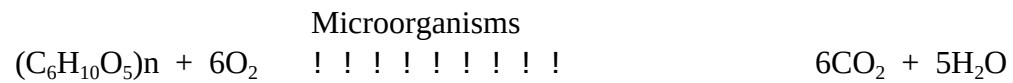
18. Stearic Acid (soap)



19. Ethanol (the alcohol contained in beer, wine, etc.)



20. Starch



where $n = 1$

MICROBES IN ACTIVATED SLUDGE

DATE: _____

TIME: _____ AM
PM

BY: _____

SAMPLE LOCATION: _____

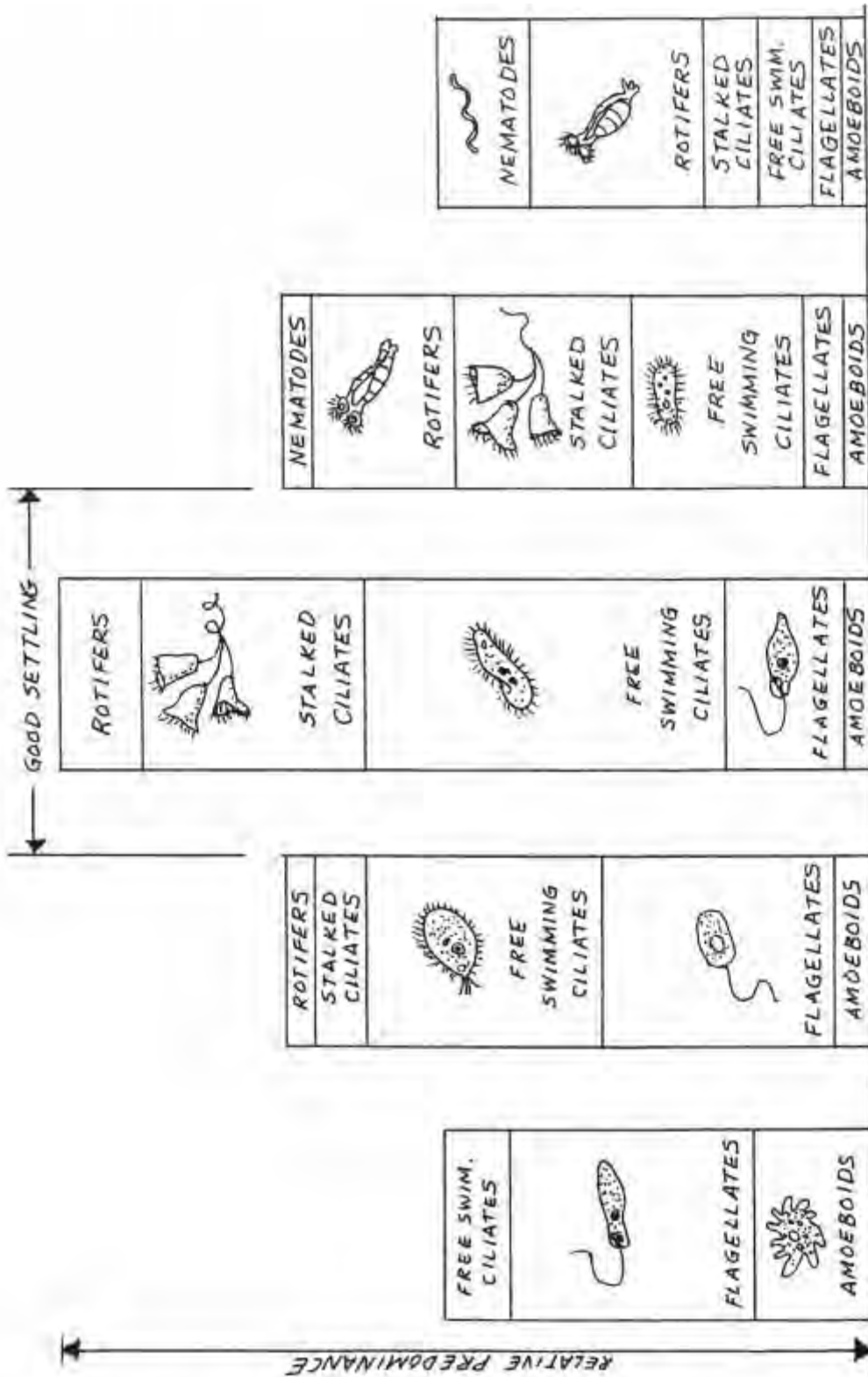
MICROBE GROUP	SLIDE 1	SLIDE 2	SLIDE 3	TOTAL
AMOEBOIDS 				
FLAGELLATES 				
FREE SWIMMING CILIATES 				
STALKED CILIATES 				
ROTIFERS 				
NEMATODES (ROUND WORMS) 				

RELATIVE PREDOMINANCE:

1. _____

2. _____

3. _____



¹²HOME RECYCLING OF GRAYWATER

OBJECTIVES

The student will do the following:

1. Design a home that recycles graywater.
2. Compute the cost effectiveness of reusing graywater.

BACKGROUND INFORMATION

Home watering of plants and gardens accounts for 65 percent of domestic water use in the southwestern states. Only 35% is actually used inside the home. Of this amount, after the usage, approximately 60 percent ends up as graywater (water not in contact with sewage). A family of three can irrigate 100 square feet of lawn with two inches of graywater a week and not use fresh drinking water.

Sources of graywater are: wastewater from sinks, bathtubs, showers, and the clothes washer (though washer water may be pathogen-containing “blackwater” if laundry includes diapers). Graywater does not come from toilets, but may be used to supply toilets.

Most existing homes would be difficult (but not impossible) to retrofit for graywater reuse, but new homes could be designed to use graywater on the lawn, flowers, or a garden.

Terms

blackwater: domestic wastewater containing human or animal waste or other sources of pathogens

graywater: wastewater from households which does not come into contact with sewage

SUBJECTS:

Science (Physics, Physical Science), Social Studies (Economics)

TIME:

2 class periods

MATERIALS:

large sheets of paper
drafting pencils
calculators
student sheets
water bills for 1 year
resource materials on
basic plumbing

sewage: waste and wastewater produced by residential, commercial, and light industrial establishments; typically discharged into sewers and sometimes, into septic tanks

ADVANCE PREPARATION

- A. Copy Student Sheets
- B. Discuss Background Information with students.

PROCEDURE

- I. Setting the stage
 - A. Hand out Student Sheet: Graywater Guidelines.
 - B. Discuss problems those guidelines may cause in designing a system for home recycling of graywater.
- II. Activity
 - A. As a design project, divide the class into teams and have each team design an approach it would follow if building a new home with the intent to reuse all sources of graywater mentioned in the Background Information section. Include necessary collection, piping, and distribution of the water in the design plan, keeping in mind that long term storage of the water would not be desirable, oversaturation of a given use area must be avoided, materials of construction must be considered, nuisance conditions must not be created, and year-round disposal must be accommodated. Cost of the system should be estimated.
 - B. Students should determine the cost of watering lawns, house plants, and gardens at their homes before designing the graywater system. (The 65 percent figure could be used to do this, or a difference in July and January water bills could also add some insight.) If sewage treatment is also a cost to the residence, then the student should figure a 60 percent reduction in cost if the graywater is totally recycled or a percent of that if the design recycles less than 100

percent of the water. A total savings cost for one year by reusing graywater should be computed. How long will it take to pay for the cost of construction of a graywater reuse home?

Real cost-benefit analysis would consider how much money would be made assuming a certain % rate that the construction money would earn if invested instead and subtracting this figure to get the real benefit. Example of project cost \$1,000, and earned \$100 per year in water costs - pay back would not be 10 years. If we assumed a 6% interest rate, the benefit would be \$100-(\$60 lost interest) or only \$40 per year. Thus it would take 25 years to pay for the project.

III. Follow-up

- A. Have student groups present their graywater recycling home plan to class.
 - 1. How did they solve the problem of graywater storage, pumping, and overabundance?
 - 2. Did they consider the winter months?
 - 3. What was each student's total cost savings in a year if his/her residence had the system designed for graywater use?
- B. Give students copy of Student Sheet: A Graywater System. How do they think their design compared to this one?
- C. Have students figure the average amount of water used each time someone showers or takes a tub bath, runs a dishwasher or washing machine, brushes teeth or washes hands. Figure this amount used for one week. Compare to how much of this amount would be needed for watering lawns, and flowers. (Make sure the design has the capability of sending water through the usual municipal water system when graywater is not needed so extensively - as in winter, long periods of rain, etc.)

IV. Extensions

- A. Have a wastewater engineer speak to the class about graywater use.
- B. Visit a residence or business that recycles graywater. Before the trip, have students make a list of questions about cost savings and problems to ask the owners.

RESOURCES

Kourik, R., Hill, A., Gray Water Use in the Landscape: How to Use Gray Water to Save Your Landscape During Droughts, Metamorphic Press, P. O. Box 1841, Santa Rosa, CA 95402, ed. 1988.

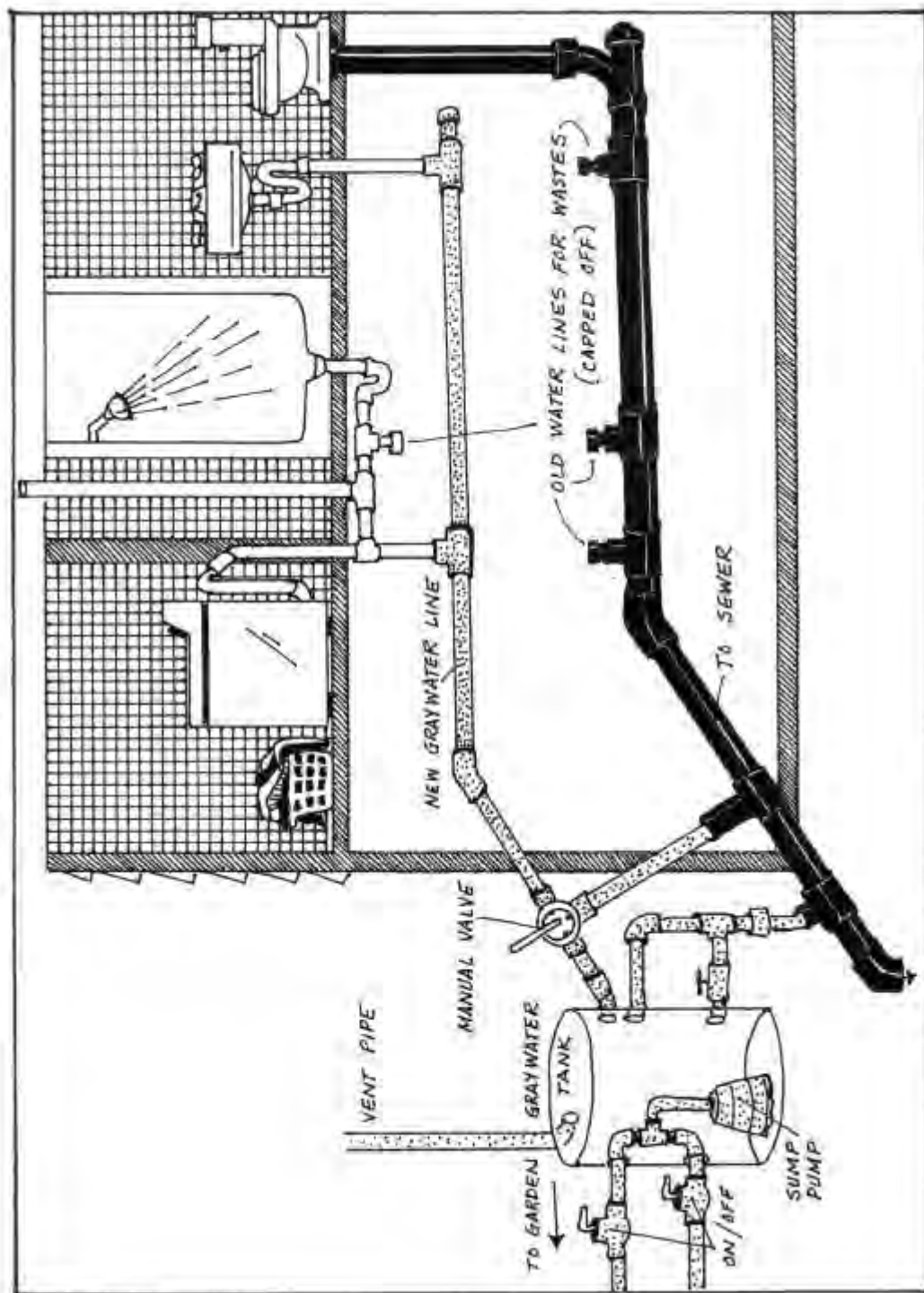
“Recycle Grey Water for Home Irrigation,” Water and Wastes Engineering, September 1979, pp. 62-66.

Student Sheet

GRAYWATER GUIDELINES

1. Use graywater promptly so that it doesn't accumulate in the storage tank.
2. Apply graywater below the soil surface, never with a sprinkler.
3. Plumb your graywater system with a valve to allow convenient switching back to the sewer or septic tank.
4. Avoid using graywater on acid-loving plants such as blueberry, heather, spruce, pin oak, crape myrtle, lily-of-the-valley, holly, mountain ash, and hemlock.
5. Use liquid detergents instead of powdered kinds because they have much less sodium. Avoid bleach and products that contain boron.
6. If you live where rainfall averages less than 12 inches a year, soak graywater-irrigated soil with six or more inches of clean water every three to five years to wash away accumulated solids.

A GRAYWATER SYSTEM



DO SEPTIC TANKS DO THE JOB?

OBJECTIVES

The student will do the following:

1. Investigate a septic tank system and tell the functions of its two major components.
2. Explain how inefficient septic systems can cause contamination of surface waters located nearby.
3. Culture bacteria and practice sterile techniques in the lab.
4. Learn about percolation tests and percometers.

SUBJECTS:

Science (Biology, Ecology)

TIME:

3 days

MATERIALS:

student sheet - article
student sheet - septic tank system
Fecal Coliform Testing Kit
water samples in bottles copies of
background information
plastic, sterile, disposable petri
dishes
disposable gloves
alcohol for clean up

BACKGROUND INFORMATION

Almost 30 percent of the U.S. population dispose their sewage and wastewater through an on-site disposal system. Some 85 percent of the on-site disposal systems in the U.S. are septic tanks.

A septic tank system contains two major components: a holding tank (the septic tank itself) and the absorption field. See Student Sheet #1. The septic tank separates the solids from the liquids. The solids settle at the bottom of the tank. There is also a scum that collects on top of the water. Both of these will remain in the tank and must be pumped out periodically.

The wastewater is passed on to the absorption field through a connecting pipe. This field is also known as the soil drain field or the nitrification field. It consists of underground perforated pipes that commonly are in a closed loop system.

As the effluent flows through these perforated pipes, human waste (containing fecal coliform bacteria) is filtered out as it passes through the unsaturated soil, percolating downward to the groundwater. To avoid contamination, rural houses with both septic tanks and a private well typically must not have their well within 100 feet of the tank, and well casings must be sealed. This is intended to prevent the

well water from being contaminated with fecal coliform bacteria and other harmful microorganisms from the septic system.

People with dwellings along lakes and rivers who have septic systems for their sewer and wastewater disposal must locate the absorption fields and pipelines no closer to the stream or lake than 50 feet, thus providing adequate filtration to remove microorganisms. However, if the ground is too wet or if the soil is too sandy, the distance may not be adequate; microorganisms may filter through to the lake or stream. Because this would contaminate lake or river waters, beaches in both public and private recreational areas should be closely monitored.

Prior to septic tank installation, percolation tests are run to determine how well the absorption field will work, and how quickly wastewater will move through it. A percometer is used to measure the infiltration rate of water through the soils where the septic tank is to be installed.

Terms

absorption field (drainfield): area where effluent from a septic tank is discharged

fecal coliform bacteria: a type of coliform bacteria found in the intestines of humans and warm-blooded animals that aids in the digestion process and is used as an indicator of fecal contamination and/or possible presence of pathogens

percolation: the downward movement through the subsurface soil layers to groundwater

percometer: an instrument to measure the rate of percolation

septic system: on-site equipment or system to treat wastewater, consisting of a septic tank and an absorption field

septic tank: a tank, commonly buried, to which all of the wastewaters from the home should flow and in which, primary digestion of the organic matter occurs by anaerobic bacteria; the main part of a septic system where scum and solids accumulate; derived from sepsis-meaning putrid decay or decay without oxygen.

ADVANCE PREPARATION

- A. Order a Fecal Coliform Testing Kit.
- B. Find sources of water (streams or lakes) that are close to homes using septic tank systems.

- C. Have the students collect bottles of water from the designated areas. Be certain that the water is collected in clean bottles, and that it is then stored in the refrigerator until used as the source of bacteria-containing water. They should also collect some water from close to the shoreline but upstream from the possible contamination. This will let them know if the lake or stream already had a fecal coliform population independent of the suspected source.
- D. Be certain that the students know the sterile procedures to be used when culturing bacteria.

PROCEDURE

- I. Setting the stage
 - A. Explain the following to students.
 - 1. Beaches may be closed if fecal coliform bacteria in sufficient numbers are found there.
 - 2. A high fecal coliform count indicates that the water had been contaminated by human or animal wastes.
 - 3. Basins of native plants may filter out the bacteria.
 - 4. A high fecal coliform count may indicate human or other animal wastes. However, there is no reliable means known to determine the source of fecal coliform bacteria.
 - 5. It would be safer, cheaper, and less trouble never to let the bacteria reach a high level in the stream or lake to begin with.
 - B. Explain to the students that whenever bacteria are cultured, there are sterile procedures that must be followed.
 - 1. Work surfaces should always be washed down with a dilute bleach solution.
 - 2. Hands should always be washed before and after working with the bacteria, and gloves should be worn during testing.
 - 3. A minimum amount of talking and movement should be permitted in the room. No dust should be stirred up by talking or movement.

4. Petri dishes should be opened only when the agar or gel is to be poured and when the gel is swabbed with the water from the lake or stream.
 5. The top of the petri dish should never be placed face-down on the counter.
- C. Learn how to grow the indicator fecal coliform bacteria. Follow the instructions in the kit.

II. Activity

- A. Explain to the students that inadequate septic tank systems along a stream or lake shoreline can contaminate the water with bacteria.
- B. Ask for volunteers to bring in bottles of water from designated areas to be tested for fecal coliform bacteria.
- C. Inoculate the gels with the water from the designated areas.
- D. Incubate the cultures for the specified time; then look for fecal coliform growth on the gels.
- E. Determine if the fecal coliform count reaches the action level. For swimming there should be no more than 200 fecal coliform/100 ml of water.

III. Follow-up

- A. If the fecal coliform level is not within the safety level, inform the proper authorities.
- B. Have the students label a diagram of a septic system and explain the functions of the two parts of the system. Tell them to write the functions under the labeled picture.

IV. Extensions

- A. Collect a bottle of water from the water around the boats in a marina. Test this water for fecal coliform bacteria.
- B. If any students have a septic system, have them bring in water samples from any wells or streams nearby (if applicable) for fecal coliform testing.

RESOURCES

National Small Flows Clearinghouse, West Virginia University, Morgantown, WV 26506-6064, 800-624-8301.

Refer to an article in the Los Angeles Times about beaches closed with health warnings.

Headline: Southland Leads U.S. in Beach Closings, Warnings.

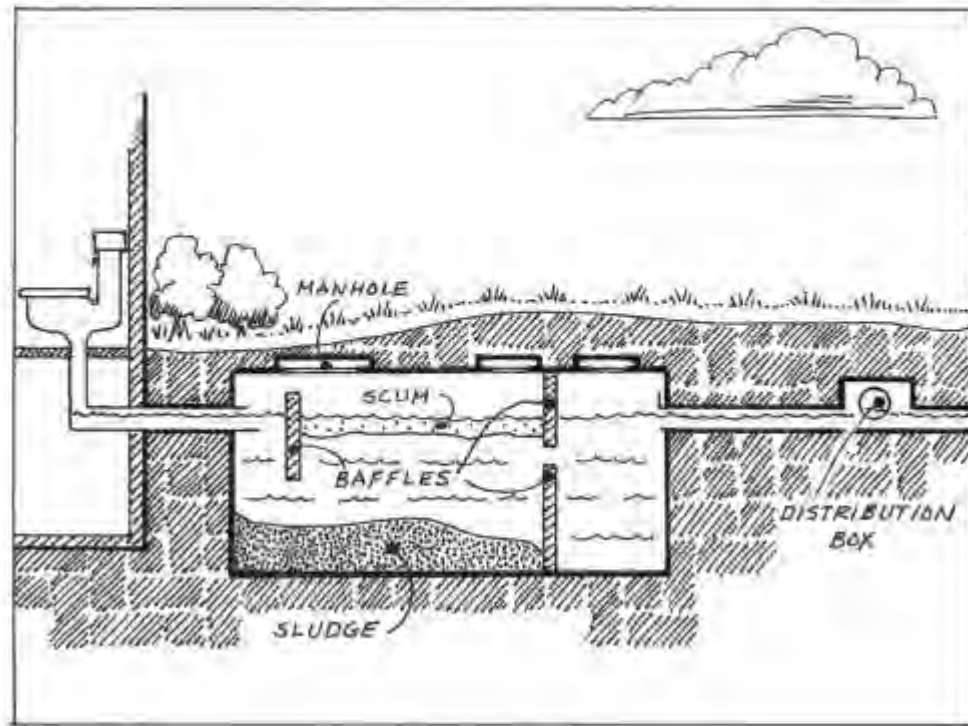
Date: August 4, 1994, **Page:** A-3, **Edition:** Orange County Edition

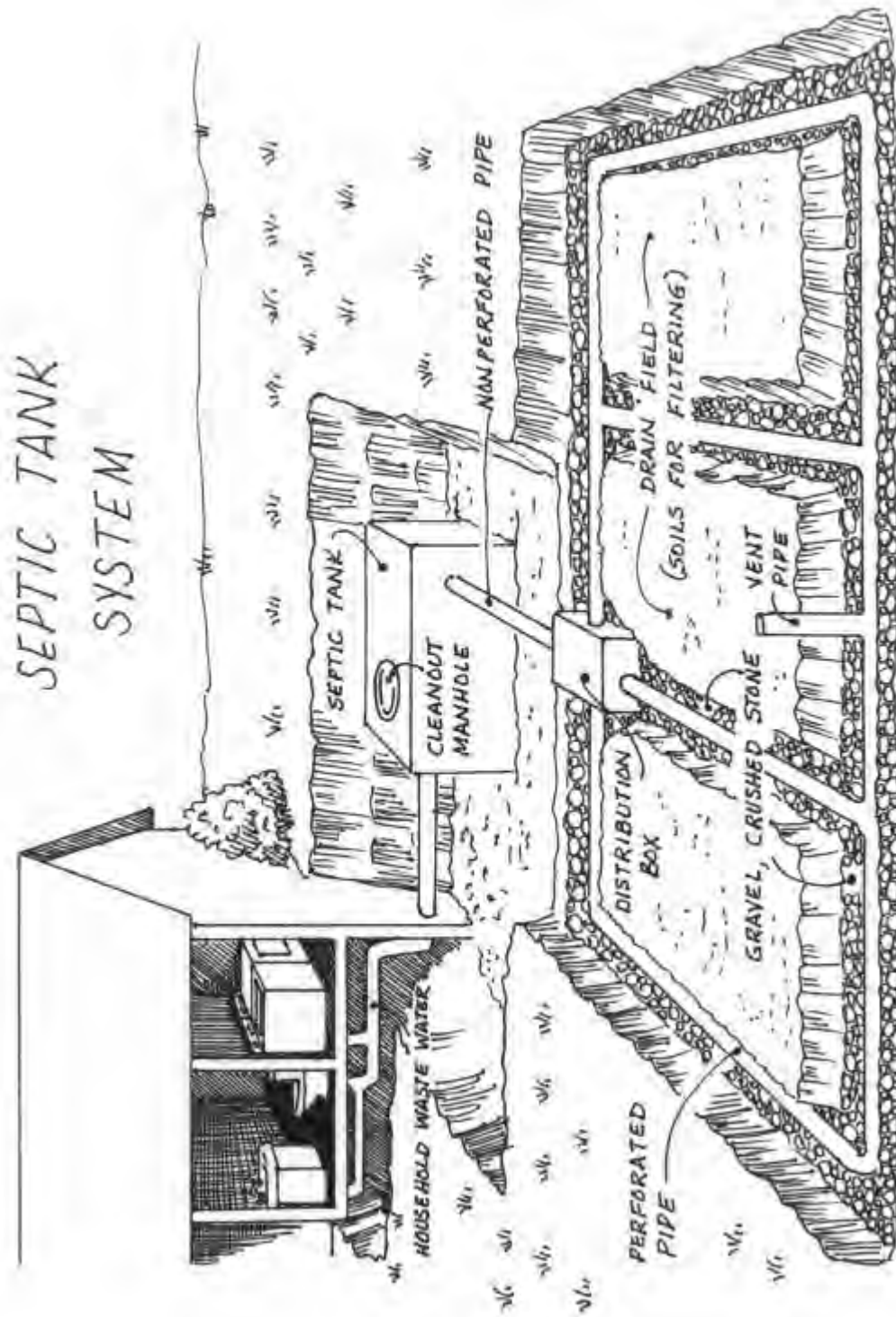
Author: Marla Cone, Times Environmental Writer

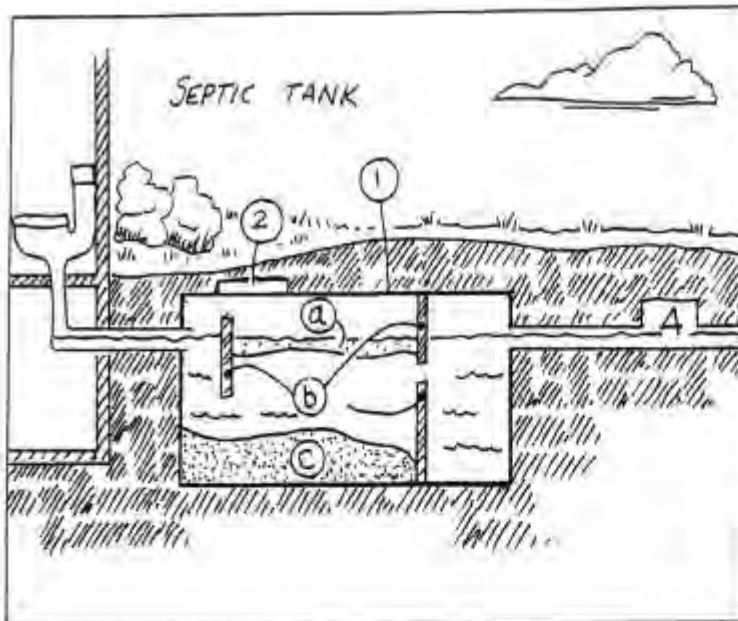
Vesilind, Peirce, and Weiner, Environmental Pollution and Control, 3rd Edition, Butterworth-Heinemann, 1990.

Water Analysis Kit, page F-69, Water Testing Fact Sheet

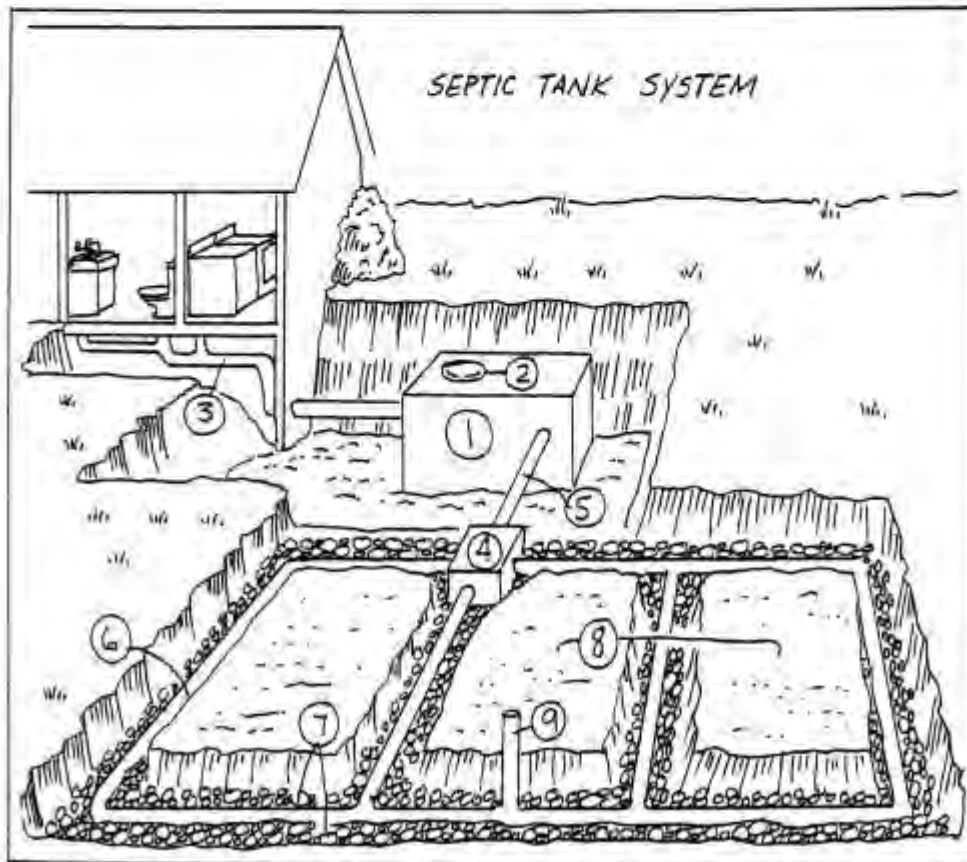
SEPTIC TANK



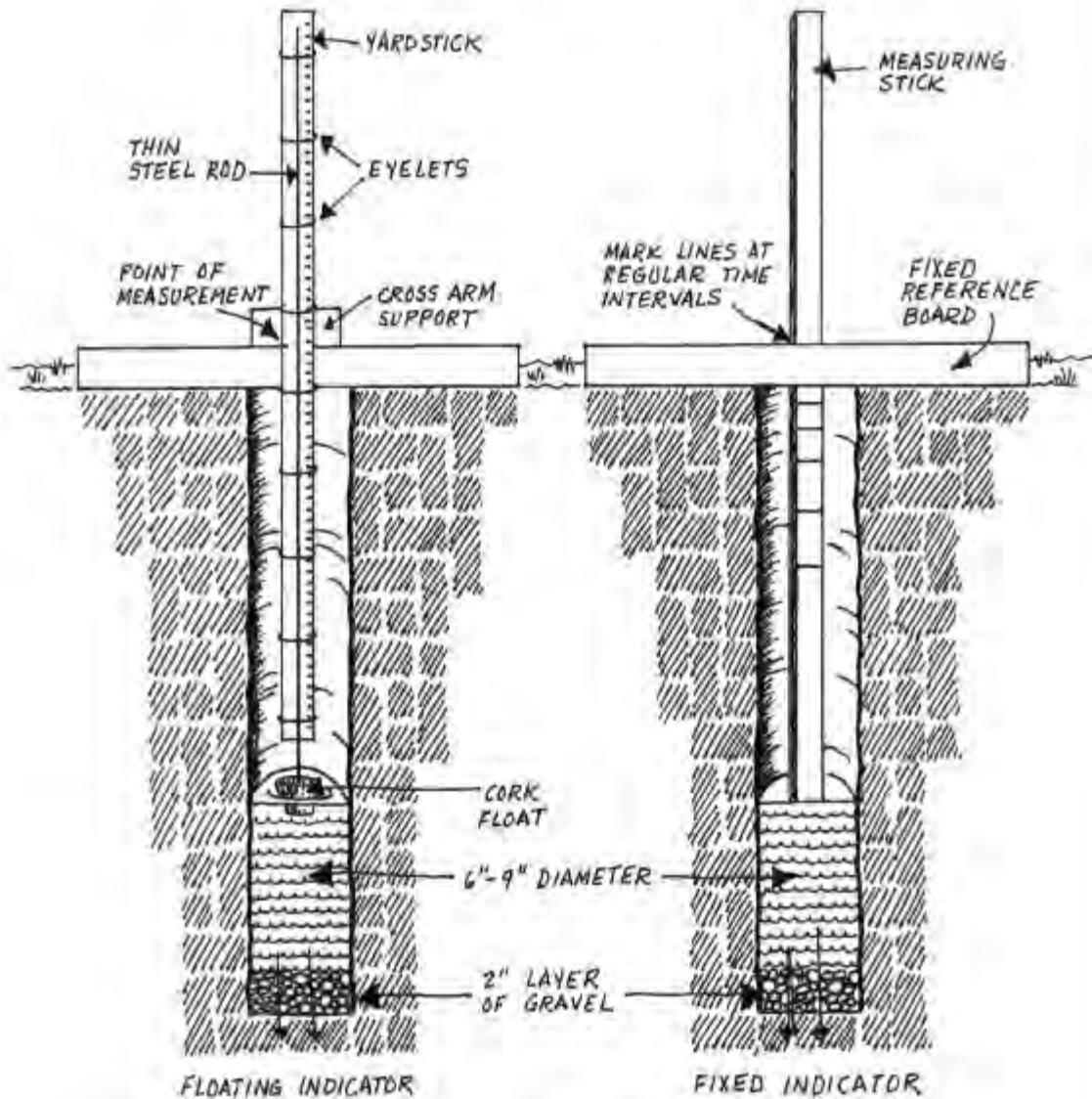




1. _____
- a. _____
- b. _____
- c. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____

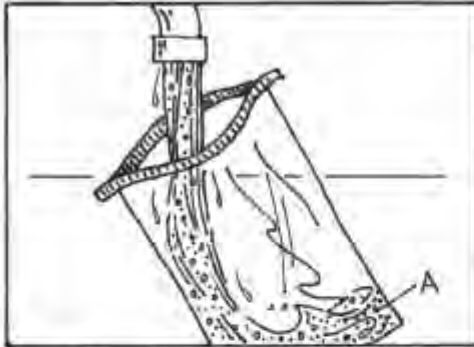


PERCOMETERS



PREPARE HOLE AND PERCOMETER. FILL HOLE WITH WATER. MEASURE TO DETERMINE RATE AT WHICH WATER PERCOLATES OUT OF THE HOLE AS IT SEEPS THROUGH SOILS.

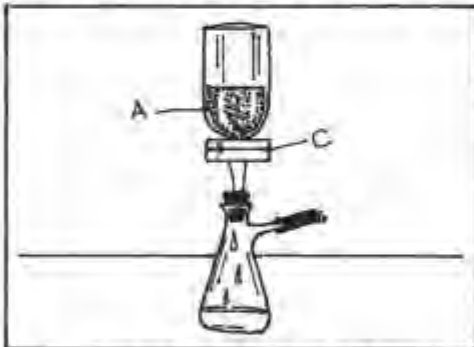
MEMBRANE FILTRATION TEST FOR BACTERIAL CONTAMINATION OF WATER



COLLECT SAMPLE (A).
DILUTE, IF NECESSARY, WITH WATER.



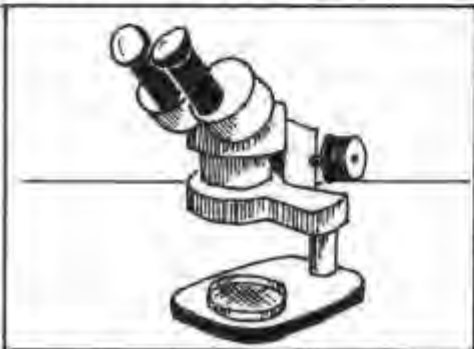
MIX MEDIUM (B).
ADD MEDIUM TO PETRI DISH.



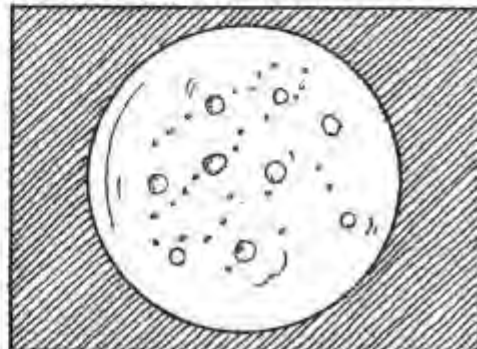
VACUUM-FILTER SAMPLE (A) THROUGH
MEMBRANE FILTER (C). RINSE FILTER.



INCUBATE FILTER (C) ON MEDIUM (B)
IN PETRI DISH AS INSTRUCTED.



COUNT TYPICAL COLONIES AT
10-15X MAGNIFICATION.



(OR) CONFIRM COLONIES AND REPORT
THE RESULTS.

LAND APPLICATION OF WASTEWATER SOLIDS

9-12

OBJECTIVES

The student will do the following:

1. Distinguish between raw/untreated and digested wastewater solids.
2. Determine if land application of wastewater solids is beneficial to increased plant productivity.
3. Describe problems with land application.

SUBJECTS:

Science (Biology, Ecology, Earth Science)

TIME:

Varies

MATERIALS:

different types of wastewater solids
(as available)
bedding trays (approx. 10"x17")
local soil
fescue (grass) seed

BACKGROUND INFORMATION

Wastewater treatment processes generate several treatment by-products, some useful and some that must be landfilled or disposed of properly.

The recycling of wastewater solids (biosolids) by land application is becoming a widespread practice. Populated states are exporting municipal biosolids to less populated, agrarian states for incorporation into soil, usually on agricultural or pasture land.

At a municipal wastewater plant, collected solids originate from two main sources: the primary clarifier that removes easily settled solids and grit, and the secondary clarifier that removes biological microorganisms.

Solids from both sources generally are then directed to further treatment or to a "digestion" process that may be anaerobic or aerobic, depending on the treatment plant. From the digesters, the solid material is usually dewatered using either sand drying beds, a mechanical dewatering process, or other method for water removal. The finished product is then stabilized and ready for recycling or disposal.

Depending on the level of pathogen treatment reduction achieved: some cities and towns offer or sell composted wastewater solids to the public for yard and landscaping use, and some apply the solids on large tracts of land with site restrictions (e.g., public access).

Land application of wastewater solids may be accomplished in several ways: in liquid form on the ground surface, in liquid form by subsurface injection, or in spraying from fixed or portable irrigation nozzles. It also may be applied dry from a spreader vehicle followed by disk cultivation into soil.

Before wastewater solids can be recycled, they must comply with federal regulations governing quality and composition. Some states also require compliance with state, as well as federal regulations. Federal regulations require strict attention to pollutant limits, as well as the management and operational standards that safeguard health and the environment.

Crops preferred for land application are non-food chains such as cotton, grass, flower bed, or grain. Crops grown for animal feed or human consumption are regulated by strict federal regulations.

The nutrient “fertilizer” value of wastewater solids is not as high as chemical fertilizers. However, because of its high organic content (microorganisms) and low cost, biosolids have value as a soil amendment as well as a fertilizer. Primarily they improve soil moisture retention and are good for topsoil replacement. In this respect, they are much better than chemical fertilizers.

With growing populations, tighter management requirements, and higher wastewater treatment levels, wastewater solids production will only increase. It is important that ecologically sound, uniform, and practical management practices be used.

Terms

aerobic: with oxygen; needing oxygen for cellular respiration

anaerobic: in the absence of oxygen; able to live and grow where there is no air or free oxygen, as certain bacteria

biosolids: sludge that is intended for beneficial use. Biosolids must meet certain government-specified criteria depending on its use (e.g., fertilizer or soil amendment).

clarifier (settling tank or sedimentation tank): a vessel in which solids settle out of water by gravity during drinking water or wastewater treatment processes

digested solids: sewage solids that have been broken down by microorganisms

raw/untreated solids: settleable solids, grit, and other solid material removed by the primary clarifier (not treated by microorganisms)

ADVANCE PREPARATION

- A. Obtain a water analysis kit that tests for minerals and nutrients. (See page F-69, Water Testing Fact Sheet).
- B. Visit the local wastewater treatment plant and/or purchase from garden shops samples of well stabilized, digested wastewater solids. (**CAUTION: DO NOT** collect raw, partial, or undigested biosolids) Examples are:
 - 1. well digested solids that have been dried on sand beds.
 - 2. composted solids.
 - 3. lime treated solids (dewatered).
 - 4. chemically treated solids (dewatered from water or wastewater treatment plants).
- C. Copy the Student Sheet. Copy the Teacher Sheet.

PROCEDURE

- I. Setting the stage
 - A. Go over Background Information and terms with students.
 - B. Divide students into work groups to test the different solids and monitor fescue growth.
- II. Activity

The purpose of this activity is to test for germination and growth rate of a grass (fescue) from seed in various well-stabilized dry solids.

- A. Use the water analysis kit to test the different types of solids for the presence of these minerals and nutrients, nitrates (NO_3^-) or total nitrogen (N), phosphorus (P), potassium (K), silica (SiO_2), iron (Fe (I)), and for pH. If a test kit is not available, allow students to use the Teacher Sheet information to complete the data table.
- B. Use bedding trays (approx. 10" x 17") as needed for types of solids available.
 - 1. Make one tray (control) using local 100% soil.

2. Mix equal volumes of soil/solids in each tray. (Use protective wear and mix with garden tools.)
3. Plant equal amount of seeds in each tray, covering seed as specified by seed manufacturer.
4. Water routinely and monitor the day to germination time and follow growth rate for 4-6 weeks.

Note: If different types of solids are limited, do the experiment with various ratios of soil to solids along with the control.

III. Extensions

For centuries, the Chinese have returned their domestic wastewater and household wastes to the soil. What can the United States learn from this practice? How does the Chinese practice compare from an environmental perspective to U.S. practices of sludge incineration, ocean disposal, landfill disposal, and/or shipping to other states or countries for disposal?

RESOURCES

Davis, Barbara, Science in Motion - Chemistry, University of Alabama, Tuscaloosa, AL

Hairston, James E., Water Quality and Pollution Control Handbook, Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36849-5612.

Metcalf and Eddy, Wastewater Engineering: Collection, Treatment, Disposal, McGraw Hill Inc., New York, NY, 1972, pp. 585-586, 627-628.

Viessman, Warren Jr. and Mark J. Hammer, Water Supply and Pollution Control, Harper Collins Publishers, New York, NY, 1985. pp. 645-647.

Water Analysis Kit, page F-69, Water Testing Fact Sheet

WHAT'S LEFT OVER

Minerals Tested For in Wastewater Solids	Mineral Present (yes/no)	Its Usefulness or Not (Explain Why)
Nitrate/Total Nitrogen		
Phosphorus		
Potassium (potash)		
Iron		
Silica		

pH = _____

1. Identify the useful materials present in the biosolids and discuss their uses.
2. What are some by-products of wastewater treatment that may not be useful as fertilizers?
3. What are some by-products of wastewater treatment that may not be useful as soil amendment ingredients?

TYPICAL PHYSICAL AND CHEMICAL COMPOSITION OF RAW AND DIGESTED WASTEWATER SOLIDS

Item	Raw/untreated solids		Digested solids	
	Range	Typical	Range	Typical
Total dry solids (TS), %	2.0-7.0	4.0	6.0-12.0	10.0
Volatile solids (% of TS)	60 - 80	65	30 - 60	40.0
Grease and fats (Ether soluble, % of TS)	6.0-30.0		5.0-20.0	
Protein (% of TS)	20-30	25	15-20	18
Nitrogen (N, % of TS)	1.5-4.0	2.5	1.6-6.0	3.0
Phosphorus (P_2O_5 , % of TS)	0.8-2.8	1.6	1.5-4.0	2.5
Potash (K_2O , % of TS)	0-1.0	0.4	0.0-3.0	1.0
Cellulose (% of TS)	8.0-15.0	10.0	8.0-15.0	10.0
Iron (not as sulfide)	2.0-4.0	2.5	3.0-8.0	4.0
Silica (SiO_2 , % of TS)	15.0-20.0		10.0-20.0	
pH	5.0-8.0	6.0	6.5-7.5	7.0
Alkalinity (mg/liter as $CaCO_3$)	500-1,500	600	2,500-3,500	3,000
Organic acids (mg/liter as Hac)	200-2,000	500	100-600	200
Thermal content (Btu/lb)	6,800-10,000	7,600*	2,700-6,800	4,000†

* Based on 65 percent volatile matter.

†Based on 40 percent volatile matter.

STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION

9-12

OBJECTIVES

The student will do the following:

1. Define storm water runoff.
2. Identify types of pollutants found in storm water.
3. Develop a plan on how to prevent the pollution of storm water at the school bus maintenance shop.
4. Develop a Best Management Practices plan for the maintenance shop.

SUBJECTS:

Science (Physical Science, Earth Science, Ecology)

TIME:

3-4 class periods

MATERIALS:

bus to travel to the school bus maintenance shop (see alternative activity)
notebook
copies of background information for each student

BACKGROUND INFORMATION

EPA has recognized that certain industries are significant polluters of storm water and has developed the storm water program to aid in reducing the pollutants being discharged into receiving streams via storm water. The main source of storm water is from rain or snow. Water travels from streets, parking lots, and building roofs to storm drains that discharge to nearby waterbodies. Communities are mainly responsible for maintaining or managing storm sewers. One way to manage storm runoff is to locate and permit each sewer and to develop a program to oversee and sample these regularly.

The focus of the storm water program is pollution prevention. Federal and state regulations require facilities to develop a pollution prevention plan or a Best Management Practices (BMP) plan. The BMP plan should be designed to reduce pollution at the source before it can cause environmental problems. The BMP plan is like a good housekeeping plan.

BMPs can include schedules of activities, prohibition of practices, maintenance procedures, and management practices to reduce or prevent the pollution of runoff from a site.

There are 5 major phases involved in developing a BMP plan for storm water runoff.

1. Planning & Organization

- a. Name a pollution prevention team.
- b. Review other BMP plans and build on other plans available such as a Spill Prevention Control and Countermeasures (SPCC) plan. The SPCC plan is a plan to help keep petroleum-related products from being discharged into the water.

2. Assessment

- a. Develop a site map.
- b. Inventory and describe exposed materials.
- c. List significant spills and leaks.
- d. Test for non-storm water discharges.
- e. Evaluate monitoring data.
- f. Summarize pollutant sources and risks.

3. BMP Identification Phase

- a. Baseline BMPs
 - 1. Good Housekeeping
 - 2. Preventive Maintenance
 - 3. Visual Inspections
 - 4. Spill Prevention and Response
 - 5. Sediment and Erosion Prevention
 - 6. Traditional Storm Water Management Practices (storm water detention ponds, collection of storm water)

- 7. Other appropriate BMPs
 - 8. Employee Training
- b. Select activity and site-specific BMPs
- 4. Implementation Phase
 - a. Implement BMPs.
 - b. Train employees.
- 5. Evaluation Monitoring
 - a. Conduct annual site inspection/BMP evaluation.
 - b. Conduct record keeping and reporting.
 - c. Review and revise plan.

Terms

best management practices (BMPs): techniques that are determined to be currently effective, practical means of preventing or reducing pollutants from point or nonpoint sources, in order to protect water quality. BMPs include, but are not limited to: structural and nonstructural controls, operation and maintenance procedures, and other practices. Usually, BMPs are applied as a system of practices rather than as a single practice.

pollutant (water): any substance suspended or dissolved in water which builds up in sufficient quantity to impair water quality

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation and increased efficiency in the use of energy, water, or other materials

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a waterbody; may pick up and carry a variety of pollutants

secondary containment for above-ground fuel storage tanks: spill containment facility that will sufficiently contain 110 percent of the capacity of the largest tank located within the area of management

waters of the state: includes every natural or artificial watercourse, stream, river, wetland, pond, lake, coastal, ground or surface water wholly or partially in the state that is not entirely confined and retained on the property of a single landowner

ADVANCE PREPARATION

- A. Reserve a school bus for the field trip.
- B. Contact the school bus maintenance shop to set up a field trip and secure cooperation in allowing students to develop a BMP plan for the shop. If the shop already has a plan, secure cooperation for the field trip to evaluate existing plan and/or revise existing plan.
- C. Copy Background Information and Student Sheets for each student.
- D. Go over terms and define.

PROCEDURE

- I. Setting the stage
 - A. Hand out Background Information and Student Sheets. Student sheets show important steps that can be taken in the community (Municipal Program) or by industries (Industrial Program) to prevent storm water pollution. Student sheets also depict common contributors to storm water pollution.
 - B. Discuss best management practices.
 - C. Lead a discussion on how storm water can increase pollution in water bodies.
 - D. Review the 5 major phases involved in developing a BMP plan.
 - E. Ask students why it would be important to name a pollution prevention coordinator or team. (Answers: 1. point of contact in an emergency and 2. clearly defines the BMP plan as a part of the coordinator/team job)
 - F. Explain that many sources of pollutants exist at automotive repair facilities. Some examples are these.
 - 1. fuel

2. engine oil and other lubricants
3. antifreeze
4. refrigerants
5. batteries
6. wash water from the washing of the interior and exterior of buses and other equipment.
7. steam cleaning fluid from the cleaning of engines and other equipment

Explain to students that when it rains at the shop and these types of pollutants come into contact with the rain water, the runoff can become polluted. Ask students about other sources of pollution that might exist at an automobile (bus) repair facility.

II. Activity

A. Take a field trip to school bus maintenance shop.

1. At the shop, identify pollution sources.
2. Is fueling conducted on site? If so, are the fuel tanks above ground or below ground? If they are above ground, do they have secondary containment?
3. Where are used batteries kept?
4. How is used oil managed?
5. Is maintenance conducted on-site?
6. How are used tires managed?
7. If oil, fuel, antifreeze, or other fluids are spilled or leaked, are they cleaned up? If so, how? (Examples: oil dry, kitty litter, sawdust)
8. What types of activities are occurring on-site that might lead to non-storm water discharges? (Examples: washing of buses and the steam cleaning of engines)

9. After identifying pollution sources, ask students to identify methods that can be used to prevent the pollution of storm water runoff at the shop.
- B. For homework, have students develop BMPs to use in developing a class BMP plan the following day.
- C. On the following day, divide students into work groups to develop a BMP plan for the shop. Combine the work into a class BMP plan.
- D. Present the class BMP plan to school bus maintenance shop.

III. Alternative activity

If a field trip is not possible, this activity can be used to show the cumulative pollution effects of storm water runoff.

- A. The materials needed are these.
 - aquarium half filled with water
 - 1 can of cola
 - 1 can of orange soda
 - 1 bag of hamburger buns
 - 1 tube of crackers
- B. Sort and distribute among the class members the “contaminants.” Make sure no one class member has very much of any single contaminant. Do not let students know that the instructor is putting the same contaminants into the second aquarium.
- C. Demonstrate the mess a single pollutant source can make by putting one contaminant into the aquarium. Have the students come one at a time and drop their “little bit” of contaminants into the first aquarium. Discuss how the resulting cumulative impacts of many small sources of pollution are often greater than single sources that are more easily regulated and controlled.
- D. Discuss why “discrete” sources (industries and wastewater treatment plants) are more easily regulated and why it is easier for these discharges to be controlled and treated.

IV. Follow-up

- A. Visit the maintenance shop in a month to evaluate the BMP plan.
 - B. Ask the shop manager to evaluate improvements in the BMP plan and to suggest revisions and/or additional improvements to the BMP plan.
- V. Extensions
- A. Develop other BMP plans for your school (chemistry class chemical disposal, erosion control on school grounds, art class paint disposal).
 - B. Have a speaker come from the city to explain the city's BMP plans for storm water management.

RESOURCES

Developing Pollution Prevention Plans and Best Management Practices Plans, EPA Guidance Document 832-R-92-006

Developing Pollution Prevention Plans and Best Management Practices Plans Summary Guidance, EPA Guidance Document 832-R-92-002

When It Rains, It Drains: What Everyone Should Know About Storm Water, EPA Guidance Document 832-F-93-002

MUNICIPAL PROGRAM

Prevent the release into the storm sewer system of hazardous substances such as used oil or household or yard chemicals.



Make sure new commercial and residential developments include storm water management controls, such as reducing areas of paved surfaces to allow storm water to seep into the ground.



Promote practices such as street sweeping, limiting use of road salt, picking up litter, and disposing of leaves and yard wastes quickly.



Collect samples of storm water from industrial sites to see whether pollutants are being released. If so, identify the type and quantity of pollutants being released.



Design and institute flood control projects in a way that does not impair water quality.

MUNICIPAL PROGRAM

Prevent runoff of excess pesticides, fertilizers, and herbicides by using them properly and efficiently. (Commercial, institutional, and residential landscapes can be designed to prevent pollution, conserve water, and look beautiful at the same time.)



Make sure that construction sites control the amount of soil that is washed off by rain into waterways.



Promote citizen participation and public group activity to increase awareness and education at all levels. Encourage local collection pick-up days and recycling of household hazardous waste materials to prevent their disposal into storm water drains.



INDUSTRIAL PROGRAM

Owners of construction sites that disturb 5 or more acres must develop a plan before beginning construction. The plan must limit that area of disturbed soil and provide controls--like sediment basins--to keep sediment from running off.



Operators of saw mills can reduce pollution by storing their materials and processing their products indoors; and removing any by-products from outdoor areas before these products come in contact with storm water runoff.



Operators of landfills should keep the storm water runoff from flowing over the pollutants and carrying them off the landfill sites.



Airport employees can reduce storm water runoff pollution by using deicing chemicals only in designated collection areas and by cleaning oil and grease spills from pavement immediately.



Chemical plant operators should develop spill prevention plans and use types of containers that do not rust or leak, eliminating exposure of materials to storm water runoff.

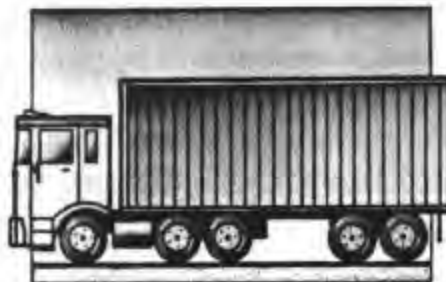


INDUSTRIAL PROGRAM

Owners of automobile junkyards should drain fluids from junked cars and properly dispose of hazardous chemicals.



Operators of trucking terminals should develop good housekeeping practices that clean up leaks and spills of oil and grease from the path of storm water runoff.



Power plant operators often store piles of coal and other fuels that have toxic components. Runoff from coal piles must be treated; other substances should be stored away from any possible contact with storm water runoff.



COMMON CONTRIBUTORS TO STORM WATER POLLUTION

Industry - At industrial sites, chemicals spills that contain toxic substances, smoke stacks that spew emissions, and uncovered or unprotected outdoor storage or waste areas can contribute pollutants to storm water runoff.



Construction - Waste from chemicals and materials used in construction can wash into our waterways during wet weather. Soil that erodes from construction sites can contribute to environmental degradation as well.



Agriculture - Pesticides, fertilizers, and herbicides used in crop production can be toxic to aquatic life and can contribute to over-enrichment of the water, causing excess algae growth, and oxygen depletion. Although storm water runoff from agriculture areas is not regulated under the EPA storm water permitting program, it is a nonpoint source of storm water pollution addressed by other EPA programs.



COMMON CONTRIBUTORS TO STORM WATER POLLUTION

Household - vehicles drip fluids (oil, grease, gasoline, antifreeze, brake fluids, etc.) onto paved areas where storm water runoff carries them through our storm drains and into our waterways.



Household - Chemicals used to grow and maintain beautiful lawns and gardens, if not used properly, can run off into the storm drains when it rains or when we water our lawns and gardens.



Household - Pet wastes left on the ground get carried away by storm water, contributing harmful bacteria, parasites, and viruses to our waterways.



BIOGRAPHY OF A RIVER

OBJECTIVES

The student will do the following:

1. Compare and contrast facts about the development, history, and importance of several rivers in the state.
2. Thoroughly research the history and development of one particular river.
3. Describe deltas and their formation.

SUBJECTS:

Language Arts, Science (Physical Science, Earth Science), Social Studies (History, Economics, Geography)

TIME:

1-2 class periods plus research time

MATERIALS:

school or local library

BACKGROUND INFORMATION

Rivers have played a vital role in the development of this country and others; this importance is reflected in the references to rivers in literature and history, both national and personal. Today rivers need protection, and one way to fuel an interest in preserving a river is to have students become familiar with their local rivers so that they feel an ownership to them. Writing a biography of a river is one way for students to combine research, interview skills, creative writing, history, and science into a single project. Keep this project fun and allow for creativity; however, set limits on what material is acceptable. If the writing is based on factual information, the project will be more realistic. If there are not enough rivers or waterways within the state, use neighboring rivers or famous rivers.

Terms

cinquain: a poem of five lines as follows:

First line	One word, giving title
Second line	Two words, describing title
Third line	Three words, expressing an action
Fourth line	Four words, expressing a feeling
Fifth line	One word, a synonym for the title

epitaph: a short composition in prose or verse, written as a tribute to a dead person

ADVANCE PREPARATION

Obtain a list of state rivers and waterways. A student could complete this list for extra credit.

PROCEDURE

I. Setting the stage

A. Begin a general discussion of familiar rivers. Ask:

1. What are the rivers in our state?
2. Who has ever seen/visited any of the rivers?
3. What did you do there?
4. Have any of your grandparents or parents told family stories about experiences on the rivers of this state?
5. Who has knowledge of other rivers in the U. S.?
6. How did rivers help in the development of this country?
7. In what ways are rivers important?

B. Explain that important people have biographies written about them. That is what students are going to do for the rivers of the state.

II. Activity

A. Assign each student (or pair, small group) a major river/waterway located within the state.

B. The river biography should include the following:

1. Birth information: This includes how the river was formed geologically, approximate time period, original course.
2. Location and description: Include a drawn or copied map of the river noting the major cities and describe the land uses along its route, its aquatic life, and

other characteristics.

3. Century report: Beginning with 1700 through the present, write a report to include:
 - a. Historical events related to or occurring near the river.
 - b. Important people related to the river or locations near the river.
 - c. Contributions/uses of the river (industry, transportation, recreation, security, agriculture)
 - d. Changes to the river and surrounding area.
4. Personal interviews: If possible, interview two people who have had personal experiences with the river. Write about their thoughts, remembrances, experiences, and other information about the river and its importance or role in their lives.
5. Death announcement: Research what could cause the “death” (no longer exists or no longer supports life) of the river. Write a fictional account of the events leading up to the death and the consequences of this death for the state.
6. Epitaph: Write an epitaph for the river in the form of a cinquain.

C. Place all the information in a folder or report and illustrate the cover.

III. Follow-up

- A. Ask each student or small group to give a five-minute presentation about his/her river sharing the most significant facts and pointing out its location on a state map.
- B. Have students be responsible for reading the biographies of at least two other rivers and write a comparison paper comparing their river with these two.
- C. Research what makes a National Scenic River.

IV. Extensions

- A. Research the role of rivers in cultural stories and myths.

- B. Read descriptions of rivers in literature such as in Huckleberry Finn, the writings of J. Wesley Powell, the River Styx, and Cleopatra and the Nile. Compare these rivers with local rivers.
- C. Have students research any songs written about their rivers or compose one themselves.

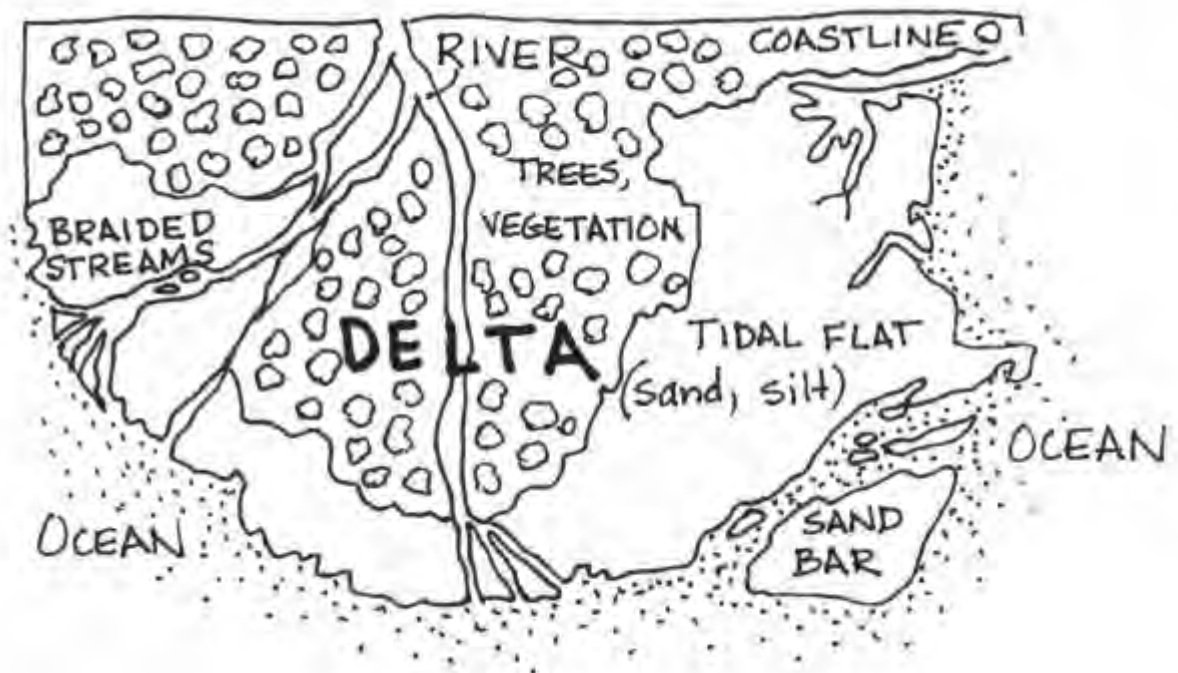
RESOURCES

Carrier, Jim, "The Colorado - A River Drained Dry ," National Geographic, Washington, D. C., June, 1991.

Ellis, William, "The Mississippi: River Under Siege ," National Geographic, Washington, D. C., November, 1993.

Jackson III, Harvey H., "Rivers of History, Life on the Coosa, Tallapoosa, Cahaba, and Alabama," University of Alabama Press, 1995.

Yates, Steve, Adopting a Stream - A Northwest Handbook, The Adopt-A-Stream Foundation, 1988.



THE DELTA

BACKGROUND INFORMATION

The sketch below shows a view of a coastal feature that is seldom seen from this angle. This is an aerial “shot” of a delta. If you were to see it from ground level, you would not be able to describe the shape unless you walked around the edges as well as across it.

This delta is built up from sand and silt sediments. The plants on it started growing after the sediments began to accumulate. Some of the larger trees would probably be over a hundred years old. Notice that in the right side of the sketch, the delta appears to have been growing faster, and a sand bar has formed. Most of the sand and silt was carried down from the river.

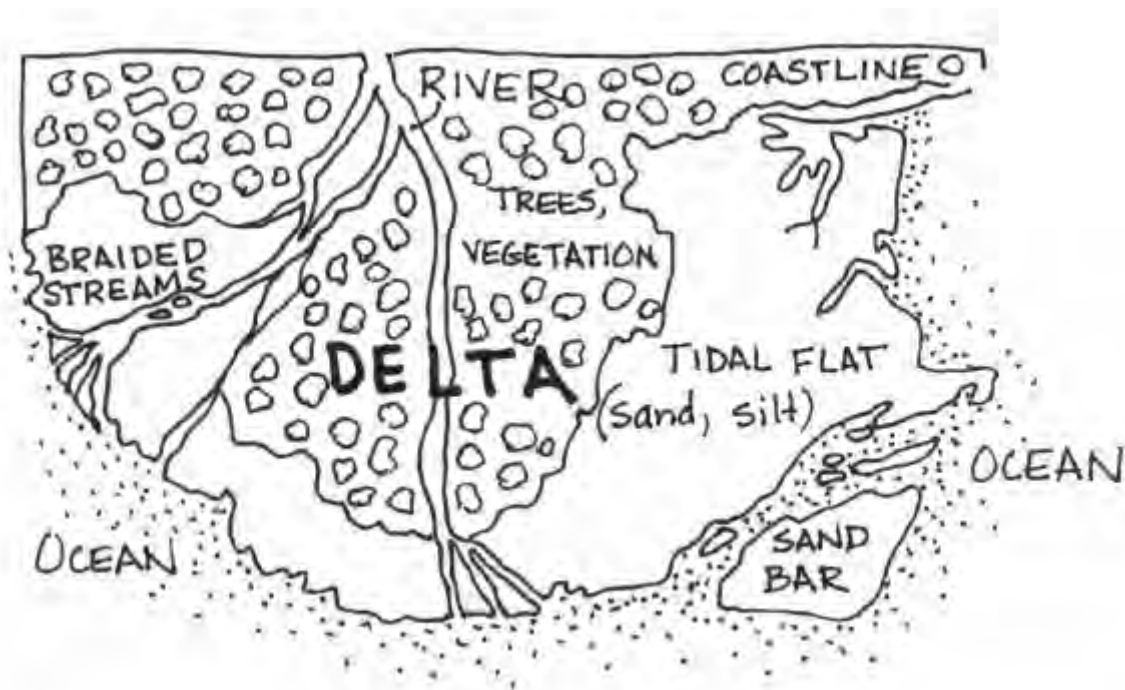
The ocean tides, currents, and wave action help to shape a delta. Ocean currents and wave action coming from about the same direction, like those responsible for causing the lopsided appearance of this delta, are at work along all coasts. Sometimes the currents flow parallel to the shore, and at other times they curve in or out. Usually they go in one general direction for months and months. At other times, they may change speed or direction. On the other hand, waves usually approach the shore at an angle that changes with the

wind. Sometimes the wind blows out to sea.

Ask students:

1. What is a delta?
2. What causes deltas to form?
3. What forms the shape of a delta?

Not all forms of pollution are bad. Deltas are important. Water, picking up dirt and moving it around, formed such important land masses as the Mississippi Delta and the Nile Delta. Sediment also formed the fertile lands on either side of the Nile River. Think of other agriculturally important places that depend on this process.



CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)

9-12

OBJECTIVES

The student will do the following:

1. Compute the amount of water that flows through a stream.
2. Demonstrate an understanding of the data from USGS that are used to monitor stream flow.
3. Explain the influence a particular amount of rainfall may have on that stream.

BACKGROUND INFORMATION

Streams, rivers, and even small tributaries have large demands put upon them by having supply waters pulled from them and by the addition of discharge waters from various sources. The capacity of any tributary, no matter how large or small, must be taken into account before it can be used for a water supply source or a discharge receiving stream.

Storm water that moves across the surface of the land is called runoff.

Factors that influence runoff to a stream include watershed size, slopes, soil types, land use, and vegetation. It is important to understand the correlation of these factors to actual water flow in a stream. A sound decision about water consumption or discharge for a given community should be based on this knowledge. (Other factors, such as the water needs of local wildlife and vegetation, also should be taken into account.)

Terms

AF: (acre foot) - volume of any substance required to cover one acre of a surface to the depth of 1 ft (43,560 ft³) or (1232.75 m³)

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in, eventually enters a waterbody; may pick up and carry a variety of pollutants

SUBJECTS:

Math, Science (Physical),
Social Studies (Geography)

TIME:

1-2 class periods
(field trip to stream)

MATERIALS:

topographical map of
community (USGS)
dot grid/graph paper
floating device
(orange or lemon peel)
stopwatch or clock
measuring tape
graph paper
USGS data on stream flow
clothes OK to get wet

stream gauging: the measurement of velocity of streams (stream velocity)

stream velocity: the volume of water in a stream flowing past a certain point per unit time, typically measured in cubic feet per second (cfs)

topographical map: a contour map designed to show elevation; commonly referred to as a “topo” map; scale 7.5' or 1:24,000

tributary: a stream that flows into a larger stream, river, or another waterbody

USGS: United States Geological Survey

velocity (linear): distance per unit time

watershed: land area from which water drains to a particular surface waterbody

ADVANCE PREPARATION

This activity has a very comprehensive extension that could be used to demonstrate streamflow and to show how different variables in a watershed can affect flow rate. Refer to the Stream Flow Table extension.

- A. Write terms and definitions on the board.
- B. Discuss the graphing and simple math to be done.
- C. Locate a site in the community to be measured for stream flow.
- D. Contact the United States Geological Survey (USGS) office in the state to get streamflow data on the stream that will be measured. Note: Not all streams have been gauged and not all of those for a sufficient time period. Be sure to choose a stream for which sufficient data are available.

PROCEDURE

- I. Setting the stage
 - A. Determine the boundaries of the watershed by looking at a topographical map of the area. The area above (upstream from) the point where the measurement will be taken is the most important. This information may also be available through the USGS office for the particular waterbody.

B. Discuss the impact of a given amount of runoff on the stream. (This cannot be determined by rainfall because a large and variable portion enters groundwater depending on soil types, slopes, and many other factors .)

C. Measure and mark a section of the stream.

II. Activity

A. Determine the linear velocity of a stream segment using a floating device.

1. Put a floating device (e.g., an orange peel or lemon peel) in the stream and clock the time it takes to get to a measured point downstream. Divide the distance traveled by the floating device in the stream segment, by the time clocked.
2. If the measurement is done near the center of the stream where velocity is expected to be highest, multiply by 0.8 to get an average linear velocity.
3. Determine linear velocity (v_l) using the following equation:

$$v_l = \frac{\text{distance traveled}}{\text{time clocked}}$$

B. Calculate the cross sectional area of the stream segment.

1. At certain intervals across the stream section, measure the depth of the stream (from shore to shore). Calculate the average depth of the stream.
2. Also, measure the width of the stream section at various intervals along the channel and calculate the average stream width.
3. Calculate the cross-sectional area ($\text{Area}_{\text{cross-sec}}$) of the stream segment by multiplying the average depth (d_{avg}) x average width (w_{avg}).

$$\text{Area}_{\text{cross-sec}} = d_{\text{avg}} \times w_{\text{avg}}$$

C. Calculate stream velocity (SV) according to the following equation.

$$SV = \text{Area}_{\text{cross-sec}} \times v_l$$

Depending on the units used for measurement, SV units will be in terms of cubic feet per second (cfs) or cubic meters per second (CMS).

III. Follow-up

Compare the flow rate to data from USGS on the same stream.

IV. Extensions

A. Study USGS Streamflow Data to understand how the waterflow increases as tributaries flow into a stream.

B. Repeat measurements after a rain and during a drought at the same point on the stream.

C. See alternative activity on Stream Flow Table Teacher Sheet.

RESOURCES

National USGS Office, Dept. of the Interior, Reston, VA 22092. 800-USA-MAPS

State Geological Contacts. (See Fact sheet pages J-1 to J-6.)

STREAM FLOW TABLE

BACKGROUND INFORMATION

Many activities can be done with a stream table. All it takes is a little imagination and a few supplies. One of the challenges in interpreting the natural landscape is that many important variables act at the same time. The stream table will allow students to control some of these variables that are largely uncontrollable in nature. For example, an artificial river can be created, sped up or slowed down, or made to flow over various types of material. These variations can help greatly in understanding how natural rivers behave.

The stream table is modeled by a flat trough containing a sand-silt mixture that can be formed into various shapes. Water enters one end of the trough through a supply hose from an elevated bucket, flows across the sand, and leaves the other end through an exit hose into a second bucket. The flow of water into and out of the trough can be controlled by opening and closing the screw clamps (or pinch clamps). The slope of the trough can be changed by moving a support, such as a brick or a wooden block, back and forth.

TIME:

1-2 class periods

MATERIALS:

 flat trough
 sand/silt mixture
 supply hoses
 3 buckets
 2 screw clamps (or pinch clamps)
 brick

List of variables the stream table will let students control for study

1. To calculate the rate of flow from the supply bucket:

Most of the stream table experiments call for students to adjust the rate of water flow to the reservoir to a certain number of milliliters per second. Doing this is easy. Simply time how long it takes (in seconds) for the supply hose to fill a 100 milliliter beaker. Then calculate the rate of flow like this (the example assumes that it takes five seconds to fill the beaker):

$$100 \text{ ml}/5\text{sec} = 20\text{ml/sec}$$

2. To control the rate of flow from the hose:

To reduce the flow rate, simply tighten the screw clamp. Opening the clamp increases flow. The rate of flow values given in the resources are approximate and can be varied up or down by

2ml/sec. Any rate between 8ml/sec and 12ml/sec will do for a resource calling for a rate of 10ml/sec. When students are sure that they have a flow of 10ml/sec, change the flow to 5ml/sec.

Teacher Sheet (cont.)

3. Keep water in the supply bucket at all times.

To help do this, an extra bucket is required. When the supply bucket is nearly empty, replace the full catch bucket with the extra bucket and transfer the water to the supply bucket. Students will have to do this every 5 minutes. Caution: Watch the catch bucket -don't let it overflow!

4. To control the flow of water leaving the stream table:

Students may want to form a lake at the lower end of the stream table. They can control the formation and depth of such a lake by adjusting the screw clamp on the exit hose. If students change the amount of water entering the stream table, the lake level will also change unless they read just the exit hose screw clamp. With the water flowing at 5ml/sec, adjust the exit hose to cause a lake to form.

5. To make a reservoir:

Students may want to make a reservoir at the end of the stream table. This is used to observe the effect of a wide, thin sheet of water. In general, a shallow reservoir molded near the top of the stream table will serve the purpose. However, students may wish to mold a larger dam when their study calls for a thick layer of sand and silt. Pile up the sand and silt with hands or use a small board.

6. To adjust the slope of the table:

If the students want to raise the upper end of the stream table a certain number of centimeters (above the table), simply slip a support under the stream table. Then, move it back and forth to get the desired height.

7. CAUTION:

- a. Watch the catch bucket. Students must keep their eyes on the catch bucket to keep it from overflowing. Students can avoid the problem in some activities by pouring less than a full bucket of water into the supply system to start with. Anytime students use more than one full bucket of water, a third bucket will be needed to trade positions with the catch bucket before it is too late.

- b. Be sure that the water supply pail is set on a box or other support about 30 cm above the table.

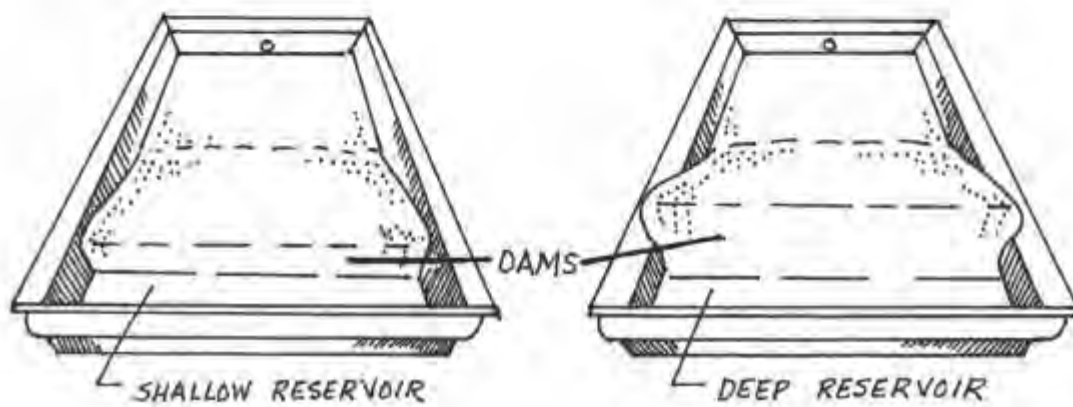
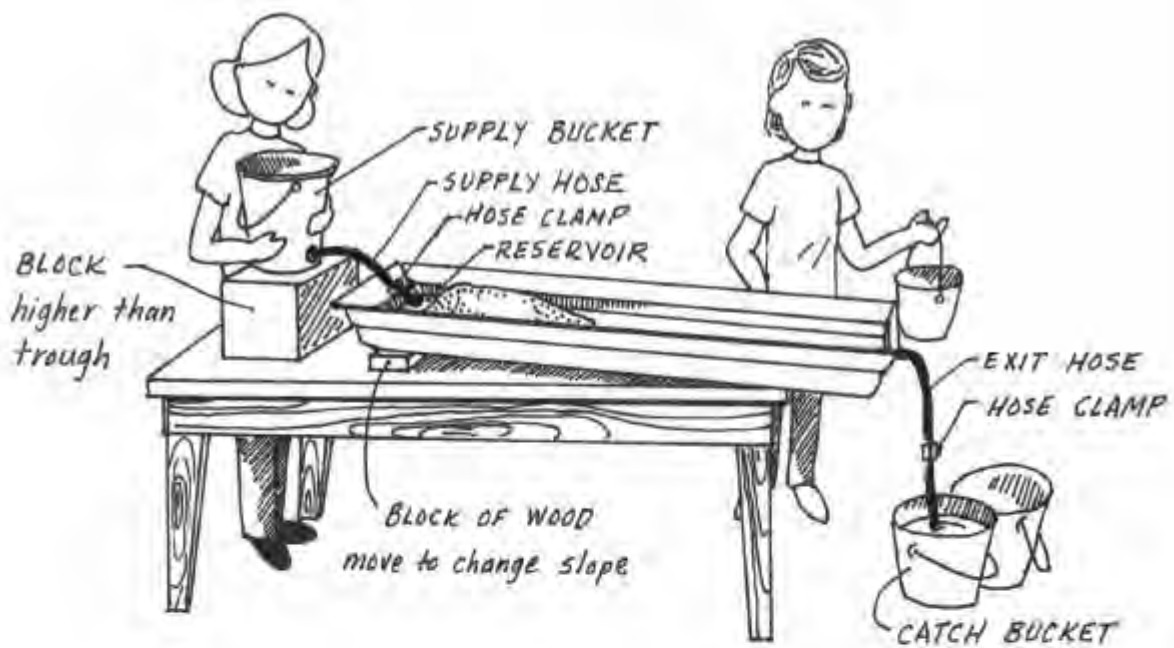
Teacher Sheet (cont.)

- c. Keep the supply hose and clamp attached at all times to control the water flow.
- d. Do not remove the sand-silt mixture from the stream table when students participate in these programs. The next class using the table will need the same sand-silt mixture.
- e. The stream table is not a perfect model. Students will not get the same effects that a real river would produce. Remember that the particle sizes used are very much out of proportion to the volume of water flowing through the stream table.

8. QUESTIONS

- a. When it rains, what percentage of water stays on the surface (later evaporating or soaking into the ground)?
(25%)
- b. What happens to the rest of the water?
(It drains down to the nearest watershed.)
- c. What influence do watersheds have on the lives of people, vegetation, topsoil, and agriculture? (discuss)
- d. Are the runoffs controllable? How and with what effects?
(Construct dams.)
- e. How does uncontrollable runoff lead to flooding in a particular area?
- f. Mention the advantages and disadvantages of runoffs.
(They create watersheds, but wash off valuable topsoil and carry pollutants.)
- g. What are common pollution sources that contaminate runoff?
(pesticides, fertilizers, oil, etc.)
- h. What can people do to prevent pollution of storm water runoff?
(discuss)

- i. Find out if your community has a storm water management, pollution prevention, or source water protection program. Learn what you can do to help.



HELP! LAKE OVERTURNING!

OBJECTIVES

The student will do the following:

1. Define the terms associated with this lesson.
2. Explain the process of overturning and its importance to aquatic life.

BACKGROUND INFORMATION

Overturning refers to the phenomenon of a lake exchanging water from the bottom to the top and from the top to the bottom. This process is very important to the health of the lake's aquatic life.

Overturning is also an important factor in the recovery of a lake after it has been contaminated with a pollutant. Lakes and ponds are lentic systems, which means that the surface water is standing as opposed to lotic or flowing systems, such as rivers. It is much harder for a lake to recover from pollution than it is for a river, even a slow flowing one, because the time period for a total overturning of a lake may be as frequently as annually or as long as 10 to 100 years. During this time, pollutants may build up and reach lethal levels, especially if the influx of contaminants is constant or in large volumes.

To understand the process of overturning, it is important to know two different categories of zones into which lakes may be divided. One category is based on the depth of the water; the other is based on the temperature of the water.

The first set of zones is determined by the depth of the water that, in turn, determines the amount of sunlight that is able to penetrate the water. The amount of sunlight determines the amount and type of plant life and thus the amount and type of aquatic animal life. The three zones in this classification are:

SUBJECTS:

Science (Biology, Earth Science, Environmental Science)

TIME:

2 class periods

MATERIALS:

student handouts, one per student
4 large sheets of drawing paper and 4 boxes of crayons
hot plate
2 beakers
food coloring
table salt
2 large glass containers with open mouth
refrigerator or ice cubes
fan
ladle
funnel
tubing

1. the littoral zone: shallow waters along a lakeshore where rooted vegetation grows; largest amount of sunlight penetration.
2. the limnetic zone: open water zone of a lake through which sunlight penetrates; located parallel the lake bottom and extending between the littoral zones; contains algae and other microscopic organisms.
3. the profundal zone: deepest area of a lake; located from the limnetic zone to the bottom of the lake; no sunlight penetrates; contains decomposing vegetation.

There is no set size for the zones because they change as other factors change. For example, if the lake fills with silt from construction runoff, the bottom will rise and the shoreline will expand causing a larger littoral zone. Also, the limnetic zone will thin because light penetration will decrease.

The second set of zones involved in the rate of lake overturn is based on temperature (thermal zones). The three zones within this classification are:

1. the epilimnion: the upper waters nearest the surface of a lake.
2. the thermocline or metalimnion: the transition zone between the top (epilimnion) and bottom (hypolimnion) zone.
3. the hypolimnion: the deepest waters in a lake.

The temperature zones of a lake change due to wind movement, solar intensity, and air temperature; thus, they are seasonal. During each season, the lake takes on different characteristics. The differences in water temperature among the zones lead to the movement of water and results in the process of overturning. A closer look at the seasonal changes shows how the process of overturning operates and brings changes to the lake. Note that this kind of overturning only occurs in temperate lakes that partially freeze in winter and thaw in spring. Some lakes in other climatic settings can also overturn, but the mechanisms are different.

Spring: As the ice from winter melts, the cold water sinks to the bottom. This is because ice is less dense than water, but water that is only slightly above the freezing temperature is denser than warmer water. Eventually the lake reaches a state in which all water is at the same temperature. There are no longer three distinct zones, only one zone. This unlayered water is easily mixed by brisk spring winds, and the oxygen and nutrients from the bottom are evenly distributed throughout the lake. This period is called the spring overturn.

Summer: The sun warms the surface of the lake, but the mild summer winds cannot mix this warmer water with the other zones. The lake again forms temperature zones, but this time the low-density surface layer is warm water. The thermocline has warm water above and cool water below. This reduces the amount

of oxygen reaching the hypolimnion and makes it unsuitable for life requiring very much oxygen. This period is often referred to as the summer stagnation period.

Fall: Fall brings cooler air temperatures that gradually cool the epilimnion. This cooling process causes the epilimnion to become deeper and finally results in the lake being a uniform temperature again, eliminating the other zones. Again the water is easily mixed by wind, and the lake enters the fall overturn period.

Winter: As the winter air temperature turns cold, the epilimnion zone cools more than the other zones. This cold water is forced to the bottom until the epilimnion becomes so cold that it freezes and becomes a layer of ice. The hypolimnion now has water that is warmer than the epilimnion. The thermocline now has colder water on top and warmer water on bottom. Because the water is not able to mix freely; no additional oxygen will reach the hypolimnion until next spring. This period is called winter stagnation.

Terms

epilimnion: one of three temperature or thermal zones located at the top of a thermally stratified lake; varies in size and temperature characteristics based on a seasonal cycle

groundwater: water that infiltrates into the Earth and fills open spaces in the soil and rock below the Earth's surface; water within the zone of saturation

hypolimnion: one of three temperature or thermal zones located at the bottom of a thermally stratified lake; varies in size and other characteristics based on a seasonal cycle

lentic system: surface water that is standing such as a lake or pond

limnetic zone: a zone in a lake extending over open water from the edge of one littoral zone to the other and above the profundal zone; characterized by floating vegetation and moderate to high sunlight penetration

limnology: the science that deals with the physical, chemical, and biological properties and features of fresh waters, especially lakes and ponds

littoral zone: a zone along the shore of a lake that is characterized by very shallow water, rooted vegetation, high sunlight penetration

lotic system: surface water that is flowing such as a river or stream

overturning (turnover): process by which water and nutrients are circulated in a lake due to the thermal processes which can occur on a seasonal basis

profundal zone: a zone in a lake extending from the bottom of the limnetic zone to the bottom of the lake; characterized by deep water, decomposing vegetation, and little to no sunlight penetration

seasonal: happening based on the yearly seasons of spring, summer, fall, and winter

stagnation: inactivity or without change

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs

temperature zones: regions characterized by different temperature characteristics

thermocline: one of the three temperature or thermal zones located between the upper and lower zones of a lake; also called the metalimnion. The thermocline is a thin boundary layer between two layers of distinctly different temperatures. The thermocline is a place characterized by dramatic vertical temperature change.

ADVANCE PREPARATION

- A. Students should be familiar with the differences between surface water and groundwater and the different types of surface water.
- B. Copy Student Sheet (crossword puzzle) and Background Information for students.
- C. Gather materials.
- D. Copy or put vocabulary words and definitions on the board.

PROCEDURE

- I. Setting the stage
 - A. Introduce this activity by asking the students, “Can sunlight reach all levels of surface water?” Let students defend their responses. They should bring out that the correct

answer depends on many factors such as the size and type of surface waterbody. Discuss the types and characteristics of surface water. What differences would the ability of light to reach various levels have on the characteristics of a lake?

B. This activity will introduce students to features of a lake that contribute to overturning (or layering) and familiarize them with the terminology.

II. Activity

A. Give the students a copy of the Background Information.

B. When all have completed reading, divide the class into 4 (or multiples of 4) groups giving each group a large sheet of paper with either Fall, Spring, Summer, or Winter written on the top and a box of crayons.

C. Instruct each group to draw a representative lake during the assigned season including both of the two categories (depth and temperature). Ask students to be prepared to explain to the class how or if the process of overturning takes place during their assigned season. (This could also be done on a chalkboard, white board, or drawn on a computer.)

D. For a temperature inversion experiment:

1. Put a volume of cold water in a glass jar followed by a smaller volume of hot water that has food coloring in it. Try adding the hot water to the jar containing the cold water without disturbing the cold water too much (use a small funnel with tubing attached and a soup ladle).
2. With the funnel and tubing, pour the water into the soup ladle first, letting it gradually fill up with hot water. Then gently overflow to the surface of the cold water. Do this for two jars, keeping the volumes ~~consistent~~ between the two.
3. Take a fan and direct airflow over the top of one of the jars. Observe how this wind affects the stratification of the water in the jar (similar to wind on a lake).
4. Repeat, but keep one jar at room temperature and the other jar hotter or colder and compare the changes in the two.

5. Alternative to this would be to:
 - a. Put colored ice cubes on top of warm water and let them thaw.
 - b. Put cold colored water in the bottom of a beaker with warm water on top and heat the bottom.

III. Follow-up

- A. After each group has presented its drawings, made corrections, and answered questions, discuss the experiment.
- B. Students should write a paragraph explaining overturning using all the terms correctly.
- C. Have students fill out the Student Sheet as a quiz.
- D. Have students study temperature change in a local lake throughout the rest of the school year.

IV. Extensions

- A. Have the students make a model of each of the stages of overturn.
- B. Have the students make a model of a lake and identify each of the physical zones.
- C. Have the students make a game based on this information.

RESOURCES

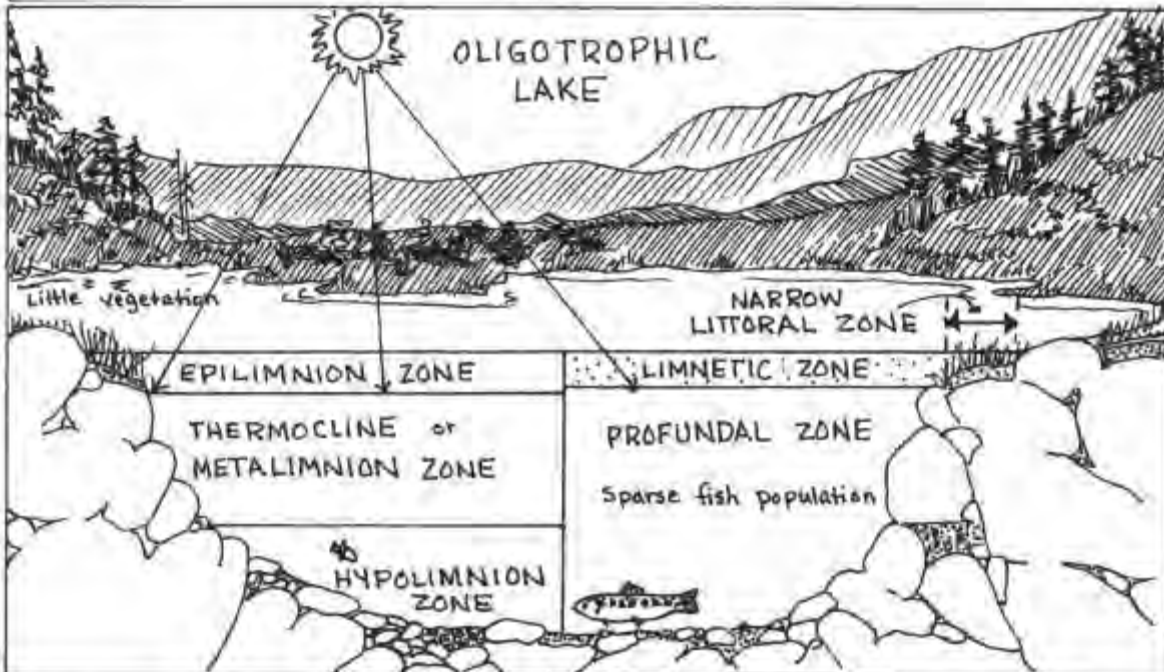
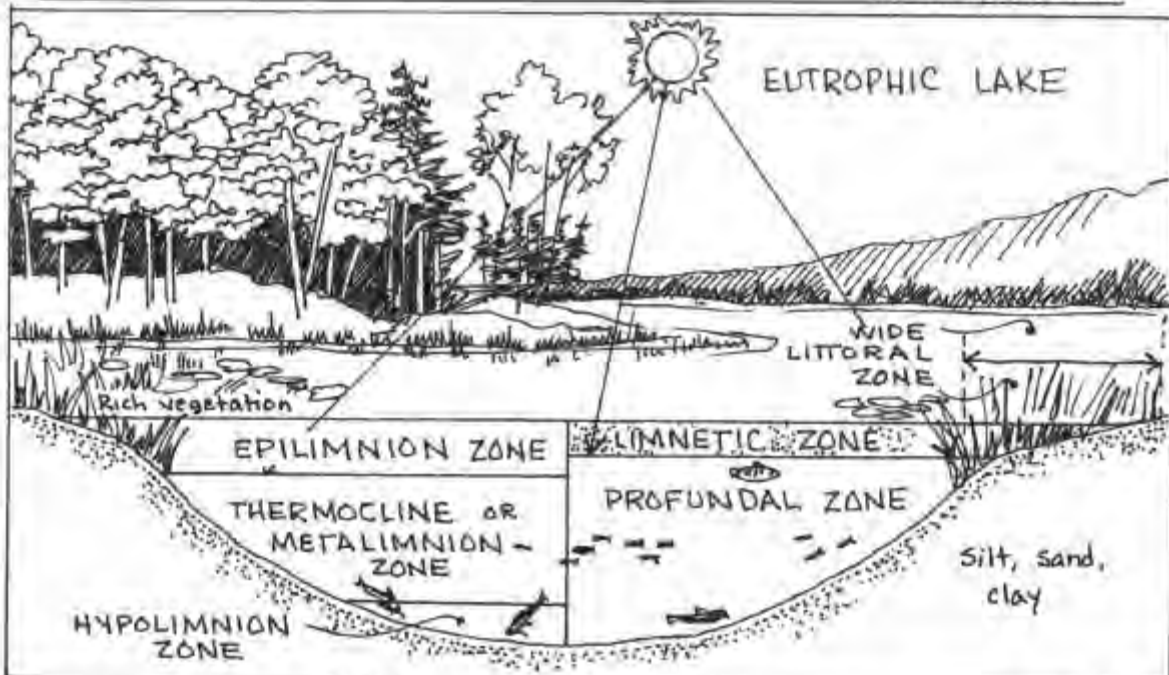
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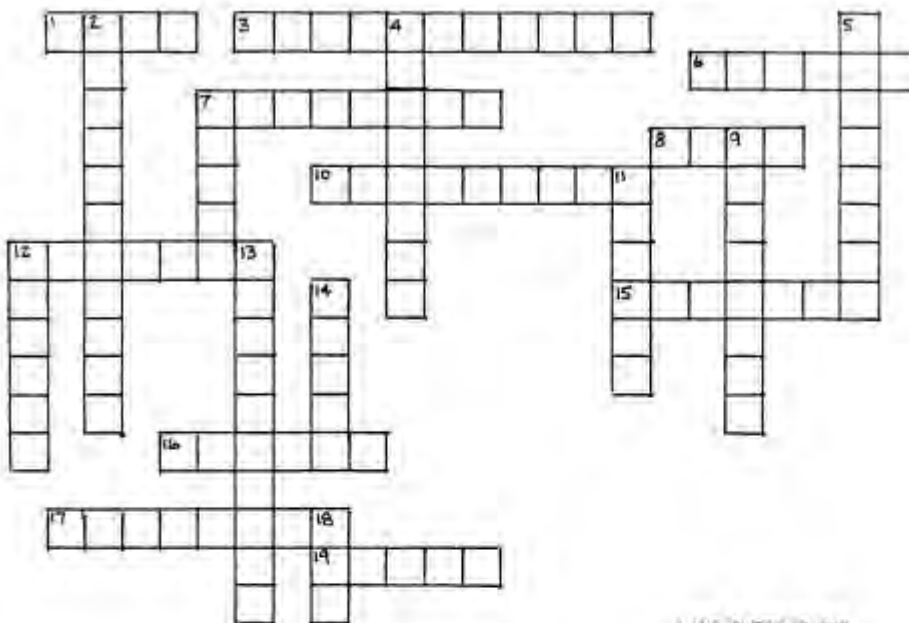
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LAKE ZONES

Student/Teacher Sheet



NAME _____



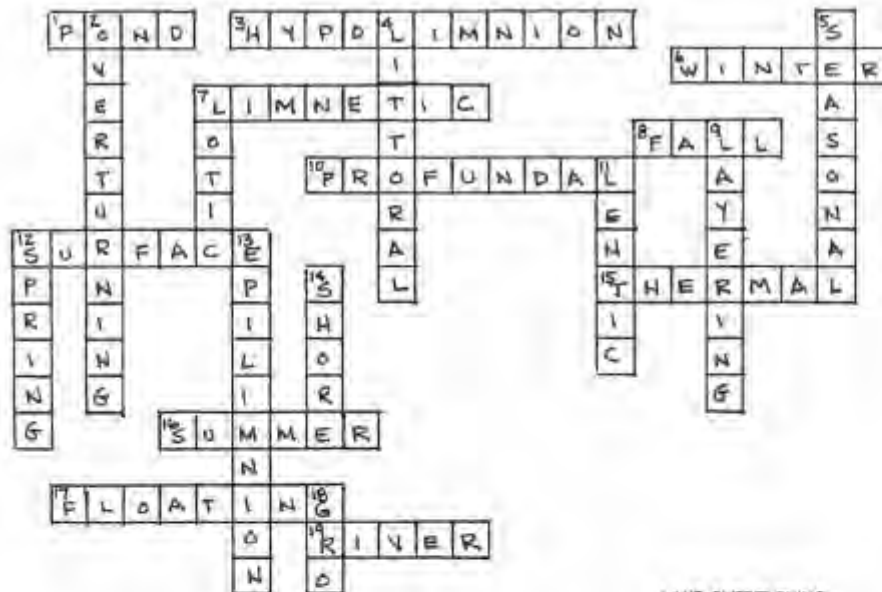
LAKE OVERTURNING

ACROSS

1. AN EXAMPLE FROM THE LENTIC SYSTEM
3. THE DEEPEST ZONE IN THE TEMPERATURE ZONE CLASSIFICATION OF A LAKE
6. SEASON WHEN THE EPIMLNION LAYER IS AT 0°C.
7. ZONE OF A LAKE EXTENDING ACROSS THE SURFACE OF THE LAKE AND ABOVE THE PROFUNDAL ZONE
8. SEASON WHICH IS THE MOST SIMILAR TO SPRING IN THE OVERTURNING PROCESS
10. DEEPEST ZONE OF A LAKE; LITTLE IF ANY SUNLIGHT
12. WATER WHICH DOES NOT SOAK INTO THE GROUND BUT BECOMES LAKES, PONDS, ETC.
15. ANOTHER TERM USED TO INDICATE THE TEMPERATURE ZONES IN A LAKE
16. SEASON DURING WHICH THE SUN WARMS THE UPPER LEVEL FASTER THAN THE WINDS CAN MIX THE WATER
17. TYPE OF PLANTS FOUND IN THE LIMNETIC ZONE
19. A _____ IS AN EXAMPLE OF A LOTIC SYSTEM.

DOWN

2. THE PROCESS OF MIXING THE WATER AND NUTRIENTS OF A LAKE
4. ZONE OF A LAKE WHERE ROOTED PLANTS ARE FOUND
5. EVENTS WHICH HAPPEN BASED ON THE SEASON OF THE YEAR
7. A CATEGORY OF SURFACE WATER WHICH IS FLOWING RATHER THAN STANDING.
9. ANOTHER TERM FOR OVERTURNING
11. A CATEGORY OF SURFACE WATER WHICH IS STANDING, NOT FLOWING
12. SEASON WHEN LAKE WATERS MIX FREELY DUE TO THE MOVEMENT OF WINDS AND THE DOWNWARD MOVEMENT OF COLD WATER FROM THE UPPER LEVELS
13. THE UPPERMOST LAYER IN THE TEMPERATURE CLASSIFICATION OF A LAKE
14. ONE BOUNDARY OF THE LITTORAL ZONE IS THE _____
18. ANOTHER TYPE OF FRESHWATER OTHER THAN SURFACE WATER



LAKE OVERTURNING

ACROSS

1. AN EXAMPLE FROM THE LENTIC SYSTEM (POND)
3. THE DEEPEST ZONE IN THE TEMPERATURE ZONE CLASSIFICATION OF A LAKE (HYPOLIMNION)
5. SEASON WHEN THE EPIMLNION LAYER IS AT 0°C. (WINTER)
7. ZONE OF A LAKE EXTENDING ACROSS THE SURFACE OF THE LAKE AND ABOVE THE PROFUNDAL ZONE (LIMNETIC)
8. SEASON WHICH IS THE MOST SIMILAR TO SPRING IN THE OVERTURNING PROCESS (FALL)
10. DEEPEST ZONE OF A LAKE; LITTLE IF ANY SUNLIGHT (PROFUNDAL)
12. WATER WHICH DOES NOT SOAK INTO THE GROUND BUT BECOMES LAKES, PONDS, ETC. (SURFACE)
15. ANOTHER TERM USED TO INDICATE THE TEMPERATURE ZONES IN A LAKE (THERMAL)
16. SEASON DURING WHICH THE SUN WARMS THE UPPER LEVEL FASTER THAN THE WINDS CAN MIX THE WATER (SUMMER)
17. TYPE OF PLANTS FOUND IN THE LIMNETIC ZONE (FLOATING)
19. A _____ IS AN EXAMPLE OF A LOTIC SYSTEM. (RIVER)

DOWN

2. THE PROCESS OF MIXING THE WATER AND NUTRIENTS OF A LAKE (OVERTURNING)
4. ZONE OF A LAKE WHERE ROOTED PLANTS ARE FOUND (LITTORAL)
5. EVENTS WHICH HAPPEN BASED ON THE SEASON OF THE YEAR (SEASONAL)
7. A CATEGORY OF SURFACE WATER WHICH IS FLOWING RATHER THAN STANDING. (LOTIC)
9. ANOTHER TERM FOR OVERTURNING (LAYERING)
11. A CATEGORY OF SURFACE WATER WHICH IS STANDING, NOT FLOWING (LENTIC)
12. SEASON WHEN LAKE WATERS MIX FREELY DUE TO THE MOVEMENT OF WINDS AND THE DOWNWARD MOVEMENT OF COLD WATER FROM THE UPPER LEVELS (SPRING)
13. THE UPPERMOST LAYER IN THE TEMPERATURE CLASSIFICATION OF A LAKE (EPIMLNION)
14. ONE BOUNDARY OF THE LITTORAL ZONE IS THE _____ (SHORE)
18. ANOTHER TYPE OF FRESHWATER OTHER THAN SURFACE WATER (GROUNDWATER)

THE AGING OF LAKES

OBJECTIVES

The student will do the following:

1. Determine the trophic condition of a local body of water.
2. Demonstrate the use of a Secchi disc.
3. Test for pH, nitrogen, phosphorus, temperature, and dissolved oxygen in a body of water.

BACKGROUND INFORMATION

Lake eutrophication is the increase over time of nitrogen, phosphorus, and other nutrients necessary for production of algae and other plants. It is an important part of the process by which lakes pass from their original nutrient-poor (oligotrophic) condition to a more productive (eutrophic) condition to become shallower with sedimentation and smaller with encroachment of marsh until, over geologic ages, lake basins are returned to land and terrestrial life. This “aging” process is called succession.

Humans speed up the lake aging process by discharging nutrients from sewage treatment plants, fertilized fields and pastures, and sediment from road, home, and commercial construction.

Nutrients can be bad for a lake if excessive enrichment causes an algal bloom. This abundance of algae eventually produces a large amount of decomposing organic matter, which depletes oxygen from the water. This can kill fish. The most productive fishing lakes have a moderate nutrient content that produces a balanced amount of algae and phytoplankton as fish food.

The study of lake conditions is called limnology and involves water testing to evaluate nutrient content, temperature, pH, dissolved oxygen (DO), profiles with depth, light penetration, and other tests that may be specific to a given location.

Terms

SUBJECTS:

Science (Chemistry, Biology, Ecology)

TIME:

several field trips

MATERIALS:

water analysis kit
Secchi disc
volunteer “lake watch” group
boat?
wader?

algal bloom: a sudden increase in the amount of algae, usually causing large, floating masses to form.

Algal blooms can affect water quality by lowering DO content and decreasing sunlight. They are usually caused by excessive nutrient addition, and can be characteristic of a eutrophic lake.

eutrophic: refers to a body of water characterized by nutrient-rich water supporting abundant growth of algae and/or other aquatic plants at the surface

limnology: the science that deals with the physical, chemical, and biological properties and features of fresh waters, especially lakes and ponds

oligotrophic: refers to any ecosystem that has nutrient-poor water

succession (lake): gradual, orderly process of changes in a lake ecosystem brought about by changes in species types and populations; occurs over long periods of (geologic) time and ultimately results in the lake reverting back to land (a terrestrial ecosystem)

ADVANCE PREPARATION

If possible, consult a local volunteer monitoring group for use of equipment and assistance in selecting and sampling a nearby lake. Equipment required includes: test kits equipped for N, P, pH, and temperature measurement; sampling equipment that will allow samples to be collected at specified depths; and a Secchi disc for measuring light penetration with depth.

PROCEDURE

Students will go to a local lake monthly over a period of one school year and sample set locations. They will evaluate profiles and seasonal changes, determine the lake's health, trophic status, and annual trends, and predict changes to come.

I. Setting the stage

Coordinate with a volunteer monitoring group to schedule sampling visits to a lake. Make a record of specified measurements at fixed, preselected locations (usually just above a dam, an inland slough, the center of the lake, or others as appropriate).

II. Activity

A. At each sampling location, determine pH/temperature/DO profiles measured at every 5 feet of depth. (Where there is a marked change in a 5-foot interval, take more

samples such as every 1 or 2 feet.) Record the data for a later plot of the results versus depth.

B. Collect water samples for N and P analysis (and pH and DO if needed). While analysis may be done later, proper sample preservation techniques should be observed. DO and pH may be run in the field using a pH/DO meter, test kit ~~chemicals~~, or pH paper.

C. Measure/record Secchi disc readings for each location or each sampling visit.

D. Plot all parameters (pH, temperature, DO, N, P) versus depth for each location per visit.

III. Follow-up

A. Analyze changes/trends in data observed over the course of the year. Is the lake more oligotrophic or eutrophic? How can you tell?

B. If eutrophic, what are the sources of its nutrients?

C. How can these nutrient sources be controlled or managed?

IV. Extensions

A. Consult the state environmental agency about the trophic status of state lakes, how the sampled lake compares, and what specific management steps could be taken to protect the lake.

B. Read about some of the world's largest lakes and their trophic status such as Great Lakes, Lake Baikal, Lake Zurich, Lake Chad.

RESOURCES

Contact state environmental agency (see lists in the appendix) to find out about local ~~volunteering~~ ~~testing~~ groups.

Water Analysis Kit, page F-69, Water Testing Fact Sheet

WATER PROFILE DATA SHEET

STUDENT(S) - _____

LAKE - _____

LOCATION - _____

[illegible]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	5

BIODIVERSITY = WATER QUALITY

OBJECTIVES

The student will do the following:

1. Learn to collect surface water samples.
2. Determine the degree of pollution in a stream by using indicator organisms and a pollution tolerance index.

BACKGROUND INFORMATION

Diverse natural ecosystems provide important ecological services including maintaining hydrological cycles, regulating climate, contributing to the processes of soil formation and maturation, storing, and recycling essential nutrients, absorbing, and breaking down pollutants. They also provide sites for inspiration, tourism, recreation, and research.

For those concerned with the effects of chemicals on wildlife, species have been used as indicators of ambient environmental conditions for many years; the canary in the coal mine is one of the most famous examples. In some cases, species can be used to indicate the biological effects of pollutants more accurately than predictions from chemical analyses. For example, the larvae of mayflies, caddisflies, stone flies, and true flies have been used to identify point sources of environmental hazards in streams and other wetlands. Earthworms, which pass large amounts of soil through their digestive tracts, are excellent indicators of ground pollution. Bees, whose body hairs electrostatically attract dust particles and collect pollutants linked with their food, water, and even air, have become an early warning system at nuclear power plants, weapons factories, testing laboratories, and solid waste dumps. Mussels, oysters, and fish are collected regularly as part of a National Status and Trends Program established by the National Oceanographic and Atmospheric Administration (NOAA) along the USA coastline.

Rivers are among the oldest and most used and abused natural features on Earth. The bedrock over which a stream flows will add different chemicals to the water as the water wears it down. Storm water runoff brings a variety of chemicals with it as it enters a river. Land use within the drainage area also impacts upon rivers. As people alter the landscape, they degrade river water. Further demands, such as water use for

SUBJECTS:

Science (Biology, Environmental Science)

TIME:

2 hours
field trip + travel time

MATERIALS:

each team will need:
measuring tape
a white enamel pan
calculator (optional)
notebook and pencil
kick seine, screen, or net
student sheets
If samples are to be preserved,
containers with 70% alcohol
(ethyl or isopropyl) solution are
needed.

manufacturing and for removing the waste of municipalities and industry, have led to the degradation of water quality. To judge the health of a river, both the diversity of organisms and physical and chemical quality of the water should be measured. It is necessary that students be aware of biodiversity and the importance of biodiversity as an indicator. By sampling streams, we can understand the concept of indicator organisms and tolerance levels. The procedures are designed so that they can be done quickly and easily, and they provide a rapid means of sampling shallow areas in order to detect moderate to severe stream pollution. The organisms are classified into three groups based on their pollution tolerance. Each of the three groups is given an index value, with the least tolerant group having the highest value. The water quality value is the total of the resulting numbers. The higher the sum, the higher the water quality. The general abundance of each kind of organism is also noted, though it is not figured into the index.

Terms

biodiversity: the number of different varieties of life forms in a given area, or an index derived from this number

indicator organism: an organism whose presence or absence typically indicates or provides information on the certain conditions within its environment

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (e.g., outlet or pipe) because it comes from many individual sources or a widespread area (typically, urban, rural, and agricultural runoff)

point source: known source of contamination

riffle: fast moving area in a stream. Usually the surface is broken by small waves or rocks; the slope of a stream bed is steeper in riffles than it is in open pools, where the water surface tends to be smoother.

PROCEDURE

I. Setting the stage

- A. Before the field trip, review safety procedures for water activities.
- B. Hand out Student Sheets and have students study the taxonomic (taxa) groups.
- C. Divide students into teams.

II. Activity

Each team will:

- A. Choose a one-meter square area representative of the riffle or shallow area being sampled.
 1. Use a kick seine, screen, or net to collect samples to be placed in white basins or bowls.
 2. Approach the sample sites from downstream to avoid disturbing the organisms at the sampling location.
- B. Three samples will be taken to be sure representative samples are collected. Samples may also be taken from some other microhabitats at the site, such as rocks in slow moving water near banks, because different organisms may be found there.
- C. Samples should be placed in pans for identification. If they are preserved, they should be put in alcohol containers.
- D. Record on Student Sheet the presence of each TYPE of organism collected and classify it by its tolerance. (Use the Student Sheet: Macroinvertebrate Picture Key.) Estimate the number of each organism type and record on Student Sheet.
- E. Calculate the stream index by multiplying the NUMBER of TYPES of organisms in each tolerance level by the index value for that level and add the resulting three numbers. DO NOT use the number of individuals.
 1. Group 1- Pollution Intolerant (Index Value =3)
 1. Stonefly
 2. Caddisfly
 3. Water Penny
 4. Riffle Beetle
 5. Mayfly
 6. Gilled Snail
 7. Dobsonfly

2. Group 2- Wide Range of Tolerance (Index Value =2)

8. Crayfish	13. Damselfly
9. Sowbug	14. Watersnipe Fly larva
10. Scud	15. Crane Fly
11. Alderfly larva	16. Beetle larva
12. Fishfly larva	17. Dragonfly
	18. Clam

3. Group 3- Very Tolerant (Index Value =1)

19. Aquatic worm	22. Leech
20. Midge Fly larva	23. Pouch Snail
21. Blackfly larva	24. Other Snails

4. Cumulative Index Values:

23 and above	= Excellent Water Quality
17 -22	= Good Water Quality
11 -16	= Fair Water Quality
10 or less	= Poor Water Quality

III. Follow-up

- A. Have each group graph the results of this activity with a bar graph using the total index number for each group.
- B. When this is completed, the groups will meet together to compare graphs.
 - 1. Make generalizations about their results.
 - 2. Record results for the class and produce a composite graph.
- C. Answer these questions.
 - 1. What is the quality of this stream?

2. What are some possible reasons for the quality of this stream?
3. When examples of organisms that are sensitive to pollution are present, what might this indicate to you?

IV. Extensions

- A. Test the stream for physical and chemical water quality parameters.
- B. Have a professional consultant in the environmental field address the class.
- C. Perform a literature search to find articles about biodiversity and water quality.
- D. Go to a site that is known to be polluted by runoff and compare to the study site done for this activity.

RESOURCES

“Citizen Stream Quality Monitoring Program,” Ohio Department of Natural Resources.

Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

“Save Our Streams” (The Izaak Walton League of America) - Pollution Tolerance Index.

TEAM MEMBERS _____

Data Record

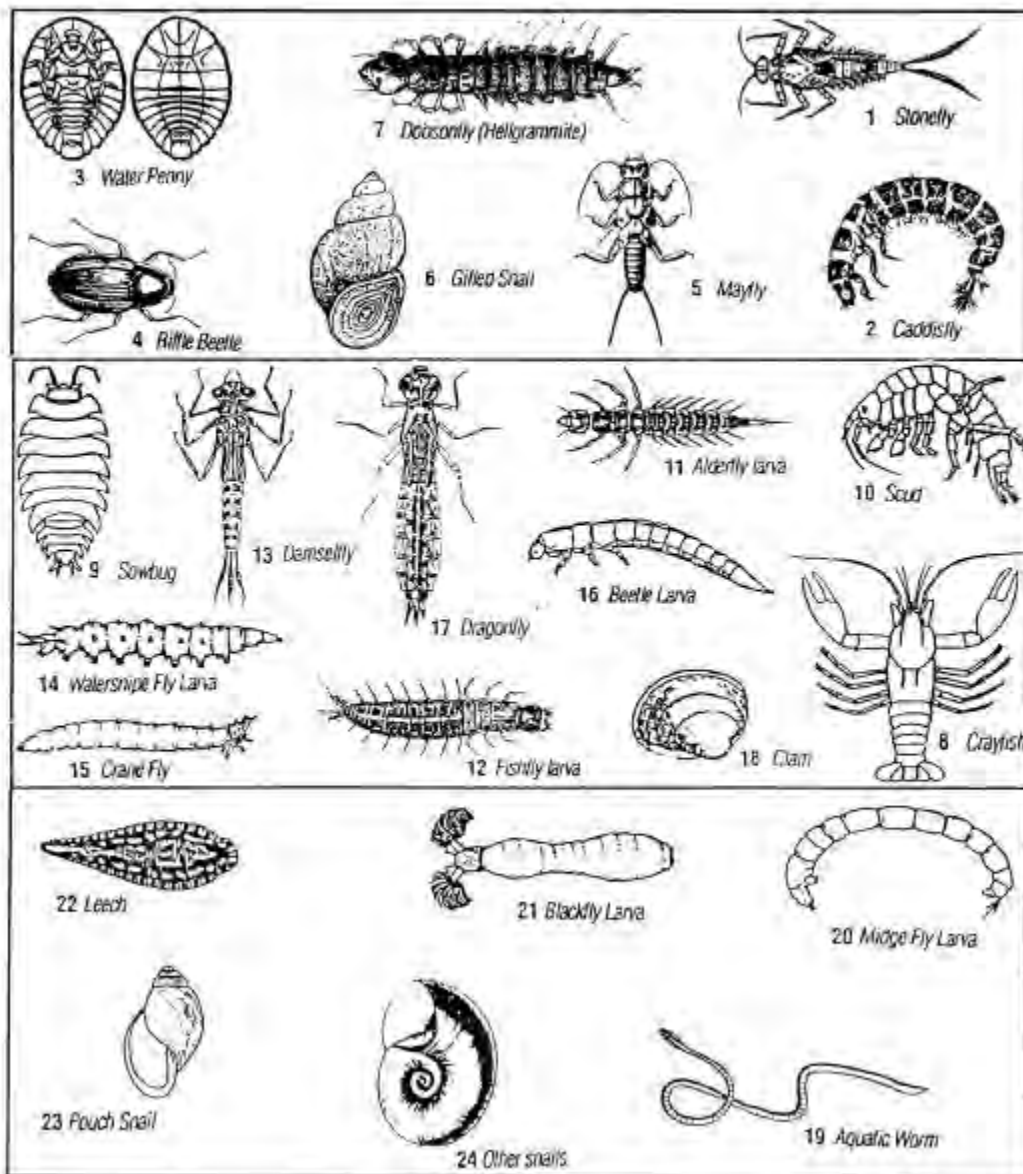
Test Site (riffle)

1. Quantity and types of organisms present in Group 1 on key.

2. Quantity and types of organisms present in Group 2 on key.

3. Quantity and types of organisms present in Group 3 on key.

MACROINVERTEBRATE PICTURE KEY



FLOODS

OBJECTIVES

The student will do the following:

1. Explain some causes of flooding.
2. Describe methods of flood control.
3. List some disadvantages of flood control methods.
4. Locate areas in danger of flooding.
5. Demonstrate use of topography maps.

BACKGROUND INFORMATION

Flooding is a natural phenomenon that occurs when a watershed receives so much water that the stream channel cannot contain the water, and the water overflows the stream banks. Causes may include excess rain, melting snow, human-made channels and diversions, overloaded storm sewers, or failures of dams or levees. Because many cities are located on or near rivers and streams to take advantage of transportation, fresh water, good soil, hydroelectric power, recreation, and aesthetic factors, floods can be expensive in terms of property damage and loss of life.

We can minimize flooding damages by not developing floodplains. Lakes, levees, and dams, have been constructed for the purpose of controlling floodwaters; however, often these “solutions” help one city and cause problems for another city downstream. They also usually cause changes in ecosystems.

Episodic flooding, such as the Johnstown floods in Pennsylvania (3 times), the Midwest Flood of 1993, and the Southeast Floods of 1994, are known to most Americans. Elsewhere in the world, seasonal flooding is a way of life. These annual floods carry in huge amounts of silt and topsoil that provide fertile ground for next year’s crops. Rainfall and river monitoring systems can now alert forecasters to warn people in danger zones to take emergency action.

SUBJECTS:

Science (Physical Science, Earth Science), Social Studies (History, Geography)

TIME:

2 class periods

MATERIALS:

large sheets of plastic (tarp or poly)
garden hose and water
sweater boxes (6)
PVC pipe, rain gutter, or
½” or ¾” poly tubing
dirt, clay, or sod
bricks
Legos ®, clay, or plaster

Terms

dam: man-made or animal-made barrier across a stream that holds and regulates flow of water

delta: a deposit of sand and soil, usually triangular, formed at the mouth of some rivers

dike: elevated structure alongside of stream that acts as a barrier to flood waters

diversions/channeling: altering the course of a river or stream causing the stream to change its direction

floodplain: relatively flat area on either side of a river that may be under water during a flood

levee: an embankment, natural or artificial, built alongside a river to limit high water events from flooding bordering land

man-made: made by humans; artificial or synthetic

natural: produced or existing in nature; not artificial or manufactured

watershed: land area from which water drains to a particular surface waterbody

ADVANCE PREPARATION

A. Collect the following, if possible, and show to students.

1. National Geographic Video - The Power of Water
2. Pictures from the '93 Midwest flooding, Bangladesh Flood, and/or other recent major floods

B. Start keeping a current events file on flooding.

PROCEDURE

I. Setting the stage

A. Discuss flooding and the problems that cause it. Also discuss the benefits of

flooding.

- B. Ask students why there currently seems to be an increase in flooding and damage from flooding.

II. Activity

- A. Have students work in groups to research and report on Johnstown floods, Midwest Flood, Bangladesh Flood, flooding of the Nile, and U.S. or other nation's flood insurance. Each group could take one topic and report to the class. Students should look into the problems as well as any benefits from these floods.

- B. Ask students to look for and bring in articles about flooding.

- C. Use a topographic map to locate areas in the community, state, and region in potential danger of flooding. A local meteorologist or geologist may be able to help answer these questions.

1. Have floods occurred?
2. When and how often have they occurred?
3. How damaging were they?

- D. Use an atlas to locate areas subject to flooding worldwide; look for large cities on a river, coast, or delta.

- E. Find out local, state, and federal regulations in the area applicable to building on a floodplain.

- F. After one group has reported on federal flood insurance, discuss pros and cons of this insurance. Compare to the insurance practices of other nations, if desired.

- G. In pairs or groups (preferably six), construct river models. Compare the capacity of a natural meandering stream to hold floodwaters versus the lack of flood-contaminant capacity of a straight channel. Use PVC pipe or rain gutter for the river; use dirt, clay, sod for the land; use bricks or plastic for nonporous surfaces; use Legos®, clay, and/or plaster for levees. One end should be higher so the river will flow. Each box needs drainage at the low end.

With six groups:

1. Groups 1 and 2: same structure except one with dikes and levees along river's edge and the other without.
 2. Groups 3 and 4: same structure except one with underdeveloped floodplain (dirt and grass or other vegetation); the other urbanized with asphalt and concrete (nonporous surfaces).
 3. Groups 5 and 6: same structure except one with fairly even terrain; one with sloping terrain.
- H. Pour an equal amount of water in high end of each one. Compare within pairs or groups and vary the amount and rate of inflow. Record observations.
- I. One person from each group should demonstrate its river to members of the other groups. Each student should record observation and variables.
- J. Discuss the different ways the water responded. Students may want to repeat some of the experiments.
- K. Have students play the role of city or county planners and ask them how they would deal with development on floodplains. Ask them if and from where relief money to pay for flood damage during flooding will come.
- III. Follow-up
- A. Discuss what kind of measures are taken to prevent flooding.
 - B. How might some of these measures affect other urban and rural areas?
- IV. Extensions
- A. Contrast and compare being a flood victim in the USA and being one in Bangladesh. Write of personal losses, present (flooded) situation, and future.
 - B. Have students pretend they are buying a house on a floodplain. Compare the costs of buying and owning the house (include insurance costs) to the costs of buying and owning a house not located in a floodplain. A local real estate agent and/or insurance agent could help with estimates.

- C. Have students discuss pros and cons of farming in a floodplain.

RESOURCES

Cobb, Charles E. Jr., "Bangladesh: When the Water Comes," National Geographic, June 1993, Vol. 183, No. 6, pp. 118-134.

Mairson, Alan, "The Great Flood of 93, " National Geographic, January 1994, Vol. 185, No.1, pp. 42-81.

National Geographic videotape "The Power of Water ."

Newton's Apple, "Floods," Public Broadcasting System, Television Show.

BEST MANAGEMENT PRACTICES FOR FORESTRY

9-12

OBJECTIVES

The student will do the following:

1. Identify which BMPs should be employed on a logging area.
2. Evaluate whether those BMPs are properly employed.
3. Measure in-stream water quality parameters to determine whether the logged area is affecting quality.

BACKGROUND INFORMATION

Until early in the 20th century, the forests in the eastern U.S. were considered inexhaustible, and were typically logged and abandoned for conversion to other uses or allowed to reforest on their own. Timber was needed for railroads, mines, and housing construction that accompanied the population expansion south and west. Much of the deforested land was farmed or grazed.

Logging practices employed during this “cut and get out” period were often abusive to the soil and surface waters. Little was known about erosion, its effects or its control. Today, however, forest land managers are sensitive to the need to protect the land during and after harvesting, and best management practices (BMPs) have been developed by each state to guide logging, road construction and other forestry activities

SUBJECTS:

Science (Physical Science, Ecology, Earth Science), Math, Social Studies (Geography), Language Arts

TIME:

2-3 class periods (possible field trip)

MATERIALS:

topographic maps (USGS) - use community
water test kit capable of analyzing for total suspended solids, pH, dissolved oxygen, and temperature
BMPs for forestry guidebook
forestry fact book if available

so that the forests can continue to produce wood products while providing wildlife habitat and protecting stream water quality. The forest activities that are primary sources of pollution are logging roads, stream crossings, skid trails and log loading areas, as well as near-stream logging. Conducted improperly, these activities can cause sedimentation (from erosion) and other adverse impacts. Forestry BMPs are designed to prevent pollution from these activities, and are very effective if properly employed.

Two methods are most commonly used to evaluate whether water quality is being protected during a forestry operation. The first is an evaluation of whether BMPs are being or have been employed. The second is to measure in-stream indicators of pollution likely to be caused by forest practices. This activity includes both approaches.

Terms

best management practices (BMPs): techniques that are determined to be currently effective practical means of preventing or reducing pollutants from point and nonpoint sources, in order to protect water quality. BMPs include, but are not limited to: structural and nonstructural controls, operation and maintenance procedures, and other practices. Usually, BMPs are applied as a system of practices rather than as a single practice.

contour: (1) imaginary line on the surface of the Earth connecting points of the same elevation;
(2) a way of shaping the surface of the land in a particular form, commonly used to prevent erosion and control water flow.

erosion: the process of detachment, transport, and deposition of soil material

filter strip: area of land that infiltrates surface runoff and traps sediment and associated pollutants

log landing: site where logs are sorted and loaded onto trucks for hauling

reforestation: restocking of a forest stand through natural regeneration or artificially planted seed or seedlings

sediment: eroded soil material, containing primarily inorganic constituents

silviculture: care and cultivation of forest trees; forestry

site preparation: the use of machines, herbicides, fire, or combinations thereof to dispose of slash (unmerchantable debris), improve planting conditions, and provide initial control of competing vegetation

skid: to drag logs with specialized equipment to a landing

slope: degree of deviation of a surface from the horizontal, measured in degrees

streamside management zone (SMZ): area left along streams to protect streams from sediment and other pollutants, protect streambeds, and provide shade and woody debris for aquatic organisms

suspended solids: small particles of solid materials in water that cause cloudiness or turbidity

USGS: United States Geological Survey

water bar: a long mound of dirt constructed across the slope to prevent soil erosion and water pollution by diverting drainage from a road or skid trail into a filter strip

waters of the state: includes every natural or artificial watercourse, stream, river, wetland, pond, lake, coastal, and ground or surface water wholly or partially in the state, that is not entirely confined and retained on the property of a single landowner

ADVANCE PREPARATION

The objective of this activity is to introduce the student to forestry BMPs, how they should be prescribed and evaluated, and how some water quality indicators may be affected by logging practices.

Locate several logging sites in the local area, preferably adjacent to streams. Sites can be in the process of being harvested prior to construction activities (land clearing), but a “true” forestry activity is preferable. A site above and below the logging area along the stream should be identified. If there is no stream below the logging area, parts of this activity can still be done. Students should be made aware of good conservation practices.

PROCEDURE

- I. Setting the stage
 - A. Put terms on the board and define. Discuss.
 - B. Discuss problems that can be caused by erosion and sedimentation from an improperly logged area or poorly designed or constructed roads.
 - C. Using the state silviculture BMP manual, identify the BMPs that should be followed on the logged area.

II. Activity

- A. Determine whether the BMPs that should have been followed were in fact followed.
- B. Observe the stream channel above and below the logged area.
 - 1. Evaluate whether eroding soil is reaching the stream channel.
 - 2. If the stream is flowing, and preferably after a storm, test for suspended solids and temperature.
 - 3. Additional parameters such as pH and DO may be tested. However, these are less likely to change as a result of logging.
 - 4. Testing water on-site for various parameters is preferred, but students may collect samples to test for suspended solids. Temperature should always be taken in the field, not in the laboratory.
- C. Data sheets created by students should include information about the logging operations/roads, approximate acreage, BMPs, stream conditions, watershed information, SMZs, forest roads, and other BMPs observed.
- D. Students should use data collected to compare operations. Comparisons can be made by group discussion, essay, graphic display, or a combination of these. (A forestry professional can be invited to the class to answer questions about the silvicultural practices.)
- E. Have students document any obvious situation that may need attention and use the information to speak to that state forestry agency representative.

III. Follow-up

- A. Ask students to think of other ways that erosion from silvicultural practices could be controlled.
- B. Have students determine if any of these BMPs could help prevent soil erosion from other practices (construction, farming, ranching, and other unpaved roads).
- C. Illustrate two hypothetical forestry operations, one with good sediment control and one with poor control, and have students identify the specific good and bad practices.

IV. Extensions

Invite a forestry professional to talk to the class about local or state forestry practices and to discuss forestry issues.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison- Wesley,
Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works,
4th Edition, Englewood Cliffs, NJ, Prentice-Hall, Menlo Park, CA, 1993.

See pages L-1 to L-6 for State Forestry Offices

SIMPLE TEST-MICROBIAL CONTAMINATION

9-12

OBJECTIVE

The student will do the following:

1. Explain the existence, growth, and possible effects of bacteria in drinking water.

BACKGROUND INFORMATION

The water we drink is not always as clean as it appears to be. Water in streams, rivers, lakes, and ponds has pollutants dissolved or suspended in it. Also, there are many naturally occurring microorganisms living in waterbodies. Some of these microorganisms (e.g., some of the bacteria and viruses), are disease-causing. Some of the waterborne diseases they cause are dysentery, typhoid fever, and infectious hepatitis. Therefore, it is most often not safe to drink water from streams or rivers without testing and/or purification. There are simple tests that check for certain types of bacteria in water.

SUBJECTS:

Science (Ecology, Biology), Health

TIME:

2 class periods

MATERIALS:

(for each group)

10 ml of three water samples
gelatin (light color, like lemon)
cotton swabs
petri dish with lid for each
student group, sterile
tripo magnifier, AGFA lenses, or
hand lenses
permanent marker

Terms

bacteria: typically one-celled, non-photosynthetic microorganisms that multiply by simple division. They occur in three main forms: spherical (cocci), rod-shaped (bacilli), and spiral (spirilla).

contaminant: an impurity that causes air, soil, or water to be harmful to human health or the environment; something that makes a substance impure, infected, corrupted, or polluted

microorganisms: microscopic or ultramicroscopic organisms (e.g., bacteria, protozoa, viruses)

protozoa: mostly microscopic animals made up of a single cell or a group of more or less identical cells. Protozoa live chiefly in water, but many are parasitic.

virus: any of a group of ultramicroscopic or submicroscopic infectious agents that cause various diseases in animals, such as measles and mumps, or in plants, such as mosaic disease. Viruses are capable of multiplying only in connection with living cells.

ADVANCE PREPARATION

- A. Prepare gelatin according to directions and pour approximately two tablespoons into each petri dish. Cover with the lids. Let cool overnight.
- B. Collect water samples from three sources. (One may be tap water. Others may be from local ponds, rivers, streams, drainage ditches.)

PROCEDURE

- I. Setting the stage
 - A. Discuss Background Information with students.
 - B. Define terms and discuss what students know about these organisms.
- II. Activity
 - A. Have students divide petri dish into four equal sections using a marker on the outside bottom part of the dish. (Be sure they keep the lids on.) Then dip a cotton swab in a sample of water, rub the cotton swab over gelatin in one marked section of the petri dish, and cover it with the lid. Repeat with the other two samples using a clean cotton swab each time and making sure that a new section is used each time. Do not allow water to run from one section to another. Incubate upside down at room temperature.
 - B. At the next class period, ask students to observe the three areas for colony growth. These will appear as circular spots on the gelatin. (The fourth section is a control.)
 - C. Have students discuss the rate of growth of the colonies. Explain that the dish

was incubated naturally at atmospheric temperature during which time each single bacterium on the gelatin multiplied to form a colony visible to the naked eye. Was there any growth in the control section? Why or why not?

- D. Ask students where they think each bacterial colony originated (from water, air, cotton swab). Have them support their answers.

III. Follow-up

Ask students:

- A. Are all water pollutants visible?
- B. What are some possible sources of bacterial pollutants?
- C. How can bacteria be removed by a water treatment plant?
- D. Did this experiment test for all types of water pollutants? (No; not chemicals, viruses, protozoa.)
- E. Are all bacteria harmful? What kinds of tests would need to be done to determine the harmful from the harmless bacteria?

IV. Extensions

- A. Conduct a similar type of experiment to monitor for sewage contamination. Collect samples upstream and downstream from a wastewater effluent site or near an area where livestock is raised. (Caution - Use latex gloves for collection.)
- B. Have students conduct research to find other types of laboratory methods to monitor bacterial contamination of water.
- C. Have students research different diseases caused by waterborne microorganisms and discuss why many of these diseases are not as prevalent today as they once were.
- D. Have students research various waterborne pathogens which are difficult to measure, control, or regulate, and which still pose serious threats to water quality. (Some examples are *Cryptosporidium parvum*, *Giardia lamblia*, *Schistosoma*, etc.) Learn about current regulations (state or federal) designed to test for and protect against such contaminants.

- E.. Have students examine various microbes with a microscope for possible identification of type.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D. , Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?

9-12

OBJECTIVES

The student will do the following:

1. Define the concept of concentration as different from an expression of total amount.
2. Explain that chemicals may be present in water or wastewater in concentrations so low that they are undetected.
3. Demonstrate changing concentrations through serial dilution.
4. Distinguish between loading and concentrations as these terms apply to wastewater effluents discharged into a receiving stream.
5. Calculate concentration and loading.

SUBJECTS:

Math, Science (Chemistry)

TIME:

1 class period

MATERIALS:

red food coloring
toothpicks
2 medicine droppers, 1 for color,
1 for water
beaker or jar of water
1 bottle that will hold 10 ml
one 2-liter soda bottle
10 ml pipette
1 liter graduated cylinder
white foam egg cartons
spectrophotometer if available
(to measure dilution)

BACKGROUND INFORMATION

Often, consumers must think not only in terms of the total amounts, but also in terms of “unit per unit” measurements. An example of this is unit pricing, where product costs for groceries are expressed in terms of total cost and cost per unit weight (e.g., cost per ounce or cost per gram). This same “unit per unit” i.e., units of pollutant per unit of water, concept is applied to water and wastewater quality

measurements.

Water is called the “universal solvent,” since many common substances are easily dissolved in water. Other substances, such as suspended solids do not dissolve in water, but are often present in water or wastewater discharges (effluent). Pollutants which are either dissolved or suspended in water are often measured or expressed in terms of “concentration,” typically milligrams per liter (mg/l) or micrograms per liter (µg/l). However, pollutants in wastewater effluents are often required, through permit conditions, to be measured in terms of “loadings” as well as concentration. Loadings are simply the total amounts (mass) of a pollutant as measured on a daily (or some other time interval) basis, such as pounds per day (lb/day) or kilograms per day (kg/day). Wastewater pollutant concentrations are also typically expressed in mg/l (parts per million, ppm) or µg/l (parts per billion, ppb).

The flow of rivers or streams can play a major role in determining the effects of a pollutant on them. This is because stream flow (also called stream velocity) is defined as the volume of water flowing over a point per time interval, which can be expressed as m³/s or cubic feet per second (cfs). Therefore, if the average flow of a river is 14 m³/s, the volume of water flowing at any one “point” of the river in one second is 14 m³. And if a different river had twice the average flow, 28 m³/s, the volume of water flowing at any one “point” of this river in one second is 28 m³. Now, if two pollutant samples of an equal amount (mass) are discharged in the two rivers described above, what would happen to the concentration of the pollutant in the two rivers? In simple terms, the river with the higher flow would have a lower concentration of pollutant, but by how much? Since concentration is a unit of mass per unit of volume, if the amount of pollutant stays the same and the flow doubles, then the concentration will be reduced by one-half. The following equations demonstrate this numerically:

<u>River I</u>	or	<u>River II</u>
$\frac{500mg}{14m^3}$		$\frac{500mg}{28m^3}$
$35.71 \frac{mg}{m^3}$		$17.86 \frac{mg}{m^3}$
$0.03571 \frac{mg}{l}$		$0.01786 \frac{mg}{l}$

ADVANCE PREPARATION

Set up lab stations with the listed materials for students to work in groups.

PROCEDURE

I. Setting the stage

A. Explain to students that they will be modeling a very common lab procedure called a serial dilution in Activity 1 that is widely used in medical and biological labs as well as water quality labs. In water quality labs, it is most commonly used to dilute water samples for coliform bacteria determinations. If students are familiar with growing bacteria in petri dishes, ask them what happens when there are too many bacteria added to the dish. (They grow all over the place, and it becomes difficult to count each colony.) The ideal is to have separate colonies such that each represents a single original cell.

B. Explain to students the material in the background and be sure that they understand about discharges into a receiving stream in high and low flow conditions.

C. Warn students about keeping droppers separate for food coloring and water.

II. Activity

A. Serial dilution:

1. Place 10 drops of red food coloring into the first egg carton well. Food coloring as it comes from the bottle is already a 1:10 dilution.
2. Use a clean dropper to add 9 drops of clean water to well #2, then take 1 drop of well #1 and add to well #2. Mix with toothpick before taking from Well #1 and adding to Well #2. Caution: Be sure that the medicine dropper that is used for the color is cleaned between each use. If not, the dilutions will be incorrect.
3. Again add 9 drops of water to well #3, then 1 drop of well #2 to well #3. Mix.
4. Repeat until there are 10 wells with liquid.
5. The food coloring in well #1 is 1 part color per 10 parts liquid. What is the concentration in well #2? Make a chart that shows each dilution all the way to well #10.

Example

Well #	Calculation	Expression of dilution
1	1/10	1 part per 10
2	1/10 x 1/10	1 part per 100
3	1/100 x 1/10	1 part per 1000
4	1/1000 x 1/10	1 part per 10,000
5	1/10,000 x 1/10	1 part per 100,000
6	1/100,000 x 1/10	1 part per 1,000,000
7	1/1,000,000 x 1/10	1 part per 10,000,000
8		
9		
10		

6. At which concentration did the color disappear? Do you think there were any parts of the red coloring in well #10? Explain.

7. What would remain in the wells if all the water were removed? Allow the water to evaporate and observe.

B. Difference between loading and concentration:

1. Fill the small bottle with 10 ml of water and add 1 drop of red food coloring. If one drop were to equal 0.01 mg of pollutant, express the resulting concentration in mg/liter. How much total pollutant in mg do you have?

2. Now add the whole 10 ml bottle to the 2-liter bottle. How many total mg of pollutant do you have? Express the concentration in mg/liter.

III. Follow-up

- A. To explain further how small 1 ppm or 1 ppb is, give students the following examples.
 - 1. Distance to the sun = 93 million miles. If you drive 93 miles, that is 1 ppm.
 - 2. Distance to the moon = 239,000 miles = 1.26 billion ft. If you move 1.26 ft., that is 1 ppb.
- B. Ask students to write other examples.
- C. Give students the pollutant concentration amounts in Extension A. Ask students if they feel these regulations are strict enough and if they think that keeping pollutants at such a low level is cost effective. Discuss. (The instructor may want to have students complete Extension A before the discussion.)

IV. Extensions

- A. The maximum contaminant levels of some pollutants in drinking water (as of 1996) are given below. Ask students to do reports on these substances and explain why they are considered to be so toxic. Students should research health effects of each substance.

arsenic	50 ppb
cadmium	5 ppb
mercury	2 ppb
endrin	2 ppb
lindane	0.2 ppb
2,4-D herbicide	70 ppb

- B. Ask students to discuss the differences between release of the toxic pollutants listed above and discharge of wastewater from treatment plants that contain ammonia, nitrates, phosphate, or BOD. (The former are either not able to be broken down or have a long life in nature; the latter, except BOD, are very biodegradable in a short period of time and typically break down into simple non-toxic compounds.)

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Seuss, Dr., The Lorax, Random House, New York, 1971. (Also available on video)

ETHICAL DILEMMAS WHAT'S A BODY TO DO?

9-12

OBJECTIVE

The student will do the following:

1. Distinguish between decisions based on ambitions and dreams versus environmental ethics surrounding water.

BACKGROUND INFORMATION

In the course of daily living, one makes many decisions. Some of those decisions will alter a life's course, and others may provide temporary comfort or discomfort. The school environment gives students the opportunity to experience and practice the decision-making process, make mistakes, and learn from the decisions and the consequences. Such is the aim of this activity. The problems deal with the conservation and protection of a valuable resource - water.

Terms

con: against; in opposition; negative consideration

ethics: the study of the general nature of values and of the specific moral choices to be made by the individual in relationships with others and his/her environment

pro: for; in support of; affirmative consideration

ADVANCE PREPARATION

Because of the nature of this activity, advance preparation is not necessary. However, if the teacher wishes, the questions may be written on index cards. This activity can be used at the end of a class or just after an assembly when there is not time for a planned lesson. It is also feasible to spend many hours of research for fact-based decisions.

SUBJECTS:

Social Studies (Economics),
Science (Environmental
Science), Language Arts

TIME:

1 class period

MATERIALS:

pen/marker
index cards
teacher sheet

PROCEDURE

I. Setting the stage

- A. Students should be made aware that the decisions they make affect all aspects of their environment.
- B. The responsibility of stewardship of the Earth is great and needs to be taken seriously.
- C. Students, as adults, should approach problems with open minds and willingness to accept responsibility for their actions.

II. Activity

- A. Have students form groups for a discussion-type setting.
- B. Distribute paper, pens, and index cards with scenarios. (See Teacher Sheet.)
- C. Instruct the students to make two lists entitled “pros” and “cons” before they make their decision.
- D. Have students read or watch *The Lorax* by Dr. Seuss.

III. Follow-up

After a predetermined amount of time, have the groups share their decisions.

IV. Extensions

- A. Require this activity as a research paper.
- B. Treat the problems as debate issues.
- C. Have students go to their school library and develop a bibliography of environmental writings.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Seuss, Dr., The Lorax, Random House, New York, 1971. (also available on video)

Suggested Scenarios:

1. A paper company builds a new mill in your area. You take a job at the plant. Later, you learn that the plant is responsible for the destruction of the woods where you hunt. The plant's water effluent is polluting the local river with dioxin and other toxic chemicals. How would you react to this?
2. Would you raise cows near the stream from which your drinking water is pumped? It is the best grazing land, and you can get the fastest growth (that means the most money).
3. There are plans for a water park near your neighborhood. It is predicted that 500,000 people would visit this park during the summer. Your town is very small and depends on the river for water and electricity. The water park will use a tremendous amount of water from the river and it will allow people to camp overnight along the river. Your town needs more jobs and income. How would you vote on this issue in an election?
4. Make up additional scenarios or write up a few actual cases.

WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?

9-12

OBJECTIVES

The student will do the following:

1. Describe indicator organism.
2. Describe fecal coliforms.
3. Explain how fecal coliforms are indicative of water quality.
4. Demonstrate a test conducted to measure coliforms.
5. Describe sources of water contamination.

SUBJECTS:

Science (Biology,
Environmental Science),
Health

TIME:

2 class periods

MATERIALS:

Hach m-Coli Blue 24
broth or Coliform
testing kit
membrane filtration
equipment
filters
petri dishes (15mm)
gloves
tweezers
water samples in bottles
incubator

BACKGROUND INFORMATION

Many concerns regarding water quality have been related to the transmission of disease. Throughout history many diseases have been waterborne. Cholera, typhoid fever, and dysentery are examples of waterborne diseases that have plagued humans until the advent of modern technology for the effective treatment of wastewater and drinking water. The following are examples of diseases that could be contracted from contaminated water, the organisms that cause them, and the association related to drinking water or other sources.

<u>Diseases</u>	<u>Organisms</u>	<u>Associated With</u>
Microencephalitis	<i>Naegleria fowleri</i>	Fecal coliform bacteria (Fecals)
Typhoid fever	<i>Salmonella typhi</i>	Contaminated water
Cholera	<i>Vibrio cholerae</i>	Contaminated water
Dysentery (gastroenteritis)	<i>Staphylococcus aureus</i>	Fecals in drinking water
Amoebic dysentery	<i>Entamoeba histolytica</i>	Fecals in drinking water
Bacillary dysentery	<i>Shigella</i>	Fecals in drinking water
Lung fluke	<i>Paragonimus westermanni</i>	Contaminated fish
Schistosomiasis	<i>Schistosoma</i>	Contaminated water

Historically, tests have been developed to measure the quality of our water and foods. By testing ambient conditions of waters for specific organisms, *indicator organisms*, water quality managers monitor the safety of the waters for their specific uses such as drinking water supply, swimming, or fish and wildlife uses. The primary characteristic for indicator organisms is that they are consistently present in human wastes in substantial numbers. The detection of these organisms in the water is a good indicator that fecal wastes are entering the water. The indicator organisms should also survive in water at least as well as other pathogenic organisms would survive. Testing for these organisms is fairly simple. People with technical training, such as operators of water treatment plants in small communities, do much of the testing.

In the U.S., the commonly used indicator organisms are the coliform bacteria. Coliforms are defined as aerobic or facultative anaerobic, gram-negative, non-endospore-forming, rod-shaped bacteria that ferment lactose to form gas within 48 hours of being placed in a growth medium at 35°C. Coliform bacteria are commensal and are common in the intestines of warm- and cold-blooded animals. They aid in food digestion. When animals defecate, the coliform and pathogenic microbes, if present, pass out of their bodies with the wastes. If these wastes find their way into a water supply, they bring bacteria and other microbes with them. Large numbers of coliform organisms indicate the possible presence of pathogens.

The fecal coliform bacteria test is easy to do but requires a precise incubation temperature of 44.5°C, not varying more than 0.2°C either way.

Fecal coliform population standards for drinking water are the same for all states and are required by the EPA. Standards for swimmers and other recreational uses are set by the states and approximate the water quality criteria given below, with some variability by state.

Swimming Pools		1 fecal coliform/100ml
Non-coastal Swimming Beaches		200 fecal coliforms/100ml
Incidental/Recreational (not swimming)		2000 fecal coliforms/100 ml
Coastal Swimming Beaches		standards same as Incidental/Recreational
Fish and Wildlife	-June-September	1,000 fecal coliforms/100ml
	-October-May	2,000 fecal coliforms/100ml

For water that is to be used as a drinking water source, the Safe Drinking Water Act does not specify a maximum fecal or total coliform level prior to treatment. However, water that is to be used for drinking purposes must be sampled for total coliform bacteria, on a schedule based on the water system's user population. No more than five percent of these samples may contain any type of coliform.

Terms

aerobic: with oxygen; needing oxygen for cellular respiration

anaerobic: in the absence of oxygen; able to live and grow where there is no air or free oxygen, as certain bacteria

aseptic: free or protected from disease-producing or putrefying microorganisms

commensal relationship: a relationship between two organisms in which one is benefited by the relationship and the other is neither benefited nor harmed

facultative anaerobic: describes an organism that can use another electron accepting molecules other than oxygen for cellular respiration, if oxygen is not present

ferment: to break down sugars only partially, producing a gas (usually CO₂) and alcohol

gram negative: the result of a certain laboratory test done on microorganisms to divide them into two groups (either gram negative or gram positive). Gram negative bacteria have a cell membrane composed of lipopolysaccharide and protein.

incubation: the phase of development of a disease between the infection and the first appearance of symptoms

indicator organism: an organism whose presence or absence typically indicates or provides information on the certain conditions within its environment

lactose: a type of simple sugar that can be digested by fecal coliform bacteria

nonendospore-forming: does not form an encapsulated nucleus resistant to most harsh environmental conditions

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (e.g., outlet or pipe because it comes from many individual sources or a widespread area (typically, rural, urban, and agricultural runoff))

pathogens: disease causing agents, especially disease-causing microorganisms

pathogenic: producing disease

point source pollution: pollution that can be traced to a single point source such as a pipe or culvert (e.g., industrial, wastewater treatment plant, and certain storm water discharges)

rod-shaped bacteria: a physical form of bacteria. These are longer than they are wide; cylindrical

ADVANCE PREPARATION

- A. Order Hach m-ColiBlue 24 broth or a Coliform testing kit.
- B. Set up membrane filtration equipment. Instructions will come with the supplies.
- C. Run off Student Sheet.
- D. Collect or have students collect water samples from the tap, bottled water, or ~~surface~~ surface water (local river, stream, wetland, lake, pond, reservoir, or ocean). Use clean ~~bottles with lids~~ bottles with lids to collect.

PROCEDURE

- I. Setting the stage
 - A. List and define terms on the board.
 - B. Discuss Background Information.
 - C. Review aseptic technique with students.

II. Activity

A. Have students write a hypothesis about what they think the results of the fecal coliform testing will be and write a brief paragraph about why they made specific predictions.

(If using a coliform testing kit, follow the directions for procedure. Otherwise follow the directions below.)

B. Filter 100ml of each sample using a small filter. Clean all equipment before ~~sating~~ and between each sample.

C. Use tweezers to remove the filter paper and place in a sterile petri dish.

D. Break open an ampule of the m-ColiBlue 24 broth and pour over the filter paper. Label each dish.

E. Incubate at 44.5°C for 24 hours.

F. Examine for growth at the end of 24 hours. Total coliform counts can be attained by counting both the red colonies and the blue colonies. For E. Coli counts, count only the blue colonies.

G. Record data on Student Sheet.

III. Follow-up

A. Have students write a statement accepting or rejecting their hypotheses. Explain why the test turned out like it did.

B. Have students list some possible sources of coliform contamination in the samples that were positive.

C. Discuss how these contaminants affect the cost of purifying drinking water. Ask students for ideas on how to prevent contamination.

IV. Extensions

- A. Students could research the different pathogenic microorganisms found in water. Each student could report on one disease.
- B. Discuss nonpoint source pollution and problems this can cause.

RESOURCES

High school biology book or high school environmental science book.

Jacobson, Cliff, Water, Water Everywhere, (Student Reading Unit About Water Quality), Hach Company, Loveland, CO, Catalog Number 21975-00. 1-800-227-HACH.

Water Analysis Kit, page F-69, Water Testing Fact Sheet

Data Sheet

List each water sample source below and record number of colonies beside each one.

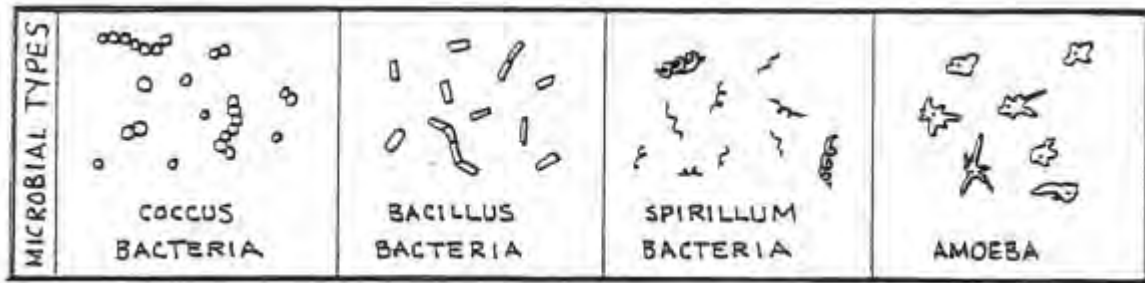
1.

2.

3.

4.

5.



TURBIDITY

OBJECTIVES

The student will do the following:

1. Define turbidity.
2. Describe the effects of turbidity on aquatic ecosystems.
3. Measure turbidity levels.
4. Compute average turbidity.

BACKGROUND INFORMATION

Turbidity is defined by the American Public Health Association as the “optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample.” In other words, “How cloudy is the water?”

The amount of suspended material present determines the ability of light to pass through water. Turbidity may be caused by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals, coal dust, and plankton. Soil erosion from agriculture, mining, logging, dirt roads, construction, and dredging operations contribute to the silt problem.

The most accurate way to determine water’s turbidity is with an electronic turbidimeter. The turbidimeter is a photoelectric cell that accurately measures the light scattered by suspended particles in a water sample. The results are reported in units called Nephelometric Turbidity Units or NTUs.

Turbidity can also be measured by filtering a water sample and comparing the filter’s color to a standard turbidity color chart or by a device called a Secchi disc that determines turbidity from a sample’s clarity.

SUBJECTS:

Science (Environmental Science, Ecology, Earth Science, Chemistry)

TIME:

1 class period

MATERIALS:

white gallon milk containers
black markers
rulers
scissors
large petri dishes
Secchi disc
meter sticks
stapler
ball of string marked in 1cm units
4-5 light-colored small buckets
dirt
water
100 mL beakers

Turbidity affects fish and aquatic life by:

1. Interfering with sunlight penetration that, in turn, results in lower oxygen concentrations and large carbon dioxide concentrations.
2. Clogging the gills of fish and shellfish and killing them directly.
3. Providing a place for harmful microorganisms to grow.
4. Reducing the visibility for certain fish to find food but, on the other hand, helping protect from predators.

The table below shows the amount of fish and plankton per acre that may be expected in ponds of different turbidities.

FACTOR	CLEAR	INTERMEDIATE	MUDDY
MEASURED	PONDS	PONDS	PONDS
Average turbidity units:	Less than 25	25-100	over 100
Amount of fish in ponds per acre:	162	94	29
Comparative amount of plankton:	12.8	1.6	1

Terms

plankton: microscopic plants and animals in water which are influenced in mobility by the movement of water (i.e., as opposed to nekton (fish) which can swim)

Secchi disc: a black and white circular plate that is used to determine water clarity

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

ADVANCE PREPARATION

- A. Discuss the use of Secchi disc with students. These discs are lowered into a pond or lake with a rope that has measurement markings on it. The disc is lowered to a point where it is no longer visible and then raised up through the water until it becomes visible. The depth of visibility is

measured and compared to a chart. The depth of visibility is determined by the degree of turbidity in the body of water.

- B. Prepare 4-5 buckets of turbid water using tap water and local soil in various ratios. Mark the ratios on the buckets. Try the Secchi disc experiment on each bucket to make sure that some have no visibility.
- C. Prepare a chart on the board for data from each group.

PROCEDURE

I. Setting the stage

- A. Use the atmosphere and its particulate matter as an example to initiate discussion of turbidity.
- B. Have students name/list particles in the air; then list particles in the water. Discuss similarities.
- C. Discuss Background Information with students and review vocabulary.

II. Activity

- A. Have the students work in 4-5 groups. Number the groups for chalkboard recording purposes.
- B. Each group needs 1 white gallon milk container, black permanent marker, ruler, large petri dish, scissors.
- C. Cut out one complete side of the milk jug and place it under the lid of the petri dish and draw a circle. Cut it out. Use the ruler to divide and mark the circle in quarters. Color 2 opposite quarters black. This will resemble a small Secchi disc that is used to measure the clarity of water. Attach a string $\frac{1}{2}$ meter in length to the middle of the disc with a stapler and mark the string every centimeter.
- D. Have students stir each turbidity bucket and then immediately lower the Secchi disc into the bucket.

E. The disc should be lowered until it is no longer visible.

F. Have one student record the distance from disc to water surface using the meter stick or by the centimeter marks on the string. Record data on Data Sheet.

G. Each group should repeat steps for each bucket and record data on Data Sheets and on the board.

H. Obtain measurements from the other groups that were recorded on the board and ~~calculate~~ an average for each sample. Record the values on the Data Sheet. The smaller the measurement, the greater the turbidity.

I. Have students compare the turbidity of a local river or stream during fair weather conditions and immediately after a storm. Ask how could one help prevent increase of turbidity resulting from farming or logging.

III. Follow-up

Have students bring in various water samples and align them by a visual observation in order of turbidity. Place each on the sheet of white paper and label the source of each. Discuss what caused turbidity in each sample by discussing the factors surrounding the body of water from which it was taken.

IV. Extensions

A. Try Secchi disc measurements on a field trip to various bodies of water.

B. Have a field biologist, hydrologist, or water quality expert discuss problems and sources of water turbidity. They may demonstrate various ways of measuring turbidity.

C. Demonstrate the removal of sediment by mixing in alum. This is done by water treatment plants.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

Jacobson, Cliff, “Water, Water Everywhere,” (Student Reading Unit About Water Quality), Hach Company, Loveland, CO, Catalog Number 21975-00. 1-800-227-HACH.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

TURBIDITY DATA SHEET

GROUP:	#1	#2	#3	#4	#5
1					
2					
3					
4					
5					
AVERAGE:					

CLEAN CLOTHES - CLEAN ENVIRONMENT?

PHOSPHATES

9-12

OBJECTIVES

The student will do the following:

1. Develop a survey form.
2. Collect data on consumer use and knowledge.
3. Design graphs using collected data.

BACKGROUND INFORMATION

Phosphate is a nutrient necessary for plant and animal growth. Almost all fertilizers contain phosphates. When it rains, varying amounts of phosphates wash from golf courses, sod farms, and farm soils into nearby waterways. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterway's quality of life. When too much phosphate is present, algae and water weeds grow wildly and choke the waterway, using up the large amounts of oxygen and causing many aquatic organisms to die.

The phosphate cycle is said to be "imperfect" because not all phosphates are recycled. Some simply drain into lakes and oceans and become lost in sediments. Phosphate loss is not serious because new phosphates continually enter the environment from other sources.

Phosphates are used in fertilizers, pesticides, industry, and cleaning compounds. Natural sources of phosphates are phosphate-containing rocks and solid or liquid wastes. Phosphates enter waterways through human and animal wastes (the human body releases about a pound of phosphates per year - or billions of pounds per year from the world's population), phosphate-rich rocks, wastes from laundries, cleaning and industrial processes, and use of farm fertilizers and pesticides. Phosphates also are used widely in power plant boilers to prevent corrosion and the formation of scale.

SUBJECTS:

Science (Chemistry, Biology), Math, Social Studies (Economics)

TIME:

2 class periods

MATERIALS:

paper
pencil/pen
computer (optional to organize data)
labels from detergent products
examples of various detergents
dish and laundry survey form for consumers (student developed)
data collection table (student developed)
water or phosphate analysis kit
(if water survey is desired)

Phosphates will not hurt people or animals directly unless they are present in very high concentrations. Even then, they will probably do little more than interfere with digestion. It is doubtful that humans or animals will encounter enough phosphate in natural waters to cause any health problem.

Total phosphate consists of organic and inorganic phosphates. The organic phosphate is formed in living or dead plant and animal tissue. Organic phosphates are important in nature and also may result from the breakdown of organic pesticides containing phosphates. Inorganic phosphate is found in soil, water, and human-produced materials (detergents). Other forms of phosphate are produced by natural processes and are found in wastewater. Poly forms are used for treating boiler water and in detergents and can break down into simpler forms in water.

A certain amount of phosphate released into a stream or river is immediately taken up by algae and plants. Too much phosphate results in excessive growth of plants and causes algal blooms. When plants die, bacteria and other microbes increase in order to break down the organic material. These microorganisms consume available oxygen that, in turn, results in the death of larger aerobic organisms such as fish. This process is called eutrophication. If eutrophication continues, the aquatic system becomes anaerobic, which gives off the rotten egg odor produced by hydrogen sulfide gases. Eutrophication occurs naturally at a very slow pace. Human interference can speed the process by introducing improperly treated sewage, industrial waste, or runoff from feed lots and farmland into receiving waters..

This activity concentrates on the phosphates in detergents. In recent years, some detergents have added to their advertising claims comments such as, “Contains no phosphates” or “Low in phosphates.” What are these phosphates, and what is all the fuss about? If they are so bad, then why have they been used in detergents? If they are or were in detergents, then how can they lead to water pollution? Compounds containing phosphate ions are usually associated with the need for high energy substances such as detergents and fertilizers. Phosphates have been used to improve the cleaning power and sudsing ability of detergents. We have culturally associated “lots of suds” with ability to clean, but this is not necessarily true. Now the makers of detergents are trying to sell their product based on their low or lack of phosphate content.

This activity will allow students to research the sources of these phosphates, survey consumer knowledge, and evaluate the impact on our waterways.

Terms

algal bloom: a sudden increase in the amount of algae, usually causing large, floating masses to form.

Algal blooms can affect water quality by lowering DO content and decreasing sunlight penetration, are usually caused by excessive nutrient addition, and can be characteristic of a eutrophic lake.

eutrophication: the process in which a body of water becomes oxygen deficient, nutrient-rich, and supports an abundant growth of surface aquatic plants and algae; natural aging cycle of lakes, normally taking centuries, but it can be rapidly accelerated when outside sources of nutrients are added, such as wastewater, fertilizer, or feed lot runoff.

phosphate: an ion composed of a phosphorus atom with 4 oxygen atoms attached (PO_4^{-3}). It is an important plant nutrient.

ADVANCE PREPARATION

- A. List terms and definitions on the board.
- B. Copy and discuss Background Information with students.
- C. Have students bring in labels from detergent products.

PROCEDURE

- I. Setting the stage
 - A. Assign students to work in groups. Have them compile data on different detergents, including cost, phosphate content, and phosphate-related advertising claims (e.g., “free of phosphates” and/or ability to create suds).
 - B. Students should collect data from all types of cleaning products, such as laundry detergents and dishwasher detergents. Predetermine the minimal number they must examine.
 - C. Students should then compile data in table form and, if possible, graph form. (A bar graph would work well.)
 - D. Have students determine if there are any local or regional phosphate-detergent bans in place. What do they prohibit? Get state/local environmental officials to discuss the ban’s effectiveness. Wastewater treatment plant data should show the effect of the ban if phosphate (or total phosphorus) concentrations before and after the ban are evaluated.
 - E. Have students design a survey form or questionnaire asking 25 people (different families):

1. Their choice of laundry detergent and dishwasher detergent.
2. Why they use that detergent. (List top three reasons.)
3. If they are aware of the effect of excessive use of phosphates.
4. Would they change detergents if their current choice were high in phosphates? Students can survey their own family and one neighbor. Do they consider cost, phosphate content and/or other factors when choosing a detergent?

F. Students will share survey results with the group and then with the class. Have groups or the entire class analyze the compiled data and draw conclusions.

G. Compare the consumer data and determine if any relationship exists among choice and cost, phosphate content, and/or other factors.

III. Follow-up

Students can analyze local rivers or lakes within the watershed for phosphate content and algal growth using a water testing kit from a supply company. This data can be compared with choice of detergents and conclusions should be drawn. Be sure to ask students if the phosphates could be coming from anywhere else.

A. Each group will turn in a report of data and conclusions.

B. Students may bring in samples of surface waters and add different detergents to each and see if there is an algal growth difference between the different detergents.

IV. Extensions

Students might want to analyze the wastewater treatment systems of upstream and downstream communities to see if there are specific processes used to reduce phosphorus. If so, they should see small phosphorus increase downstream of effluent discharge. If no phosphorus removal, they may see significant increase in stream phosphorus concentration (depending on flow of plant and flow of stream).

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

WHAT TURNED THE CREEK ORANGE?

9-12

OBJECTIVES

The student will do the following:

1. Describe how land disturbed by surface mining becomes more porous, permeable, and vulnerable to leaching--properties not necessarily fixed by reclamation.
2. Demonstrate how water leaches elements from soils and rocks, dissolves minerals, and carries them elsewhere through groundwater.
3. Explain how large concentrations of elements ~~naturally~~ present in small amounts can adversely affect plant growth. (Extension)

BACKGROUND INFORMATION

When land has been mined in a way that removes coal or other resources from a shallow depth, the surface of the ground is disturbed over many acres. It may be disturbed down to a depth of 30-50 feet. All the soil is removed, and ground that might have more or less solid rock beneath the soil is broken up to excavate the seam of coal.

To prevent large-scale erosion at closed surface mining sites, mining companies are now required by law to reclaim the site by replacing soil and planting cover vegetation and trees. After mining, an attempt is made to contour the surface and direct runoff toward a settling pond. If this is correctly engineered, erosion and damaging runoff are controlled while plants establish themselves and a natural reclamation occurs. After reclamation, if the land looks

SUBJECTS:

Science (Earth and Physical)

TIME:

1 class period

MATERIALS:

sample of iron ore (limonite, hematite, or magnetite)
weak acid (vinegar will do)
bag of soft cookies with chocolate chips or raisins
toothpicks
newspaper sheets
PVC pipe, 6-8 inches diameter, 12-18 inches long, with 4-6 holes about 0.25 inch diameter) holes about 4 inches from end
sand
plastic dishpan or shallow pan about 15" x 15"
jug of water
package of Koolaid ® - cherry or orange
optional: gravel-sized crushed sandstone

the same on the surface, with grass, weeds, and trees becoming established, is it really the same in all of its characteristics? Before mining activities, rainfall seeped slowly down through soil and rock until it reached a relatively impervious rock layer. Mining of groundwater above and below the water table was slow through many small channels that had probably been established over hundreds or thousands of years. After reclamation, rainwater that does not run off over land will penetrate the soil and a layer of disrupted rocks. It will flow more readily due to increased amounts of open spaces between blocks of rock and cracks within the rock. In some areas, remaining seams of coal or organic-rich shale associated with coal may contain sulfide minerals that are chemically converted to sulfate minerals on exposure to air or oxygen-rich groundwater. Sulfate minerals readily dissolve in the water making the water more acidic (actually, like very diluted sulfuric acid). The size of the rock chunks creates a much greater surface area for the rainwater to contact coal. In addition to the sulfate minerals already dissolved, this acidic water causes additional leaching of minerals and natural elements from the rock. Some elements, therefore, get into groundwater in much greater concentrations than normally found. When that groundwater reappears in a spring or stream, it will be carrying those increased chemical concentrations to other areas far away from the originally mined land. The acidic waters that are formed in this way are called acid mine drainage.

Terms

acid mine drainage: acidic waters that are formed in mine areas from water coming into increased contact with sulfate and sulfide minerals. This forms sulfuric acid.

contour: (1) imaginary line on the surface of the Earth connecting points of the same elevation (2) a way of shaping the surface of the land in a particular form, commonly used to prevent erosion and control water flow

leaching: the removal of chemical constituents from rocks and soil by water (Leach = to leak)

permeability: the capacity of a porous material to transmit fluids. Permeability is a function of the sizes, shapes, and degree of connection among pore spaces, the viscosity of the fluid, and the pressure driving the fluid.

reclamation: bringing land that has been disturbed by some process back to its original condition

settling pond: usually a human-made pond that is designed to remove many of the particulates from runoff water

ADVANCE PREPARATION

A. Go over Background Information with students.

- B. Present terms and define.

PROCEDURE

I. Setting the stage

A. Ask students to imagine that they are walking a trail in a wilderness area. The wilderness area is bordered, over the hill from the river, by many acres where mining was done 10 years ago. Grass and trees now cover that land. They have taken a trail that leads up a ravine where a stream is running down toward the river below. An old growth forest with very large trees borders the stream; it is shaded and cool in the ravine. As they walk upstream, they begin to notice a change in the color of the stream water. At first it is barely noticeable but gets progressively more intense. There is a definite red-orange color in the water. The farther they go upstream, the more intense the color becomes; and they begin to notice red-orange particles that have been deposited on the stream bottom where the water is slower. Finally they reach the source of the stream, which is a spring coming out of a hillside. The red-orange color is very bright here, and red-orange particles and deposits can be clearly seen where water is slowly seeping and bubbling out.

B. Ask students to suggest possible causes for the red-orange color. Remind them of the mining activity and try to picture the topography of the land with the old mines on the surface at the top of the hill from this ravine. Lead their thoughts in the direction of possible minerals that might cause that color. Show the iron ore sample and ask how iron might be dissolved.

II. Activity

A. Put the iron ore sample into the weak acid. Agitate to increase dissolution. A crushed sample with more surface area will work best. If only a single chunk is available, you might put that in the acid a week ahead of this presentation. A bright red-orange color should appear on the rock surface where oxidation occurs, and some should dissolve in the acid solution.

B. To demonstrate earth disturbance from mining, give teams of two students a cookie and a toothpick on a sheet of newspaper. Tell each team that one person is to "mine" the chocolate chips or raisins out of the cookie using only the toothpick as a mining tool. The student must mine the cookie with as little disturbance as possible but

attempt to get maximum yield of "resource." The other team member may help by holding the cookie still. That team member's job is to use his/her fingers to put the cookie back to original condition. Have teams display their success; judge how much resource they mined and how well they reclaimed the land.

C. To demonstrate permeability of disturbed land, set the PVC pipe on its end in the shallow pan, holes nearer the bottom. Fill loosely with sand to a depth about 6-8 inches above the holes. Pour enough water in the top to make a depth of about 4-6 inches. Ask students what they think will happen. Let them observe until water comes draining out of the holes. Then pour dry Koolaid® drink mix on top of the sand and repeat with more water, again asking students to predict what will happen. After they have observed the colored Koolaid® draining out of the holes, have a student pack the sand very tightly down in the pipe, using a plastic drink bottle bottom or other tool. Ask students what difference they think packing will make. Repeat with the water and discuss.

D. (Optional): use gravel-sized crushed sandstone as a substrate to compare with the sand. Students may also want to compare the time it took for the liquid to drain with both substrates.

III. Follow-up

A. Ask students what they know about the presence of iron in water, rocks, and soil. Many soils and groundwaters have a fairly high concentration of iron, which may be seen as a rusty red or yellowish color. Ask them whether this is natural, harmful, a nuisance, etc.

B. Ask students:

What is formed when iron is leached out of rock by acidic water that causes the rusty red color? (iron oxide or rust) What is the chemical formula for this? (Hint: The iron reacts with the oxygen in the acid.)

C. Have students come up with a chemical formula for the formation of sulfuric acid from pyrite (FeS_2) and water.

D. Have students describe and explain what happened in the PVC pipe demonstration. How does this demonstrate land disturbed by mining?

IV. Extension

Have students research the effects of high concentrations of iron on plant growth, and explain or tell what might be done to correct soils with too much iron. An experiment could be done to

observe effects of iron on plants. The typical problem is too little iron in the proper form, causing yellowing of leaves!

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley,
Menlo Park, CA, 1989.

Camp McDowell Environmental Center, Route 1, Box 330, Nauvoo, Alabama 35578,
205-387-1806 (phone), 205-221-3454 (fax).

THERMAL POLLUTION

OBJECTIVES

The student will do the following:

1. Explain why raising the temperature of a body of water is considered pollution.
2. Demonstrate the effects of temperature on the dissolved oxygen content of water.

BACKGROUND INFORMATION

SUBJECTS:

Science (Physical Science, Biology)

TIME:

1 class period

MATERIALS:

dissolved oxygen test kit
4 bottles that can hold 100-300ml
ice water & warm water

Water plays a role in absorbing and transferring heat from sun to Earth and back to the atmosphere. Water has a higher specific heat than most other substances, which means it can absorb more heat per gram than many other substances. Water can absorb about four times more heat energy than an equal mass of air for a given change in temperature. Temperature is a measure of the rate at which the substance's molecules are moving, and water molecules have the ability to absorb more heat energy before increasing molecular motion. When water molecules evaporate, breaking away from other molecules to form steam or vapor, the heat energy of the dispersed molecules is converted into kinetic energy. This reduces the heat energy of the remaining water and thus cools the water. Living things utilize this process to dissipate heat, and the Earth dissipates heat this way as well.

Thermal pollution may be a problem where industrial sources use water as a coolant. These industrial environments include conventional industry and coal-fired, oil-fired, or nuclear-powered electricity plants. Thermal pollution occurs when the temperature of the coolant water reaches the point where it can kill or harm fish or other wildlife. Thermal pollution results when water is used for absorbing heat and returned to a receiving stream before cooling back to normal stream temperature. This type of polluting discharge is regulated just as chemical pollutants are. Some other things that can cause thermal pollution are: loss of tree coverage over a body of water due to logging or construction, damming of water that slows water movement down and causes temperature to increase, and increased turbidity, which adds more color to water, causing more heat absorption. The major effect of thermal pollution is a reduction in the dissolved oxygen (DO) of a stream, which affects plant and animal life. Many species of fish cannot live in low oxygen streams. Most of the popular game fish, such as salmon or trout, that “run” streams need high oxygen levels (7-10 ppm). Fish, such as catfish and carp, can tolerate lower oxygen levels (3-4.5 ppm). High temperatures and the resulting low oxygen also interfere

with breeding activities and egg and larval development of many organisms including amphibians and insects.

Terms

concentration: strength or density, as of a solution, as in amount of solute per volume of solution

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water

kinetic energy: the energy of a body resulting from its motion

parts per million (ppm): a measurement of concentration of 1 unit of material dispersed in 1 million units of another (for water, same as mg/l)

specific heat: the number of calories needed to raise the temperature of one gram of a given substance 1°C , relative to the number of calories (one calorie) needed to raise the temperature of 1 gram of water 1°C

ADVANCE PREPARATION

Read carefully and practice the procedure for the DO kit ahead of time. Two can do it more easily than one. The manipulations take some practice.

PROCEDURE

I. Setting the stage

- A. The procedure can be done first without explanation, asking students to infer the problems with thermal pollution. The teacher may wish to give the explanations first.
- B. The method used for determining oxygen in water is one widely used in water laboratories. The greatest problem for accuracy is introduction of air bubbles in bottles during the procedure by agitation.
- C. In this experiment, agitation will be done deliberately as a way of demonstrating the differences in oxygen holding capacities of water at different temperatures.

- D. The teacher should do the agitation and then have the students work in pairs on each DO determination.

II. Activity

- A. Fill the four bottles with water: 2 with water that has been cooled with ice, 2 with hot water out of the tap or that has been warmed (boiling is optional). Try to fill slowly and carefully, with little force or agitation. Leave an air pocket at the top of each bottle.
- B. Cap and agitate by shaking one of the cold bottles and one of the warm bottles. Then uncap and allow all four bottles to sit uncapped while the tests are done.
- C. Follow the instructions to get a DO value for each of the four bottles.

III. Follow-up

Ask students to discuss the following:

- A. Based on the results of the activity, what effect does increased temperature have on dissolved oxygen? Try to explain why.
- B. What is the normal percentage of oxygen in air and in water? (21% in air, and 0.0007% in water, by volume)
- C. Is there a limit to how much oxygen may be good for organisms? (People can die from too high of a percentage of oxygen.)
- D. What happens to the heat in cooling towers? Is that a form of air pollution? Heat is greatly increased in the air over cities. Should clean air regulations regulate the release of heat from air conditioners?
- E. What compounds are more efficient absorbers of heat than water? (Freon, alcohol)
- F. When fast-running streams are dammed or naturally slow down, what happens to the oxygen content? Why? Does that affect the species of fish living in that area? Explain.

- G. Why are trout usually found only in mountain streams?
- H. Discuss how warm water animals, such as manatees, tend to congregate around power plant discharges. Also discuss how this affects them. (They get stuck in pipes and are cut up or killed by blades.)

IV. Extensions

Ask students to research the following:

- A. Optimum water temperatures and oxygen levels needed by different species of game and non-game fish.
- B. How the temperatures and oxygen levels determined in A. affect thermal pollution regulations for different stream classifications.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

GROUNDWATER BASICS

9-12

OBJECTIVES

The student will do the following:

1. Compute math problems dealing with volume of groundwater.
2. Calculate average porosity in one type of aquifer.
3. Calculate the volume of water that will supply a particular well and its recharge rate.

SUBJECTS:

Math (Advanced), Science (Physics)

TIME:

1 class period

MATERIALS:

calculator
paper
pencil
student sheet and figures

BACKGROUND INFORMATION

Groundwater accounts for a major portion of the world's freshwater resources. Estimates of the global water supply show groundwater as 0.6 percent of the world's total water and 60 percent of the available fresh water resources. The total volume of readily available global groundwater is about $4.2 \times 10^6 \text{ km}^3$ as compared to $0.126 \times 10^6 \text{ km}^3$ (kilometers cubed) stored in lakes and streams. Next to glaciers and icecaps, which do not have readily available water, groundwater reservoirs are the largest holding basins for fresh water in the world hydrologic cycle (Figure 1).

The age of groundwater may range from a few years or less to tens of thousands of years or more. For the United States, it is estimated that about 25 percent of precipitation becomes groundwater.

It is estimated that the total usable groundwater in storage is about equivalent to the total precipitation for ten years, or the total surface runoff to streams and lakes for 35 years, although all of this groundwater is not available for practical use. In the United States, groundwater storage exceeds by many times the capacity of all surface reservoirs and lakes, including the Great Lakes.

Recoverable groundwater is that water released from storage in the subsurface zone of saturation whose capacity is the total volume of the pores or openings in soil or rocks that are filled with water. The porosity values of specific materials are shown in Figure 2.

Groundwater movement is dependent on the degree of interconnection of the porous space (permeability)

and the gradient or slope of the water table. These factors vary greatly depending on the aquifer type. Groundwater in a carbonate aquifer can occasionally move through limestone caverns as rapidly as surface water (1-3 ft/sec). In sandy aquifers, groundwater can move as slowly as 3 ft/day or even as slowly as 1 in/day. For those reasons, groundwater cleanup, or remediation, can only be done by enhanced methods.* These methods are complex and expensive, making groundwater pollution prevention quite economical. There are obvious health protection reasons for groundwater pollution prevention, as well.

Terms:

carbonate aquifer: underground layer of limestone that is saturated with usable amounts of water

gradient: change of elevation, velocity, pressure, or other characteristics per unit length; slope

hydrologic cycle: the cyclical process of water's movement from the atmosphere, its inflow and temporary storage on and in land, and its outflow to the oceans; cycle of water from the atmosphere by condensation, and precipitation, then its return to the atmosphere by evaporation and transpiration.

permeability: the capacity of a porous material to transmit fluids. Permeability is a function of the sizes, shapes, and degree of connection among pore spaces, the viscosity of the fluid, and the pressure driving the fluid.

porosity: the spaces in rock or soil not occupied by solid matter.

water table: upper surface of the zone of saturation of groundwater

ADVANCE PREPARATION

- A. Copy Figures 1 and 2, Student Sheets, and Activity Section for students.
- B. Complete the math problems before students are given them. (See the teacher sheet.)
 - * For information on enhanced methods, see activity "Groundwater: Cleaning Up" in this chapter.

PROCEDURE

- I. Setting the stage
 - A. Give students Conversion Student Sheet, Figures 1 and 2, and Activity Section.
 - B. If students need help with the math, give them the Hint Page.

II. Activity

Problems:

- A. How many gallons are represented by $4.2 \times 10^6 \text{ km}^3$ of global groundwater?
- B. If $1 \times 10^6 \text{ mi}^3$ of subsurface water exists in a volume of the earth's crust that covers $5 \times 10^7 \text{ mi}^2$ of the land surface land is $\frac{1}{2}$ mile deep, what is the average porosity (in %) of the upper layer of the Earth's crust?* (assuming that the entire depth is saturated)
- C. If a recharge area of a water well measures 1000 acres and the well is 800 meters deep, and soil porosity is that of a sand and gravel mix, what volume of water might theoretically supply the well?*
- D. In question C above, what is the annual recharge rate (gallons/year) if precipitation is 55 inches per year, 7 inches of which become groundwater?

*Note: Solutions to B, C, and D are oversimplifications of these types of determinations but generally demonstrate the principles of recharge, yield, and infiltration calculations.

RESOURCES

Bouwer, Herman, Groundwater Hydrology, McGraw Hill Book Company, New York, NY, 1978, pp. 2-3, 6-8.

Groundwater and Wells, Johnson Division, UOP, Inc. St. Paul, MN, 1975, pp. 17-18.

Groundwater Pollution and Hydrology, Princeton University Short Course, 1983, pp. 1-2.

The Earth's Water Resources

SOURCE	SURFACE AREA (mi²)	WATER VOLUME (mi³)	% OF TOTAL WATER
Surface water freshwater lakes = ½ mi. deep	330,000	30,000	.009
Saline lakes	270,000	25,000	.008
Stream channels	---	500	.0001
Subsurface water <½ mi. deep	50,000,000	1,000,000	.31
Subsurface water >½ mi. deep	50,000,000	1,000,000	.31
Soil moisture + water in vadose zone	50,000,000	16,000	.005
Glaciers/ice caps	6,900,000	7,000,000	2.15
Atmosphere	197,000,000	3,100	.001
Oceans	139,500,000	317,000,000	97.2
TOTAL		326,000,000	

Figure 1

Porosities

Porosities of specific materials. Approximate ranges are:

Materials	Porosity, percentage
Silts and clays (that have not been significantly compacted)	50 - 60
Fine sand	40 - 50
Medium sand	35 - 40
Coarse sand	25 - 35
Gravel	20 - 30
Sand and gravel mixes	10 - 30
Glacial till	25 - 45
Dense, solid rock	<1
Fractured and weathered igneous rock	2 - 10
Permeable, recent basalt	2 - 5
Vesicular lava	10 - 50
Tuff	30
Sandstone	5 - 30
Carbonate rock with original and secondary porosity	10 - 20

CONVERSIONS

$$1 \text{ yd}^3 = 27 \text{ ft}^3$$

$$1 \text{ acre} = 4047 \text{ m}^2$$

$$1 \text{ hectare} = 10,000 \text{ m}^2$$

$$1 \text{ m} = 3.28 \text{ ft}$$

$$1 \text{ acre} = 43,560 \text{ ft}^2$$

$$1 \text{ ft}^3 = 7.48 \text{ gal}$$

$$1 \text{ m}^3 = 35.31 \text{ ft}^3$$

HINT PAGE - Use Student Sheet on Conversions.

A. To start this problem, look at the conversion sheet.

1. Convert to m^3 .
2. Convert m^3 to ft^3 .
3. Convert ft^3 to gallons.

B.

1. Porosity =
$$\frac{\text{mi}^3 \text{ of H}_2\text{O}}{\text{mi}^3 \text{ of soil}} \quad \frac{(\text{volume of H}_2\text{O})}{(\text{volume of soil})}$$

2. Volume = area x depth.

(mi^3 of soil = mi^2 of land x depth in miles)

C.

1. Convert acres to meters.
2. Volume = area x depth.
3. Water yield = volume x porosity (convert to decimal).

D.

1. Convert inches to ft.
2. Convert ft to meters.
3. Convert acres to m^2 .
4. Multiply area (m^2) x rainfall that becomes groundwater (m) = m^3 .
5. Must convert m^3 to ft^3 first.
6. Convert ft^3 to gallons.

A. To start this problem, you must look at the conversion sheet.

1. Convert to m^3 .

$$4.2 \times 10^6 \text{ km}^3 \times \frac{1 \times 10^9 \text{ m}^3}{1 \text{ km}^3} = 4.2 \times 10^{15} \text{ m}^3$$

2. Convert m^3 to ft^3 .

$$4.2 \times 10^{15} \text{ m}^3 \times \frac{35.31 \text{ ft}^3}{1 \text{ m}^3} = 1.483 \times 10^{17} \text{ ft}^3$$

3. Convert ft^3 to gallons.

$$1.483 \times 10^{17} \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 1.11 \times 10^{18} \text{ gal}$$

B.

1. Porosity = $\frac{\text{mi}^3 \text{ of H}_2\text{O}}{\text{mi}^3 \text{ of soil}} = \frac{(\text{volume of H}_2\text{O})}{(\text{volume of soil})}$

2. Volume = area x depth.

$$\begin{aligned} \text{mi}^3 \text{ of soil} &= \text{mi}^2 \text{ of land} \times \text{depth in miles} \\ \text{mi}^3 \text{ of soil} &= (5 \times 10^7) \times 0.5 = 2.5 \times 10^7 \text{ mi}^3 \end{aligned}$$

$$\text{Porosity} = \frac{1 \times 10^6}{2.5 \times 10^7} = 0.04 \text{ or } 4\%$$

C.

1. Convert acres to meters.

$$1000 \text{ acres} \times \frac{4074 \text{ m}^2}{1 \text{ acre}} = 4.074 \times 10^6 \text{ m}^2$$

2. Volume = area x depth.

$$4.074 \times 10^6 \text{ m}^2 \times 800 \text{ m} = 3.26 \times 10^9 \text{ m}^3$$

3. Water yield = volume x porosity (convert to decimal).

$$3.26 \times 10^9 \text{ m}^3 \times 0.20 = 6.52 \times 10^8 \text{ m}^3$$

- D. 1. Convert inches to ft.

$$7 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = 0.58 \text{ ft}$$

2. Convert ft to meters.

$$0.58 \text{ ft} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = 0.177 \text{ m of rain into groundwater}$$

3. Convert acres to m².

$$1000 \text{ acres} \times \frac{4047 \text{ m}^2}{1 \text{ acre}} = 4.047 \times 10^6 \text{ m}^2$$

4. Multiply area (m²) x rainfall that becomes groundwater (m) = m³.

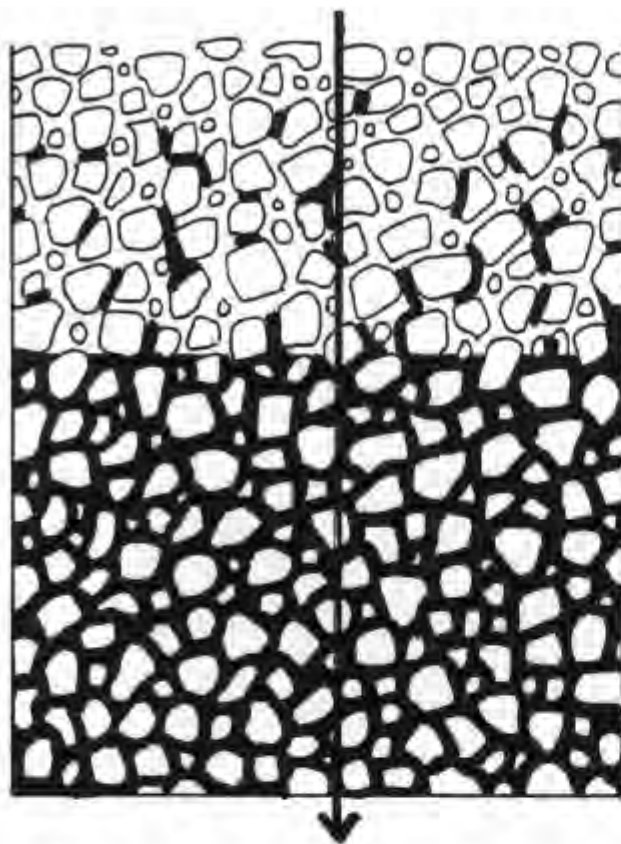
$$4.047 \times 10^6 \text{ m}^2 \times 0.177 \text{ m} = 7.16 \times 10^5 \text{ m}^3$$

5. Must convert m³ to ft³ first.

$$7.16 \times 10^5 \text{ m}^3 \times \frac{35.31 \text{ ft}^3}{1 \text{ m}^3} = 2.53 \times 10^7 \text{ ft}^3$$

6. Convert ft³ to gallons.

$$2.53 \times 10^7 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 1.89 \times 10^8 \text{ gal}$$



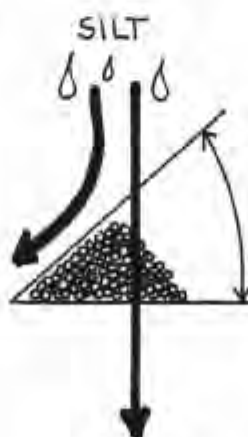
Soils usually consist of many different sized particles.

ZONE OF AERATION
Supports plant growth

ZONE OF SATURATION
Groundwater



Large particles
Low angle of repose
High permeability



Medium-sized particles
Medium angle of repose
Medium permeability



Small particles
Large angle of repose
Low permeability

FROM GROUND TO WATER

OBJECTIVES

The student will do the following:

1. Define groundwater.
2. Describe some problems involving groundwater.
3. Discuss ideas relating to groundwater issues.

BACKGROUND INFORMATION

Groundwater begins with precipitation that seeps into the ground.

The amount of water that seeps into the ground will vary widely from place to place depending on slope of the land, amount and intensity of rainfall, and the type of land surface.

Many people think of groundwater as underground lakes or streams; however, ground-water is simply water filling spaces between rock grains or fractures and fissures in rocks. A body of rock or sediment that can yield water in a usable quantity is called an aquifer.

Rain and snowmelt percolating down through the soil are the sources of groundwater. Plants consume much of the water that enters the soil, and a small amount is held on the soil grains. Some water in the soil evaporates, and some flows out of the soil into lakes and rivers.

Groundwater is usually in very slow motion. The rate of groundwater flow is determined by the slope of the water table and the sizes of the pores among the rock and soil particles.

Groundwater does not occur all the way to the core of the Earth. Beneath the water-bearing rocks everywhere, at some depth the rocks are water-tight. This depth may be a few hundred feet or, more than likely, tens of thousands of feet.

Terms

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater

SUBJECTS:

Language Arts, Science
(Physical Science, Earth
Science)

TIME:

1 class period

MATERIALS:

student sheets:
The Hidden Resource -
Groundwater Keeping It Safe
Keeping It Protected

fault: a fracture in the Earth's crust accompanied by displacement of one side of the fracture with respect to the other

fracture: a break in rock that may be caused by compressional or tensional forces

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

pore: a passage; channel; a tiny opening, usually microscopic

saturated zone: a portion of the soil profile where all pores are filled with water. Aquifers are located in this zone. There may be multiple saturation zones at different soil depths separated by layers of clay or rock.

saturation: being filled to capacity; having absorbed all that can be taken up

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

transpiration: process in which water absorbed by the root systems of plants moves up through the plants, passes through pores (stomata) in their leaves or other parts, and then evaporates into the atmosphere as water vapor; the passage of water vapor from a living body through a membrane or pores

unsaturated zone: a portion of the soil profile that contains both water and air; the zone between the land surface and the water table. The soil formations do not yield usable amounts of free-flowing water. It is also called zone of aeration and vadose zone.

water table: upper surface of the zone of saturation of groundwater

ADVANCE PREPARATION

Have copies of Student Sheets ready for class distribution.

PROCEDURE

I. Setting the stage

- A. Have terms and definitions on the board.
- B. Have students write terms and definitions in journals if vocabulary words are to be used as part of an overall unit word study.
- C. Give students copies of one or more of the Student Sheets that are to be used. Allow for independent reading time or assign sections to be read individually.
- D. Have a class discussion of handouts led by teacher or student. Have on hand several leading questions that may be developed in class discussion; these could come from Background Information.

II. Activity

- A. Read the Student Sheets on Groundwater. Write a newspaper article addressing groundwater problems.
- B. Create a three-frame comic strip addressing one problem involved in groundwater contamination.
- C. Compose a well-written business letter (using the form suggested in your English textbook) to an official in the area, or ask one in the local state agency to speak to the class concerning groundwater in the area. Follow up with a thank-you letter.
- D. Write a newspaper story relating your findings of the groundwater situation in your area.
- E. Prepare a lesson plan for presentation to a fifth-grade class in which groundwater issues are addressed. Include terms and definitions, questions for discussion, and a short follow-up quiz.

III. Extensions

CRYPTOQUOTE: Here's how it works: One letter stands for another letter; double letters, single letters, punctuation, and frequency of use are all clues. Usually E is the most frequently used letter, and THE is the most frequently used three-letter word. Have fun!

FW XBPZRFPXQ WZWXPT LZJJZAW

YFJJAWB AH JZMKZQ HVAR JFWQHZZJB

FWQ AWX IKWQVXQ LZJJZAW YFJJAWB

HVAR JZMKZQ ZRUAKWQRXWPB FWWKFJJT

JXFO ZWPA YVAKWQ-SFPXV ZW PIX

KWZPXQ BPFPIXB.

Solution:

An estimated 90 billion gallons of liquid from landfills and 100 billion gallons from ~~from~~ ^{quid} impoundments annually leak into groundwater in the United States.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Fact Sheet on Water, U.S. Environmental Protection Agency, Washington, D.C. (pamphlet).

“Ground Water: The Underlying Issue”, Alabama Geological Survey, Tuscaloosa, AL (pamphlet).

The Hidden Resource - Groundwater

Every day Americans rely on a resource that is “hidden” in its natural surroundings. Hidden beneath layers of soil and rock is the Earth’s largest freshwater supply: groundwater. The estimated supply of groundwater in the lower 48 states is 65 quadrillion gallons or about 4 times the amount of water in the Great Lakes. It is the source of water for about half of the U.S. residents and nearly 97 percent of the rural population.

Groundwater originates as precipitation. It seeps into the ground, filling the spaces and pores between soil particles or the fractures and fissures in rocks. The underground area where all the pores and spaces are filled with water is called the saturated zone. Different geological formations hold varying amounts of water, but those that yield water in usable quantities are called aquifers. Usually, groundwater flows slowly through an aquifer; the rate can be as little as half an inch per year. The flow can be considerably faster in limestone caverns, volcanic lava tubes, or large rock formations where groundwater may resemble underground streams.

As water travels through the soil and rock, it picks up water-soluble materials and carries them along. Some of the materials in groundwater occur naturally, but many constituents in groundwater are the result of human land use activities. Different soils have different capacities to filter and absorb wastes. However, once groundwater is contaminated, it is difficult and may be impossible to clean up. When possible, cleanup is very expensive and may require many years.

In many geological formations, groundwater moves so slowly that contamination can remain undiscovered for years until the contaminated groundwater is brought to the surface by springs or wells. During that time, the pollutants can spread and contaminate large volumes of otherwise usable groundwater.

Potential sources of contaminants that threaten groundwater in the United States include the following:

- C ~23 million septic systems
- C ~390 million tons of municipal and industrial waste in 6,000 landfills
- C ~1.7 million active oil and gas wells and ~1million abandoned wells
- C ~72,000 active coal and mineral mines; ~60,500 oil and gas; ~1,500 metal mines; ~5,000 coal; ~6,000 active non-metal
- C ~1.1 billion pounds of pesticides used each year; 660 million pounds of Alachlor and Atrazine used per year
- C ~50 million tons of fertilizer used each year
- C ~306 million gallons of improperly disposed motor oil
- C ~1.2 million underground storage tanks
- C ~7.4 million tons of deicing salts applied to highways each winter; Snow Belt states receive 100 metric tons per road mile during the winter

KEEPING IT PROTECTED

An estimated 90 billion gallons of liquid from landfills and 100 billion gallons from liquid impoundments annually leak into groundwater in the United States.

Listed below are some of the ways to make sure that future generations will have clean, safe groundwater supplies.

- C Have your septic tank pumped out every three to five years.
- C Do not store pesticides, fertilizers, and herbicides near a well.
- C Make sure abandoned wells are properly filled in and sealed.
- C Store home-heating oil in an above-ground storage tank where leaks can be easily detected.
- C Use fertilizers and pesticides on lawns and gardens sparingly and follow all label directions for mixing, use, and disposal of empty containers.
- C Report chemical or toxic spills on land, in the air, or in the water by calling the 24-hour National Response Center toll-free at 800-424-8802.
- C Do not pour toxic or hazardous substances into sinks or toilets, on the ground, or into sinkholes.
- C Collect used motor oil and recycle it at used-oil collection centers or service stations.
- C Cover your wellhead with a cap and grade the soil around the wellhead so that runoff water is diverted away from the well.
- C Test your well water for bacteria and nitrates once a year.

KEEPING IT SAFE

Everyone has a role to play in keeping our water supplies safe. Everyday activities affect water quality. By being cautious about the use of hazardous substances - pesticides, fertilizers, herbicides, paints, fuels - and the disposal of all types of waste, every citizen can help keep our water resources safe and clean.

Consider some of the following alternatives to hazardous household chemicals and products:

- ☐ Use lotions or gels instead of aerosol sprays.
- ☐ Use rechargeable batteries.
- ☐ Use 1 part vinegar to 32 parts water to wash floors.
- ☐ Use a mixture of salt and lemon juice to clean copper.
- ☐ Use dry cornstarch or baking soda as a rug cleaner.
- ☐ Use non-phosphate detergents.
- ☐ Use cedar chips as an alternative to moth balls.
- ☐ Use 2 tablespoons of vinegar to 1 quart of water as a window cleaner.

WHAT'S THE LEVEL?

OBJECTIVES

The student will do the following:

1. Describe, using scientific terms, the movement of the water table.
2. Locate the saturation zones and identify the function of each.

BACKGROUND INFORMATION

Conservation and protection of groundwater are vital issues. Before students can understand the movement of water and other groundwater concepts, they must understand the role of the water table and the soil's ability to determine its rise and fall. This activity involves using researched material (vocabulary terms) and critical thinking skills to develop a model of this concept.

Terms

bedrock: the solid rock that underlies all soil, sand, clay, gravel, and loose material on the Earth's surface; the bottom layer

impermeable (substance): a substance through which other substances are unable to pass

percolation: the downward movement through the subsurface soil layers to groundwater

unsaturated zone: a portion of the soil profile that contains both water and air; the zone between the land surface and the water table. The soil formations do not yield usable amounts of free-flowing water. It is also called the zone of aeration and vadose zone.

waterlogging: condition that occurs when the water table rises too near the surface causing plants to die as a result of water filling air spaces in the soil

SUBJECTS:

Science (Environmental Science, Physical Science), Art

TIME:

1-2 class periods

MATERIALS:

for each group:

list of terms and dictionary and/or environmental glossaries

2 identical sponges (4 x 6 is a good size)

1 shallow pan large enough for the sponges to fit into lying flat

4 cups of water in a measuring cup or beaker

index cards or construction paper

markers or pens; colored pencils

food coloring

student sheets

water table: upper surface of the zone of saturation of groundwater

zone of saturation: that region below the surface in which all voids are filled with liquid

ADVANCE PREPARATION

- A. Gather the materials.
- B. Copy Student Sheets -- one per group.

PROCEDURE

I. Setting the stage

A. The purpose of this activity is for students to utilize information gained from defining terms and then discover answers on their own. Therefore, they should be given additional suggestions until they have had time to figure out the model for themselves.

B. There are several ways to approach this lab. Usually the students will stack the two sponges on top of each other and pour the water over them until they become saturated. However, some students may pour the water into the pan, saturate one of the sponges, and set the dry sponge on top. And still others may dunk the sponges into the cup of water, wring them out, and then proceed.

C. The sponges represent the soil and are similar to soil because they have the ability to hold water and air within their pores, become saturated, and dry out. The sponges also allow for the percolation of the water down to the zone of saturation. The pan, being an impermeable substance, represents the bedrock and thus does not allow the water to penetrate but instead blocks its flow and starts the water table rising. The water will represent groundwater when it is held within a completely saturated sponge, soil water when it is held within a within a damp (but unsaturated) sponge and precipitation when it is poured over the top of the sponges.

D. It is important that the students define the terms prior to building the model and answering the lab questions. Remind students that they may have to use several sources to get a definition they understand.

II. Activity

A. Give each lab group of students the following materials:

1. List of terms and a dictionary and/or environment glossaries (on Student Sheet)
2. Two identical sponges
3. Shallow pan
4. Four cups of water in a measuring cup or beaker
5. Index cards or construction paper
6. Markers or pens; colored pencils
7. Student lab sheet

B. Tell students to read the directions on the lab sheet and complete the lab. They may not work with or discuss this lab with another group. They are to turn in the lab sheet and model when they have finished.

III. Follow-up

A. Have each group orally explain its model to the teacher or to other groups.

B. Join two or more groups and let them go over their answers, adding or deleting information as needed, until they have a clear understanding of the materials.

IV. Extensions

A. Let students simulate climate conditions, such as drought or high temperatures, and note the changes.

B. Assign students to research the process of waterlogging and devise an experiment to test the procedure.

C. Have students research what happens to plants, homes, septic tanks, and roads when the water table is only one foot below the surface.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

NAMES OF GROUP MEMBERS: _____

DIRECTIONS:

As a group, build a model that illustrates all of the terms listed below and then use this model to answer the statements in STEP FOUR.

STEP ONE: Define the following terms:

1. water table:
2. zone of saturation:
3. unsaturated zone:
4. impermeable:
5. permeable:
6. percolation:
7. bedrock:

STEP TWO: Construct a model that illustrates each of the terms defined above, using only the following materials:

2 identical sponges
1 shallow pan
4 cups of water in a measuring cup or beaker

STEP THREE: Draw a picture of your model and label all parts.

STEP FOUR: Answer the following by using the terms you have defined.

1. Does soil saturate from the top to the bottom or from the bottom to the top? Explain your answer.

2. Does the water table level change positions? If yes, what brings about these changes. If no, why not? Explain your answer.

3. Why is soil able to become saturated?

4. Compare and contrast the materials you were given to their natural counterparts.

5. Hypothesize what would happen to the plant life on the surface if the water table were to rise close to the surface.

6. Hypothesize what would happen to the plant life on the surface if the water table were to fall to the bedrock.

WHAT GOES ON DOWN UNDER?

9-12

OBJECTIVES

The student will do the following:

1. Explain some sources for the recharge and discharge of groundwater.
2. Identify the connection between surface and groundwater.
3. Describe the relationship between soil grainsize and water flow rate.
4. Identify a rock type and geological formation.

BACKGROUND INFORMATION

Many people depend on groundwater for their supply of drinking water. Groundwater is water in the ground, and it occurs everywhere beneath the land. This does not mean that any well will encounter a sufficient quantity of water that will flow at an acceptable rate. On the contrary, the rate at which wells will flow, or the rate at which water can be pumped from them, varies from a trickle to more than a million gallons a day.

Why is this? This variability results from the way that water occurs underground. Some people believe that groundwater comes from underground lakes and rivers. While it is true that many caves do contain a lot of water, nearly all groundwater is actually found in tiny cracks and holes in the rock. Some rocks contain many holes that are well connected to one another; these rocks contain substantial amounts of easily produced water and are called aquifers (from the Latin words aqua and ferre, meaning “water” and “bring”). Tight rocks, those with few and small holes that may be poorly connected, produce very little water and are called aquitards or aquicludes. Aquicludes block water flow almost completely, whereas aquitards permit some flow of water, albeit commonly at such a low rate that it is of little use. There are no true aquicludes; any rock will transmit some water. However, some rocks transmit water at such an infinitesimal rate that it might as well be none at all. Aquifers are rock units that have much open space

SUBJECTS:

Science (Ecology, Earth Science, Physical Science)

TIME:

2-3 class periods

MATERIALS:

per group:

one clear container (plastic sweater box)

gravel to fill container over 2cm

two 500 ml paper cups

1 pump dispenser (from lotion or soap bottle)

sod (about 1 square foot per container)

500 ml of water

grease pencils

scissors

ice pick

coffee filter

soil samples

(aquifers are porous). These open spaces are well connected so that fluids may flow easily through the rock (aquifers are permeable). A porous and permeable rock is like a sponge; it can hold a lot of water, and it can give up a lot of water quickly. Aquifers tend to be interlayered with aquitards and aquicludes so if a deep well is drilled, there might be several different aquifers that could be tapped to supply water. The water in different aquifers under the same piece of land can be very different; the aquifers may be, to all intents and purposes, separate.

Even where large rivers or lakes could provide abundant water, many people choose to drill wells for their drinking water. This is because groundwater is less likely to be polluted than surface water. Most of the potential sources of pollution (for instance, farms, paper mills, or septic tanks) are at the surface or very close to it (for example, underground storage tanks). Thus, most pollution occurs at or very near the surface, and nearly all surface waters show at least some signs of pollution. However groundwater is somewhat protected from this contamination. Water travels slowly in the subsurface with speeds of inches or feet per day. Thus, even if some unwanted substances enter the ground, they may take a long time to penetrate deeply enough to affect the groundwater supply. Also, deeper aquifers that underlie aquicludes may be isolated from surface-derived contamination. Groundwater is commonly treated with chlorine to kill bacteria if it is to be used for drinking, but most groundwater needs no other treatment. Groundwater is a priceless resource that we ought to conserve, protect, and use wisely.

Terms

aquiclude: a low-permeability unit that forms either the upper or lower boundary of a groundwater flow system

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater

aquitard: a low-permeability layer of rock or clay that can store water but transmits it very slowly from one aquifer to another

artesian well: a well that produces water without need for pumping due to pressure exerted by confining layers of soil

discharge: the outflow of groundwater from a flowing artesian well, ditch, or spring

dowsing: to search for a source of water or minerals with a divining rod

drawdown: the lowering of the water table as water is removed from an aquifer

geologic map: a map of the Earth's surface with surface geologic formations superimposed over existing features such as roads, streams, lakes, and other features

geological formation: a body of rock identified by lithic characteristics and stratigraphic position; the fundamental unit in lithostratigraphic classification

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

hydraulic head: the height of the free surface of a body of water above a given subsurface point; the sum of elevation, pressure, and velocity components at a given point in an aquifer

igneous rock: rock that solidified from a hot, liquid state

lithic: of stone

lithostratigraphy: the arrangement of rocks in layers or strata; the branch of geology dealing with the study of the nature, distribution, and relations of the stratified rocks of the Earth's crust

metamorphic rock: rock made by heating and pressurizing preexisting rocks

outcrop: the exposure of bedrock or strata projecting through the overlying cover of detritus and soil

permeability: the capacity of a porous material to transmit fluids. Permeability is a function of the sizes, shapes, and degree of connection among pore spaces, the viscosity of the fluid, and the pressure driving the fluid.

porosity: a description of the total volume of rock or soil not occupied by solid matter

recharge: (1) to replenish a waterbody or an aquifer with water; (2) the replacement of any water that may have flowed out or been pumped out of the aquifer

road cut: a hill, ridge, or mountain side excavated for a road right-of-way. Road cuts leave exposed strata, rock, and soil that can be viewed in their natural state if not covered or vegetated.

sedimentary rock: a rock that consists chiefly either of small pieces of rock cemented together (sandstone) or of crystals that grew from water (rock salt, limestone)

sinkhole: a hole caused by collapse of the land surface, commonly because underlying limestone rock has dissolved away

water table: upper surface of the zone of saturation of groundwater

well: a bored, drilled, or driven shaft or dug hole. Wells range from a few feet to more than miles in

depth, but most water wells are between 100 and 2,000 feet in depth.

ADVANCE PREPARATION

- A. Copy Student Sheet and collect materials.
- B. The teacher may wish to put 8-10 small holes, using an ice pick, into one cup for each group.

PROCEDURE

I. Setting the stage

- A. Discuss Background Information with students.
- B. Put terms with definitions on the board.
- C. Divide students into groups of 3-4. Distribute materials.

II. Activity

A. Construct a model of an aquifer.

1. Have students use gravel to construct subsoil aquifers in the plastic container. Cover the gravel with sod on each side of the container to represent hills with a valley between. The valley is only to contain gravel to a height of about 2 cm.
2. Have one student in each group hold the cup with the holes over the model.
3. Then have another student pour 500 ml of water into the cup for a simulation of rain. Tell students to note how the water infiltrates the gravel to become groundwater. Also, have them note what happens to the water falling on the sod.
4. Have a third group member draw a line with a grease pencil at the water level in the container all the way around the container. Note: The pencil mark illustrates the water table. Explain that a pond is formed when the water table is higher than the land surface.

5. Have a student in each group insert the pump into one of the hills on the side of the valley, pushing the bottom down to the groundwater.

6. Allow students to press the pump several times after the water has begun to flow. Catch the water in the paper cup with no holes. Instruct students to observe what is happening to the water table. Where did the water go? What is happening to the pond?

7. Discuss the concept of discharge. Discuss the effect of groundwater pumping on natural streams and lakes.

8. Have students answer these questions:

a. Where does groundwater come from? (snow, sleet, rain: precipitation)
Water could move from a stream or lake to recharge a water table if the table is below the stream level.

b. What would happen to a neighborhood if a well were drilled near a stream or pond and enough water pumped to lower the water table? (Some water from a stream or lake would be removed by the pump through the well. If enough water were removed, the stream or pond might go dry.)

B. Ask students to discover aquifer conductivity by doing the following:

1. Take samples of soil from various locations in the community.

2. Describe the samples' grain size, color, and any other observed physical characteristics.

3. Place a standard volume in a coffee filter holder or other suitable container.

4. Pour a known volume of water through the different samples.

5. Measure the time it takes for the water to pass through the various soil samples and record.

6. Analyze the relationship between soil grain size and the rate of time it takes for the water to pass through the sample. Write a brief statement about this.

C. Have students identify a rock-type, geological formation and determine the possibility of an aquifer by doing the following:

1. Stop at a road cut and pick up a rock that is indicative of the area.
2. Determine the location of the sample site on a road map.
3. Locate a geologic map of the area and determine the formations in the area.
4. Determine whether the rock is of metamorphic, igneous, or sedimentary origin.
5. While at the outcrop, look for groundwater seeps.
6. Draw a sketch of the outcrop.
7. Analyze the rock and the formation. Determine if it is an aquifer.

D. Pass out the puzzles and post or pass out the word list.

III. Extensions

A. Have students research different types of aquifers in different regions of the country and present findings to the class.

B. The Student Sheet Puzzle could be timed or done as a contest and a quiz given with the terms used in it.

C. Students could do library research on their local aquifer. The results of this research could be turned in as research papers, presented to the class, or presented in other places, such as a local meeting of conservation or environmental group or city council.

RESOURCES

College or university libraries and Geology departments can also be very helpful. Many informative brochures about groundwater have been published by a variety of entities.

The environmental agency in each state. (See list in back of guide.)

The Geological Survey in each state. (See list in back of guide.)

The U. S. Geological Survey.

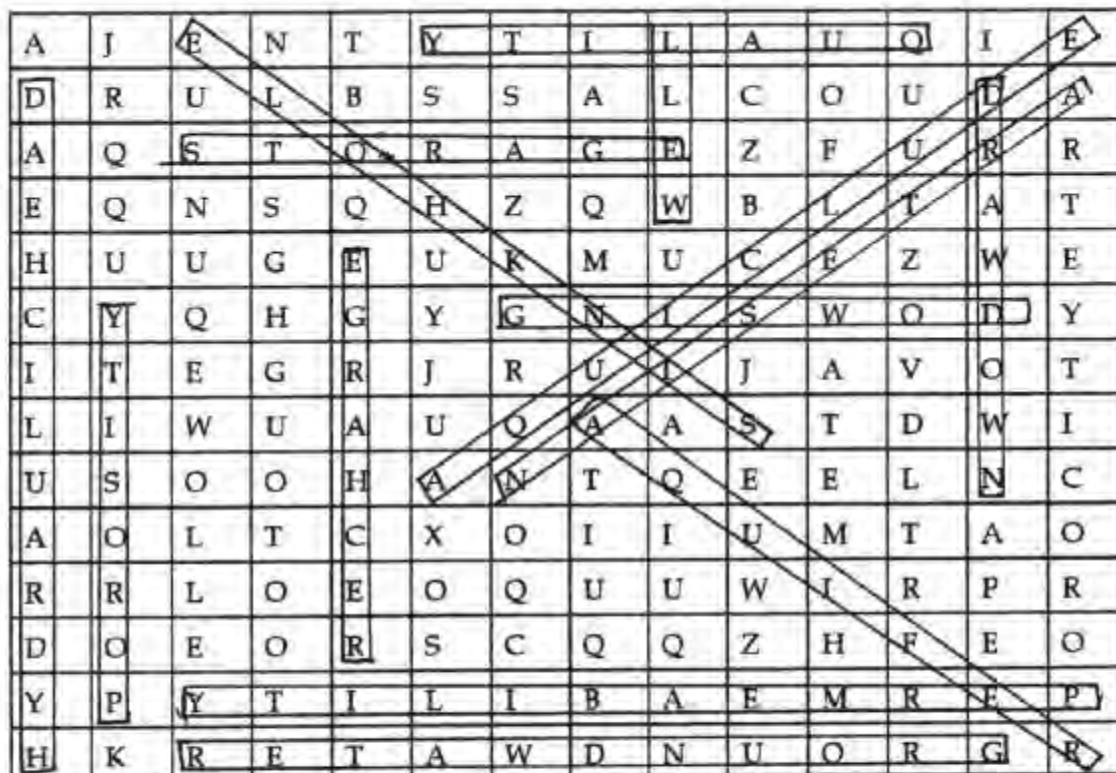
GROUNDWATER PUZZLE

A	J	E	N	T	Y	T	I	L	A	U	Q	I	E
D	R	U	L	B	S	S	A	L	C	O	U	D	A
A	Q	S	T	O	R	A	G	E	Z	F	U	R	R
E	Q	N	S	Q	H	Z	Q	W	B	L	T	A	T
H	U	U	G	E	U	K	M	U	C	E	Z	W	E
C	Y	Q	H	G	Y	G	N	I	S	W	O	D	Y
I	T	E	G	R	J	R	U	I	J	A	V	O	T
L	I	W	U	A	U	Q	A	A	S	T	D	W	I
U	S	O	O	H	A	N	T	Q	E	E	L	N	C
A	O	L	T	C	X	O	I	I	U	M	T	A	O
R	R	L	O	E	O	Q	U	U	W	I	R	P	R
D	O	E	O	R	S	C	Q	Q	Z	H	F	E	O
Y	P	Y	T	I	L	I	B	A	E	M	R	E	P
H	K	R	E	T	A	W	D	N	U	O	R	G	R

artesian
 aquiclude
 aquifer
 dowsing
 drawdown
 groundwater
 hydraulic head
 permeability
 porosity

sinkhole
 storage
 well
 quality
 recharge

GROUNDWATER PUZZLE



DO YOU DRINK IT?

9-12

OBJECTIVES

The student will do the following:

1. Create an aquifer model.
2. Locate major U.S. aquifers.
3. Explain how a well works.
4. Examine a well's relationship to the water table.
5. Apply principles of well placement.
6. Explain different ways that ground is contaminated.

BACKGROUND INFORMATION

An aquifer is an underground layer of rock or soil that holds the water called groundwater. The word "aquifer" is derived from the Latin "aqua" meaning "water," and "ferre" meaning "to bring" or "to yield." The ability of a geological formation to yield water depends on two factors - porosity and permeability. Porosity is determined by how much water the soil or rock can hold in the spaces between its particles. Permeability means how interconnected the spaces are so that water can flow freely between them.

There are two types of aquifers. One is a confined aquifer, in which a water supply is sandwiched between two impermeable layers. These are sometimes called artesian aquifers because, when a well is drilled into this layer, the pressure may be so great that water will spurt to the surface without being pumped. This is an artesian well. The other type of aquifer is the unconfined aquifer, which has an impermeable layer under it but not above it. It is the most common type.

Aquifers may be categorized according to the kind of material of which they are made. A consolidated aquifer is composed of a porous or fractured rock formation. Most unconsolidated aquifers are composed of buried layers of sandy, gravelly, or soil-like material.

SUBJECTS:

Science (Physical Science, Ecology, Earth Science), Social Studies (Geography)

TIME:

2 class periods

MATERIALS:

3-liter soda bottles
aquarium gravel
sand (coarse)
pump from a liquid dispenser
blue, yellow, & red food coloring
paper cups
straws
student sheets
droppers
scissors or razor blades
markers

The top surface of the groundwater is called the water table. The water table depth varies from area to area and fluctuates due to seasonal changes and varying amounts of precipitation. Excessive pumping from the aquifer (wells) can also lower the water table.

Perhaps the largest aquifer in the world is the Ogallala aquifer located in the midwestern United States. This aquifer is named after a Sioux Indian tribe. It is estimated to be more than two million years old and to hold about 650 trillion gallons (2,500 trillion liters)! It underlies parts of eight states, stretching about 800 miles (1,288 km) from South Dakota to Texas. The Ogallala aquifer supplies vast amounts of water to irrigate the crops in this vitally important agricultural area.

Not only is groundwater used to irrigate crops, but it is also used for drinking water. About half of the U.S. population gets its drinking water from groundwater. Wells reach into the water table and bring water to the surface by being pumped by hand, windmill, or motor-driven devices. In ancient days, these wells were dug by hand and lined with stones or bricks to prevent the sides from collapsing. Today, most are formed by drilling a 2-4 inch (5-10 cm) hole and lining it with metal or plastic piping.

The biggest problem facing well water is contamination. Sources of groundwater pollution are leaking underground storage tanks, leaking septic tanks or septic tanks with inadequate drainfields, landfill seepage, animal waste, fertilizer, pesticides, industrial waste, road salt, and some natural contaminants. Another big problem causing groundwater contamination is abandoned wells that are not properly closed. These leave direct channels for contaminants to enter the aquifers. Some wells are even used to inject waste materials into the ground. When a groundwater source is contaminated, it is very difficult and expensive to clean up. The best way to protect well water is to prevent contamination from occurring.

Another type of well is an underground injection well. This type of well is used as a means of wastewater disposal, aquifer recharge, or solution mining of an economically significant mineral from a geologic formation. The most prevalent use of underground injection, however, is for wastewater disposal.

Underground injection wells have even been classified into categories by the U.S. EPA. They are as follows:

Class I	Municipal and hazardous/non-hazardous industrial waste
Class II	Oil and gas field wastes and enhanced recovery injection
Class III	Solution mining
Class IV	Shallow hazardous waste disposal (banned)
Class V	All other types of injection (floor drains, storm drains, etc.)

In most states, Class I hazardous and IV wells are prohibited. All states that have oil and natural gas production have Class II wells. Class III, or mining wells, inject water to solution mine a desired mineral (as salt). Injection wells not fitting any of these categories are Class V wells. Septic systems serving 20 or more people a day and floor drains found at service stations and car washes are examples of Class V wells.

Note: Two background information charts (A&B) should be supplied with this background narrative.

Subsurface disposal by wells depends on the capacity of the geologic formation to attenuate wastes that are properly injected into it.

Terms

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater

aquifer recharge: the addition of water by any means to an aquifer

artesian aquifer: an aquifer that is sandwiched between two layers of impermeable materials and is under great pressure, forcing the water to rise without pumping. Springs often surface from artesian aquifers.

attenuation: dilution or lessening in severity

confined aquifer: an artesian aquifer

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

impermeable (substance): a substance through which other substances are unable to pass

solution mining: a type of mining wherein water is injected into a well to remove a desired mineral

unconfined aquifer: an aquifer containing unpressurized groundwater, having an impermeable layer below but not above it

underground injection well: a type of well used for wastewater disposal, aquifer recharge, solution mining of minerals

water table: upper surface of the zone of saturation of groundwater

ADVANCE PREPARATION

A. Collect materials for activities.

1. Each student can be asked to bring one 3-liter bottle and a pump from a liquid dispenser, or each group may prepare a group water pump model.

2. Fill three dropper bottles with water. Tint the water in each with a different color of food coloring. Set aside.

B. Make a transparency of U.S. Aquifer Map. Make enough copies for students.

C. Make a transparency of Well, Well, Well Map. Make enough copies for students.

D. Make copies of Background Information and sheets on Pathways To Groundwater Pollution for students.

E. Make a transparency of Model Example Sheet.

PROCEDURE

I. Setting the stage

A. Pass out Aquifer Map, Well, Well, Well Map, Background Information, and Pathways to Groundwater Pollution sheets.

B. Divide students into working groups of 3, 4, or 5.

C. Ask students to read Background Information, look at Pathways to Groundwater Pollution sheets, and discuss information in their groups.

D. Put terms on the board and have students copy on the Background Information sheet.

II. Activity

A. Show the students the transparency of the U.S. Aquifer Map.

1. Explain that the crosshatching on this map marks the places in the continental U.S. where abundant fresh water is available from aquifers. In these areas,

large groundwater supplies are used by industries, communities, and agriculture. In the areas where there are no markings, there is less likely to be plentiful groundwater available. These places will, however, have wells that supply individual households and livestock operations. Remind students that small aquifers exist almost everywhere, and that the map shows only major aquifers.

2. Ask the students to answer the following by naming states.

a. Name several states where plentiful groundwater is available almost everywhere. (Florida, Mississippi, Louisiana, Iowa, Delaware, Nebraska, Michigan, New Jersey)

b. Name several states that have the least groundwater in many places. (Montana, Washington, Oregon, Idaho, Pennsylvania, Kentucky, West Virginia, Vermont, New Hampshire)

c. Where does your state rank with groundwater supplies? What is groundwater used for locally?

d. Why does your group think that some states do not have very much groundwater?

e. What is an advantage in an area where aquifers are small? (Contamination will not spread as easily.)

B. Show the students the transparency of the Well, Well, Well, Map.

1. Tell the students that one way to keep a well free of contaminants is to select a good site before it is drilled. Tell them that they are not considering the direction of groundwater flow in this activity, but that this would actually be a big consideration.

2. Tell students that they are to mark the place on their map where they think the well should be dug. They may illustrate this in any manner they choose.

3. Have students identify the possible groundwater contaminants on this map. Ask them if they can think of other possible contaminants.

C. Set out materials needed to make water pump and contamination models. Instruct students to follow directions.

1. Using the 3-liter bottle, cut off about $\frac{1}{2}$ the top. Remove the black bottom and fill the remaining clear portion with approximately 2 inches (2.5 to 3.7 cm) of gravel and then 2 inches of sand. (Use transparency of model.)
2. Pour in 2 to 3 inches (5 to 7.5 cm) of water colored blue with food coloring and mark the location of the water table with a black or blue marker.
3. Place the pump into the gravel with the tube extending into the water.
4. Pump water out of the model, catching the water in the cup.
5. Discuss how contaminants like agricultural waste, sewage, road salt, and other surface contaminants can get into the groundwater. Demonstrate this by using the yellow food coloring on the surface of the sand and “rain” on your model. Pump more water out of the well. Observe results.
6. Place a straw into your model to represent an abandoned well. It should reach the same depth as your pumping well. Pour a contaminant (red food coloring) into abandoned well. Pump more water out of the pumping well. Compare this means of contamination with the surface contamination.

III. Follow-up

- A. Have students list at least four possible sources of groundwater contamination.
- B. Have students demonstrate knowledge of vocabulary by using the terms correctly in an explanation of groundwater, wells, and groundwater contamination.
- C. Students should try simulating other types of contamination (leaking underground storage tanks) with their model.
- D. Using the Background Information on underground injection wells, answer the following.
 1. Some states, such as Florida, use injection wells to recharge valuable aquifers used for drinking water. List the pluses and minuses of this practice as it relates to environment and public health. What Class well would this be? Why?

2. Class II wells are used to re-inject salt water or liquid waste from oil and gas production. They are also used for further recovery of oil when reservoirs are depressurized but recoverable product remains. What is this called? How does it work?

IV. Extensions

A. Have students contact their local health department to obtain guidelines on digging new wells.

B. Share with students the following information about dowsing or “water witching” and divining rods. Some people will not have a well drilled without calling a water “witch” or “dowsers” to locate the groundwater. Water witches or dowsers have been around for thousands of years. They use metal or wooden sticks (“divining rods”) to locate places where wells should be drilled. Some even predict the depth of the water table. Dowsers are not always successful in their efforts, but many people believe in their special ability to find water. Ask students to research the local use and efficacy of dowsing.

C. Write the American Groundwater Trust (6375 Riverside Drive, Dublin, Ohio 43017) for more information about wells and groundwater protection.

RESOURCES

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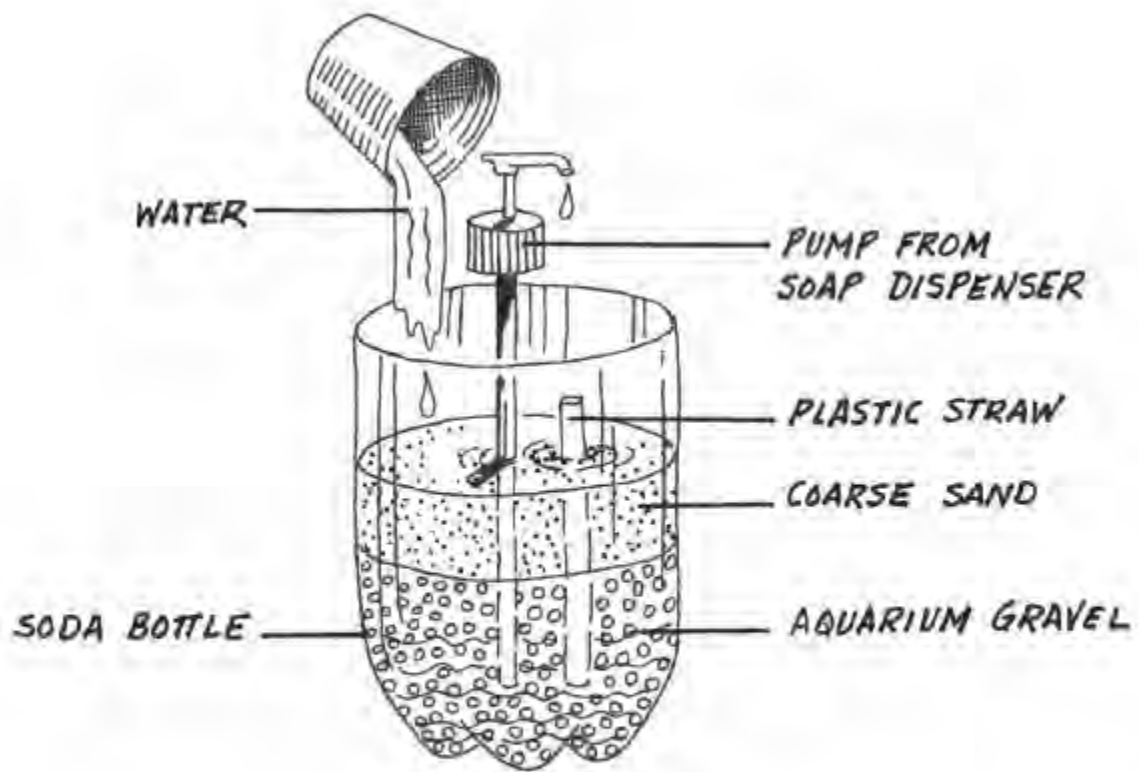
Branley, F.M., Water for the World, T. Y. Crowell, New York, 1982.

“Groundwater Pollution Control,” American Groundwater Trust, Dublin, Ohio, 1990.

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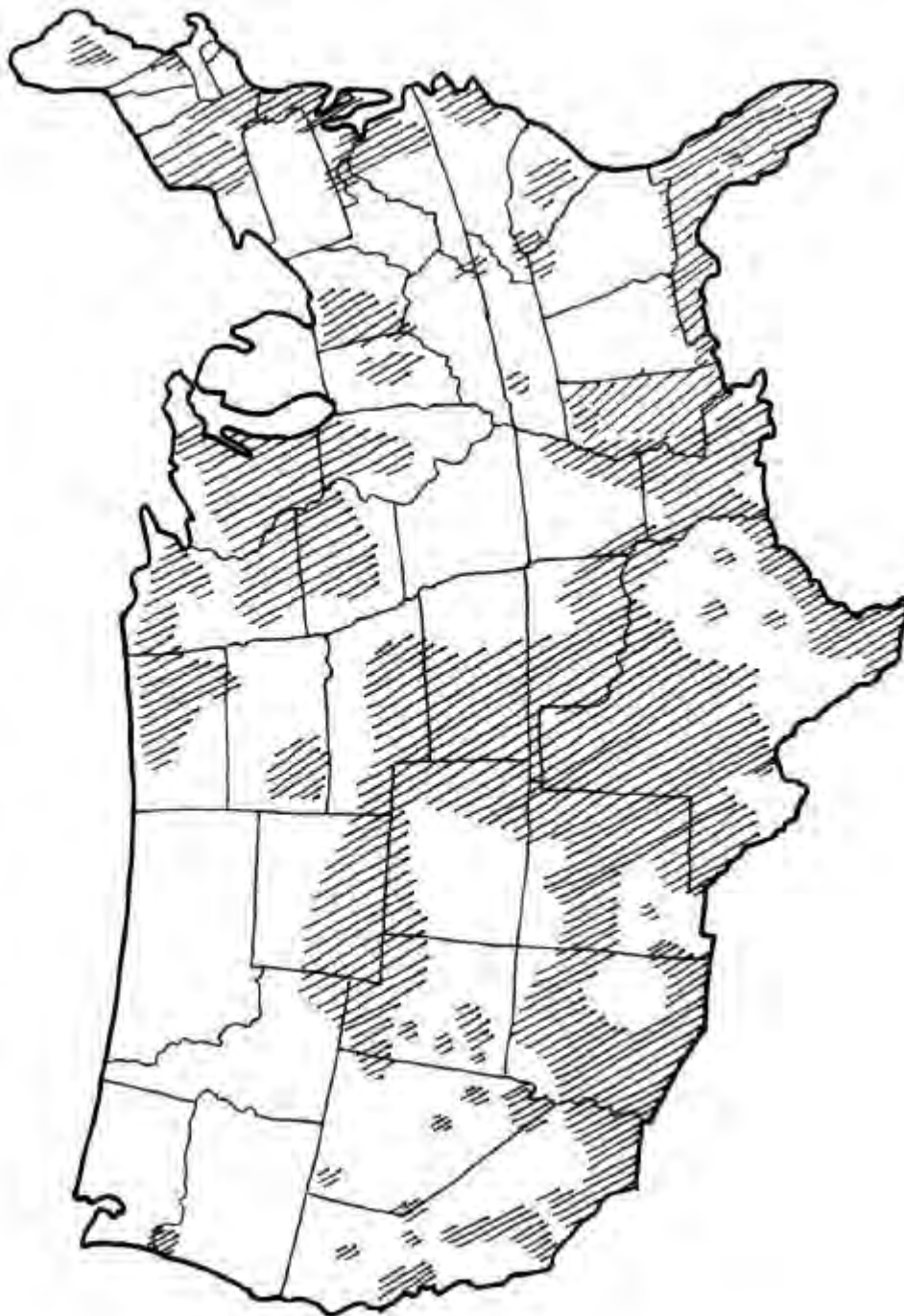
Grades 3-5 Water Sourcebook.

U.S. Department of the Interior, Water Dowsing, 1993, p. 15.

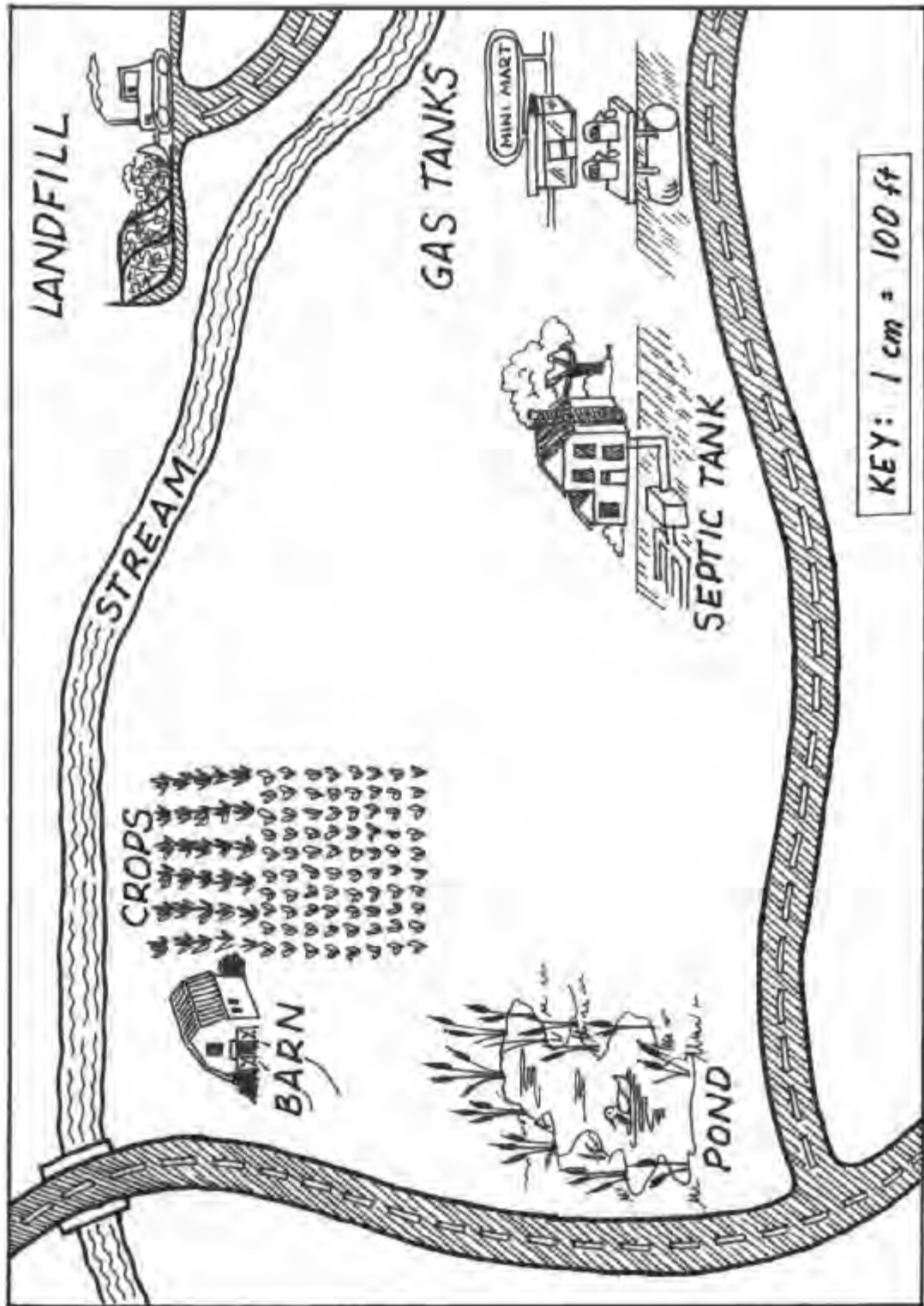


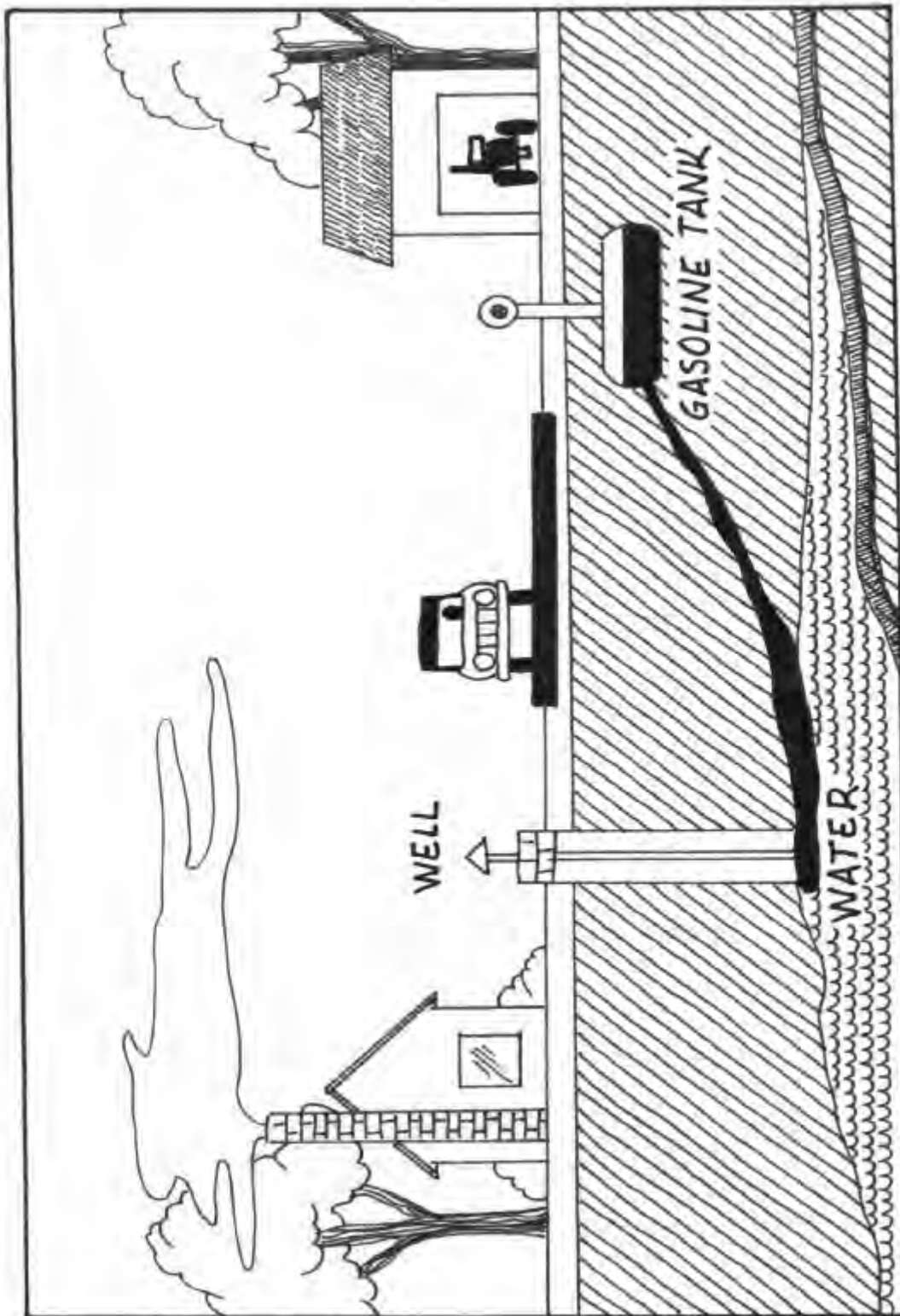
WATER PUMP MODEL

MAJOR UNDERGROUND SOURCES OF WATER

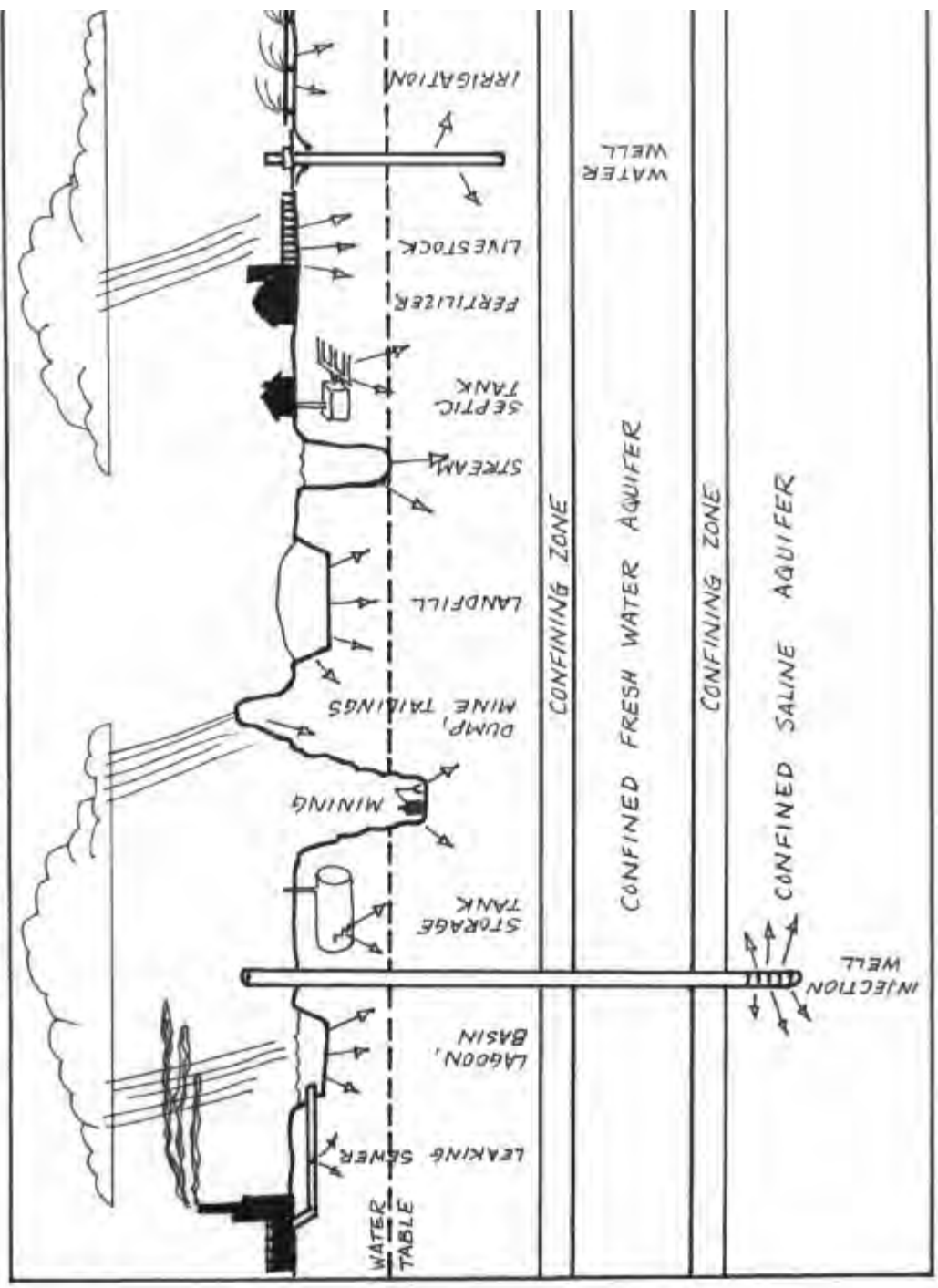


WELL, WELL, WELL MAP

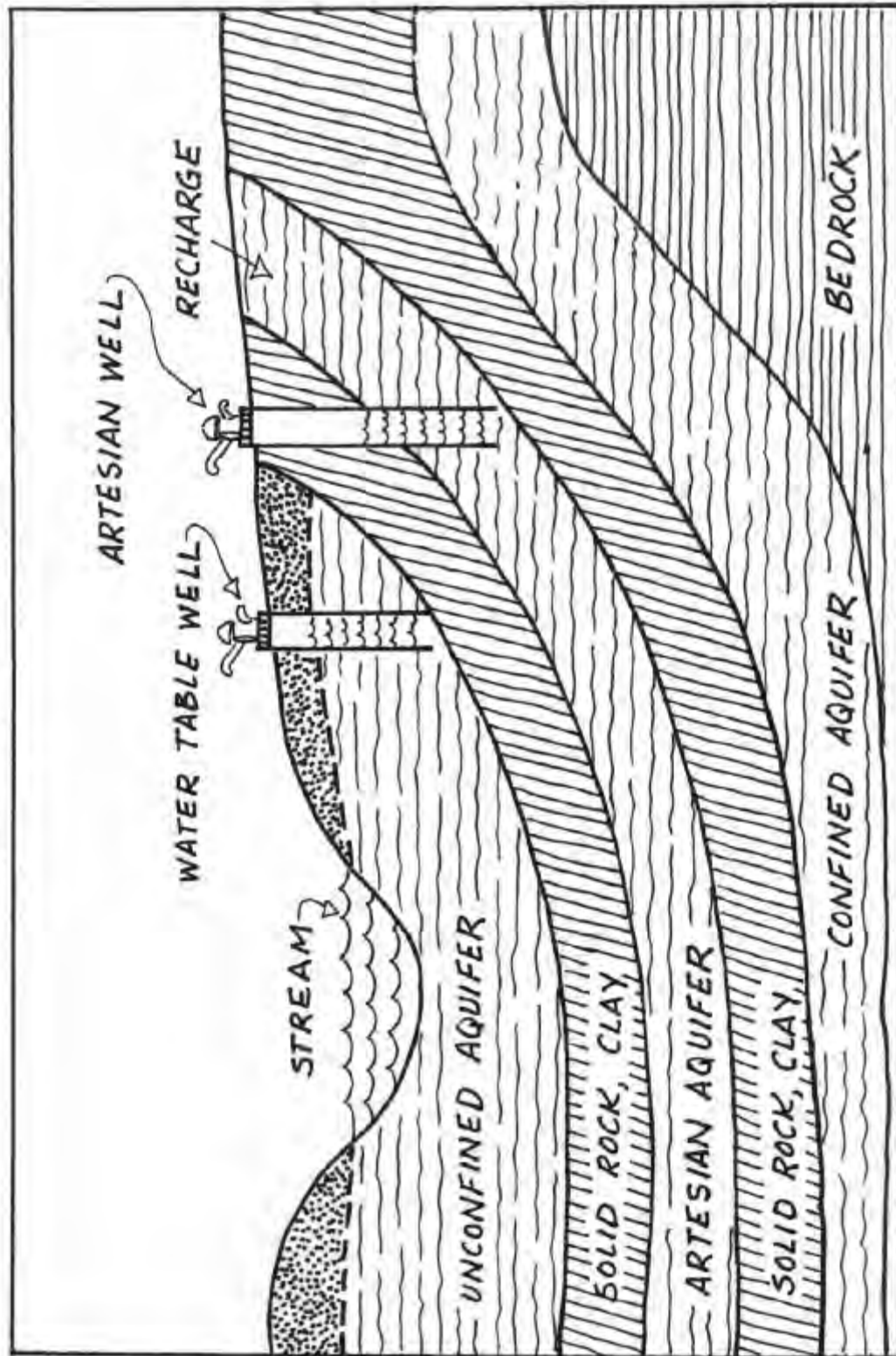




PATHWAYS TO GROUNDWATER POLLUTION



AQUIFER DIAGRAM



HYDRAULIC HEAD

S9-12

OBJECTIVES

The student will do the following:

1. Apply knowledge of the controlling variables for groundwater flow.
2. Demonstrate groundwater flow direction based on hydraulic head observations.

SUBJECTS:

Science (Physical Science, Physics), Math

TIME:

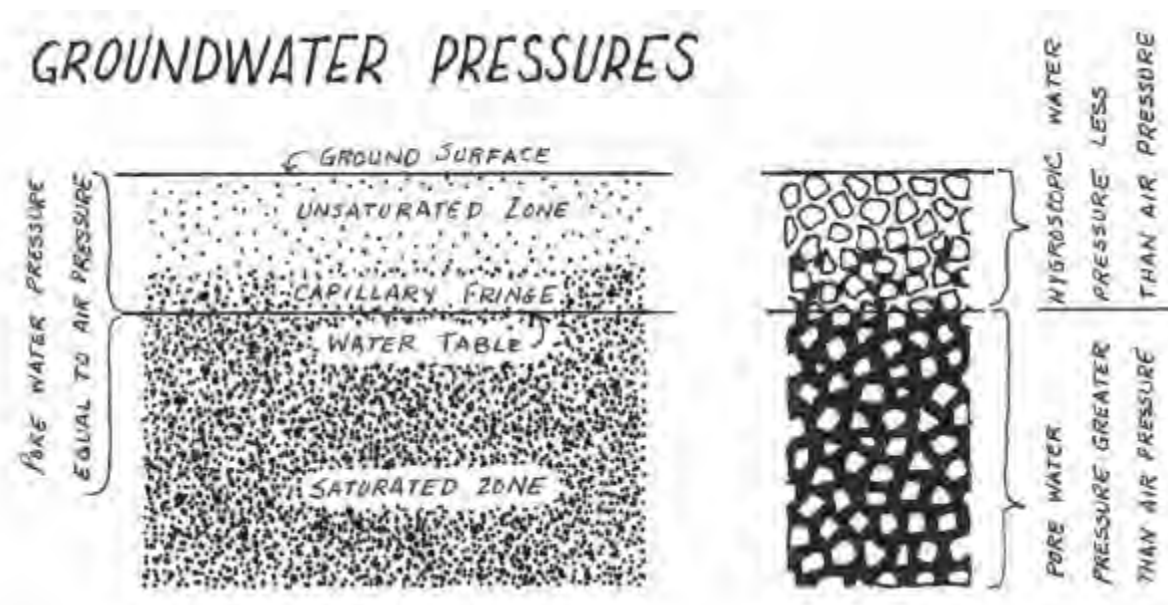
1 class period

MATERIALS:

copies of student sheets and background information

BACKGROUND INFORMATION

The water in the ground (groundwater) fills pore spaces in the subsurface rocks and sediments. The water in the lower part of the zone of porosity fills all the pore spaces and creates a saturated material (Figure 1).



The groundwater is stored or flows through the pore spaces and is acted on by three outside forces. These forces are: (taken from Fetter, 1988)

1. gravity- that which pulls water downward.

2. external pressure- a combination of atmospheric pressure and the weight of overlying sediments and water.
3. molecular attraction- that which causes water to adhere to other surfaces and to itself.

When it hits the ground, rain will be drawn by gravity downward through the soil zone to a zone saturated by water. The external pressure on the saturated zone creates a pressure (fluid pressure) in the saturated zone. At this depth, the fluid pressure is greater than the external pressure. However, as the top of the saturated zone is approached, the fluid pressure decreases until at some depth the pressure of the fluid in the pores is equal to atmospheric pressure. This surface, where fluid pressure is equal to atmospheric pressure, is called the water table and defines the top of an unconfined aquifer.

In addition to the outside forces acting on the groundwater, there is an energy contained in the groundwater that causes the water to move. The total energy in groundwater consists of three components: pressure, velocity, and elevation of the water body (elevation head). Because groundwater velocities are low, this energy component is essentially zero. The remaining components can be defined by an equation called the Bernoulli equation (Figure 2). In this equation, the potential energy at a given point (hydraulic head) is equivalent to the elevation at a point of measurement (elevation head), such as a well screen, plus the depth of the water column that rises in a well (pressure head). The pressure head and how high the water column rises in a well are functions of the external pressure (Driscoll, 1986).

Figure 2

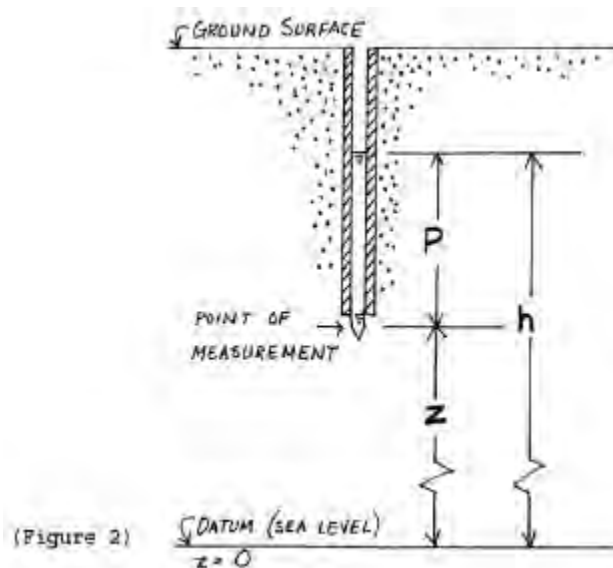
Bernoulli's Relationship

$$h = Z + P$$

Where: h = hydraulic head

Z = elevation head

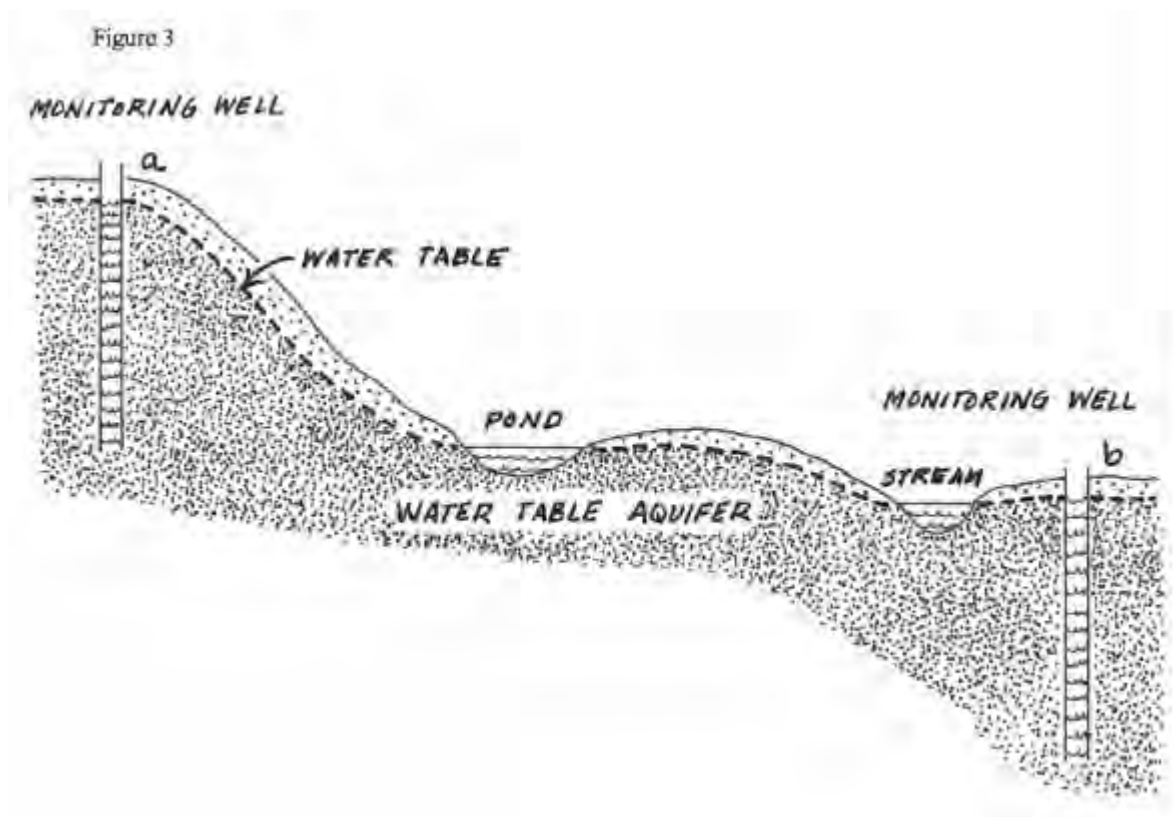
P = pressure head



In a water table or unconfined aquifer, the top of the saturated zone is at atmospheric pressure, which is constant across a site. Because the pressure head is constant across the site, this component is generally not taken into consideration when calculating the energy to drive groundwater to a point of discharge. Therefore, the height of the water column, z , represents the actual energy available to drive water through aquifer materials to a point of discharge like a well or spring (Driscoll, 1986).

Just as heat flows through solids from higher to lower temperatures, groundwater flows through porous media from higher to lower hydraulic head. This concept is easiest to imagine when considering water table aquifers. The water table, because it is at atmospheric pressure, will follow approximately the contours of the surface topography (Figure 3). The differences in elevation head between point a, at a higher elevation head, and point b, at a lower elevation head, force the groundwater towards the lower energy potential or towards the lower elevation head. The rate of groundwater flow towards a well or spring is proportional to the difference in elevation head between the source (high) and discharge (low) areas.

Figure 3



Terms

atmospheric pressure: the pressure or force per unit area, exerted by the atmosphere on any surface beneath or within it

Bernoulli Principle: the statement in hydraulics that under conditions of uniform steady flow of water in a conduit or stream channel, the sum of the velocity head, the pressure head, and the head due to elevation at any given point is equal to the sum of these heads at any other point plus or minus the losses in head between the two points due to friction or other causes

elevation head: the elevation of the point at which the hydrostatic pressure is measured, above or below an arbitrary horizontal datum

fluid pressure: the mechanical energy per unit mass of a fluid, at any given point in space and time, with respect to an arbitrary state and datum (fluid potential)

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

hydraulic head: the height of the free surface of a body of water above a given subsurface point; the sum of elevation, pressure, and velocity components at a given point in an aquifer

pore space: the volume of the open spaces in rock or soil

porosity: the spaces in rock or soil not occupied by solid matter

pressure head: the height of a column of liquid supported, or capable of being supported, by pressure p at a point in the liquid

saturated zone: a portion of the soil profile where all pores are filled with water. Aquifers are located in this zone. There may be multiple saturation zones at different soil depths separated by layers of clay or rock.

unconfined aquifer: an aquifer containing unpressurized groundwater, having an impermeable layer below but not above it

unsaturated zone: a portion of the soil profile that contains both water and air; the zone between the land surface and the water table. The soil formations do not yield usable amounts of free-flowing water. It is also called the zone of aeration and vadose zone.

water table: upper surface of the zone of saturation of groundwater

ADVANCE PREPARATION

- A. Copy Background Information and Student Sheets for students.
- B. Copy or put on board terms and definitions for students.
- C. Enlarge and make transparencies of Figures 1-3 in Background Information.

PROCEDURE

I. Setting the stage

- A. Discuss Background Information using transparencies.
- B. Review vocabulary.

II. Activity

A. Have students complete the Infiltration, Discharge, and Flow Direction Student Sheet by indicating the direction of flow of groundwater based on differences in elevation heads. Indicate, above the picture, points where water is likely to infiltrate the water table or discharge into a surface water body.

B. Have students calculate the differences in head elevations between the highest point of the water table or $h_{\max}$ and the water bodies, Lake 1 (h_1) and 2 (h_2), on either side of the island.

Discussion questions:

- 1. Since h_1 is greater than h_2 , does any water from L_1 flow across the island to discharge into L_2 ?
Answer: $h_{\max}$ is greater than h_1 ; therefore, water is flowing from the island into L_1 , and the water from L_1 does not contribute to L_2 .
- 2. If the island were to experience drought and there were no more precipitation, what would happen to the water table and groundwater flow conditions?
Answer: The water table would decline, probably becoming a nearly flat surface, and provide a gradient of flow between L_1 and L_2 .

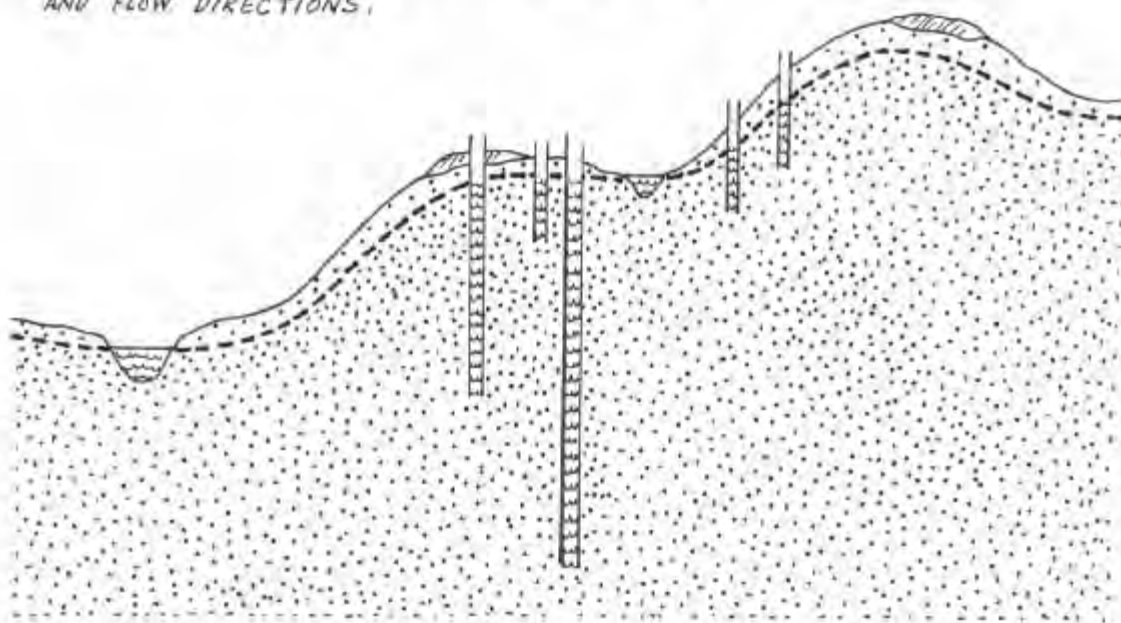
RESOURCES

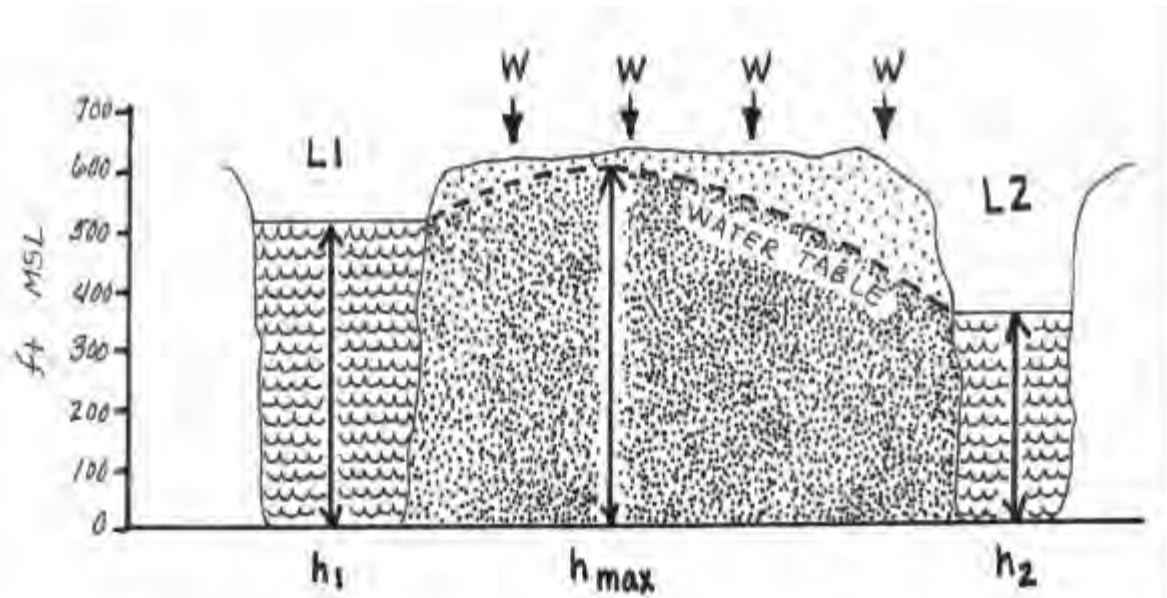
Bates, R.L. and Jackson, J.A., Editors, 1987, Glossary of Geology, 3rd Ed., American Geological Institute, p. 788.

Driscoll, F.G., Groundwater and Wells, 2nd Ed., Johnson Division, 1986, p. 1089.

Fetter, C.W., Applied Hydrogeology, 2nd Ed., Merrill Publishing Co., 1988, p. 592.

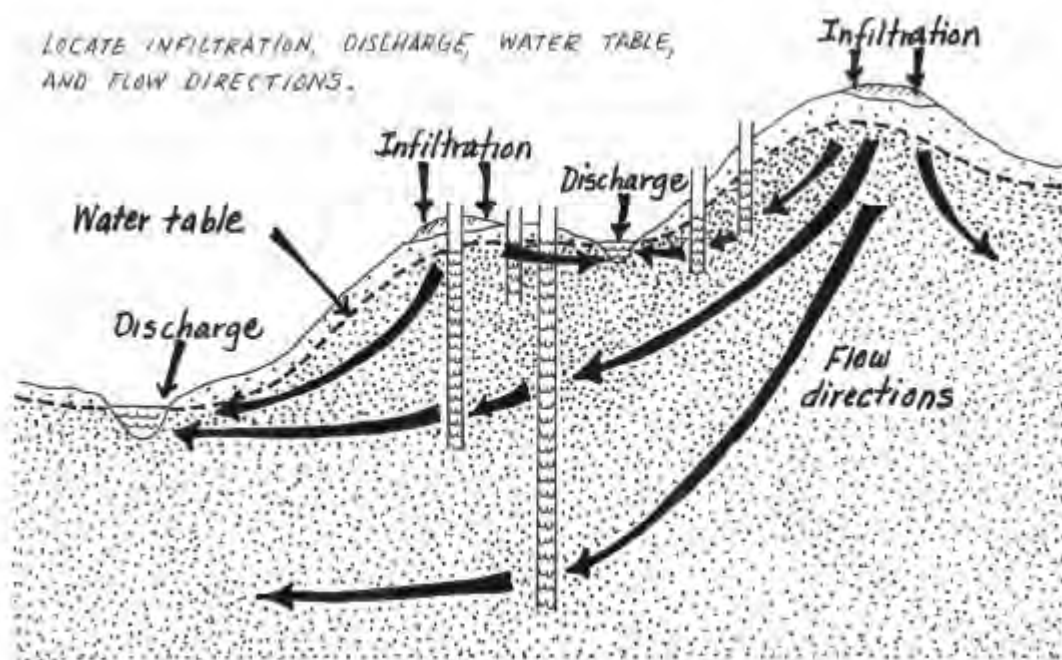
LOCATE INFILTRATION, DISCHARGE, WATER TABLE,
AND FLOW DIRECTIONS.

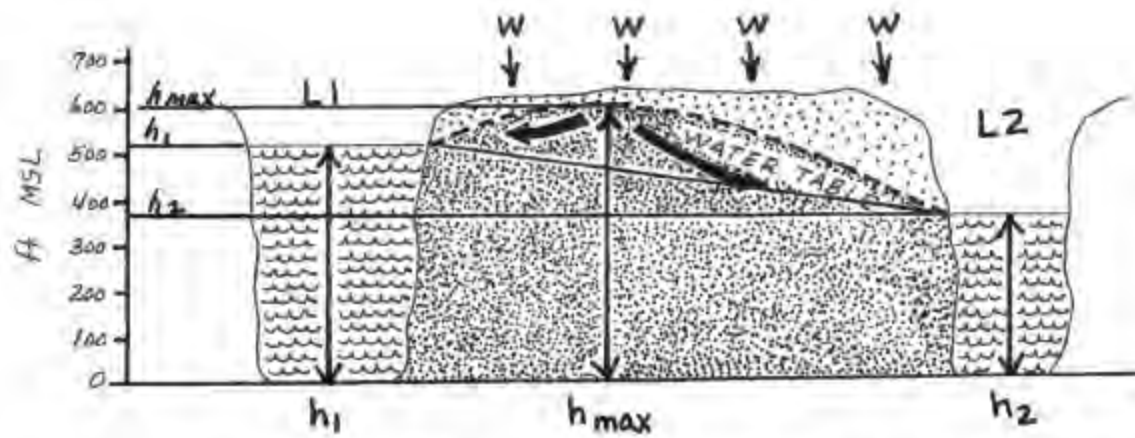




UNCONFINED FLOW, SUBJECT TO INFILTRATION / EVAPORATION

CALCULATIONS





UNCONFINED FLOW, SUBJECT TO INFILTRATION / EVAPORATION

CALCULATIONS

$$h_{max} - h_1 = 600 \text{ ft} - 525 \text{ ft}$$

$$\Delta h_1 = 75 \text{ ft}$$

$$h_{max} - h_2 = 600 \text{ ft} - 365 \text{ ft}$$

$$\Delta h_2 = 235 \text{ ft}$$

FLOW NETS

9-12

OBJECTIVES

The student will do the following:

1. Determine the directions of groundwater flow using flow nets.
2. Apply the concept of pressure head and groundwater flow conditions to solve several logistical problems.

SUBJECTS:

Science (Physical Science), Social Studies (Economics, Political Science)

TIME:

1 class period

MATERIALS:

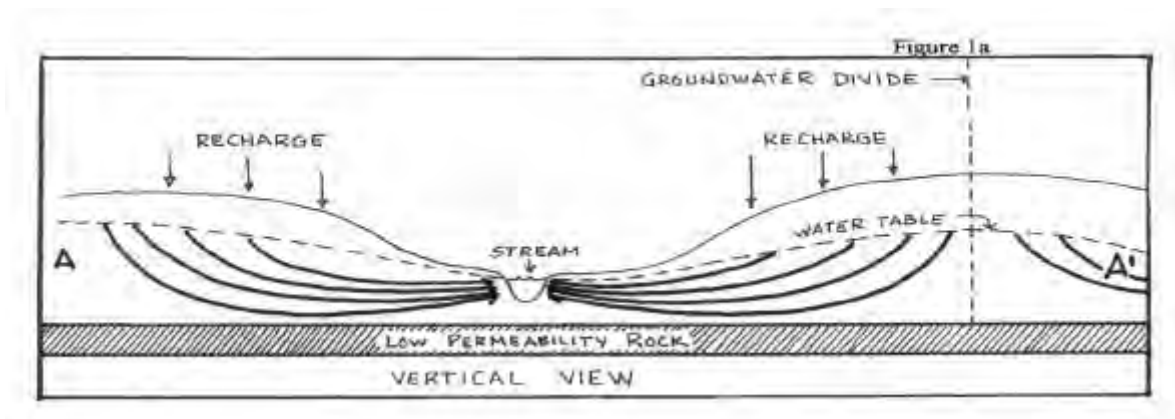
copies of background information
student sheets

BACKGROUND INFORMATION

Flow nets provide a general knowledge of the regional groundwater flow patterns that the hydrologist can use to determine such information as areas of recharge and discharge. Freeze and Cherry (1979, pg. 168) have stated that flow nets are an important concept of hydrology. They state, “The proper construction of flow nets is one of the most powerful analytical tools used by the hydrologist to analyze groundwater flow.”

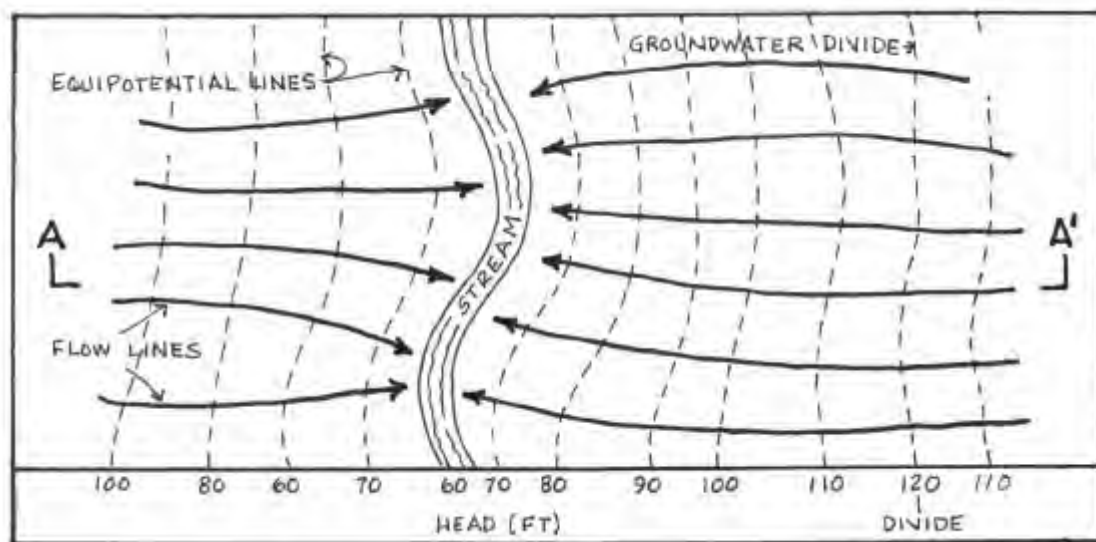
In water table aquifers, groundwater behaves much like surface water in its patterns of flow. For instance, the water table surface, in porous media such as sand and gravel, generally follows the topography of the land (Figure 1a). Similar to surface water flowing from the top of a hill down into a stream valley, groundwater flows from the groundwater divide to the lower elevation and may discharge into the stream valley as a spring.

Figure 1a



The surface of the water table is referred to as potentiometric surface because it represents the elevation (or total head) of the groundwater and can be defined by water levels in wells. The potentiometric surface is represented on a map by a series of contour lines (equipotential lines) that connect points of similar head in an aquifer (Figure 1b). These lines and surfaces are similar to the land surface and the contour lines represented on a topographic map. Once the potentiometric surface has been defined by the equipotential lines, the groundwater flow direction can be determined. Groundwater flows perpendicularly to equipotential lines and from the higher to the lower head.

Reading: Xeroxed attachment from Driscoll, 1987, pages 79-81.



Terms

discharge area: an area where groundwater flowing toward the surface escapes as a spring, seep, or baseflow or by evaporation and transpiration

equipotential line: a line in a two-dimensional groundwater flow field such that the total hydraulic head is the same for all points along the line

flow line: the line of flow of groundwater

flow net: the set of intersecting equipotential lines and flow lines representing two-dimensional steady flow through porous media

groundwater divide: a crest of the water table with flow going in opposite directions on either side

homogeneous: (1) uniform throughout in structure or make-up (for a substance or material); (2) of the same or similar nature or kind (for a group)

hydraulic head: the height of the free surface of a body of water above a given subsurface point; the sum of elevation, pressure, and velocity components at a given point in an aquifer

infiltration: the flow of water downward from the land surface into and through the upper soil layers

isotropic: having physical properties, such as conductivity and elasticity, that are the same regardless of the direction of measurement

potentiometric surface: a surface that represents the level where water will rise in a tightly cased well. The water table is the potentiometric surface for an unconfined aquifer.

recharge area: an area where infiltration moves downward into an aquifer

unconfined aquifer: an aquifer containing unpressurized groundwater having an impermeable layer below but not above it

water table: upper surface of the zone of saturation of groundwater

water-table aquifer: an unconfined aquifer

PROCEDURE

I. Setting the stage

A. Copy the Background Information and Student Sheet for students.

B. Make transparencies of figures in Background Information.

II. Activity

A. From the potentiometric surface map shown in the Student Sheet, have students sketch the path of water movement for groundwater that originates at the circled 800 in the upper left hand corner of the map. Assume the aquifer is homogeneous and isotropic. (Figure and exercise for IRIS Groundwater Hydrology Program, Regional Flow Course I, Module B- Lesson 2.) The student should use straight edges with right angle to make his/her flow lines perpendicular to the equipotential lines.

B. In class discussion, ask the students these questions.

1. Where is the groundwater flowing according to your constructed flow lines?

Answer: They should show that groundwater from the 800 line splits and flows towards the cities of Waukesha and Milwaukee.

2. What could create the closed loop configuration of the equipotential lines

Around Milwaukee and Waukesha? Answer: City wells and their constant pumping created a bowl shape from pulling water down toward wells.

3. If the cities of Milwaukee and Waukesha turned off all the pumps in their public water supplies, what would happen to the potentiometric surface? To what point would the groundwater be flowing? Answer: The surface would eventually flatten out, and the equipotential lines would become straight and almost parallel to the shore of Lake Michigan. Groundwater would be flowing towards Lake Michigan. (This question shows how an aquifer can be affected by a high volume of withdrawal from pumps in the water supply wells. The volume extracted can change the configuration of the potentiometric surface.)

III. Follow-up

A. Have students research the source of their community's water supply. Have them call or write to the city water board or authority to find out specifics about their aquifer (if groundwater is the source).

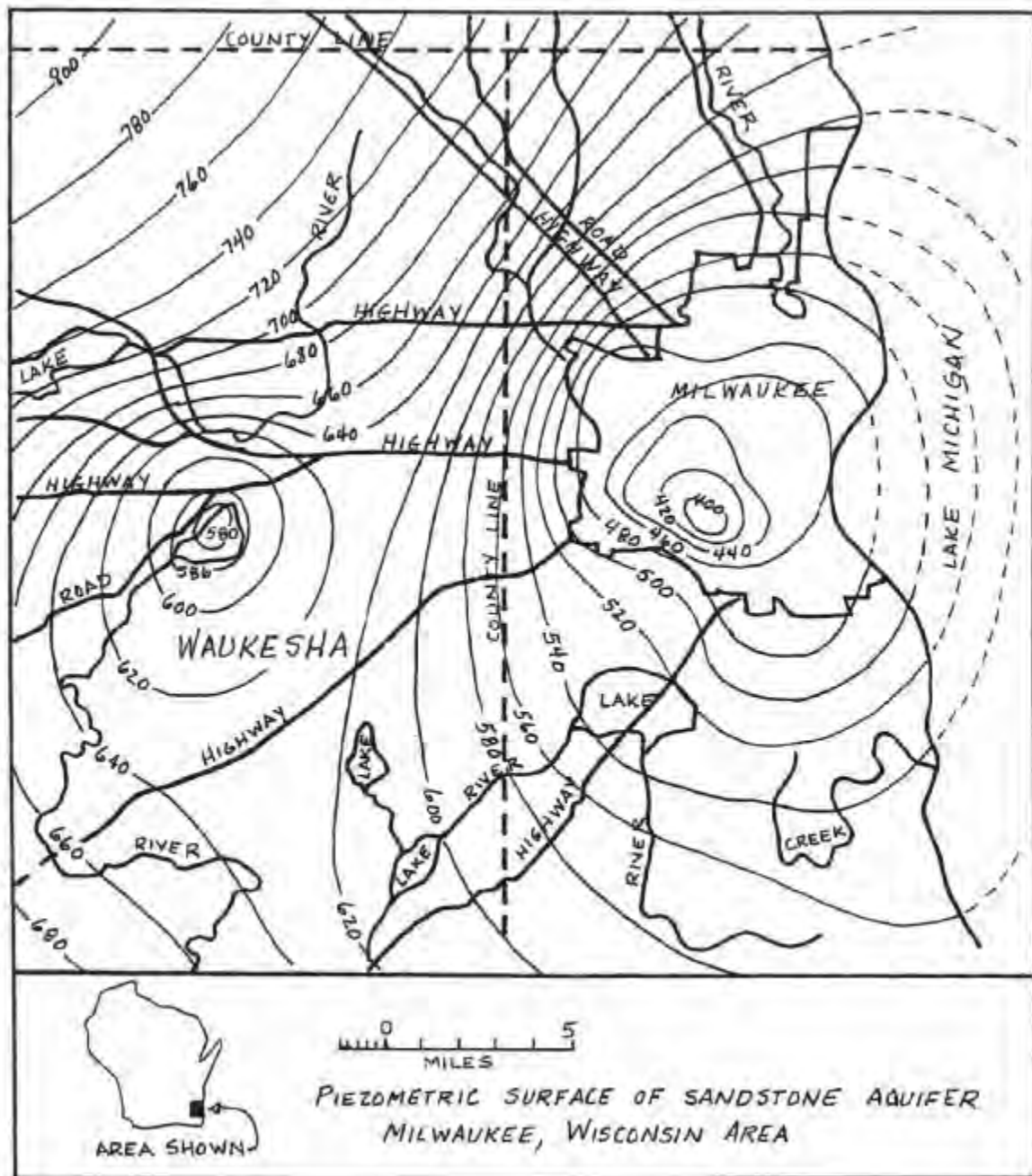
B. Invite someone from the local water system to speak to the class if groundwater is used, and/or schedule trip to a well field.

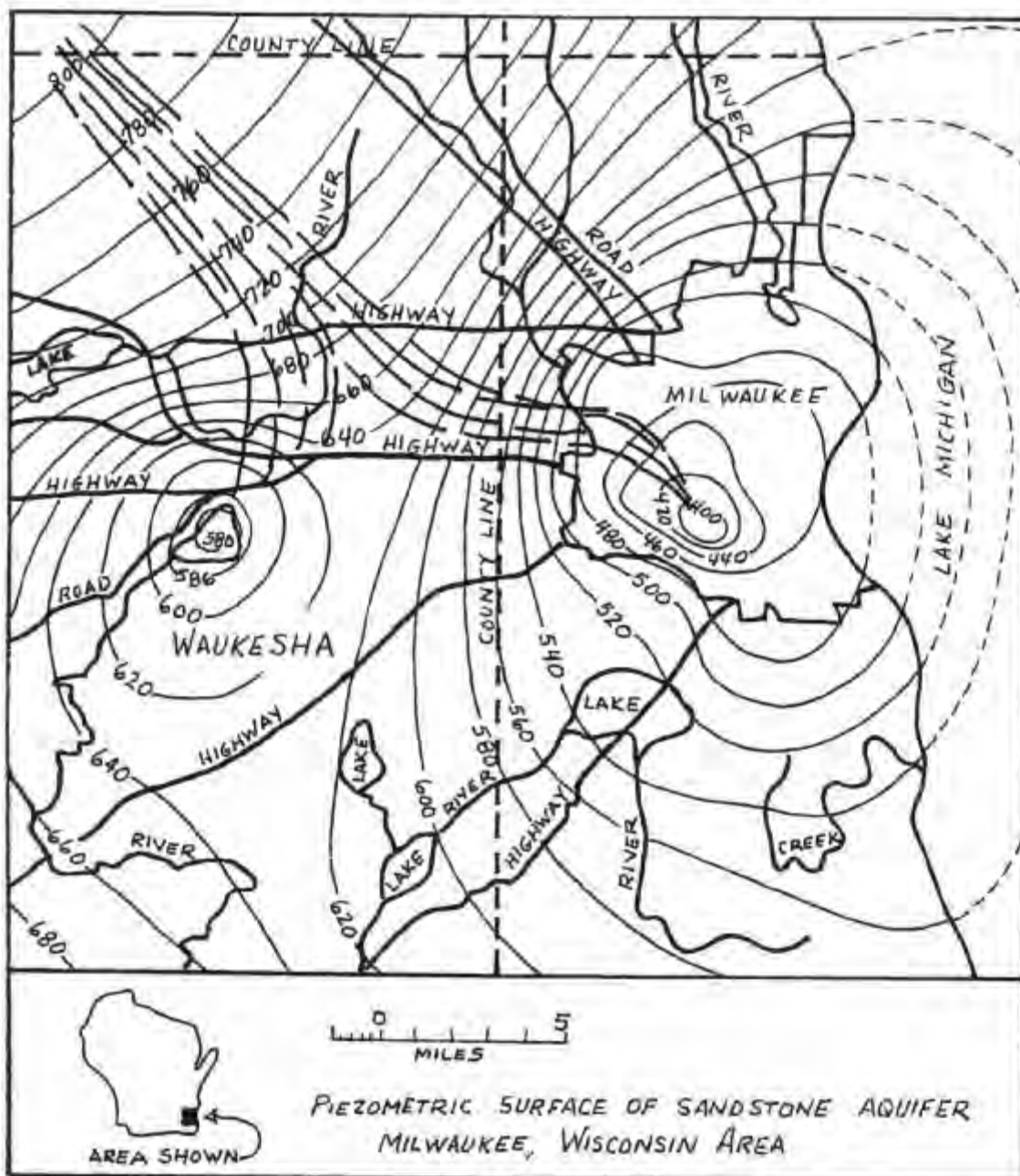
IV. Extensions

If your area uses groundwater in any capacity, get potentiometric surface maps in the area. The local or state environmental or geological agencies may have access to these. Complete the same exercise with these maps.

RESOURCES

Freeze, R. A. and Cherry, J. A., Groundwater, Prentice-Hall, Inc., 1979, p. 604.





GROUNDWATER: CLEANING UP

9-12

OBJECTIVES

The student will do the following:

1. Create a model and display board that informs other students and/or the public about different aspects of groundwater contamination that pose a threat to health and human safety.
2. Illustrate some remediation activities that aid in correcting these problems.

BACKGROUND INFORMATION

Groundwater is one of the Earth's most valuable resources. During the late 1970s, the realization of the threats to the nation's groundwater supplies and the implications of those threats became evident to natural resource managers and society as a whole. Publicity about situations such as that encountered at Love Canal triggered both concern and demands for action. Enactments followed, such as the Resource Conservation and Recovery Act (RCRA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and Safe Drinking Water Act (SDWA); forming the major thrust of the federal government's groundwater protection policy.

In July 1991, a new "Groundwater Protection Strategy" was outlined in the final report of the Environmental Protection Agency's Groundwater Task Force. The Task Force was established in 1990 by EPA's Administrator to develop a comprehensive, national approach to addressing groundwater protection concerns. EPA selected a "pilot state" for each region to help outline and refine the process for developing a core groundwater protection program.

Some possible sources of groundwater contamination are listed below.

1. Leaking underground storage tanks (examples: gasoline tanks at service stations)

SUBJECTS:

Science (Environmental Science, Physical Science, Earth Science), Social Studies (Political Science, Government)

TIME:

2-8 class periods

MATERIALS:

box (cardboard or other)
various colors of paint
poster board
thin strips of paper
glue
pencil
narrative material

2. Septic tanks (domestic or commercial wastewater on-site disposal systems)
3. Leaking above-ground storage tanks (ASTs) (examples: bulk fuel terminals, ASTs containing heating fuel)
4. Spills and leaks of solvents, fuels, and other chemicals being transported by rail, truck, or pipeline (example: train derailment)
5. The improper disposal of hazardous chemical wastes into septic tanks, unpermitted injection wells, and unpermitted dumping areas
6. Unpermitted dumps and landfills where solid and hazardous wastes have been disposed without proper engineering and geologic considerations

Once polluted, groundwater must be cleaned up or remediated, if possible. There are several methods of remediation with pluses and minuses described in the following paragraphs.

AIR SPARGING

Engineers have used air sparging since about 1985 to clean contaminated aquifers. In air sparging, wells are used to inject a gas, usually air, beneath contaminated soils or aquifers. The air causes turbulence and groundwater mixing, which increase the rate of soil and water contaminant desorption. Contaminants move into the air phase, and extraction or vacuum wells pull these vapors through the vadose zone to the surface. Air sparging and soil vapor extraction technologies rely on contaminant mass transport and biodegradation. Experienced engineers can design a system to enhance either process. In both cases, oxygen transport is essential for the technology to work. The air sparging system will usually consist of air sparging wells, a soil venting system, vapor monitor probes, groundwater recovery control, and air emissions control. (See Student Sheet Figure 1 for illustration.)

CHEMICAL OXIDATION TECHNOLOGY

Chemical oxidation technology was developed to destroy dissolved organic contaminants (fuels and solvents) in water. The technology uses ultraviolet (UV) radiation and hydrogen peroxide to oxidize organic compounds present in water at parts per million (ppm) levels. This treatment technology produces no air emissions and generates almost no residue, sludge, or spent media that require further processing, handling, or disposal. Ideally, end products are water, carbon dioxide, halides (for example, chloride), and, in some cases, organic acids. The technology uses medium pressure mercury vapor lamps to generate UV radiation. The principal oxidants in the system, hydroxyl radicals, are produced by direct photolysis of hydrogen peroxide at UV wavelengths.

In Figure 2 on the Student Sheet, contaminated water enters the oxidation unit through a section of pipe

containing a temperature gauge, a flow meter, an influent sample port, and hydrogen peroxide and acid injection points. Contaminated water is dosed with hydrogen peroxide before the water enters the first reactor. After chemical injections, the contaminated water flows through a static mixer and enters the oxidation unit. Water then flows through the six UV reactors, which are separated by baffles to direct water flow. Treated water exits the oxidation unit through a pipe equipped with a temperature gauge, an effluent sample port, and a base injection point. Base may be added to the treated water to adjust the pH to meet discharge requirements.

This system is used to treat landfill leachate, groundwater, and industrial wastewater all containing a variety of organic contaminants including chlorinated solvents, pesticides, polynuclear aromatic hydrocarbons, and petroleum hydrocarbons.

IN-SITU BIOREMEDIATION

Advancing technology is allowing scientists to isolate different microbes capable of performing many beneficial functions. Several thousand different kinds of microbes are found naturally in soil; however, only a small percentage of them are capable of breaking down contaminants. Furthermore, not all of these pollution-consuming microbes are capable of quick and effective biodegradation.

Engineers and microbiologists have spent a number of years experimenting with and developing several of the most effective strains of synergistic microorganisms with metabolic pathways capable of degrading a variety of hydrocarbon-based contaminants under either aerobic or anaerobic conditions.

These microbes are naturally occurring and are not genetically engineered. Microbial formulas are made up of a number of different strains of microorganisms that work symbiotically to remove a large variety of contaminants from the surrounding environment. Cultures are resilient to fluctuations in pH, salinity, and temperatures that frequently occur in the field. Microbes have successfully remediated contaminants in temperatures as low as 40 degrees Fahrenheit. Microbes have remediated a variety of contaminants ranging from PCPs, PCBs, DDT, and BTEX chemicals to paint thinners, municipal sewage, chlorinated solvents, and creosote.

Once all of the contaminants have been removed from the site, the microbes become self-consuming, leaving behind organic material that acts as a fertilizer.

Terms

above-ground storage tanks (ASTs): any type of container used above the surface to store products. Regulated ASTs include those containing 660 or more gallons (in one container) or 1320 gallons (in more than one container) of oil of any kind and which pose a potential discharge to surface waters.

air sparging: injecting air into groundwater to help remove contaminants

bedrock: the solid rock that underlies all soil, sand, clay, gravel, and loose material on the Earth's surface; the bottom layer

biodegradation: the breakdown of materials by living things into simpler chemicals

chemical oxidation: a means of destroying dissolved organic contaminants in water using ultraviolet (UV) radiation, hydrogen peroxide, or other processes

hazardous waste: waste materials that are dangerous to human health and/or the environment

in-situ bioremediation: a means of degrading hydrocarbon-based contaminants at the site of contamination

injection well: a well in which fluids, such as wastewater, saltwater, natural gas, or used chemicals, are injected in the ground for the purpose of disposal or to force adjacent fluids like oil into adjacent into the vicinity of producing wells

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

plume: an area where a contaminant has spread out

soil venting: vacuum extraction or soil vapor extraction; a means of reducing concentrations of volatile chemicals in petroleum products absorbed into soils in the unsaturated zone. A vacuum is applied to the soil to create a negative pressure gradient that causes movement of vapors toward extraction wells. The volatile chemicals are then removed through the wells, treated, and discharged into the atmosphere or reinjected to the subsurface.

synergistic: more than one agent working together to produce enhanced combined effects (i.e., a greater total effect than the sum of the individual effects)

underground storage tank (UST): any tank, including underground piping connected to the tank, that has at least 10% of its volume underground and contains petroleum products or hazardous substances (except heating oil tanks and some motor fuel tanks used for farming or residential purposes)

vadose zone: the zone of aeration between the Earth's surface and the water table; area of the soil that contains both air and water; same as unsaturated zone--zones between land surface and the water table

ADVANCE PREPARATION

- A. Collect or have students bring in all the materials for construction of a groundwater model.
- B. Copy and review Background Information.
- C. Put terms and definitions on the board.
- D. Some organizations loan out working groundwater models. Check with your local extension agency, department of environmental management, or water resources research institute to see if these are available. (See Teacher Sheet.)

PROCEDURE

I. Setting the stage

- A. Hand out Background Information and Student Sheets. Discuss with students.
- B. Plan a time and place to display the final product of this activity. It may be used for school and/or community display.
- C. If a groundwater model can be obtained, use it along with the activities provided with the model to demonstrate the hydrogeologic cycle and how the effect of (remediation) pumping and treating a groundwater contaminant plume removes the contaminant that is a threat to health and human safety.

II. Activity

Construct a three-dimensional (box) model of the surface and subsurface of the Earth, showing surface features, soil, bedrock, and groundwater with various sources of contamination present from man-made materials. Label each area on the model with a flag for reference to a written explanation of the area on the display board. (See Student Sheet Figure 3 for drawings.)

Construction of Groundwater Model

1. Draw on sides of box. Trace in soil/bedrock contact and successive geologic beds going downward toward the bottom of the model.

2. Draw line through soil parallel to top of bedrock with a sloping downhill or downgradient slant to represent the water table and its direction of flow.
3. Paint the soil and bedrock earthy colors, and paint the area in the soil below the water table line a blue water color to the top of bedrock.
4. After placing possible sources of contamination on top of the model, paint contamination moving straight down below the source on the side of the model toward the water table.
5. Show contamination entering the water table and flowing in the direction of groundwater flow.
6. Cut and glue thin strips of white paper around areas of the “plume” of contamination to represent monitoring of the vertical and horizontal extent of the plume. To represent remediation of the plume, glue more strips into the plume and show contaminant extraction or destruction through the appropriate technology.
7. On the top of the model representing the ground surface, use toothpicks or pins to locate flags with letters that cross reference the area of concern to a reference letter on the display board so that the area and activity can be described.

III. Extensions

- A. Have students research state and federal laws and any local ordinances that protect groundwater.
- B. Assemble a display board that informs people in the local community how their groundwater resource is invaluable for human needs and how it is protected.
- C. Present material on the display board that informs people in the local community how their groundwater resource is invaluable for human needs and how it is protected.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Figure 1

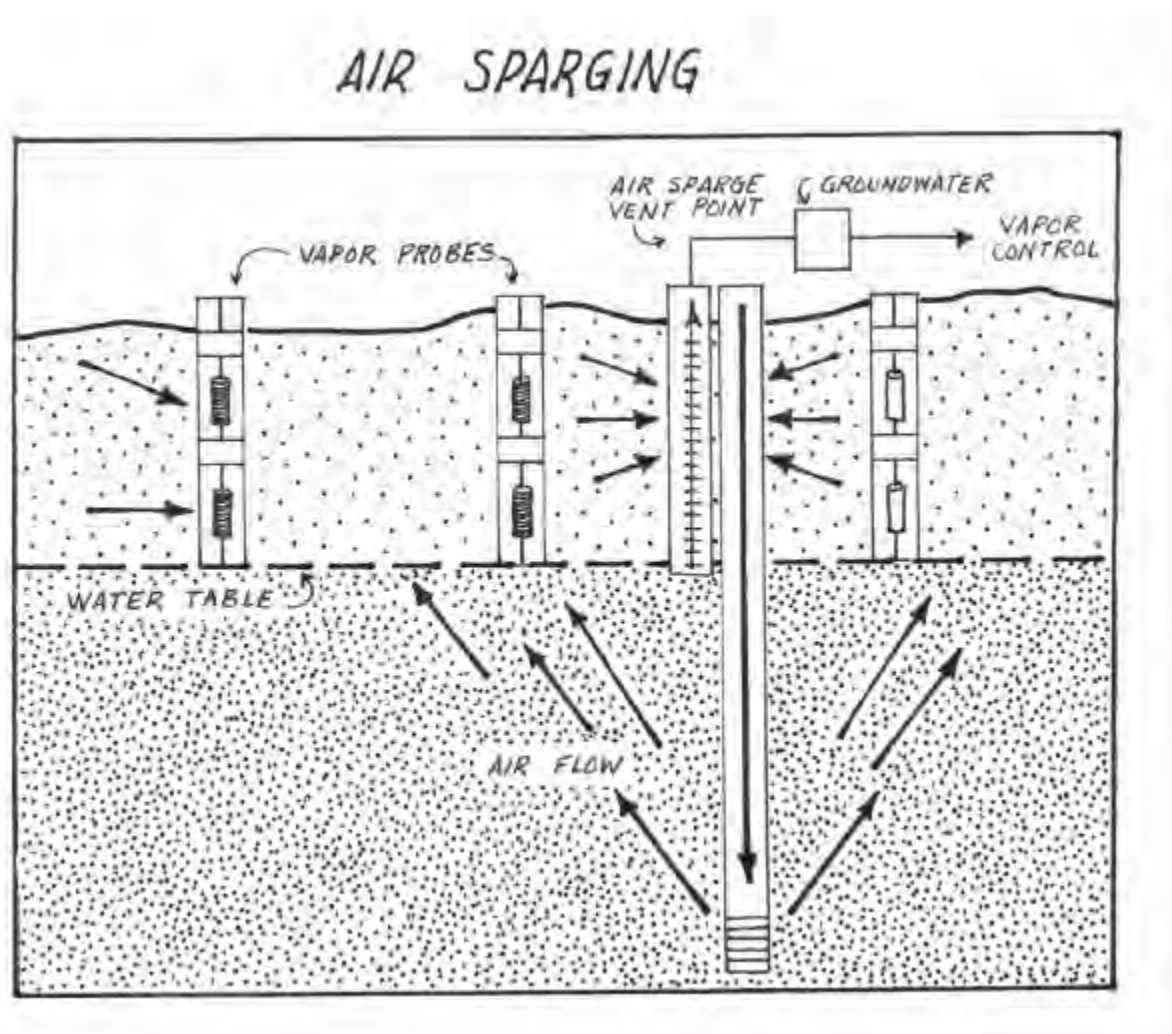


Figure 2

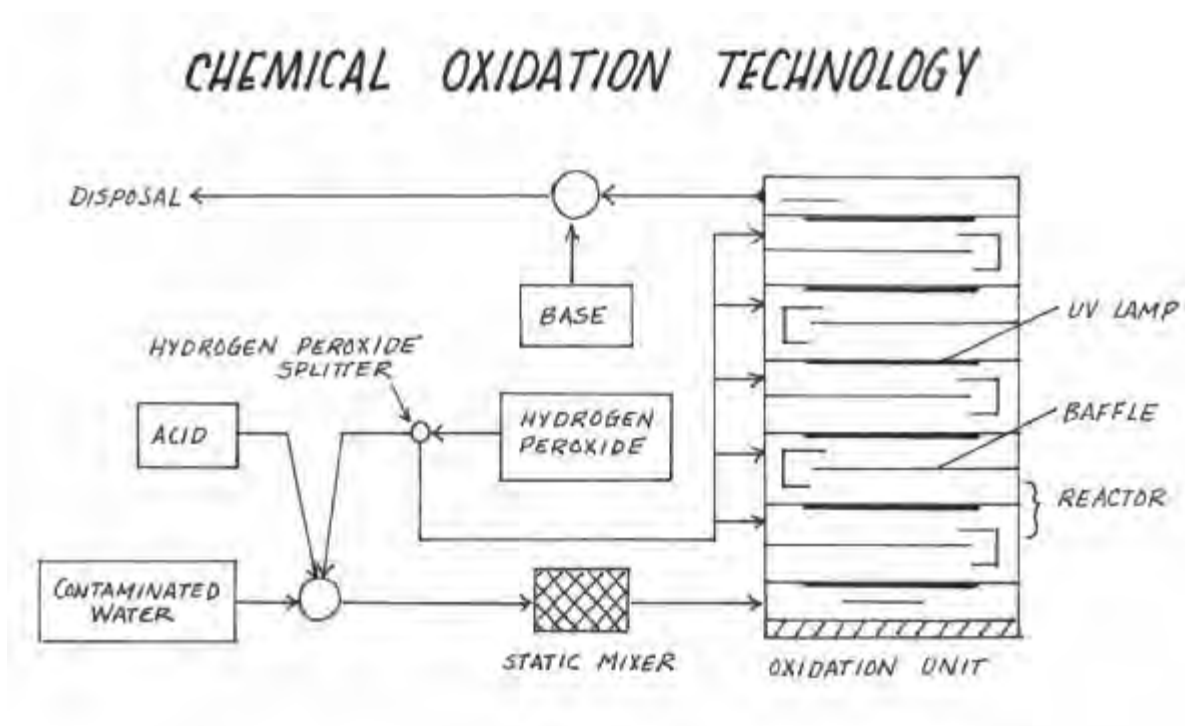
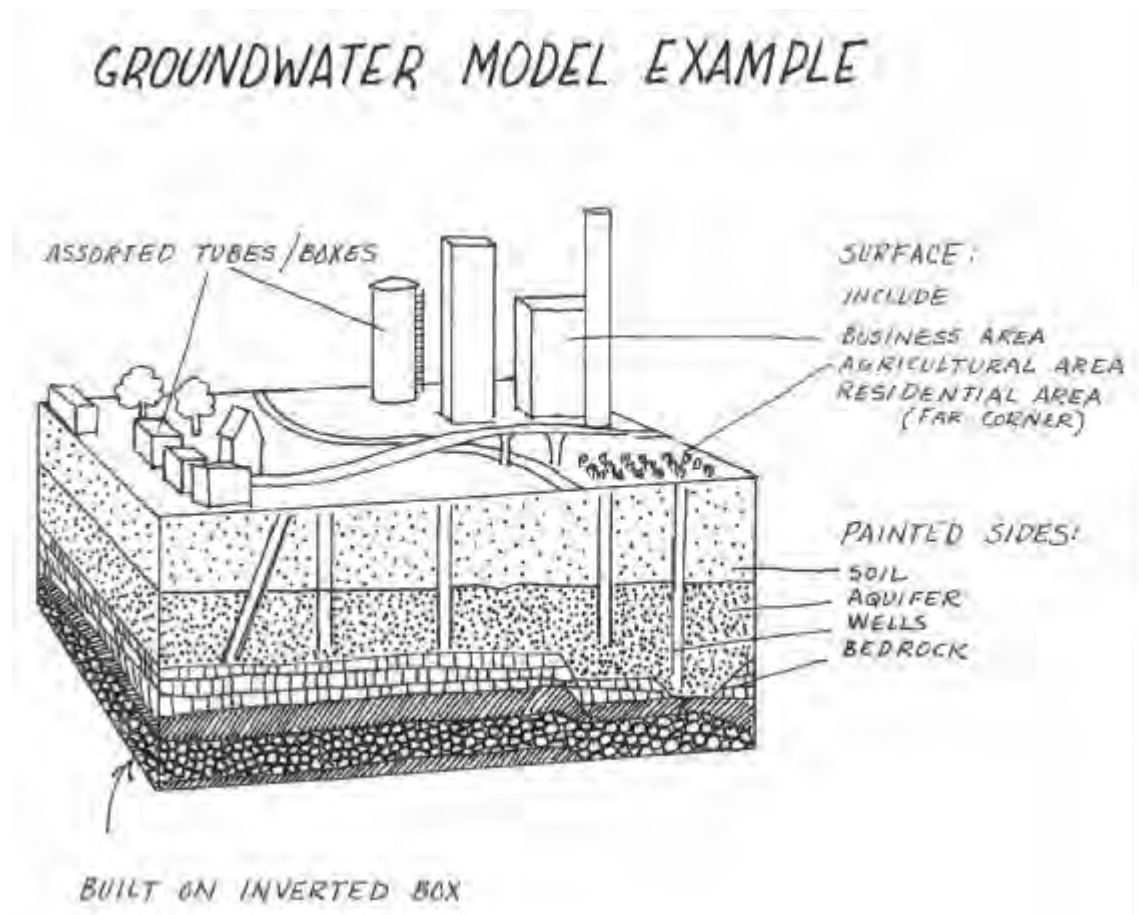
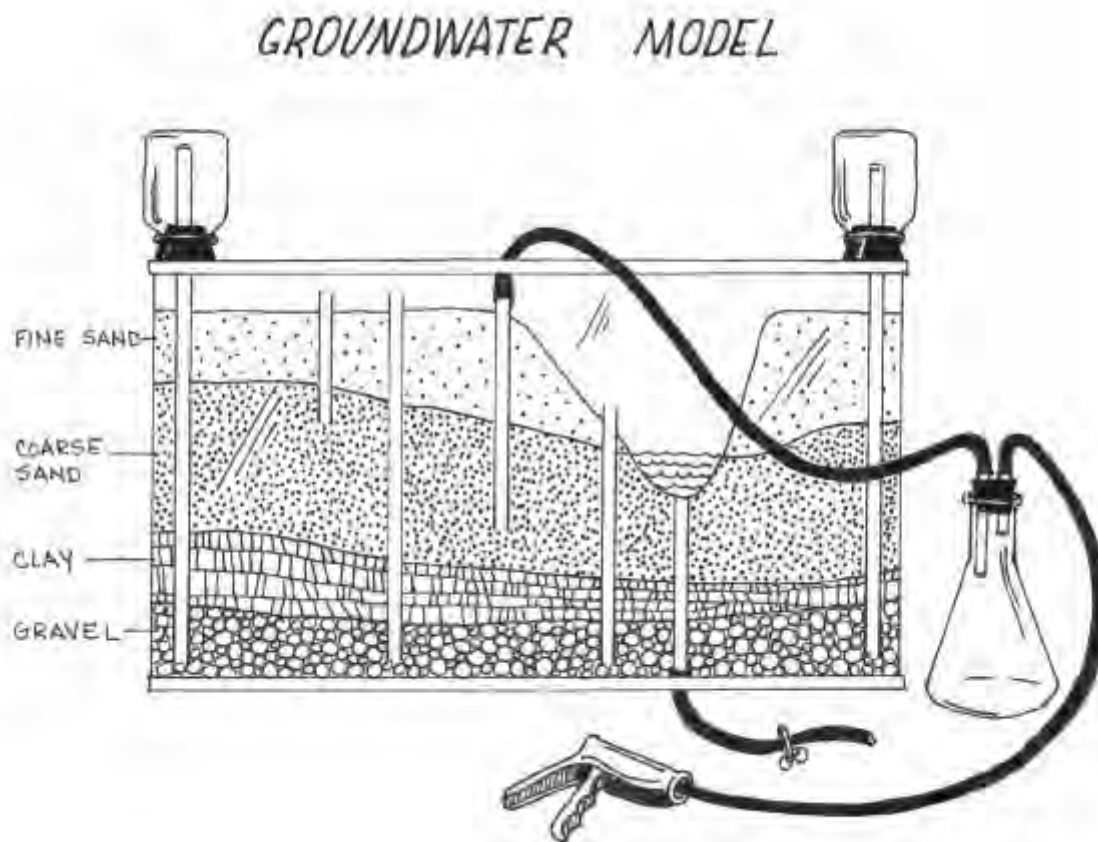


Figure 3





This groundwater model is a very effective tool for demonstrating the hydrogeologic cycle, for showing the effects of well pumping, and for showing how human activities can contaminate groundwater

WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?

9-12

OBJECTIVES

The student will do the following:

1. Explain the potential impact of the environment on health.
2. Describe some carcinogenic contaminants and possible sources of them.
3. Develop possible ways to work toward lessening or eliminating the contaminants from the environment.

SUBJECTS:

Science (Ecology, Social Studies (Geography), Health

TIME:

1 class period

MATERIALS:

colored pencils
student sheets

BACKGROUND INFORMATION

Chemicals introduced into the environment may find their way into groundwater and become hazards. The Environmental Protection Agency (EPA) has set drinking water standards that list amounts in mg/l (ppm) above which a health hazard could be posed either immediately or over the long term at sustained exceedance levels. They also list some possible sources for carcinogens and other hazardous compounds.

Terms

carcinogen: cancer-causing agent

hot spot: region where an unusually high number of deaths are due to cancer that might be linked to environmental contamination

parts per million (ppm): a measurement of concentration of 1 unit of material dispersed in 1 million units of another (for water, same as mg/l)

ADVANCE PREPARATION

- A. Copy Student Sheets for each student.
- B. Become familiar with Ellen's story.

PROCEDURE

I. Setting the stage

Share Ellen's story with the students. Distribute Student Sheet Limestone Ridge drawing and (optional) EPA Standards (located on Factsheet pages F-73 thru F-77).

II. Activity

A. Have students follow the coded key, complete the schematic using the given information, and answer the questions.

B. Discuss findings as a group

III. Follow-up

A. Have students write a statement accepting or rejecting their hypotheses. Explain why the test turned out like it did.

B. Have students list some possible sources of coliform contamination in the samples that were positive.

C. Discuss how these contaminants affect the cost of purifying drinking water. Ask students for ideas on how to prevent contamination.

IV. Extensions

A. Have students ask questions of relatives and friends to try to discover any potential "hot spots."

B. Have students write a letter to the EPA regarding a problem they may discover from their questions (A) or write a "simulated letter" regarding the problem in the activity (the "hot spot" on Limestone Ridge Road).

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX 1996.

Chiras, Daniel D. Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

“National Primary Drinking Water Standards,” EPA, Washington D.C, February, 1994. (Latest version obtainable from the Safe Drinking Water Hotline, 1-800-426-4791).

Nebel, Bernard J. And Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

ELLEN'S STORY - LIFE (AND DEATH) ON LIMESTONE RIDGE ROAD

Ellen had lived on Limestone Ridge Road for 44 years, all of her life except for the four years she had gone away to college. She was typical of many of the residents of Limestone Ridge Road whose parents and grandparents had lived there before them. All of the households obtained their drinking water from wells, and most of the families had been farmers for several generations.

In the 40 years Ellen had lived on the road, many of the residents had died, especially in the last ten years. Ellen's parents and sister had died of cancer in the last ten years.

Ellen had just returned from yet another neighbor's funeral, a neighbor who had, coincidentally, died of cancer. As Ellen began to think about those who had died in the last ten years, she was astonished to realize that almost every death she could remember could be attributed to cancer!

Ellen began a neighborhood drawing recording deaths by the house location of each, recording surrounding industry at its location, and also recording what information she could obtain about chemicals that had been used in farming along the road.

It is important to note that farmers are among the highest occurrences of skin cancer due to long/frequent exposure to sun. Therefore, all cancer sources may not be totally due to drinking water.

Name: _____ Period: _____ Date: _____

LIMESTONE RIDGE ROAD DATA

OF HOUSEHOLD
MEMBERS
(INCLUDES DECEASED)HOUSEHOLD
DEATH INFORMATION

4	A. Male, age 54, heart attack; Female, age 52, cancer
2	B. Male, age 72, cause unknown
1	C. Female, age 62, cancer
5	D. Male, age 14, cancer
5	E. Male, age 53, cancer
4	F. Female, age 64, cancer; Male, age 68, cancer; Female, age 47, cancer
2	G. Male, age 62, heart attack
4	H. Female, age 41, cause unknown
2	I. No deaths in ten years
3	J. No deaths in ten years
2	K. Female, age 60, cancer
0	L. Unoccupied house
6	M. Male, age 51, cancer
3	N. No deaths in ten years

KNOWN CHEMICAL USE

1. In fields behind houses E-H and K; ALACHLOR, SIMAZINE, NITRATES.
2. In fields behind houses M and K: METHOXYCHLOR, HEXACHLOROBENZENE, NITRATES.

Record the above information on the schematic drawing of the neighborhood. Use the following KEY:

(RED DOT)cancer death	(BROWN SHADING)	herbicide
(ORANGE DOT)heart disease death	(PURPLE SHADING)	insecticide
(YELLOW DOT)cause unknown		pesticide

Answer the following questions:

- a. How many deaths have occurred in the past ten years along this section of Limestone Ridge Road?
- b. What percentage of the deaths were caused by:

Cancer? _____ Heart Attack? _____
- c. What appear to be some environmental factors that could have influenced the development of cancer? _____

- d. If you lived in this neighborhood, what could you do to try to change the contaminant levels in the area? _____

- e. Have students research the carcinogenic nature of each chemical.
- f. Assess neighbor's well depth.
- g. What is the direction of groundwater flow?

1. Look at student's color coded drawing, or prepare an overhead transparency of the drawing and color code with input from students.

2. a. 13 deaths

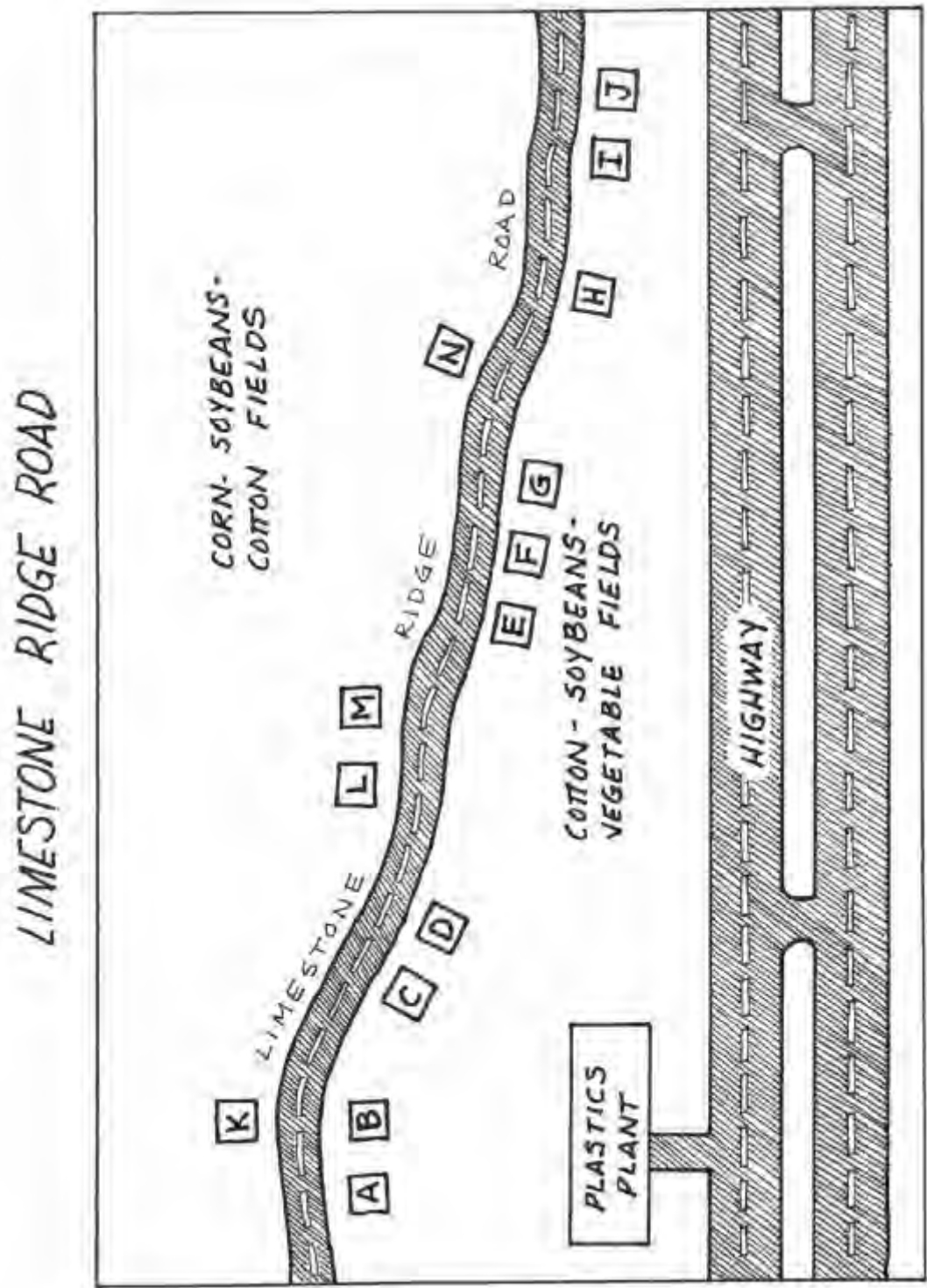
b. $9/13 = 69\%$ of the deaths were due to cancer

c. $2/13 = 15\%$ of the deaths were due to heart attack

d. Answers will vary -

Could include: limit or eliminate contaminants sprayed on crops; check and change, if needed, by-products of plastics plant.

NOTE: Accumulated contaminants in the soil would be difficult to "clean-up."



RADON IN WATER

9-12

OBJECTIVES

The student should learn the following:

1. The meaning of "radon".
2. The human health threat from radon in water and air.
3. When water should be tested for radon.
4. The general ways radon can be removed from homes and water.
5. Where there is a higher probability of finding radon problems.

SUBJECTS:

Science (Ecology), Social Studies (Geography), Math

TIME:

1 class periods

MATERIALS:

Handouts of Student Sheets

BACKGROUND INFORMATION

Radon-222 is a naturally occurring radioactive gas formed from the decay of uranium and radium found throughout the earth's crust. It decays into solid particles which adhere to dust and other particles in the air. These can then be breathed into the lungs, causing lung cancer. The risk is a function of total radon concentrations and the duration of exposure. In fact, radon is the second leading cause of lung cancer after smoking, causing an EPA-estimated 14,000 deaths per year. Since radon has a half-life of 3.8 days, it has sufficient time to move through soils or water and into a home.

Radon is colorless, odorless and tasteless, so its presence in water or air can only be determined by testing. It is the most serious problem for humans when it enters a home from the soil beneath the foundation or it is brought in with well water and escapes to the air. EPA has established an action level of 4 pCi/L for indoor radon. This means that if a home measures at 4 pCi/L or above, the homeowner should have it fixed. The 4 pCi/L action level does not represent a "safe" level. Radon is a carcinogen, so no level is absolutely safe. However, it is a natural part of the environment, so there is no such thing as a "0" radon level. Radon is not one of the radionuclides currently regulated in drinking water, though standards have been proposed.

Radon is fairly soluble in water, thus will dissolve in groundwater when released by surrounding soil or rock. If a well is dug into a geologic stratum which has a high uranium/radium content, the radon can find its way into the well water and eventually be brought into the home. When someone turns on a

faucet, takes a shower, or runs a dishwasher, the radon will escape to the air where it can be breathed. There is some risk from ingesting or drinking water with high radon levels, however the primary health risk is from breathing radon decay products in the air.

The release of dissolved radon into the house air is often referred to as "de-gassing" of the water. De-gassing occurs primarily when the water is brought into contact with air, facilitating escape of radon from the water. The most de-gassing occurs when the water is aerated or sprayed, as in a shower. Heating the water will decrease radon solubility, also causing release of the dissolved radon.

When a town's drinking water comes from surface waters instead of groundwater, radon is usually not a problem. It has a chance to escape to outdoor air before being brought into the home. As a rule of thumb, it takes 10,000 pCi/L of radon in water to increase the level in a home by 1 pCi/L. However, this can vary widely. If a home measures less than 4 pCi/L, then even if its water supply source is a well, the water probably does not need to be sampled for radon. If the home measures above 4 pCi/L and has a well, then radon in water may be a contributing factor.

Radon problems in homes, however, are relatively easy to fix. The most common approach is called active soil depressurization. In this method radon-containing soil gas is drawn away from the foundation before it can enter the home, and is vented to the outdoors where it is quickly diluted in outside air. One or more pipes are inserted through the slab into the soil below. The pipes are connected to a fan, usually in the attic, and extended through the roof. The fan draws the radon through the pipe and vents it above the roof level. If the home has a crawl space, the same general approach can be used, except the pipe is run through a plastic vapor barrier which is placed on the soil.

If water is contributing to the indoor radon problem it must be treated as well. The water can be passed through a vessel containing activated carbon. The radon and its decay products are adsorbed onto the carbon, where they can decay away. The water can also be aerated, causing the radon to degas, or stored for a time above ground. The latter two approaches are not as practical for homes however.

EPA has developed a Map of Radon Zones as a guide for radon officials. The authors evaluated the radon data which had been collected from around the country, then looked at geological maps to determine where the uranium content was the highest. Every county in the United States was then rated Zone 1, 2 or 3, with Zone 1 counties being the most likely to have homes with radon levels greater than 4 pCi/L. However, homes with elevated radon levels have been found in both Zone 2 and Zone 3 counties. A separate book was prepared for each state to provide the background details for the county designations. Because such information is continually being updated, EPA recommends that every home be tested, regardless of its location.

Terms

aeration: exposing to circulating air

picocuries per liter (pCi/L): units for measurement of radioactive element concentrations in water and in air

radon: colorless, odorless, tasteless, naturally occurring radioactive gas formed from natural deposits of uranium that can cause lung cancer. It can enter the home around plumbing pipes and through cracks and openings in the foundation. It can also be brought in with the home's water supply.

radon decay products: the radioactive elements that immediately follow radon-222 in the decay chain. They are ultrafine solids that tend to adhere to other solids, such as dust particles in the air, or lung tissue if inhaled.

solubility: ability or tendency of one substance to blend uniformly with another

ADVANCE PREPARATION

Contact the State Radon Program to obtain a state book of Map of Radon Zones. Copy the appropriate state map, Map of Radon Zones, drawing of the house (without entry routes identified), drawing of Mesa Village, and questions.

PROCEDURE

I. Setting the stage.

A. Present background information and terms.

B. Discuss the drawing of Mesa Village.

II. Activity.

A. Distribute Student Sheets of questions on Mesa Village. Have students answer questions individually or as a group.

B. Distribute drawing of the home. Have students attempt to identify possible radon entry routes.

C. Distribute or show Map of Radon Zones and appropriate state map. Have students find where they live. What Zone is the school in?

D. Answer any general questions.

III. Follow-up.

Have students research:

A. Where their drinking water comes from. Does it represent a potential radon problem?

B. Whether their state drinking water program tests for radon in water. If so, what kind of results have been found?

C. Whether anyone they know has tested for radon. What were the results?

D. If the home had elevated radon levels was it fixed? How? Was radon in water a contributing factor?

E. The uranium decay chain. The difference between alpha, beta and gamma emitters. What do radon decay products emit?

RESOURCES

A Citizen's Guide to Radon, EPA 402-K92-001, September 1994.

Consumer's Guide to Radon, EPA 402-K92-003, August 1992.

Home Buyer's and Seller's Guide to Radon, EPA 402-R93-003, March 1993.

Radon Reduction Techniques for Detached Houses, 2nd Edition, EPA 625/5-87/019, January 1988.

Radon Reduction Techniques for Existing Detached Houses, 3rd Edition, EPA 625/R-93/011, October, 1993.

Removal of Radon from Household Water, EPA OPA-87-011, September, 1987.

Map of Radon Zones, EPA 402,R-93-071, September 1993.

Mesa Village

Residents of Mesa Village heard there might be a radon problem in their area. They decided to have a couple of houses tested for indoor radon and radon in water. They selected House #2 and House #4. The following results were obtained.

House #2	=	Indoor Radon	8 pCi/L
	=	Radon in water	30,000 pCi/L
House #4	=	Indoor Radon	3 pCi/L
	=	Radon in water	10,000 pCi/L

1. Looking at the schematic of Mesa Village, were Houses #2 and #4 an adequate sample? Why or why not?
2. What else can be noted about the sampling?
3. How much of the indoor radon might have come from well water and how much from other sources?

Houses #1 and #5 were tested with the following results:

House #1	=	Indoor Radon	6.2 pCi/L
	=	Radon in water	23,000 pCi/L
House #5	=	Indoor Radon	13 pCi/L

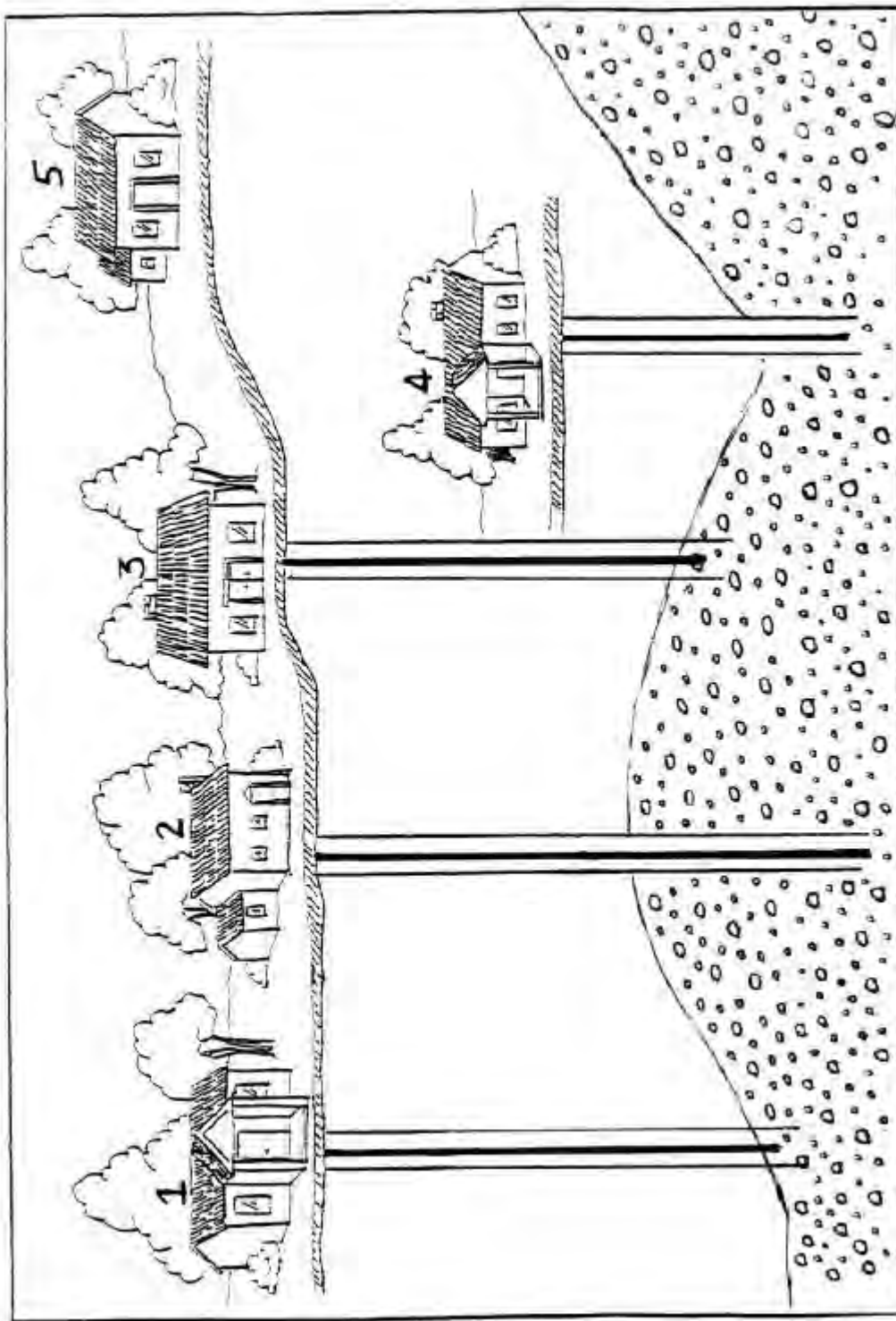
4. How much of the indoor radon might have come from well water and how much from other sources?
5. House #5 does not have a well. Where did the radon come from?
6. How did the radon get into House #'s 1 and 5?

House #3 was tested with the following results:

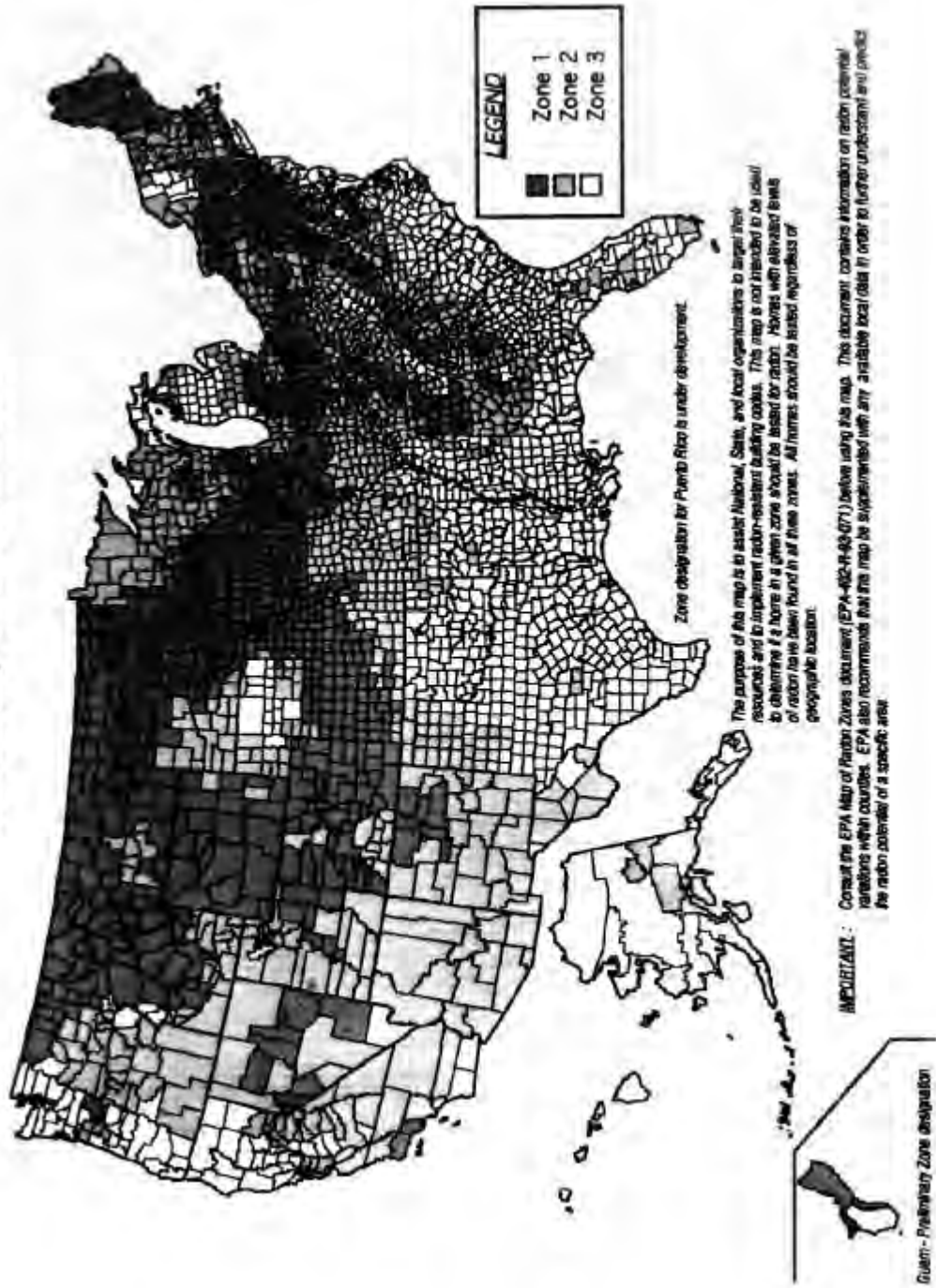
House # 3	=	Indoor Radon	3 pCi/L
	=	Radon in water	45,000pCi/L

7. How would you explain the low indoor level, given the high radon in the water level?
8. Given the half-life of radon, would it be practical in home situations to simply store water until the radon concentrations dropped to a level which would not cause a problem? Why or why not?

MESA VILLAGE



EPA Map of Radon Zones

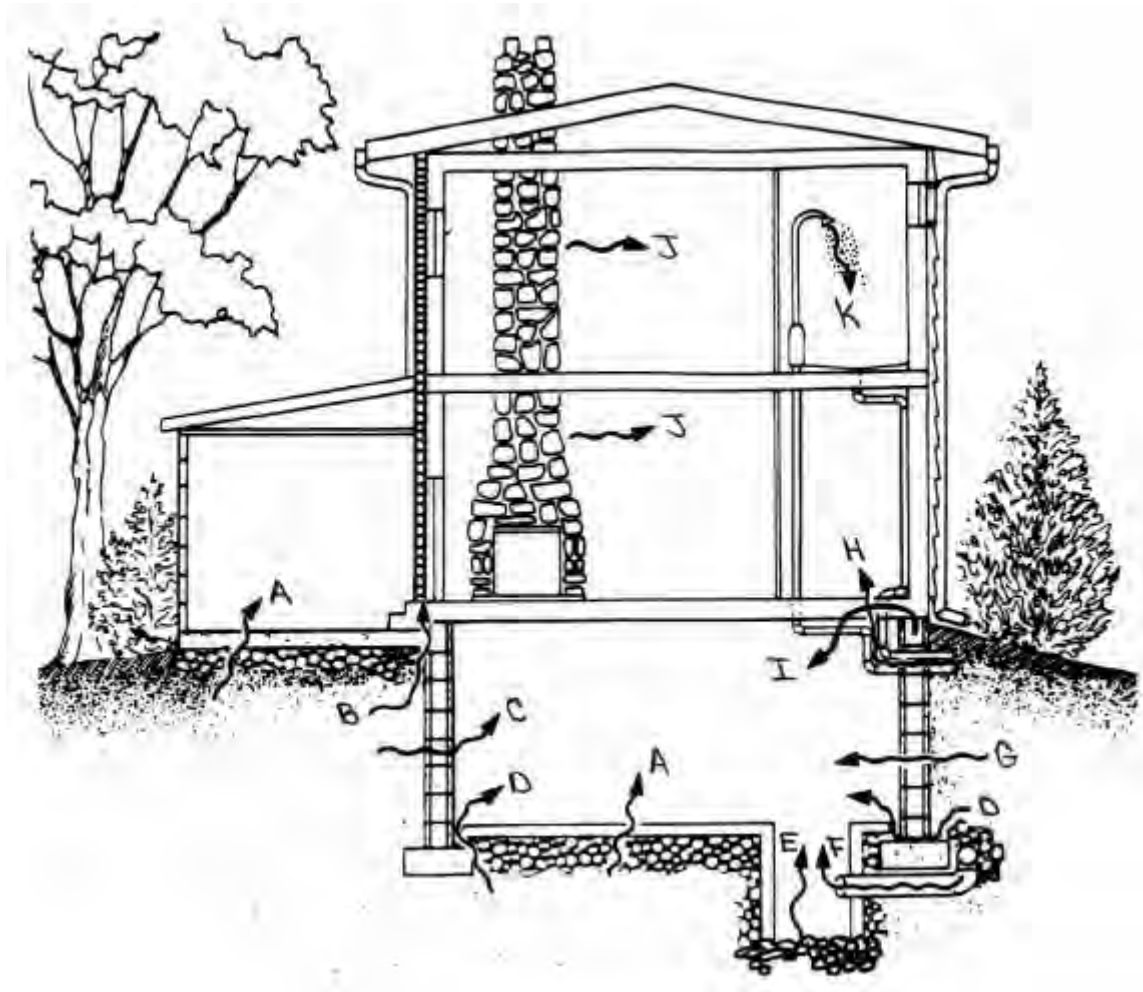


Answer Sheet

1. Houses #2 and #4 do not provide an adequate sample because:
 - a) Every home should be tested
 - b) A house with a high radon level can be right next door to one with a low level.
2. The water should not be tested for radon until the levels inside the home are found to be above 4 pCi/L.
3. Using the 10,000 to 1 rule of thumb:

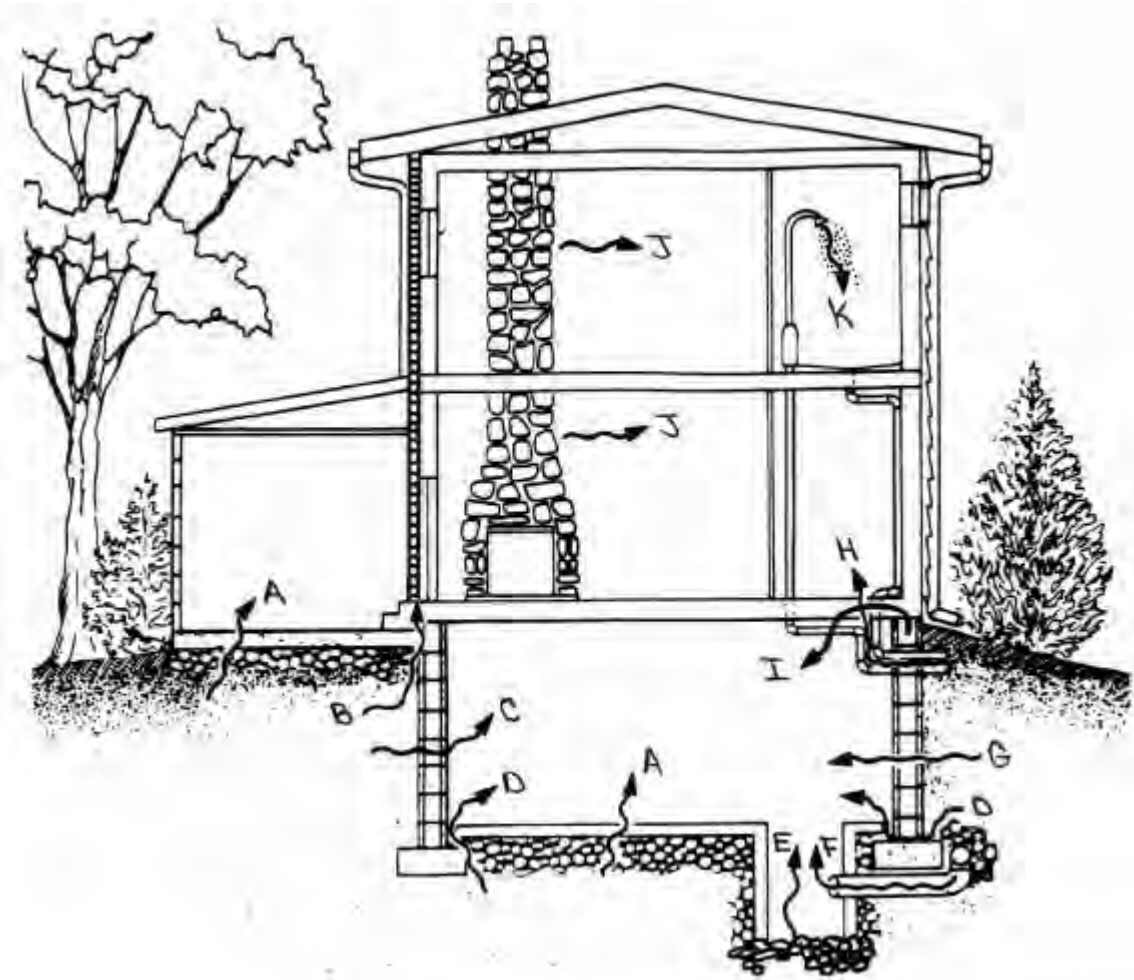
House #2	=	5 pCi/L from other sources
	=	3 pCi/L from water
House #4	=	2.9 pCi/L from other sources
	=	0.1 pCi/L from water
4. Using the 10,000 to 1 rule of thumb, approximately 2.3 pCi/L came from the water and 3.9 pCi/L from other sources.
5. Probably from the soil beneath the house. In some instances radon can be emitted from building materials.
6. Using the schematic of the house, show how radon came in through cracks in the foundation, floor to wall joints, the shower. etc. in House #1.
7. The owner of House #3 could be a single person or someone who travels a lot, resulting in less water usage. The owners of Houses #1 and #2 could have large families who would use much more water. If the water is not turned on, the radon does not escape to the air.
8. No, because too much storage capacity would be needed.

LABEL THE MAJOR RADON ENTRY ROUTES



A. _____
 B. _____
 C. _____
 D. _____
 E. _____

F. _____
 G. _____
 H. _____
 I. _____
 J. _____
 K. _____

MAJOR RADON ENTRY ROUTES

- A. Cracks in concrete slabs
- B. Spaces behind brick veneer walls
- C. Pores and cracks in concrete blocks
- D. Floor-wall joints
- E. Exposed soil, as in sump

- F. Weeping (drain) tile
- G. Mortar joints
- H. Loose fitting pipe penetrations
- I. Open tops of clock walls
- J. Building materials, such as rock
- K. Water (from some wells)

LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION

9-12

OBJECTIVES

The student will do the following:

1. Define waste and leachate.
2. Describe a sanitary landfill in terms of its construction and function.
3. Identify some common chemical and physical properties of leachate and the problems these can cause in groundwater.
4. Identify sites in the community that are possible sources of contaminants in runoff waters and groundwaters due to unsupervised, unprotected garbage disposal sites.

BACKGROUND INFORMATION

Most of our household waste is buried in landfills. An important factor in how landfills are built is how they contain waste and prevent waste from contaminating nearby soil and water sources. The possibility of leachate contaminating soil and groundwater exists wherever wastes are disposed.

Leachate is a fluid that has passed through or emerged from the waste in a landfill, picking up a variety of suspended and dissolved materials along the way. Leachate generation depends on the amount of liquid originally contained in the waste (primary leachate) and the quantity of precipitation that enters the landfill through the cover or that which comes in direct contact with the waste (secondary leachate) prior to being covered. Factors that affect leachate generation are: climate (rainfall), topography (run-on/run-off), landfill cover, vegetation, and type of waste.

SUBJECTS:

Science (Chemistry, Environmental Science), Math

TIME:

3-4 class periods per procedure
homework
1 month (minimum) for leachate collection

MATERIALS:

plastic garbage can (30 gallon)
clear Plexiglas®, +/- 4" x 30"
(Be sure to modify this if you choose to use a 13 gallon kitchen trash can.)
membrane filtrate
5 to 10 gallons of soil
screw-in, plastic faucet with securing nut
a small piece of screened wire +/- 2" square
caulking compound
waterproof glue for plastic
one gallon of distilled water
coliform bacteria test
laboratory thermometer
student work sheets (included)
gloves

In unlined landfills, the leachate continues to leach into the ground and may contaminate groundwater. Many old landfills used a simple clay liner for containing leachate (clay is one of the most non-permeable soils). Newer landfills are required to meet federal and state requirements to prevent environmental contamination (Subtitle D landfills). These landfills have sophisticated liner systems often made of heavy-duty, high density polyethylene (HDPE) plastic, where leachate is collected at the bottom. The leachate is typically treated on-site or is pumped out and sent to a local wastewater treatment plant. Treated leachate can be disposed of in a number of ways (e.g., discharged to surface waters or recirculated back into the landfill). Some States also allow continued use of clay liners, if the liner meets federal and state performance standards, and if leachate is properly collected, treated, and disposed of.

In this lesson, the landfill model represents the construction of a Subtitle D sanitary landfill to hold municipal waste.

A common convenient procedure for disposal of household and domestic garbage is to take it to the nearest ravine, hollow, or back road and leave it in a completely unprotected situation. Because this kind of behavior is such an accepted and uncontested way of life for many households, the effect of this garbage upon water quality can be overwhelming. Often there is absolutely no regard for the contamination potential of some of these items. The results of this can be the introduction of very toxic substances into the streams and groundwater. An understanding of the long-term harmful effects of these actions would influence the future actions of students and their counterparts toward proper garbage disposal. Such an understanding of the part of the community leaders will possibly influence legislation and enforcement.

Terms

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater.

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation.

leachate: a liquid that results from water collecting contaminants as it trickles through wastes, or soil containing agricultural pesticides or fertilizers

percolate: to drain or seep through a porous and permeable substance; to filter such as a liquid passing through a porous body (water through soil to the aquifer)

residue: something that remains after a part is taken away

ADVANCE PREPARATION

- A. Make copies of Student Sheet (3).
- B. Ask students to come up with some of the materials to construct the sanitary landfill model.

PROCEDURE

I. Setting the stage

A. Discuss with the students the following:

- 1.What is waste?
- 2.What does the term “biodegradable” mean? *(Note that some of the elements necessary for biodegradability - air, water, and sunlight - are not available in a landfill. Without air, water, or sunlight, there is no degradation.)*
- 3.What are the sources of waste? Give examples.
- 4.What happens to the waste from our homes, schools, and businesses?
Then what? (Lead students to the conclusion that most waste is buried in a landfill.)
- 5.Why is waste disposal an important issue?
- 6.Have students identify some local sites where household garbage is disposed illegally.
- 7.Discuss the possible effects of illegal disposal on surface water and groundwater.

B. If possible, make arrangements for students to visit the nearest landfill site or arrange a presentation by a local waste management or public health expert. Explain how a landfill is constructed. Discuss:

- 1.Site selection.
- 2.Methods and operations.
- 3.Chemical and biological reactions occurring in a completed landfill.

4.Methane gas and leachate movement and control.

5.Landfill design criteria and regulations.

C. Ask the students to describe what they think the properties of landfill leachate might be (in terms of pH, bacteria, and suspended solids) and what the processes occurring in its formation might be. (Seeing the landfill operation or hearing a presentation by a landfill operator first will give students a better understanding. As a less-than-complete-but-effective alternative, have students take a trip to the school dumpster. (This may reveal the early formation of leachate, as liquid wastes have probably started to accumulate in the bottom of the container.) Students could test the pH of leachate from the school dumpster.

D. Ask each student to bring to class a small plastic bag containing household wastes, including foodstuffs (vegetable and fruit peels, no meat or dairy products), yard trimmings or plant residue, metal, paper, plastic, and cloth. As they bring the small bags of waste, have them deposit the bags in a larger bag or other large container.

E. Have the materials and equipment gathered for constructing the landfill model. (See student Sheet: Construction of a Sanitary Landfill Model.) Divide the class into teams.

II. Activity

A. Give the teams copies of the Student Sheet: Construction of a Sanitary Landfill Model, and proceed with the landfill model construction and waste preparation.

B. To prepare for the simulated rainfall, determine the average annual precipitation for your geographic area. Information is available from the state climatologist or local extension agent of National Weather Service.

1.Divide the average annual precipitation by 52 to calculate the average weekly precipitation.

2.Measure distilled water to equal the amount of the calculated average weekly precipitation and sprinkle it over the soil in the model landfill.

3.Repeat the addition of “average weekly precipitation,” keeping a record of the number of “weeks,” until water begins to collect in the bottom of the model landfill. (*The liquid that collects in the bottom is a leachate.*) Be prepared to allow several weeks of adding precipitation to obtain enough leachate to perform this activity.

C. Monitor the temperature by inserting a thermometer as far as possible into the center of the landfill model and keeping a daily record of temperature readings. This can be an excellent graphing exercise.

D. One month after the addition of water, withdraw all of the leachate from the model and test for pH, total suspended solids (liquid weight minus weight of solids), hardness, coliform bacteria (optional), and other water quality parameters for which tests are available.

1. Compare the results of these tests with the properties of distilled water and graph the results.

2. Discuss what can be done to prevent leachate from contaminating groundwater and surface waters.

Explain to the class that leachate contamination can be controlled through landfill design and operational requirements (i.e., exclusion of hazardous waste and liquids). For example, landfill liners and leachate collection systems help to control contamination.

E. How Leachate Contaminates Groundwater

To determine how leachate, once it has reached an aquifer, contaminates groundwater, conduct the following experiment:

Material Needed:

4 petri dishes

4 steel nails

Soap

Rubbing alcohol

Paper towels

Universal indicator paper

A sample of the leachate

Household ammonia

Household vinegar

Tap water

Safety goggles

1. Measure the acidity of the leachate from this activity with universal indicator paper. Compare it with indicator dipped in tap water, household ammonia, and household vinegar.

2. Clean the nails with soap and water, rinse with alcohol, and dry with paper towels. Be careful not to touch the nails with bare hands after rinsing.

3.Fill each of the four petri dishes about half full. Place tap water in one, leachate in the second, household ammonia in the third, and household vinegar in the fourth. Place one nail in each dish.

4.After a few days when the liquid has evaporated, observe the nails. Record the observations. Have the nails changed in appearance?

F. How Leachate Affects Plants

To perform another experiment with the leachate sample, ask the students to bring to class an egg carton containing nine eggshell halves.

You will also need the following materials:

3 different types of soil (clay, loam, sand)

Approximately 20 small plants 1" to 2" high (radishes germinate quickly)

Soil testing kit

Student Record Sheets (included)

1.Discuss soil structure and compare soils with three different structure types - heavy (clay), medium (loam), and light (sand).

2.Have the students prepare three seed beds from each of the three soil types, using the eggshell halves as containers. (Have the students prick tiny drainage holes in the bottoms of the eggshell halves.)

3.Have the students sow several radish seeds in each shell half and keep them moist during germination. (Plastic wrap laid on top will hold moisture in the soil.)

4.When the radish plants are one or two inches high, water one bed of each soil type with distilled water (control group), one bed of each soil type with leachate drawn directly from the landfill model, and the other bed of each type with leachate that has been passed through a column of soil. (Discuss the movement and dilution of leachate, including how continued movement changes the degrees of dilution.) Use the same measured volume of liquid on each plant. (Be sure not to overwater.)

5.Have the students record the condition of the plants after one hour, 24 hours, and 48 hours. Observe for signs of obvious ill effects (or, as might be possible, temporarily beneficial effects for added nutrients in the leachate). Record the observations on the Student Sheet: How Leachate Affects Plants.

G. How Leachate Affects Living Things

Measure 1 ml of leachate in a container and add 99 ml of distilled water (to simulate the dilution of leachate due to normal movement through soil.)

1. Place 10 to 20 living Daphnia in the container. (Daphnia are any of a variety of small freshwater crustaceans of the genus Daphnia, some species of which are commonly used as food for aquarium fish.)

2. Record any changes of activity or obvious death after 1 minute, 2 minutes, and 5 minutes.

H. CAUTION: MAKE SURE STUDENTS TAKE PROPER PRECAUTIONS, SUCH AS WEARING PROTECTIVE CLOTHING, GLOVES, AND GOGGLES, BEFORE PARTICIPATING IN THE FOLLOWING SEGMENT OF THE EXPERIMENT:

Include hazardous wastes - household chemicals such as hazardous pesticides, nail polish remover, cleaning fluids - in your landfill model. Have leachate samples analyzed at a laboratory. How might this leachate affect groundwater? Should household hazardous wastes be placed in municipal solid waste landfills? If not, what should we do with them?

Continue testing plants watered with leachate samples that have passed through increasingly more soil.

III. Follow-up

Discuss the results of this lesson in terms of the following:

A. The need for monitoring streams, wells, and springs located below the elevation of landfill sites.

B. The importance of reporting unusual odors in drinking water and knowing to whom such information should be reported. Place a listing of agencies to report unusual odors and environmental hazards to students. Teachers can prepare an "Inquiry Sheet" that can be easily completed with necessary information and sent to the appropriate person(s).

RESOURCE

EPA Facts About Leachate Collection, June 1992

Construction of a Sanitary Landfill Model (using a 30-gallon garbage container)

1. Cut a 2" x 30" vertical strip from a 30-gallon (or larger) garbage container, leaving the container intact 3 inches above the bottom.
2. Glue a 4" x 32" piece of Plexiglas® to the inside of the container and over the cutout. This will allow you to view the contents of the model landfill. This window will show the strata of waste and soil. (The window may be marked in increments of inches to help with layering the soil and waste.)
3. Before inserting a screw-in faucet on the side or the bottom of the elevated model, cover the back of the faucet (the opening inside the tub) with the screened wire. This will help keep waste material from flowing out with the leachate. With caulking compound, seal around the faucet.

Preparation of Waste

In a sanitary landfill, the accepted ratio of soil cover to waste is 1:12 (6" of soil: 72" of waste). In this model, 1" of soil cover will be used for 12" of waste. (*If you use a smaller trash can, try to stick to this ratio, if possible.*)

4. Place one layer of waste in the landfill model.
5. Cover the first layer of waste with 1" to 2" of damp soil. Tightly pack the soil cover by pounding it firmly to simulate a real landfill situation.
6. Continue the layering and compacting until the landfill model is full. The final layer should be 4" of soil.

<u>Control Soil Samples</u>		
Soil Type #1	pH _____ K _____	P _____ NO ₃ ⁻ _____
Soil Type #2	pH _____ K _____	P _____ NO ₃ ⁻ _____
Soil Type #3	pH _____ K _____	P _____ NO ₃ ⁻ _____

<u>Pure Leachate on Soil Samples</u>		
Soil Type #1	pH _____ K _____	P _____ NO ₃ ⁻ _____
Soil Type #2	pH _____ K _____	P _____ NO ₃ ⁻ _____
Soil Type #3	pH _____ K _____	P _____ NO ₃ ⁻ _____

<u>Leachate through Soil on Soil Samples</u>		
Soil Type #1	pH _____ K _____	P _____ NO ₃ ⁻ _____
Soil Type #2	pH _____ K _____	P _____ NO ₃ ⁻ _____
Soil Type #3	pH _____ K _____	P _____ NO ₃ ⁻ _____

How Leachate Experiment Affects Plants:

Control Soil Samples	<u>Plant Conditions After:</u>		
	1 Hour	24 Hours	48 Hours
Soil Type #1 _____			
Soil Type #2 _____			
Soil Type #3 _____			

Pure Leachate on Soil Samples	<u>Plant Conditions After:</u>		
	1 Hour	24 Hours	48 Hours
Soil Type #1 _____			
Soil Type #2 _____			
Soil Type #3 _____			

Leachate through Soil on Soil Samples	<u>Plant Conditions After:</u>		
	1 Hour	24 Hours	48 Hours
Soil Type #1 _____			
Soil Type #2 _____			
Soil Type #3 _____			

LEAKING UNDERGROUND STORAGE TANKS

9-12

OBJECTIVES

The student will do the following:

1. Define USTs.
2. List existing environmental hazards caused by USTs.
3. Explain how problems with USTs are remediated.
4. Understand some of the costs associated with UST remediation.

BACKGROUND INFORMATION

Underground Storage Tanks, or USTs, are basically storage tanks placed underground. Throughout the world, the petroleum industry uses most of the USTs. Local gasoline stations use, by far, the largest number of USTs. Most of them have two to four 4,000 to 12,000 gallon tanks underground. Some rural homeowners may also use USTs for residential or farming purposes.

Problems with USTs arise when they begin to leak. Motor fuel contains hydrocarbons and additives that pose health risks to people, animals, and plants. Nature can break down these hydrocarbons through a method called bioremediation. Unfortunately, nature's work is slow compared to our needs. These dangerous compounds may transmit quickly through soil and can find their way down to an aquifer.

Nationally 51% of the U.S. population relies to some extent on groundwater as a source of drinking water. Aquifers are where these drinking water sources are stored underground. When aquifers become contaminated by hazardous chemicals, the effects can be devastating. Even if people, plants, and animals do not become ill or die, contamination may persist for years; remediation may cost millions of dollars.

SUBJECTS:

Science (Physical Science, Environmental Science),
Social Studies (Economics),
Math

TIME:

2 class periods

MATERIALS:

2 sheets of graph or
bookkeeping paper per
student group
calculators (optional)

Previous common practice was to place unprotected steel USTs and piping in the ground and forget about them. Unprotected steel can be highly subject to corrosion, though, especially in aqueous environments. In 1994, it was estimated that 1.2 million USTs existed in the U.S., many of which could be leaking or leak at some time in the future. Now, new tanks (and related piping) are required to meet federal and state requirements intended to prevent leakage to groundwater. Tanks which do not meet these requirements must be removed, replaced or upgraded by 1998.

Awareness of the problem and new environmental regulations have prompted companies to provide products that will increase UST safety. Liners, double-walled tanks and piping, or fiberglass tanks can be used in UST systems. Sound older, unprotected steel tanks and piping can be upgraded with corrosion protection systems.

Today tank owners are federally required to demonstrate financial responsibility, that is, the availability of funds to clean up a leak or spill should one occur from a tank or line. Most states have established trust funds, paid for by motor fuel sales taxes, to satisfy this requirement. Many states and the federal government are encouraging the insurance industry to take over this job allowing the states to retire their funds.

Federal, state, and sometimes local, governments regulate USTs. They ensure that owners and operators of USTs meet various requirements. Regulatory inspections may cover a variety of procedures that owners and operators must follow. Some of these are listed below.

Owners/operators of USTs must:

1. Register all active UST systems with the appropriate agency.
2. Meet leak detection requirements for both tanks and piping by choosing an appropriate method, depending on size and type of tank system (Figure 2).
3. Install corrosion protection and spill overfill equipment on existing systems no later than December 22, 1998.

Terms

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater

bioremediation: a biologically mediated corrective process that occurs naturally over time; humans may speed up this process through technology (see in-situ bioremediation)

corrosion: a substance formed or an action of wearing away by chemicals; formed by deterioration

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

hydrocarbons: a very large group of chemical compounds consisting primarily of carbon and hydrogen. The largest source of hydrocarbons is petroleum (crude oil).

inspect: to examine in detail, especially for flaws

inventory: a detailed list of items in one's view or possession, especially a periodic survey of all goods and materials

leaking underground storage tank: underground storage tank which has spilled, leaked, emitted, discharged, leached, disposed, or otherwise allowed an escape of its contents into groundwater, surface water, or subsurface soils

pressurize: to put (gas or liquid) under a greater than normal pressure

record: an account, as of information, set down in writing as a way of preserving data collected on a specific subject

suction: a force causing a fluid or solid to be drawn into interior space or to adhere to a surface due to the difference between external and internal pressures

underground storage tank (UST): any tank, including underground piping connected to the tank, that has at least 10 % of its volume underground and contains petroleum products or hazardous substances (except heating oil tanks and some motor fuel tanks used for farming or residential purposes)

ADVANCE PREPARATION

- A. Copy Student Sheet, Background Information, and procedure for students.
- B. Put terms and definitions on the board.
- C. Divide the class into work groups and hand out materials.
- D. Give students time to read and discuss materials. During discussion, have groups list environmental hazards caused by USTs and discuss how they are remediated.

- E. After class discussion of USTs, have students proceed with activity within their groups.

PROCEDURE

I. Setting the stage

A. The State of California's massive cleanup fund began in 1990. The Underground Storage Tank Cleanup Fund allows UST owners to comply with new regulations by helping finance tank removal and groundwater cleanup. Funding has already assisted in "the cleanup of some 25, 700 leaking underground tanks."

B. The average cost for tank removal is about \$10,000. The soil and groundwater cleanup after contamination occurs is where costs really balloon. For the purposes of this activity, the complex and individualized costs will be generalized; and a standard figure for the cleanup of leaking tanks will be set at \$400,000.

C. The funds for the Underground Storage Tank Cleanup Fund are generated by a fee charged to the owners/operators of underground petroleum storage tanks. A proposal is to increase the current 0.06 of a cent per gallon to 1.2 cents per gallon fee. Estimates show that this increase would provide an additional \$676 million to the "trust fund."

D. Sacramento County has 3, 390 underground tanks, of which 519 are known to be leaking and 299 have been cleaned. Yolo has a total of 572 tanks including 121 leaking ones and 65 cleaned sites. Placer County has 994 tanks including 218 leaking tanks and 31 cleaned ones. And Eldorado County has 714 tanks including 31 leaking ones and 25 that have been cleaned.

II. Activity

A. Using the data listed, determine how many USTs still need to be replaced in the four counties listed. List them individually by county and include a total. List the number of leaking tanks by county and the total.

B. Using the assumed costs, determine how much money will be needed to replace and clean up all of the tanks in the four counties listed. Include these subtotals: Cleanup for Leaking Tanks, Tank Removal for Leaking Tanks, Cleanup and Tank Removal for Leaking Tanks, Tank Removal for all Tanks, and Total Tank Removal and Cleanup.

C. Report how much money will need to be generated by the fund to accomplish final cleanup within five years (for the four counties listed).

D. At 1.2 cents per gallon, how many gallons will need to be sold to generate the needed funds for the four counties listed?

E. If the new fee passes, the 1.2 cent per gallon fee will probably be passed down to the consumers through increased gas prices. Do you feel that it is unfair to the consumers to be made responsible?

F. If the four counties contained over 2 million people, can you imagine how many USTs there would be in Los Angeles and Orange Counties, which include over ten million people? Do you think the final cleanup of all USTs in California will be achieved in five years? What other way could they generate funds?

III. Follow-up

A. Ask students where their drinking water comes from. If any get water from groundwater, ask these students if there are any USTs in their area.

B. After the class generates a survey sheet, have students interview a gas station owner or manager. Be sure they include questions about how old the tanks are, if they have caused problems, the last time they were inspected, who does the inspection, how leaks are detected.

C. Give a quiz on USTs. Ask students to define UST, list environmental problems caused by USTs, explain how problems with USTs are remediated.

IV. Extensions

A. Some of the regulatory rules for USTs are listed in this activity. Have students read over these and study the Student Sheet figures.

B. Have students find out if groundwater is checked in the local area for petroleum contamination. Who is responsible for checking on USTs in the area?

RESOURCES

Dictionary of Scientific and Technical Terms, McGraw-Hill, 1994 Ed.

Pickett, Diane, Personal Interview, Brown and Root Environmental.

"Tank Owners Brace for Shift to Private UST Coverage," National Petroleum News, Vol 87, July 1995.

"Underground Tank Owners Seek Some Clarity," The Business Journal Serving Greater Sacramento, Vol 11, August 15, 1994.

"Musts for UST's. A Summary of Federal Regulations for Underground Storage Tank Systems, Solid Waste and Emergency Response, 5403W, EPA 510-K-95-002. July 1995.

Answer Sheet

1. Tanks that need to be replaced and cleaned:	Eldorado	689
	Placer	963
	Sacramento	3,091
	<u>Yolo</u>	<u>507</u>
	Total	5,250

Leaking Tanks:	Eldorado	31
	Placer	218
	Sacramento	519
	<u>Yolo</u>	<u>121</u>
	Total	889

Non-Leaking Tanks:	Eldorado	658
	Placer	745
	Sacramento	2,572
	<u>Yolo</u>	<u>286</u>
	Total	4,261

2. Determining Costs -

Tank Removal for Leaking Tanks

$$\begin{array}{rcllcl} \text{\# of Leaking Tanks x Cost of Tank Removal} & & & & & \\ 889 & \times & \$10,000 & = & \$8,890,000 \end{array}$$

Cleanup for Leaking Tanks

$$\begin{array}{rcllcl} \text{\# of Leaking Tanks x Cost of Cleanup} & & & & & \\ 889 & \times & \$400,000 & = & \$355,600,000 \end{array}$$

Cleanup and Tank Removal for Leaking Tanks

$$\text{\# of Tanks x Cost of Cleanup} + \text{\# of Tanks x Cost of Tank Removal} =$$

$$\begin{array}{rcllcl} 889 \times \$400,000 & + & 889 \times \$10,000 & = & \\ \$355,600,000 & + & \$8,890,000 & = & \$364,490,000 \end{array}$$

Tank Removal for Non-leaking Tanks

of Tanks x Cost of Tank Removal =

$$4,261 \quad \times \quad \$10,000 \quad = \quad \$42,610,000$$

Total Cost for Tank Removal and Cleanup

Total for Leaking Tanks + Total Cost for Non-leaking Tanks

$$\$364,490,000 \quad + \quad \$42,610,000 \quad =$$

\$407,100,000

3. \$407,100,000

4. 1.2 cents = \$0.12

fee per gallon x # of gallons sold = amount generated

\$0.12 x # of gallons sold = \$407,100,000

Divide by \$0.12 on both sides of the equation

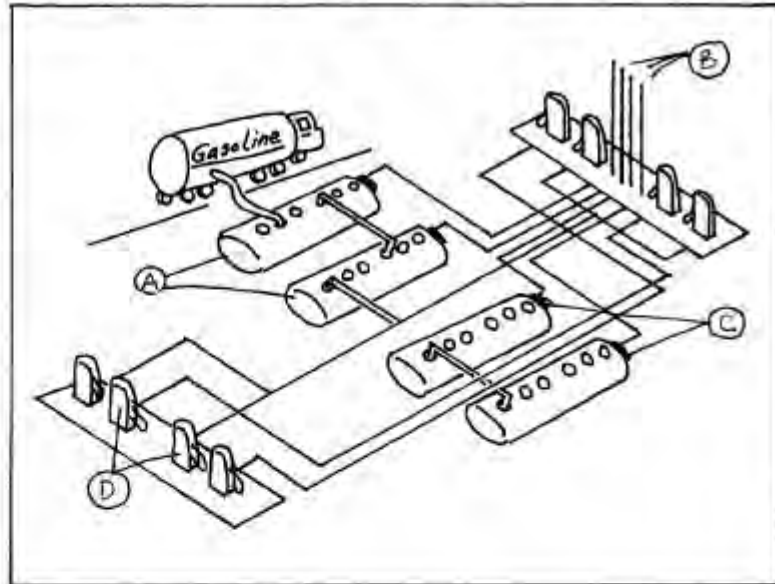
of gallons sold = 3,392,500,000

TYPICAL TANK FACILITY

Student Sheet

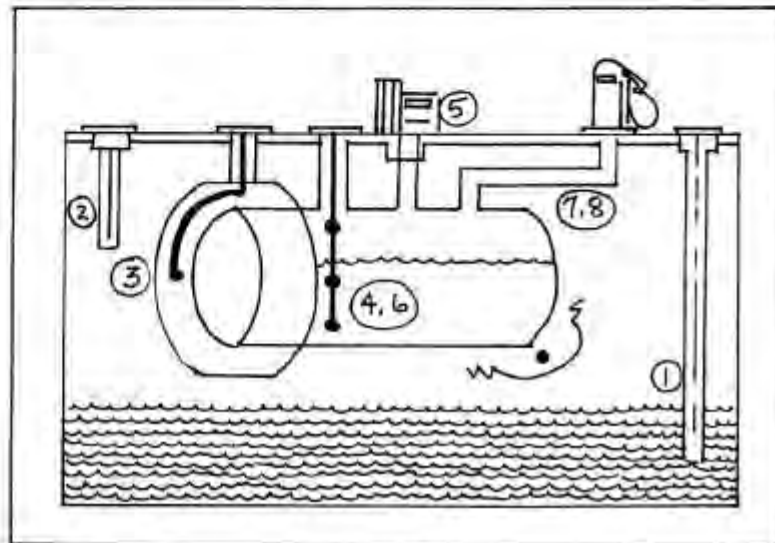
Identify the indicated parts in the drawings:

- A. _____
- B. _____
- C. _____
- D. _____

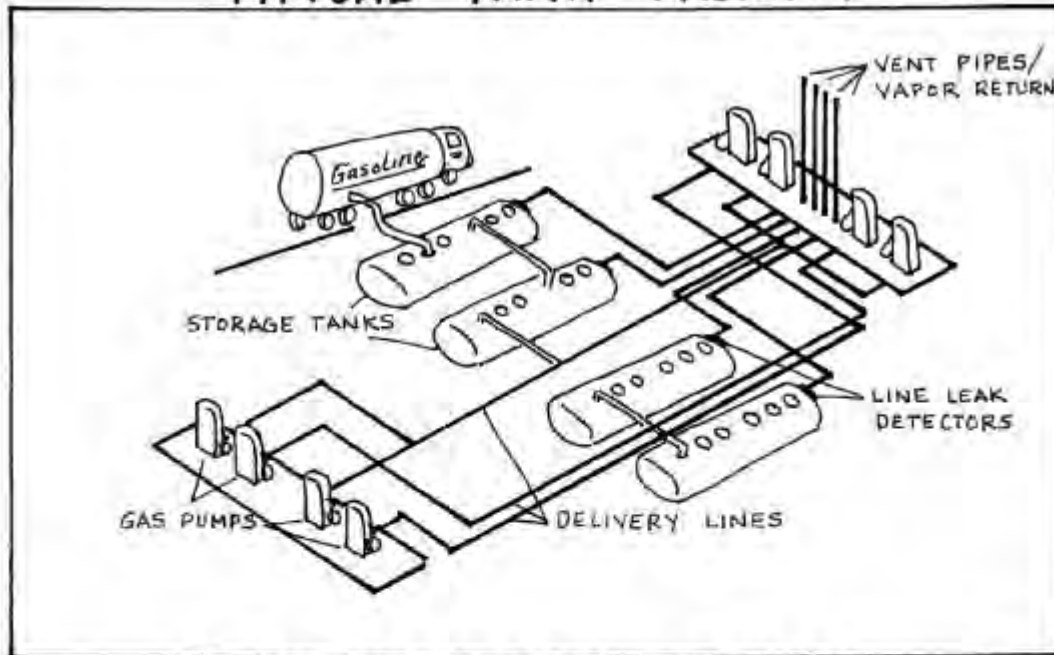


- 1. _____
- 2. _____
- 3. _____
- 4. _____
- 5. _____
- 6. _____
- 7. _____
- 8. _____

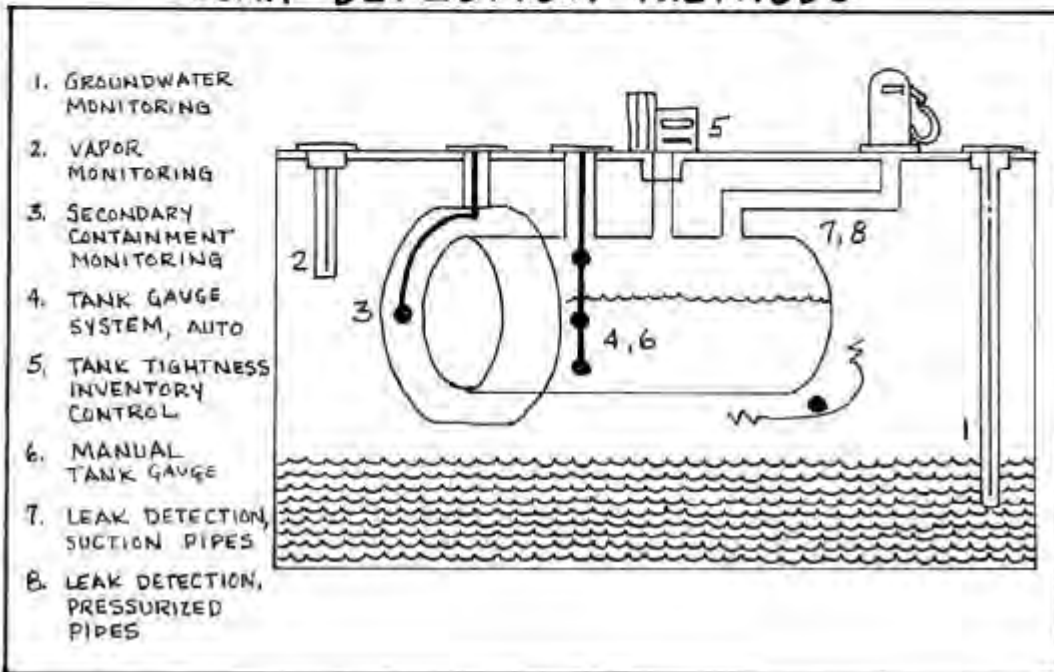
LEAK DETECTION METHODS



TYPICAL TANK FACILITY



LEAK DETECTION METHODS



An Alternative to the “What I Did on Summer Vacation - What I Can Do on Summer Vacation.”

OBJECTIVES

The student will do the following:

1. Explore environmentally friendly activities ~~former~~ vacation on the Gulf.
2. Create a travel guide for these activities.

BACKGROUND INFORMATION

The Gulf of Mexico, America’s shining sea, is in trouble. A natural vacation spot, it is in danger from entrepreneurs, tourists, and residents. Students should think about their personal responsibility in preserving the integrity of this area. Normal vacation activities might impact the environment. With some guidance, students can learn how to make the most of a coastal vacation. Amusement parks, miniature golf courses, go-cart courses, water slides are generally the same whether they are in Nashville, Tennessee, or Panama City, Florida. Students should be learning to appreciate their environment, to see the possibilities for entertainment that are indigenous to particular areas. By exploring the different vacation possibilities, students may begin to see an alternative to the generic, often unsatisfying vacation that so many American families take.

Many states and countries have found that “eco-tours” are big business. Money can be made by allowing the public access to naturally beautiful areas with minimal harm to the environment. A discussion of ways to improve the economy of an area without harming the environment could be interesting.

SUBJECTS:

Science (Biology, Ecology),
Language Arts

TIME:

1 class period for introduction
1 week for research
3 class periods to prepare
brochure

MATERIALS:

research for coastal wetlands
travel brochures (for
photographs) - available at
travel agencies or
Chambers of Commerce of
coastal cities
paper
colored paper
scissors
glue
staples for actual booklets
student sheets

ADVANCE PREPARATION

A. Check with the biology/ecology teacher in your school for materials concerning the environmental problems of the Gulf. Also check the availability of resources in your school library. If materials are scarce, you might want to write to:

The Gulf of Mexico Program
Building 1200, Room 103
Stennis Space Center, MS 39529-6000

or call (601) 688-7940

This agency can send you pamphlets and other materials for resources for students. Student sheets of some of their materials are included.

PROCEDURE

I. Setting the stage

- A. Have students write a paragraph about what they might like to do on a vacation to the Gulf.
- B. Have some volunteers read their paragraphs aloud.
- C. Discuss how some of these activities impact upon the coastal environment.
- D. Explain that students are going to make a travel brochure listing environmentally friendly activities for a Gulf vacation.
- E. Divide class into groups of four.
- F. Have each group select a leader/spokesperson.
- G. Hand out and allow time for groups to go over student sheets.

II. Activity

- A. Groups should organize and assign duties for completing the brochure.

- B. After one week of out-of-class research, students should plan to compile, edit, and publish their work in three days of class time. These brochures may be handmade or computer generated if you have that capability.

III. Follow-up

- A. Students should complete their own evaluation sheets. (Included)
- B. You should evaluate their work based on:
 - 1. Information gathered (amount and accuracy).
 - 2. Appropriateness of format.
 - 3. Their own evaluation.

IV. Extensions

- A. Have students copy their brochures and share with other classes.
- B. Arrange for students to give oral presentations to elementary classes on environmentally responsible beach vacations.

RESOURCES

American Automobile Association (members may contact their local offices).

Chamber of Commerce or Tourist Bureaus.

Gulf of Mexico Program, Public Information Center, Building 1200, Room 103, Stennis Space Center, MS 39529-6000. Phone: (601) 688-7940

EVALUATION SHEET

1. What was your job on this project?

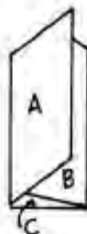
2. List three things you learned from this project.
 - a. _____
 - b. _____
 - c. _____

3. How will working on this project affect your life-long attitude toward vacationing at the Gulf? Vacationing anywhere?

INSTRUCTIONS FOR MAKING A TRI-FOLD BROCHURE:



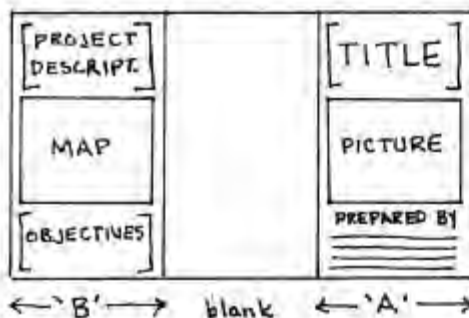
1. Lay your sheet of $8\frac{1}{2} \times 11$ paper out in a "landscape" orientation.
2. Mark off 3 sections, each $3\frac{5}{8}$ " wide, with a light or dotted line.



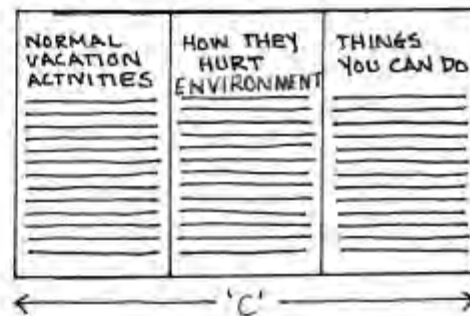
3. Fold the right side over the middle, creating 'page B', the right fold.
4. Fold the left side over, creating 'page A', the front cover.
5. The inside, 'C', is now divided into 3 columns.
6. Unfold the paper and lay it flat to add your headlines, text, and pictures.

USE THE FOLLOWING GUIDELINES FOR THE LAYOUT OF YOUR BROCHURE:

SIDE ONE



SIDE TWO



If using a Desktop Publisher on a computer, remember to select 'landscape' orientation, a 3-column layout, and use the same general guidelines for your brochure.

This page is blank.

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UNDERSTANDING MARINE RESOURCES

9-12

OBJECTIVES

The student will do the following:

1. Define “resource.”
2. Determine the resources required for personal wants and needs.
3. Classify the resources as “renewable or nonrenewable.”
4. List and classify marine resources as renewable or nonrenewable.

SUBJECTS:

Social Studies
(Economics),
Science (Environmental
Science)

TIME:

1 class period

MATERIALS:

blank paper
pictures of resources from
magazines

BACKGROUND INFORMATION

People have always instinctively recognized the importance of coastal areas. An investigation of the reminders (shells and bones) of any early coastal village will show how everyday life was connected to the ocean. Along with providing for the dietary needs of the village, the sea provided the raw materials needed for shelter, transportation, economic exchange and social needs. Can you guess how? Today, people still like to live near the coast. It is no coincidence that many of the great cities in the world are located near, or have access via a river, to an ocean. Of the approximately 267 million people living in the U.S. (in 1997), over half of them live in coastal counties.

Animals and plants are a major marine resource. Fish and shellfish, high in protein and other essential vitamins while containing no saturated fats, provide 60% of the world's population with more than 40% of their animal protein. Over 1 billion people receive their entire annual protein supply from the sea. In the U.S., we use five times as much seafood for "fishmeal" in food for poultry and land animals than for human consumption. Marine plants provide less than 1% of our food (compared to 80% from land plants). Some current uses for marine plants include being used in bakery and dairy products, meats, soft drinks, and industrial applications such as tire manufacturing (due to the colloidal and gelling compounds common in seaweed). In the future, marine plants may be a possible food source to feed an ever increasing world population. The ocean contains vast amounts of energy and mineral resources. Besides providing large amounts of oil and gas, new technology is being developed to harness energy generated by the ocean

through tidal, wind, wave, and thermal power. Another resource provided by the ocean is transportation. Tankers and freighters efficiently ship commodities to ports and harbors throughout the world. The wetlands in the coastal areas are a tremendous resource. Coastal wetlands provide the habitat for fish, shellfish, waterfowl, and mammals. Coastal estuaries and marshes are among the most productive areas in the world providing organic matter for the base of the food chain and the spawning grounds for fisheries. Marine recreation is on the rise. People crowd to beaches and coastal areas to enjoy fishing, boating, swimming, scuba diving, shell collecting...the list continues. Today, like our ancestors before us, we are rediscovering that the aesthetic joy of the sea can nourish our physical and spiritual well being. Each time resources of the ocean are misused, we jeopardize this enormous, much undiscovered, realm. As inhabitants of Earth, we should always be aware that the future of our planet is intricately bound to the health of our oceans.

Terms

aesthetic: of or relating to the sense of the beautiful; artistic quality or appearance

hydrologic cycle: the cyclical process of water's movement from the atmosphere, its inflow and temporary storage on and in land, and its outflow to the oceans; cycle of water from the atmosphere, by condensation and precipitation, then its return to the atmosphere by evaporation and transpiration.

nonrenewable resource: a resource in a fixed amount; all minerals, coal, crude oil, and natural gas

renewable resource: a resource that can be grown or replenished in some manner from year to year; plants and some animals

resource: natural assets: air, water, soil, oil, gas, coal, trees, minerals, land, wildlife, people; the materials needed for the satisfaction of wants and needs

wants and needs: those things people desire for sustenance and quality of life

ADVANCE PREPARATION

- A. Review Background Information and terms. Discuss resources in general.
- B. Have each student bring in one picture of a renewable resource and one of a non-renewable resource.
- C. Have students also bring in pictures showing use of the ocean as a resource.

PROCEDURE

I. Setting the stage

Have students make a chart with three columns:

NEEDS & WANTS; RESOURCE NEEDED; NONRENEWABLE OR RENEWABLE RESOURCE.

II. Activity

Determine which resources are needed to supply a student's wants and needs, using brainstorming and pictures on display.

- A. Students will list their own wants and needs in the first column.
- B. Students will list the resources needed to supply these wants and needs in the second column.
- C. In the third column, students will indicate whether the resource needed to supply their wants and needs is renewable or nonrenewable (R or N).

III. Follow-up

Answer these questions after the charts are completed.

- A. Do you need more renewable or nonrenewable resources to supply your wants and needs?
- B. Will you use more or less renewable and/or nonrenewable resources in the future?
- C. What resources did you list that either come from a marine environment or could come from one?
- D. Make a list of any resource that you have used or might use that comes from the sea. (Review the Background Information)
- E. Can you think of some renewable resources from the sea that are not being fully utilized? List these and explain how they could be used.

IV. Extensions

- A. Make another chart (marine resources used; renewable or nonrenewable resource) putting marine resources in column one and identifying them as renewable or nonrenewable in column two.
- B. Answer these questions about marine resources.
 - 1. Does everyone use the same marine resources?
 - 2. Will more marine resources be used in the future?
 - 3. Which nonrenewable marine resources would you miss the most?

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

RIVER INPUT INTO THE GULF OF MEXICO

9-12

OBJECTIVES

The student will do the following:

1. Trace the path of one river that drains into the Gulf of Mexico.
2. Research the major sources of pollution in each major city along the chosen river.
3. Research possible agricultural pollution.
4. Describe how a long river carries pollution all the way down its path to the Gulf of Mexico.

SUBJECTS:

Science (Biology), Social Studies (Geography), Language Arts

TIME:

3 class periods and research time

MATERIALS:

atlas

BACKGROUND INFORMATION

There are 44 major rivers that empty into the Gulf. The freshwater flowing into the salty waters of the Gulf lowers the salinity in parts of the Gulf making possible the rich estuarine life. However, the rivers not only bring freshwater into the Gulf; but they also bring sediment, nutrients, pollutants, contaminants, and debris along with the freshwater. The Mississippi River is by far the largest source of freshwater flowing into the Gulf. Annual freshwater input from the Mississippi averages 724 billion cubic feet.

Estuaries are usually shallow bodies of water, where freshwater from rivers empties into and mixes with ocean saltwater. Highly productive areas, estuaries provide nourishment and suitable habitat to many forms of marine life. Over 95% of the commercial fisheries depend on estuaries at some point in their harvesting cycle. Estuaries are the nursery grounds for many marine fish, shellfish, invertebrates, and mammals. During storm events, estuaries and coastal marshes act as flood buffers to absorb the excess energy and water flow. Along with supplying living and non-living resources and meeting transportation and recreation needs, estuaries and their rivers have long been used for disposing of effluent from sewage treatment plants. This is due to the natural capacity of estuaries and rivers to assimilate and treat waste. But there are limits.

Improper waste disposal exceeding an estuary's assimilative capacity will most often negatively affect marine resources.

Channelization of rivers and waterways threatens estuaries by diminishing the natural buffering capacity of meandering, vegetative rivers resulting in extreme fluctuations of water flow into the estuaries. During storm events, channelization rapidly moves large amounts of freshwater into the bay causing a salinity decrease that may be detrimental to the shellfish and aquatic plants. Though marine plants and organisms inhabiting an estuary are naturally capable of adapting to fluctuations in salinity, channelization can result in extreme salinity variations that will stress even the most tolerant of marine organisms.

Nonpoint source pollution (runoff from: urban development, highways, septic systems, agricultural areas, and marinas) increases with increased population along waterways leading to the Gulf (see extension). As the population along coastal waterways increases, more homes, roads, parking lots, and buildings will need to be constructed to serve the population needs. During rain events, contaminants (nutrients, oil, grease, metals, bacteria, and sediment) will be washed into the estuary. Excess sediment lowers the penetration of light in the water column. Phytoplankton (drifting plants-usually microscopic) depend on light; therefore, the primary productivity of phytoplankton can be decreased because of excess sediment from construction and farming. Phytoplankton are the bases of the estuary/Gulf food web. But too much nutrients is not a good thing. An excess of nutrients through industrial discharges, faulty septic tanks, lawn fertilizers, and poor agricultural practices can cause a phytoplankton "bloom" (an increase in phytoplankton numbers and biomass) that can lead to "red tides" and "hypoxic areas" (oxygen deficient areas due to decomposition in the Gulf).

Freshwater inflow is not constant and is not evenly distributed throughout the Gulf of Mexico. River discharges peak during late spring but can be altered by unusual weather conditions. Rivers connect the Gulf of Mexico with the interior part of the United States. Many interior cities are vitally linked to the Gulf through transportation of tons of raw and manufactured materials such as wheat and oil.

Some rivers with drainage area over 1000 square miles:

Texas=Rio Grande, Nueces, San Antonio, Guadalupe, Colorado, Brazos, Trinity, Neches, Sabine (TX-LA);

Louisiana=Calcasieu, Atchafalaya, Mississippi, Bogue Chitto, Pearl (LA-MS);

Mississippi=Pascagoula;

Alabama=Tombigbee, Alabama, Mobile;

Florida=Escambia, Choctawhatchee, Apalachicola, Ochlockonee, Suwannee, Withlacoochee,

Peace.

Terms

“bloom” (algal bloom): a sudden excessive growth of algae that can affect water quality adversely; large floating masses of algae; characteristic of a eutrophic lake

channelization: the straightening and sometimes deepening of stream or river channels to speed water flow and reduce flooding. A waterway so treated is said to be channelized. However, channelization can cause unstable situations and may cause adverse environmental impacts.

contaminant: an impurity that causes air, soil, or water to be harmful to human health or the environment; something that makes a substance impure, infected, corrupted, or polluted

delta: a deposit of sand and soil, usually triangular, formed at the mouth of some rivers

discharge: (1) the outflow of groundwater from a flowing artesian well, ditch, or spring; (2) the release or emittance of a substance

estuarine: formed or deposited in an estuary; of or having the characteristics of an estuary

estuary: a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouth of rivers, and includes bays, lagoons, sounds, and marshes.

eutrophic lake: a lake containing a high concentration of dissolved nutrients; often shallow, with periods of oxygen deficiency

hypoxic: containing very little or decreased oxygen

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (e.g., outlet or pipe) because it comes from many individual sources or a widespread area (typically, urban, rural, and agricultural runoff)

nutrients: compounds, minerals, or elements needed by living organisms to carry on their functions. Nitrogen, phosphorus, potassium, and other elements are examples of nutrients required for plant growth.

phytoplankton: any of the many species of plants (such as algae) that consist of single cells or small groups of cells that live and grow freely suspended in the water near the surface

point source pollution: pollution that can be traced to a single point source such as a pipe or culvert (e.g., industrial, wastewater treatment plant, and certain storm water discharges)

pollutant (water): any substance suspended or dissolved in water that builds up in sufficient quantity to impair water quality

primary productivity (producers): in an ecosystem, those organisms, mostly green plants, that use light energy to construct their organic constituents from inorganic compounds

red tide: a reddish discoloration of coastal surface waters due to concentrations of certain toxin-producing dinoflagellates. Can cause pulmonary irritations in man and can cause death of marine mammals.

salinity: the amount of salt dissolved in water

sediment: eroded soil material, containing primarily inorganic constituents

ADVANCE PREPARATION

- A. Discuss Background Information.
- B. Put terms on the board and define.
- C. Divide students into work groups of 4, 5, or 6.
- D. Check your library for encyclopedias or other books that will have information about the rivers that flow into the Gulf of Mexico.

PROCEDURE

- I. Setting the stage
 - A. Have student groups pick one river that flows into the Gulf of Mexico. Make sure each group picks a different river.
 - B. Have groups write down the major cities (and states) along the river.

C. Have each student in the group pick a major city along the river. One student in each group should research agricultural practices along the river.

D. Explain that students are supposed to research the industries of their cities to see what possible pollution might be added to the river. They may also want to note other interesting facts about their city or farm practices in the surrounding area.

II. Activity

A. Allow time for students to research their cities.

B. The students need to research what kinds of pollution result from their city's industries or from surrounding agricultural practices. Students should also consider the nonpoint source pollution from their cities.

C. Have members of the group compile their information about industries, agriculture, and nonpoint source pollution.

D. Groups should prepare a report on their river and present to the class. They may be creative with their presentations (such as tell something about the history of the river). They should also have a list of possible pollutants their river may be carrying to the Gulf and the sources of these pollutants.

III. Follow-up

Ask students to answer the following questions after all groups have presented their reports.

A. What are the major pollutants that are transported by rivers into the Gulf?

B. What effects do these pollutants have on the Gulf?

C. Would you feel comfortable eating seafood from the area of the Gulf into which your river drains?

D. Do you think that any of the pollutants your river carried were reduced in toxicity as they traveled down the river?

E. Are all pollutants harmful to the Gulf and the estuaries around it?

F. What could be done to reduce the harmful pollutants that go into the Gulf?

G. Why do you or do you not think estuaries should be protected?

IV. Extensions

A. Discuss “blooms” (algal blooms) and red tides and the problems they cause. Relate this to the river pollution reports.

B. Look into the concept of channelization, the way this occurs, and the problems it causes.

C. What effect do floods have on pollution of these rivers?

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

WETLANDS, USA - MORE THAN SWAMPS!

9-12

OBJECTIVES

The student will do the following:

1. Define wetlands.
2. Construct a wetlands model.
3. Explain the importance of wetlands ecosystems.
4. Defend the need to preserve wetlands.

BACKGROUND INFORMATION

Wetlands are a prime natural resource and include such areas as swamps, bogs, prairie potholes, cypress domes, riverine bottomlands, coastal marshes and tundra wetlands. Many wetlands are transitional areas located between dry lands and deeper aquatic systems like rivers and lakes. Wetlands are located in various parts of the U.S. All of these damp areas have tremendous importance in terms of productivity. Wetlands provide feeding, spawning, and nursery grounds for finfish and shellfish. They provide habitat for about half of all endangered species of plants and animals. Wetlands lessen global warming by locking up huge amounts of carbon in peat rather than

SUBJECTS:

Science (Biology, Ecology), Social Studies (Geography), Language Arts

Extensions for: Science, Math, Social Studies, English, Art, Journalism, Business, Music

TIME:

1-2 class periods
plus extension or homework

MATERIALS:

copies of student sheets
for model:
pan
modeling clay
piece of indoor-outdoor carpet
jar of muddy water

allowing CO₂ to be released in the atmosphere. They also clean the water by absorbing and filtering pollutants and stabilizing shore lines, and they provide a buffer against floodwaters and storm tides. They may serve as “holding” tanks to recharge wells and aquifers.

Some wetlands develop in low-lying areas where water drains and collects. Others border salt or fresh bodies of water, such as oceans, rivers, or ponds, while still others are isolated in forests and urban areas. As transitional zones between upland and aquatic systems, wetlands often support both terrestrial and aquatic species, contributing to the local and regional diversity of plants and animals.

Two hundred years ago, the United States had 220 million acres of wetlands. Now we have less than 100 million acres. As of 1996, the loss was around 300,000 acres each year. Half of the Florida Everglades is gone; half of Connecticut’s coastal wetlands and 2/3 of the prairie potholes are gone. California has only 9% of its wetlands remaining, Iowa 11%, and Indiana and Missouri 13%. Students must learn about wetlands so they can be involved in legislative efforts to halt their loss. Any legislation that weakens the definition and regulation of wetlands will probably cause greater loss.

Terms

bog: freshwater marsh with build-up of peat and high acidity that typically supports mosses adapted to acidic soil conditions (particularly, sphagnum); many are located in colder regions

bottomlands: lowlands along streams and rivers that are typically flooded

cypress domes: small, depressional swamps, typically with tall cypress trees at center, characterized by subsurface hardpan overlain by organic matter

estuary: a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouths of rivers, and includes bays, lagoons, sounds, and marshes.

forested wetland: wetland dominated by trees. "Trees" (for the purpose of this definition) are defined as woody vegetation with diameter greater than 3 inches at breast height (approx. 4 feet from ground level).

freshwater marsh: a wetland frequently or continually inundated by freshwater, characterized by emergent herbaceous vegetation

mangrove swamps: tropical, wet, coastal areas dominated by mangroves (trees). Mangroves have extensive root systems which form a dense thicket, providing cover for aquatic life.

prairie potholes: shallow, marsh-like ponds which serve as primary breeding grounds for ducks and

migratory birds found in North Dakota, South Dakota, Minnesota, and Canada

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a waterbody; may pick up and carry a variety of pollutants

salt marsh: estuarine habitat submerged at high tide, but protected from direct wave action, and overgrown by salt-tolerant herbaceous vegetation; aquatic grasslands (coastal "prairies") affected by changing tides, temperatures, and salinity

swamp: wetland dominated by shrubs and trees

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

ADVANCE PREPARATION

- A. Copy Student Sheets.
- B. Have terms and definitions on the board.
- C. The teacher may want to show a video of wetlands. Some suggestions are listed below.

The Realm of the Alligator (Okefenokee Swamp)
Creatures of the Mangrove
Life on the Edge
There is a Place

PROCEDURE

- I. Setting the stage
 - A. Discuss terms.
 - B. Allow students time to read the two student sheets. Discuss the student sheets and Background Information. Ask students how controlling pollution in a watershed helps protect wetlands.
 - C. Have students describe and discuss conditions of wetlands within their areas (state, county) or other wetland areas with which they may be familiar.

D. To demonstrate how wetlands slow water movement and trap pollutants and sediment, do the following:

1. Using a metal pan or plastic container, spread a layer of modeling clay in the bottom forming a hill in one end. This section will represent the land. Leave the other end of the pan empty to represent a lake or ocean. Make a slope on one side with the modeling clay.
2. Place a piece of indoor-outdoor carpeting to fill the space across the pan along the edge of the clay. The carpeting represents the wetland buffer between dry land and open water. Set the model aside.
3. After reviewing what wetlands are, explain the characteristics of the wetland life, the variety of habitats, and the complexities within.
4. Demonstrate the wetland model by pouring water slowly in the pan on the higher side of the clay. Let students observe where water has settled and where it has been trapped in the piece of carpeting. The water that is slowed in the carpeting represents different functions of the wetland.
5. Apply the slow-moving water notion to the different functions performed by the wetland.
6. Lead a classroom discussion on why wetlands are essential and important in the natural settings and environment.

II. Activity

Have students:

- A. Construct an exhibit for the school library that includes maps of local wetlands and explanation of differentiating characteristics.
- B. Construct a poster/collage with the following theme: The Importance of Wetlands. Include newspaper/magazine articles and at least 10 illustrations.
- C. Write a five-paragraph essay on the importance and the need to preserve wetlands. Additional information from your school/city library may be helpful. Consult English text for correct format.
- D. Prepare a lesson on wetlands that you could present to a middle school science club

or class. Include visuals.

III. Follow-up

Play a game with the terms. Write definitions for each word on separate 3x5 cards and do the same with the terms. Give each student one definition and one term. Start game by one person reading his/her definition. The person in the room who has the matching term must say it and then read his/her definition. The game continues until all definitions have been read and identified.

IV. Extensions

- A. Science: Make posters illustrating the different kinds of wetlands.

Marshes (palustrine)

Swamps and Floodplain forests (palustrine)

Bogs (palustrine)

Rivers and Streams (riverine)

Lakes and Ponds (lacustrine)

Coastal Wetlands (marine)

Tidal Marshes (marine)

Tundral Wetlands

or

visit and study a local wetland. Identify birds and wildflowers that live there.

- B. Math: Find out how much wetland area your state loses per year. (Contact EPA or Geological Survey). Figure how long it will be until your state (if it continues at its present rate) has no wetlands left.
- C. History: Choose one diminished wetland area in your state. Research its demise and prepare an "obituary."
- D. English: Create a scenario where "progress" demands that a wetland be drained. Students should write persuasive essays (pro or con) about the situation. Give them enough information so that they can internalize and generate a viewpoint.

- E. Art: Create a mural (all students can contribute) to celebrate the beauty and diversity of a wetlands area. The mural can be created on heavy white paper and displayed in a common area in your school.
- F. Journalism: Publish a “Wetlands Watch” pamphlet with articles, pictures, and interviews about wetlands’ problems.
- G. Business: Create a scenario where business people must choose between gross profits and the integrity of vital wetlands. Have your students write a thesis statement. Make sure the scenario has balance.
- H. Music: Have your students do some creative song writing celebrating the beauty of or mourning the loss of America’s wetlands. Recordings of these songs can be played near the mural (art) and the poster display.

RESOURCES

“Consequences of Wetland Loss and Degradation,” United States Environmental Protection Agency, March, 1993.

“Economic Benefits of Wetlands,” United States Environmental Protection Agency, March, 1993.

EPA Wetlands Hotline - 1-800-832-7828

“More Facts About Wetlands,” United States Environmental Protection Agency, March, 1993.

“Values and Functions of Wetlands,” United States Environmental Protection Agency, March, 1993.

FUNCTIONS OF WETLANDS

1. Wetlands provide habitats for fish, wildlife and plants. They are critical to the survival of a wide variety of organisms. They also provide food, water, or cover for many species.
2. Wetlands provide critical habitats for endangered species. A number of rare and threatened species depend on wetlands for their survival.
3. Wetlands provide flood control and protection. Some wetlands store flood waters or water that collects in isolated depressions. Wetland plants can help to slow the speed of flood waters to protect nearby properties.
4. Wetlands improve water quality serving as excellent water filters to remove nutrients, wastes, and sediment from runoff water before they reach an open body of water. These nutrients, wastes and sediment may cause algae blooms or decrease the volume of a lake, pond, or river.
5. Wetlands provide shoreline erosion control. Those located between rivers and high ground to help to buffer shorelines against erosion. Wetland plants strengthen the sediment by binding soil with their roots. They also dampen wave action.

6. Wetlands reduce storm damage by serving as buffers between the winds and waves of storms and the coastal areas. Property located behind wetlands along shorelines and large lakes often fares much better during storms than unprotected areas.
7. Wetlands facilitate groundwater recharge. As the water moves slowly through or ~~sits~~ the wetlands, some will seep down into aquifers below.
8. Wetlands provide a variety of natural products. These range from fish, shellfish, and wildlife to timber, berries, and wild rice.
9. Wetlands provide areas for recreation, rest, and enjoyment. Hunting, boating, and ~~fishing~~ are allowed in many wetland areas. Artists and photographers enjoy capturing the beauty of wetlands in their crafts. Tourists and visitors often find peace and appreciation for these natural areas.
10. Wetlands facilitate education and research. Although much is known about the functions of wetlands, researchers are still studying these environments and the species that thrive there in an attempt to discover more fully the benefits that they bring to humans.

Student Sheet

WETLANDS

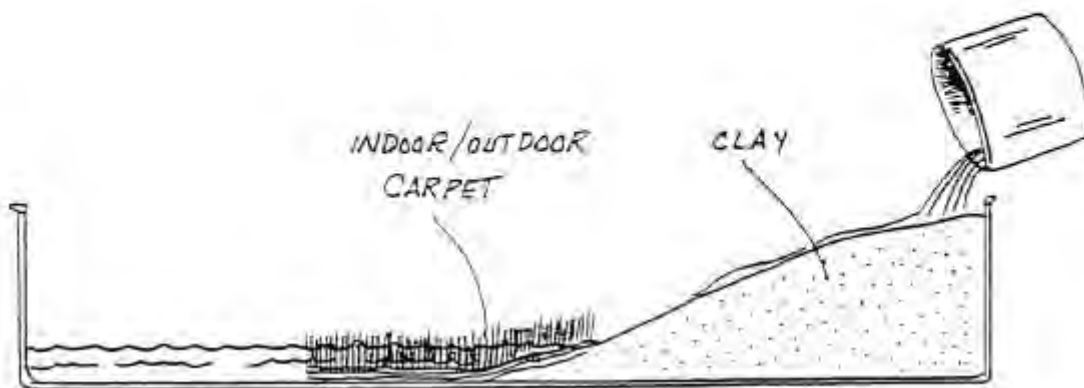
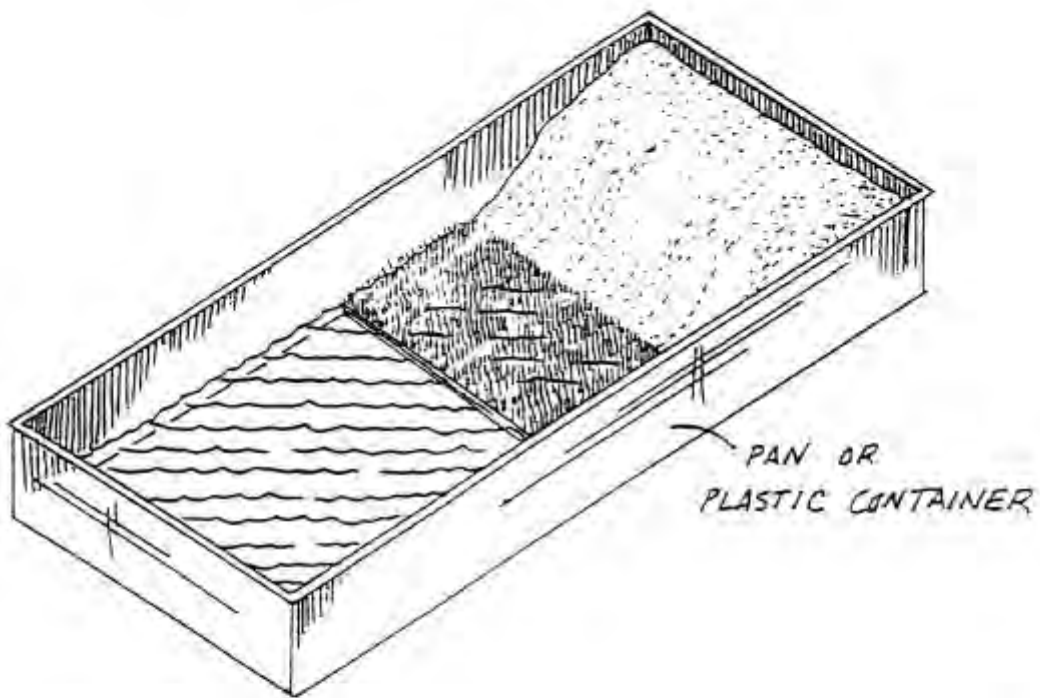
Wetlands are a prime natural resource consisting of swamps, bogs, prairie potholes, cypress domes, river bottomlands, coastal marshes and tundra wetlands (see illustrations). They are often transitional areas located between dry lands and deeper aquatic systems. Wetlands are located in various parts of the United States (see map). All of these damp areas have tremendous importance in terms of productivity and water quality.

Some wetlands develop in low-lying areas in the landscape where water drains and collects. Others border salt or fresh bodies of water, while still others are isolated in forests and urban areas. As transitional zones between upland and aquatic systems, wetlands often support both terrestrial and aquatic species.

Wetlands have the ability to filter runoff water as it flows back toward sources of surface water. They can serve to remove natural and man-made pollutants from the water cycle. However, they cannot remove them all. As more and more pollutants are added to the environment by the activities of people, the wetlands are less and less effective in purifying water.

Two hundred years ago, the United States had 220 million acres of wetlands. Now we have less than 100 million acres. The loss is around 300,000 acres each year. Half of the Florida Everglades is gone, as are half of Connecticut's coastal wetlands and 2/3 of the prairie potholes. California has only 9% of its wetlands remaining, Iowa 11%, and Indiana and Missouri 13%. Any legislation that weakens the definition and regulation of wetlands will probably cause greater loss.

WETLANDS MODEL



WETLANDS IN THE UNITED STATES



MARSH



BOG



LAKE / POND



SWAMP



RIVER / STREAM



COASTAL

KNOW YOUR GULF

OBJECTIVES

The student will do the following:

1. Define terms that will help in the study of subjects pertaining to the Gulf of Mexico.
2. Create a polyhedron with the words.

BACKGROUND INFORMATION

The Gulf of Mexico is one of the United States' greatest resources. Its ecosystems and habitats support a wide diversity of plant and animal life. Nearly 40 percent of total U.S. fishing comes from Gulf fisheries. The Gulf also supports industries like shipping, and oil and natural gas drilling. However, this rich natural resource is in trouble due to pollution of its water. Some of this pollution is caused by the industries, but it is also caused by runoff from the land. Coastal areas are becoming very crowded with people who bring with them an increase in pollution. There are many terms associated with the Gulf area. This activity allows students to become familiar with some of these terms.

Terms

See Student Sheet.

ADVANCE PREPARATION

- A. Copy the Word List on the Student Sheet.
- B. Collect a classroom set of dictionaries.
- C. Copy the teacher sheet with the circle pattern and cut 20-4" paper circles for each student. (The students can cut these, but advance preparation will save time. Also, the teacher should make

SUBJECTS:

Science (Biology), Math

TIME:

1-2 class periods

MATERIALS:

terms
dictionaries
poster board or heavy
construction paper
white paper
scissors
glue sticks
colored pencils
felt tip markers
string or ribbon
student sheets

one polyhedron ahead of time to show the class.)

D. Assemble circles, markers, glue sticks, colored pencils, string, or ribbon.

PROCEDURE

I. Setting the stage

Introduce your unit on the Gulf of Mexico by sharing the Background Information with your students. Emphasize to them that an understanding of the vocabulary is essential to their discussion of the Gulf.

II. Activity

A. Using the dictionaries, students should define the terms on the student sheet.

B. Give each student 20 circles or have them cut out the circles themselves.

C. Students should fold edges of each circle to make an equilateral triangle.

D. On the side to which the edges have been folded, students should write one vocabulary word and color or decorate it however they choose. Continue until all 20 are completed.

E. The 20 circle/triangles should then be glued together (folded edges out) in this way - 5 on top (paint on top); 5 on bottom (paint on bottom); 10 in middle.

HINT - Glue top together, then bottom, then middle and attach the three sections to each other. This will form the polyhedron. Attach string or ribbon to polyhedron.

III. Follow-up

A. The polyhedrons may be displayed throughout the room.

B. Tear apart one of the polyhedrons or just put terms on 20 circles. Distribute one term to each student and have each one do some research on how this term applies to the Gulf of Mexico. Have students report to the class on their terms. If the term is a structure in the Gulf, they should be able to locate it or areas in which it is found on a map.

IV. Extensions

- A. Discuss problems in the Gulf of Mexico.
- B. Have students write brief reports using the 20 terms on the Gulf and what they think could be done about some of the pollution problems.

RESOURCES

Gulf of Mexico Program, Public Information Center, Building 1200, Room 103, Stennis Space Center, MS 39529-6000. Phone: (601) 688-7940

Weber, Michael, Richard T. Townsend, and Rose Bierce, Environmental Quality in Gulf Mexico: a Citizen's Guide, 2nd Ed., Washington, D.C., Center for Marine Conservation, June 1992.

WORD LIST

1. anhydrite
2. barrier reef
3. bathymetry
4. brackish
5. continental shelf
6. coral reefs
7. dolomite
8. eddy
9. escarpment
10. estuary
11. fecal coliform bacteria
12. geology
13. gulf
14. gulf stream
15. lagoon
16. limestone
17. loop current
18. oceanography
19. reef
20. salinity
21. sediment
22. watershed
23. osprey
24. mullet (fish)
25. great blue heron (bird)
26. lesser scamp (salt marsh duck)
27. cordgrass (spartina)
28. salt-marsh aster (plant)
29. tern (bird)
30. brown pelican (bird)
31. nutria (mammals)
32. salt-marsh pinks (plant)
33. monarch butterfly (insect)
34. menhaden (fish)
35. red-breasted merganser (bird)
36. pinfish (fish)
37. redfish (fish-red drum)
38. oyster (mollusk)
39. shrimp (crustacean)
40. flounder (fish)
41. barnacles (crustacean)
42. blue crab (crustacean)
43. hermit crab (crustacean)
44. marsh periwinkle (mollusk)
45. dragonfly (insect)

1. **anhydrite:** a white to grayish or reddish mineral of anhydrous (free from water) calcium sulfate (CaSO_4), occurring as layers in gypsum deposits
2. **barrier reef:** a rock or coral reef, aligned roughly parallel to a shore and separated from it by a lagoon
3. **bathymetry:** the measurement of the depth of the ocean
4. **brackish water:** water that is a mixture of fresh and salt water
5. **continental shelf:** a shallow, submarine plain of varying width forming a border to a continent and typically ending in a steep slope to the oceanic abyss
6. **coral reef:** erosion-resistant marine ridge or mound built slowly over thousands of years by coral polyps (tiny animals) bound together with algal material and biochemically deposited carbonates
7. **dolomite:** a mineral $[\text{CaMg}(\text{CO}_3)_2]$ consisting of a calcium magnesium carbonate found in crystals and in extensive beds as a compact rock
8. **eddy:** a current (of water or air) running contrary to the main current
9. **escarpment:** a long cliff or steep slope separating two comparatively level or more gently sloping surfaces
10. **estuary:** a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouths of rivers, and includes bays, lagoons, sounds, and marshes.
11. **fecal coliform bacteria:** a type of coliform bacteria found in the intestines of warm-blooded animals that aids in the digestion process and is used as an indicator of fecal contamination and/or possible presence of pathogens

12. **geology:** a science that deals with the structure and history of the Earth and its life, especially as recorded in rocks
13. **gulf:** a large area of a sea or ocean partially enclosed by land
14. **gulf stream:** the oceanic current that brings warm Gulf of Mexico water up along the east coast of the U.S. and across the Atlantic to the British Isles
15. **lagoon:** a shallow body of water, especially one separated from the sea by sandbars or coral reefs
16. **limestone:** a rock that formed chiefly by accumulation of organic remains; consists mainly of calcium carbonate
17. **loop current:** oceanic current that enters the Gulf of Mexico through the Yucatan Channel and/or exits through the Straits of Florida (Parent of the Gulf Stream)
18. **oceanography:** a science that deals with the oceans and includes the delineation of their extent and depth, the physics and chemistry of their waters, marine biology, and the exploration of their natural resources
19. **reef:** a strip or ridge of rocks, sand, or coral that rises to or is near the surface of a body of water
20. **salinity:** the amount of salt dissolved in water
21. **sediment:** eroded soil material, containing primarily inorganic constituents
22. **watershed:** land area from which water drains to a particular surface waterbody
- 23-45. Some organisms from coastal areas. Students could look these up to find out what they look like; type of organism, life cycle, etc.

Instructions for Polyhedron

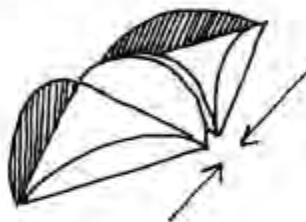
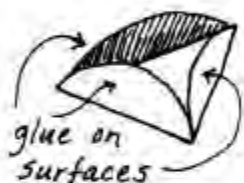
Use lightweight poster board or heavy construction paper.

1. Cut 20 circles per student.
2. Fold each circle into an equilateral triangle.
3. Glue the edges of triangles (with edges out);

 5 with points up - for top
 5 with points down - for bottom
 10 alternating point up, point down - for middle
4. Glue top to middle; then middle to bottom.
5. Staple string or ribbon for hanger.

INSTRUCTIONS FOR MAKING A POLYHEDRAL "BALL"

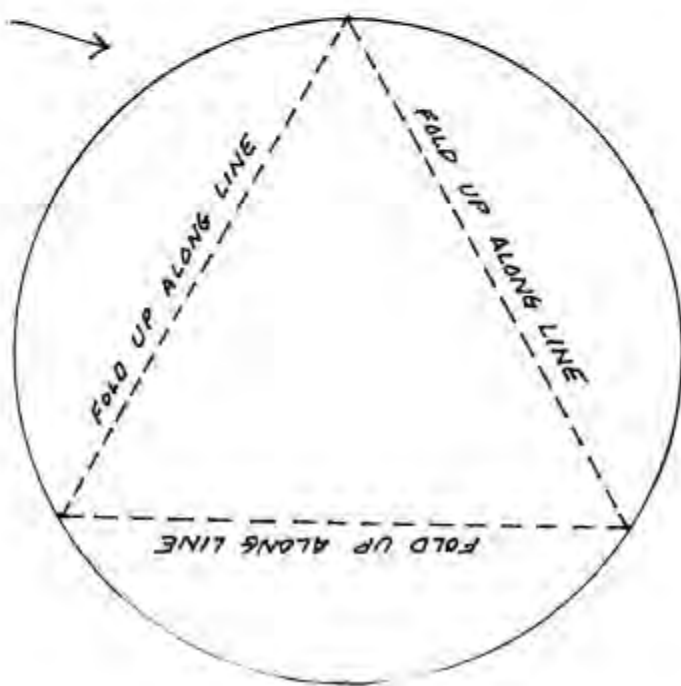
1. Copy and cut out 20 circles using the pattern below.
2. Fold the three sections of the circle up along the dotted lines.
3. Flatten, and have the students write one vocabulary word on the opposite side, keeping the word within the triangle.
4. Refold and use gluesticks to glue the outer circle sections together. (If using poster boards, you may need to staple sections also.)



5. Continue to glue sections until all 20 pieces have been used.
6. Keep arcs to the inside.

PATTERN

Cut 20



SEA MARGIN DIVERSITY

9-12

OBJECTIVES

The student will do the following:

1. Describe various coastal regions.
2. Recognize defining characteristics of each coastal habitat and learn its name.
3. Locate significant coastal waters on a map.
4. Contribute to a model that depicts major coastal habitats.

BACKGROUND INFORMATION

One of the most dynamic and ecologically important places of our planet is where land, air, and sea meet. These areas have been influenced by changing sea levels over the past thousands of years as well as by the constant action of waves, winds, and tides. Perhaps the most profound influence in modern times has come at the hands of people through their ignorance of the importance of coastal wet areas. Recently we thought of any coastal areas that did not have a white sandy beach as a wasteland that needed draining, filling in, or some other modification that would render it suitable for our needs. We now understand that our label “wasteland” could not have been more inaccurate. Instead, it is one the most fertile, productive places on Earth, serving as a sanctuary and nursery for much of the life in the sea. Many species produce eggs and juvenile stages that require the lower salinity, the mud, or the grassy cover found in numerous coastal habitats, especially estuaries. We also now realize coastal areas’ importance as a storm buffer, absorbing the impact of wind and waves so that less damage is sustained inland where greater human populations reside. And finally, their importance as a biological filter has been realized. It is in this role, perhaps, that coastal areas are most important. Many pollutants people produce are naturalized in these vast expanses and even help feed the detrital mill so basic to the entire system.

SUBJECTS:

Science (Environmental Science), Social Studies (Geography), Art

TIME:

2 class periods

MATERIALS:

teacher sheets
acetate sheets
student sheets
blue & brown paint
small diameter wire
plastic trees and plants
Astroturf ® (2 sq. ft.)
plywood 4' x 4' (or larger)
broom straw
flour (at least 10 lbs.)
salt (at least 5 lbs.)
bottle of vegetable oil
water
large mixing bowl
U.S. or world map

Coastal regions compose an array of features with a complex shoreline. Not all have the important functions described, but each has unique characteristics that make it an important habitat.

Terms

bay: a body of water partly enclosed by land but with a wide outlet to the sea

delta: a deposit of sand and soil, usually triangular, formed at the mouth of some rivers

detritus: decomposed or disintegrated organic matter (found in water and on land) and associated microbial elements

distributary: a branch of a river that flows away from the main stream

estuary: a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouths of rivers, and includes bays, lagoons, sounds, and marshes

fjord: narrow, deep valleys carved by glaciers and flooded by the sea

gulf: a large area of sea or ocean partially enclosed by land

lagoon: a shallow body of water, especially one separated from the sea by sandbars or coral reefs

mangrove swamps: tropical, wet, coastal areas dominated by mangroves (trees). Mangroves have extensive root systems which form a dense thicket, providing cover for aquatic life.

mud flats: large estuarine expanses composed of rich muds exposed at low tides

salt marsh: estuarine habitat submerged at high tide, but protected from direct wave action, and overgrown by salt-tolerant herbaceous vegetation; aquatic grasslands (coastal “prairies”) affected by changing tides, temperatures, and salinity

sound: long, broad inlet of the ocean larger than a strait or channel, connecting larger bodies of water

strait: a narrow passage that connects two larger bodies of water

tidal creeks: meandering creek-like channels within salt marshes and mud flats, through which seawater enters and leaves as the tide rises and falls

tidal flats: flat-topped banks of sand and silt that comprise the most elevated portion of the salt marsh

ADVANCE PREPARATION

- A. Make transparencies of the teacher sheets “Margins of the Sea” and “Estuary.”
- B. Make copies of “Margins of the Sea” and “Estuary” student sheet.
- C. Have materials available for the extension activities.

PROCEDURE

I. Setting the stage

- A. Discuss what coastal regions are, share the background information, and list all terms and definitions.
- B. Ask students how coastal regions have impacted them. (If they have been to the beach, name the seafood they have eaten and understand that each kind may have begun life in a coastal habitat.)
- C. Point out coastal regions on a U.S. or world map.

II. Activity

- A. Display transparency of “Margins of the Sea.”
 - 1. Locate each coastal region.
 - 2. Discuss the identifying characteristics that make it unique.
- B. Display the “Estuary” transparency.
 - 1. Identify and discuss the smaller habitats found in this environment.
 - 2. List ways this richest of coastal ecosystems is so important to marine life and to humans.
- C. Point out major coastal regions that can be seen on a large map. Identify estuarine environments of the U.S.

III. Follow-up

- A. Review shape, appearance, and characteristics of coastal regions.
- B. Hand out student sheet "Margins of the Sea."
 - 1. Have students label each region.
 - 2. Let them check their understanding as the transparency key is shown again.
- C. Have students identify coastal regions and estuaries on a map.

IV. Extensions

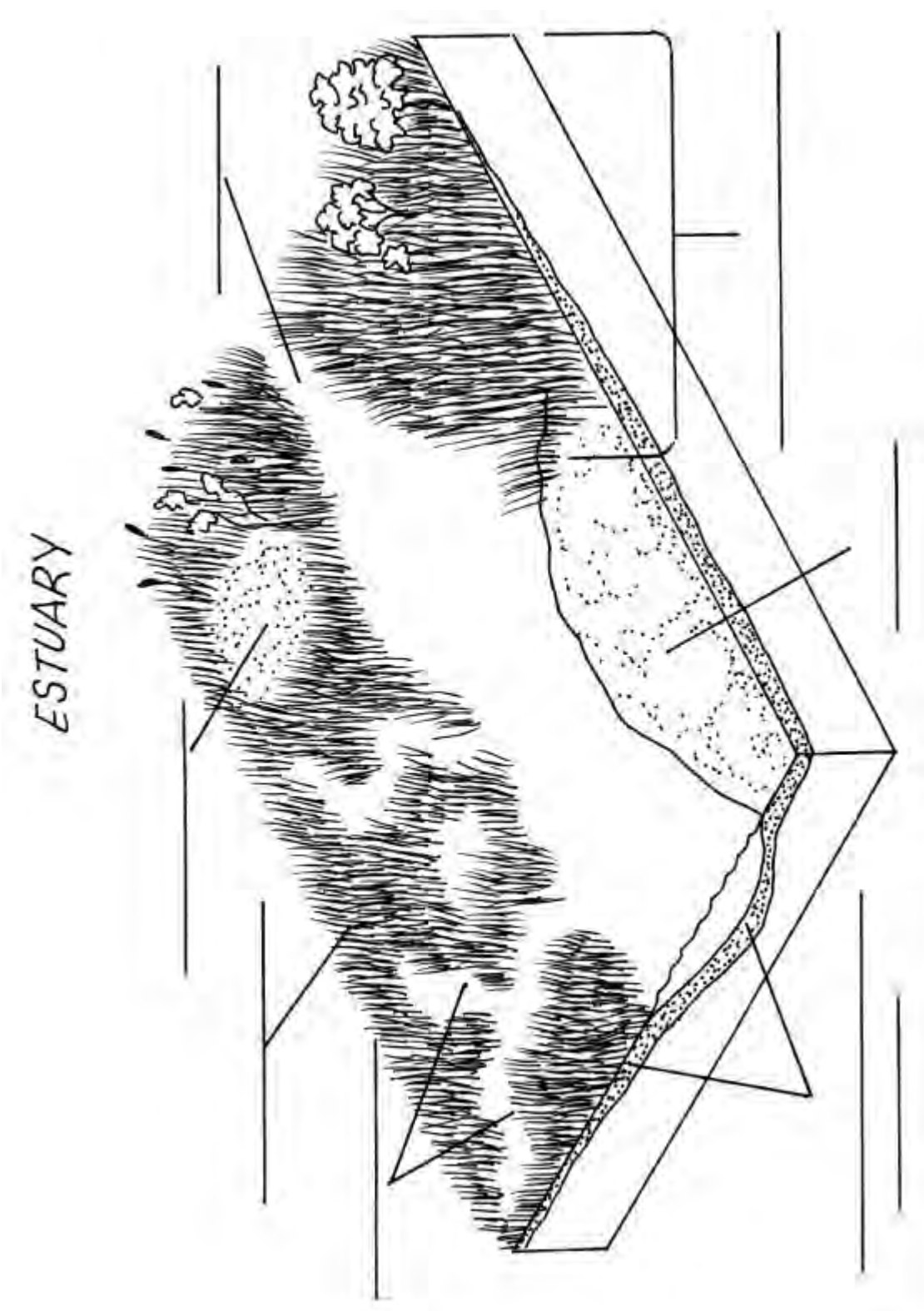
- A. Divide class into groups (determined by number of habitat models being built), or each class could contribute to a single model. Each group (or class) makes modeling clay by mixing 2 parts flour to 1 part salt with water and vegetable oil. The clay is used to mold a model that depicts a coastal habitat. The habitat is placed in one section of the plywood form so that it fits beside others creating an entire coastal region. Straw, astroturf, plastic plants, and wire can be used at students' discretion to make realistic features. Areas under water may be painted blue while land features may be painted brown. The finished product should reinforce the concepts of coastal habitat studies.
- B. Have students research the plant and animal life of their habitat and report their findings to the class.

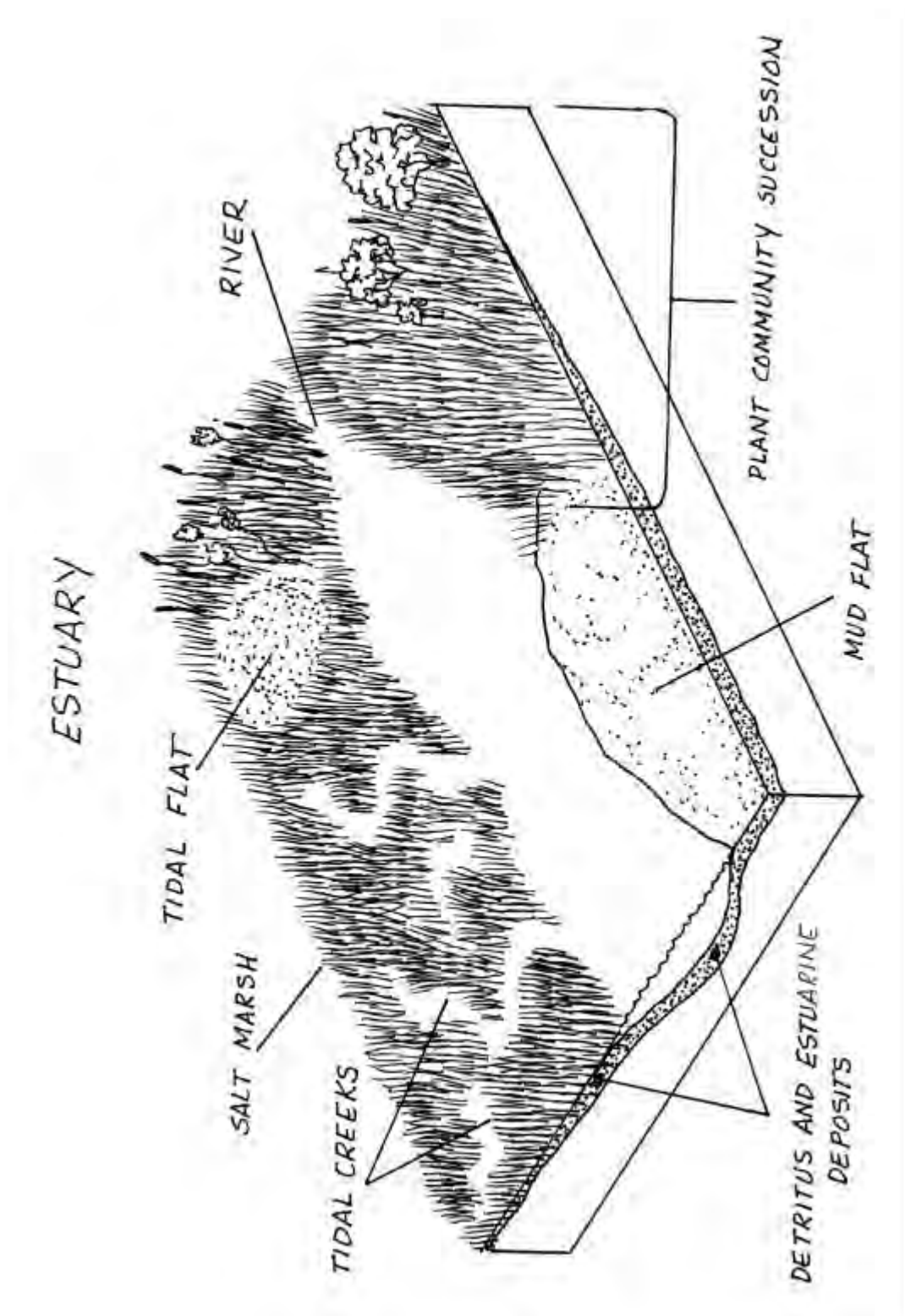
RESOURCES

Gross, M. Grant, Oceanography: A View of the Earth, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1990.

Sumich, James L., An Introduction to the Biology of Marine Life, W.C. Brown Publisher, 3, 4 6 0 Kerper Boulevard, Dubuque, IA, 1992.

3-5 Water SourceBook.

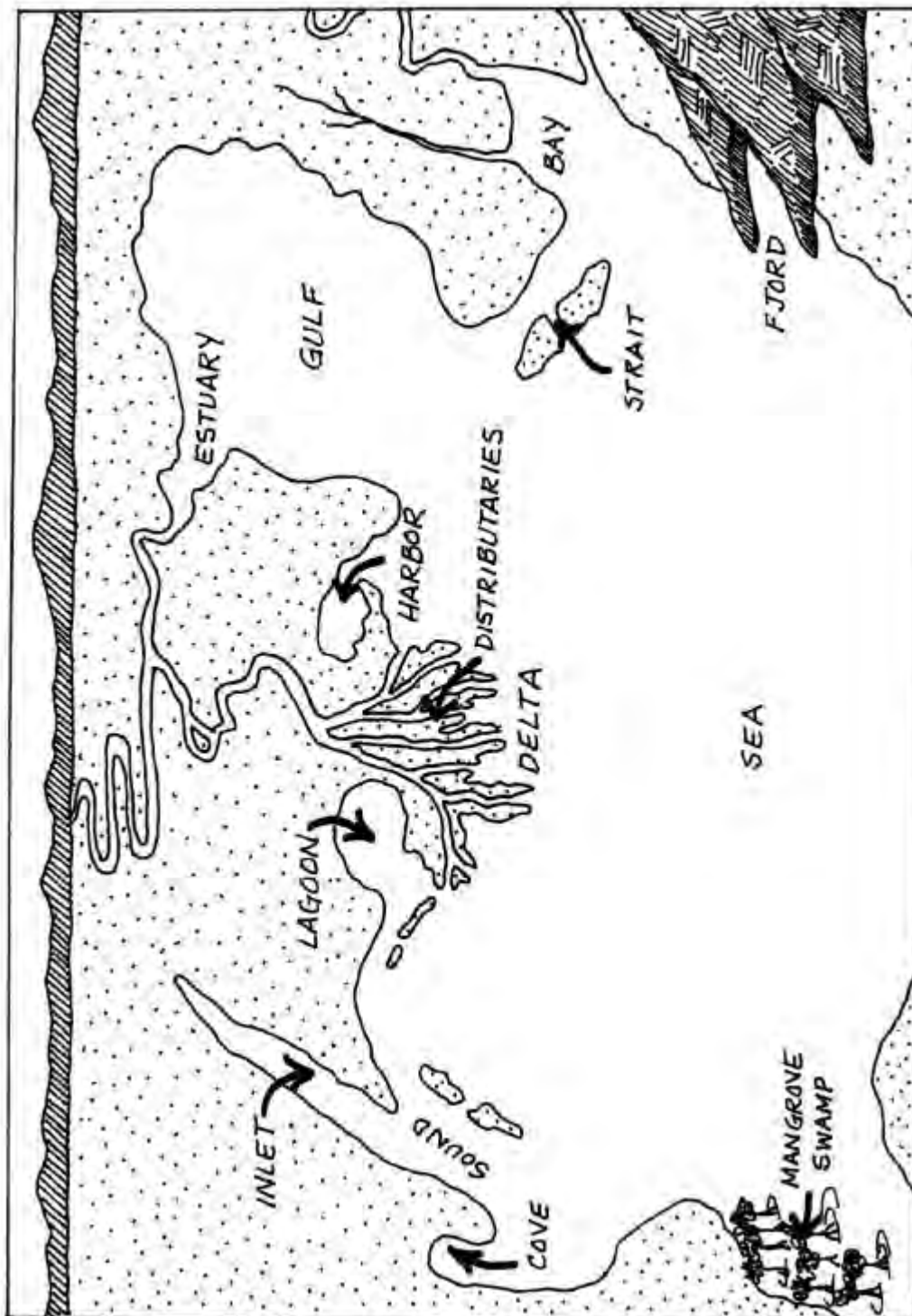




MARGINS OF THE SEA



MARGINS OF THE SEA



ESTUARIES: INTERFACE BETWEEN SEA AND LAND

9-12

OBJECTIVES

The student will do the following:

1. Describe the five types of estuaries and functions of estuaries.
2. Identify where estuaries lie in the U.S.
3. Explain the value of estuaries in maintaining the integrity of natural ecosystems, especially coastal ecosystems.
4. State the impact human use and misuse has on estuaries.

BACKGROUND INFORMATION

Ours is a water dependent planet. Our land areas are bordered by the enormous body of water we call the 'sea'. Some of the most dynamic areas on Earth are found at the interface of land and sea, especially in areas we know as estuaries. Estuaries are areas of unusual activity and have production comparable to our most productive agricultural lands - more than five tons per acre per year! There are three good definitions of an estuary: (1) a semi-enclosed coastal body of water that has a free connection with the open sea and within which seawater is measurably diluted with freshwater from land drainage; (2) deep-water tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partially obstructed, or sporadic access to the open ocean and where ocean water is at least occasionally diluted by freshwater runoff from land; and (3) a marine ecosystem where freshwater enters the ocean.

Five important functions of estuaries are: (1) they provide nursery areas for 90 percent of our commercial seafood populations; (2) they provide food for most of these populations; (3) they provide shelter for many small marine animals; (4) they act as a storm buffer to prevent floods and absorb energy from storms such as hurricanes; and (5) they detoxify wastes. Also, we now appreciate the importance of microscopic photosynthetic phytoplankton, benthic plants, and marsh grasses in

SUBJECTS:

Science (Ecology, Biology),
Social Studies (Geography)

TIME:

2 class periods

MATERIALS:

modeling clay
petri dishes (5-6 inch)
or plastic plates
food coloring
ice trays or paper cups
wall map of the United States
5 different colored push pins
maps

keeping the ocean “alive.” All of these are found in estuaries. They also provide needed habitat for millions of birds, both local and migratory. Many of our most beautiful birds depend on estuaries and other wetlands.

Estuaries seem to have been relatively rare features during most of Earth’s history. As the last Ice Age withdrew and sea level rose, estuaries were formed along the continental shelf. There are five basic formations: (1) Drowned river valley - the classic estuary, wider than deep and triangular in shape. Examples are Chesapeake, Delaware, Savannah, Hudson, and Mobile Bay. It consists of marshes, mudflats, and tidal creeks. These are coastal plain estuaries. (2) Fjord-drowned glacial valley - usually in arctic and polar regions, u-shaped, deeper than wide, small river discharge, large tidal volume, important to shipping; located in Valdez, Alaska, New Zealand, and Norway. (3) Deltaic - the most changeable, fluvial depositions, river discharge great, very subject to waves, tides, longshore currents, storm damage, sediment lay down; locations: Mississippi River, Amazon River, and Nile River. (4) Bar-built - the most dynamic, a series of bars or islands created from offshore deposition of sand, washed down by rivers or from deep water, the sand walks up the continental shelf and stabilizes. Bar-built estuaries are usually laterally extended along shore and are long, narrow, and low. Examples are a sand spit or barrier island. The estuary exists on the leeward side. These can change quickly and are controlled by oceanic movements. Examples of bar-built estuaries are the Mississippi Sound, Cape Cod, Long Island, and Chandeliers Islands as well as many islands along the west coast of Florida. (5) Tectonic - estuaries formed when the Earth’s crust shifts suddenly as in an earthquake, volcanic eruption, or a tsunami. Tectonic estuaries have no definite shape, and San Francisco Bay is an example of one.

Worldwide, we have destroyed 50 percent of the estuaries and damaged 25 percent more. The southeastern United States has 90 percent of the estuaries located in the U.S. The Atlantic coast has 30.8 percent, the Gulf of Mexico has 60.1 percent, the Pacific has 7.1 percent, and the Great Lakes region has 2.0 percent. Over two-thirds of the water runoff from the United States drains into the Gulf of Mexico.

The physical environment of an estuary includes intertidal emergent wetlands, seagrass meadows, soft bottoms, hard substrates, and aerial habitat. The biotic component includes: animals-mollusks, arthropods, reptiles, fish, birds, mammals, and an extensive interstitial community; and plants-Spartina, Juncus, Salicornia, Distichles, shrubs, phytoplankton, benthic plants, bacteria. The mud in an estuary can be eight feet thick! The mud is, for the most part, anaerobic and very rich in nutrients. The pulse of the tides, creating a daily or twice daily flushing, brings renewal and diversity of temperature, salinity, and DO (dissolved oxygen).

Limiting factors, such as elevation, tides, temperature, salinity, desiccation, and predation, mean that animals must be adaptable to live in the estuarine environment. Nowhere is the food web more apparent and fragile than in the estuary.

Human impact is the greatest stress. Estuaries are subject to sudden changes due to development, filling, dredging, discharging, and dumping to accommodate human needs. Two-thirds of the human population

lives on one third of the land near the coast! Of course that's where the estuaries are located! Humans redirect the enormous forces of nature and often think nothing will happen. People have only recently begun to appreciate the values and functions of estuaries in the natural world. Small activities have large unforeseen consequences. By-products of human activity such as industrial wastes, heat, solid wastes, agricultural runoff (silt, herbicides, pesticides, organic matter), and private citizen wastes (septic tanks, inadequate oil and chemical disposal, litter), all adversely impact upon estuaries. Some pesticides are retained in the body and build up in the progression of the food chain (biological magnification). Levees eliminate precious sediment. Dams cut off fresh water. Runoff from pavement and roofs causes erosion and carries pollutants to the estuaries killing animals and plants. Overfishing can lead to extinction and destroys the fishing industry. Channelization can contaminate freshwater areas and funnel pollutants without giving the estuary the chance to carry out its detoxifying function.

All this may sound very dire, but most of the harm to estuaries was done before we knew and appreciated their values and functions. Great efforts are now being made to protect our remaining estuaries and even to reclaim estuaries that were damaged or completely destroyed.

Terms

bar-built estuary: type of estuary formed by a series of bars or islands created from offshore depositing sand, washed down by rivers or in from deep water. The sand walks up the continental shelf and stabilizes. A bar-built estuary is usually laterally extended along the shore, and is long, narrow, and low.

benthic: living on the bottom of a lake or sea; pertaining to the ocean bottom

bioaccumulate: to accumulate larger and larger amounts of a toxin within the tissues of organisms in each successive trophic level

biological magnification (biomagnification): bioaccumulation occurring through several levels of a food chain; process by which certain substances (such as pesticides or heavy metals) are deposited into a waterway, are eaten by aquatic organisms which are in turn eaten by large birds, animals, or humans, and become concentrated in tissues or internal organs as they move up the food chain.

biotic: living or derived from living things

channelization: the straightening and sometimes deepening of stream or river channels to speed water flow and reduce flooding. A waterway so treated is said to be channelized. However, channelization can cause unstable situations and may cause adverse environmental impacts.

deltaic estuary: type of estuary formed by a delta

drowned river valley: type of estuary that is wider than deep and triangular in shape

emergent: rising from a surrounding liquid

estuary: a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouths of rivers, and includes bays, lagoons, sounds, and marshes.

fjord-drowned glacial valley: type of estuary usually found in arctic and polar regions, U-shaped, deeper than wide, that has a small river discharge and a large tidal volume; important shipping

fluvial: found in, produced by, or relating to a river

interstitial: of, forming, or occurring in a small or narrow space between things or parts

intertidal: of, or pertaining to a shore zone bounded by the levels of low and high tide

leeward: in the direction toward which the wind blows; of the side of anything away from the wind

levee: an embankment, natural or artificial, built alongside a river to limit high water events from flooding bordering land

tectonic estuary: type of estuary formed when the Earth's crust shifts suddenly as in an earthquake, volcanic eruption, or a tsunami; has no definite shape

tsunami: a huge sea wave caused by a submarine disturbance such as an earthquake or volcanic eruption

ADVANCE PREPARATION

- A. Collect materials.
- B. Freeze colored water in ice trays or paper cups (the form of the ice does not matter). The equivalent of three square ice cubes is usually sufficient.
- C. Put terms and definitions on the board.

PROCEDURE

- I. Setting the stage

- A. Discuss Background Information.
- B. Have students locate the different types of estuaries on a wall map and mark each type with one color of push pin. Discuss estuaries that students may have visited or seen.
- C. Discuss how so many estuaries have been damaged or destroyed. Talk about values, natural stresses, and human impact. Try to find solutions for misuse and destruction of estuaries.

II. Activity

This is a sea level rise activity to demonstrate formation of estuaries.

- A. Hand out clay and petri dishes and have students construct a coastline with raised areas indicated by the clay in various formations inside the dishes.
- B. Give each student or partners, if they work in partners, three cubes of ice and let them place the ice on the clay in the dish. The teacher may want different students to create models that will form the different types of estuaries.

1. As the ice melts, they can see an island get covered or a ditch or valley fill in.

2. Have students look at the different models to see if they can identify the types of estuaries formed. It may be necessary to reform some models if the water did not fill in where expected.

III. Follow-up

Have students:

- A. Write a one-page summary about the types of estuaries, their function, and human impact on them. Students should be able to describe the estuary type, give one United States location for that type, discuss benefits of an estuary, and discuss destruction and remediation.
- B. Test term knowledge by taking a vocabulary quiz.

IV. Extensions

- A. Use the same model to observe circulation patterns and record findings.
- B. Discuss food webs in estuaries.

- C. Discuss possible results of estuary destruction.
- D. Visit an estuary.
- E. Trace where your nearest waterbody empties into the sea.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Gulf of Mexico Program, Public Information Center, Building 1200, Room 103, Stennis Space Center, MS 39529-6000. Phone: (601) 688-7940

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Posters of estuaries are available from: National Marine Estuary Programs, and U.S. Environmental Protection Agency (U.S. EPA) Regions (check Appendix R-1 to R-8)

United States Geological Survey maps (see list in Appendix J-1 to J-6 for State Geological Contacts)

EROSION KILLS THE HABITATS THAT FEED YOU!

9-12

OBJECTIVES

The student will do the following:

1. Define the role of barrier islands, shorelines, beaches, and dunes in defending areas of abundant biological activity.
2. Compute the amount of time necessary to have islands “erode away” given a certain amount of erosion per year.
3. Describe the socio-political and economic impact of erosion of coastlines.

SUBJECTS:

Science (Ecology), Math, Social Studies (Political Science, Economics, Government)

TIME:

2 class periods

MATERIALS:

student sheet
ruler
handouts of hypothetical situation and questions

BACKGROUND INFORMATION

Shorelines, beaches, dunes, and barrier islands are often the main defense to protect (estuaries, wetlands, bays, and coastal properties against erosional force such as hurricanes, storms, and tides.

Estuaries, wetlands, coastal swamps, marsh lands, and bays are habitats and areas of extensive biological productivity. If erosion damages or destroys these areas, the economy of a region can suffer; even hunger can result, especially if the local population depends on fish as the major source of food protein.

Coastlines can erode several to many feet per year. For example, along the Gulf of Mexico, erosion rates can be as high as 60 feet per year.

Terms

barrier island: a ridge of sand and gravel thrown up parallel to a coastline by the waves and tides leaving a lagoon behind it

bay: a body of water partly enclosed by land but with a wide outlet to the sea

erosion: the process of detachment, transport, and deposition of soil material

estuary: a marine ecosystem where freshwater enters the ocean. The term usually describes regions at the mouths of rivers, and includes bays, lagoons, sounds, and marshes

gulf: a large area of a sea or ocean partially enclosed by land

habitat: the place or type of site where a plant or animal naturally or normally lives and grows

wetland: areas that periodically have waterlogged soils or are covered with a shallow layer of water resulting in reduced soil conditions. Wetland areas typically support plant life that is adapted to life in wet environments

ADVANCE PREPARATION

Photocopy Hypothetical Situation sheets and questions.

PROCEDURE

I. Setting the stage

Set up the hypothetical situation with your students. Discuss pertinent terms. Divide class into two groups, one for each country.

II. Activity

A. Have all members of each group perform the required computations, answer the questions about their assigned country, and compare responses. Have each group choose a reporter to present its country's case the next day.

B. On the following day, have each reporter present the group's findings. Facilitate a discussion on options each country might have to try to feed its population.

III. Follow-up

Have students choose actual locations worldwide, research erosion rates, and calculate how many years it would take for one mile to erode at that particular location using a constant rate.

IV. Extension

Have students research ways to slow down coastline erosion and present findings to the class

for extra credit.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley,
Menlo Park, CA, 1989.

“Coastal and Shoreline Erosion,” The Gulf of Mexico Program Public Information Center Building
1200, Room 103, Stennis Space Center, MS 39529-6000, (pamphlet) Phone: (601) 688-7940

Jacobson, Jodi, “Swept Away,” World Watch, January/February 1989, pp. 20-26.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works,
4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

HYPOTHETICAL SITUATION

Countries A and B have shorelines protected by many small, mostly sandy barrier islands. These barrier islands protect areas of great biological activity, and native and commercial fishermen supply much of their countries protein sources from the catches made in these protected areas. Both countries have large, rapidly growing populations and share fishing rights in East Bay. Unfortunately, rises in sea level and the cutting of most of the trees of Country C, an island, have increased wind and erosion rates so that Country B is seeing erosion rates of 72-75 feet per year on the islands, while Country A has a rate of only 10 feet of erosion per year.

DIRECTIONS:

Using the key and assuming the majority of erosion will occur from the side of each island facing the sea, calculate the number of years necessary for the numbered islands of your country to literally “erode away.”

For Country A

#1
#2
#3
#4
#5

for Country B

#6
#7
#8
#9

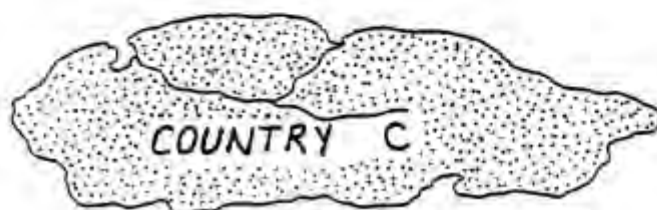
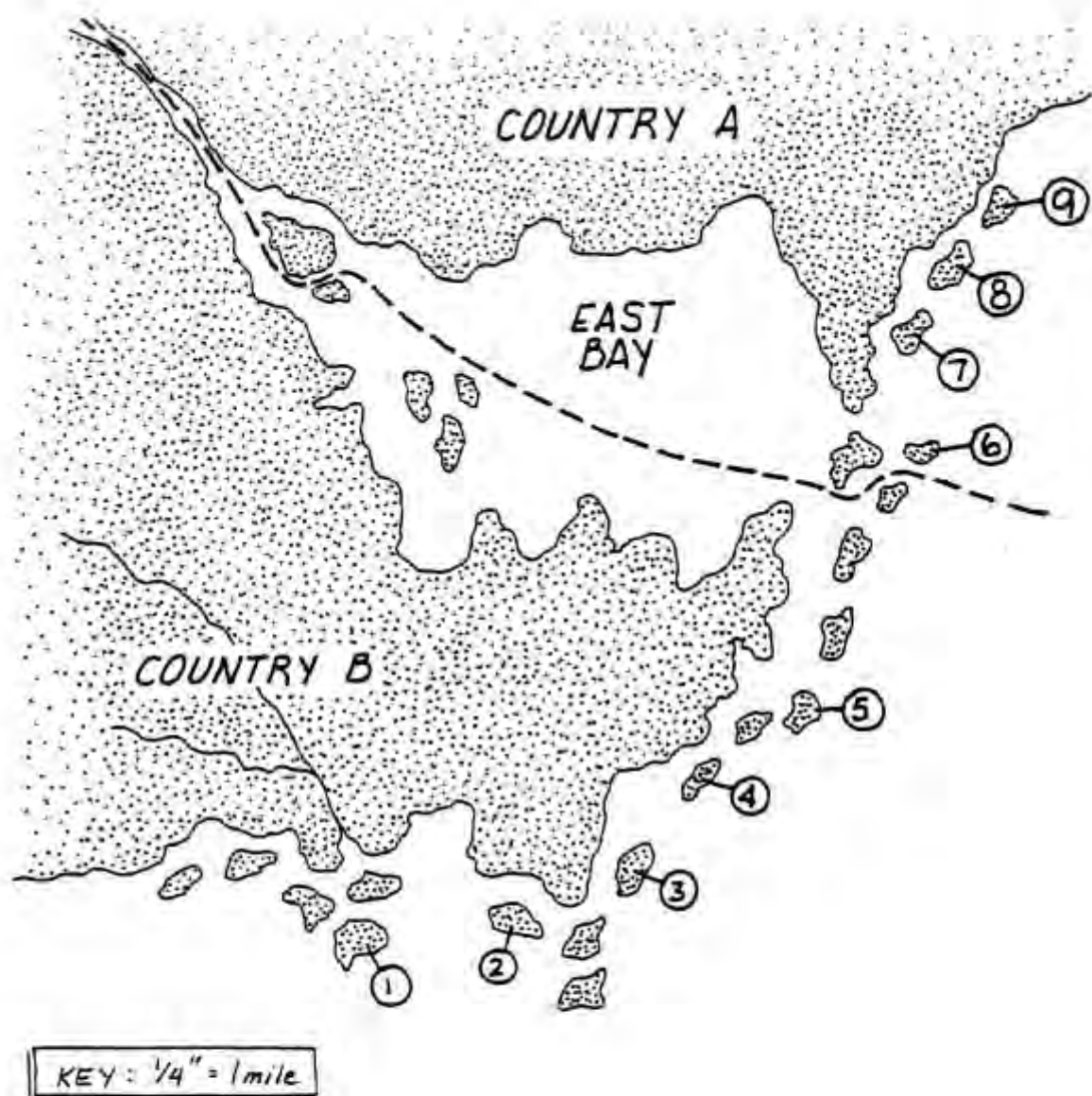
QUESTIONS

Country B:

Suppose that erosion decreases your fishing catches by 50% while your population grows 10%. What could be some possible consequences in your relationship to A? What could be some changes in your fishing patterns?

Country A:

Suppose your fishing catches decrease only 10% in the same time, and your population increases only 5%. How would these changes affect your relationship with Country B?



OIL SPILLS

OBJECTIVE

The student will do the following:

1. Explain the effect and effectiveness of techniques (sinking, absorption, and disposal) used to get rid of oil floating in seawater.

BACKGROUND INFORMATION

Every year, millions of gallons of oil are released into the environment, either accidentally or intentionally. This oil comes from tanker accidents, blowouts or spills at offshore drilling rigs, and from runoff and dumping of waste oil by people and industries.

In 1979 a huge blowout occurred at the Ixtoc I oil well in the southern Gulf of Mexico. Over 184 million gallons of oil leaked into the environment. It took eight months to cap the well. As horrendous as that seems, releases from offshore wells during normal operations and during transportation of oil add much more oil to the environment annually than occasional accidents.

Oil tanker and supertanker accidents only account for about 10 to 15 percent of the annual input of oil into the world's oceans, but they can be disastrous when they occur. Most of the rest comes from leaks at wells, purging of tanks, and seepage from natural sources. The largest tanker accident to date was in 1983 when the tanker *Castillo de Bellver* caught fire and released 78.5 million gallons into the ocean off the coast of Capetown, South Africa.

In March of 1989, the tanker *Exxon Valdez* hit a reef and released 11 million gallons of oil into the Prince William Sound of Alaska. More than 33,000 seabirds, nearly 1,000 sea otters, and more than 100 bald eagles were killed.

The type and amount of damage from an oil spill depend on a number of factors such as type of oil, weather conditions, what kinds of organisms are in the area, and the season.

SUBJECTS:

Science (Ecology, Chemistry, Biology)

TIME:

1 ½ class periods

MATERIALS:

water (from faucet)
table salt
scale
empty 1-liter bottle with cap
beaker containing heavy-grade motor oil (gear oil 80W) or crude oil
five 250ml beakers
two 10ml measuring cylinders
teaspoons
small dish of sawdust
foam granules (made by breaking up a foam cup)
small dish of plaster of Paris
detergent (dishwashing liquid)
stop watch
waterproof felt-tip marker
student sheet

Crude (unrefined) oil is actually a mixture of hundreds of different substances. Some are very toxic; some are relatively harmless. Some evaporate into the air, some dissolve in water, some float, and some sink. Some are very sticky and tend to coat whatever they contact.

The effects of an oil spill are many and varied. The most obvious effect is the waste of a valuable resource, the oil itself. While attempts to recover the spilled oil are made, much is lost and much of what is recovered is not usable because of contamination from the clean-up process or the environment.

Some of the components of crude oil, such as benzene and toluene, are extremely toxic (poisonous). Sticky oil coatings smother many organisms. Oil destroys the insulation and buoyancy of marine birds and animals, so that many drown or die of exposure to cold water and air. Fish gills are clogged. Animals that ingest the oil or eat other organisms contaminated by the oil may be poisoned or have their digestive systems clogged.

Oil companies, governmental agencies, and people who are concerned about the environment have tried a number of ways to clean up spilled oil. It is always a difficult, expensive effort. Even as recently as the *Exxon Valdez* spill, many of the methods used were still in the experimental stage; and some of the experiments didn't work well. Sometimes people's efforts to clean up after a spill may do more damage than good.

Terms

benzene: (1) a clear, flammable, poisonous, aromatic liquid, C_6H_6 , obtained by scrubbing coal gas with oil and by the fractional distillation of coal tar. It is used as a solvent for fats and in making lacquers, varnishes, many dyes, and other organic compounds; (2) a structural unit in the molecules of organic aromatic compounds.

blowouts: when an oil well blows its top and spews crude oil into the air

crude oil: unrefined petroleum; a mixture of many different hydrocarbons

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in eventually enters a waterbody; may pick up and carry a variety of pollutants

supertanker: a very large ship used to carry crude oil

toluene: a colorless, liquid, flammable, poisonous hydrocarbon, C_7H_8 , obtained originally from balsam of Tolu but now generally from coal tar or petroleum; used in making dyes, explosives, and as a solvent; structurally consisting of a methyl radical attached to a benzene ring

toxic: harmful to living organisms

ADVANCE PREPARATION

- A. Make copies of the Student Sheet: DATA TABLE.
- B. Collect materials.
- C. Discuss Background Information with students.
- D. Put terms and definitions on the board.

PROCEDURE

I. Setting the stage

SAFETY PRECAUTIONS - Oil is flammable! BE CAREFUL! Be sure to extinguish all flames when carrying out this experiment.

II. Activity

- A. Make artificial seawater by weighing out 5g of table salt and adding it to the 1-liter bottle. Fill half the bottle with warm water from the faucet, put on the cap, and shake the bottle until the salt has dissolved. Fill the bottle to the top with water to produce “seawater” with approximately the same concentration found in the ocean.
- B. Label five beakers A, B, C, D, and E. Fill each of the beakers $\frac{1}{2}$ full of seawater.
- C. Measure out 5ml of oil in the measuring cylinder and pour into beaker A. Repeat this step with beakers B, C, D, and E.
- D. Look at the five beakers and record what you see in each one in the Data Table.
- E. Sprinkle one heaping teaspoon of sawdust into beaker A.
- F. Sprinkle one heaping teaspoon of foam granules into beaker B.
- G. Sprinkle one heaping teaspoon of plaster of Paris into beaker C.

H. Measure out 10ml of detergent in a measuring cylinder and pour into beaker D.

I. Do not add any treatment to beaker E. This will be the control beaker.

J. After 5 minutes, look at the five beakers and record on the Data Table what you see in each one. 6

K. Leave the beakers for 24 hours.

L. After 24 hours, look at the five beakers and record on the Data Table what you see in each one. 6

III. Follow-up

Write a report on what happened to the oil in each beaker after 5 minutes and after 24 hours. Answer these questions in the report.

A. Which treatment was most effective in making the oil sink?

B. Which treatment was most effective in soaking up the oil on the surface?

C. Did any treatments have no effect on the oil?

D. Which treatment do you think would be most effective at dispersing an oil slick at sea?

E. Would it be practical to use this method in the ocean? If not, why not?

IV. Extensions

A. Ask students to come up with new ways of removing oil from water and test them.

B. Have students come up with their own solutions for cleaning up water and compare theirs with those of other students. They may come up with some that are already used, or they may come up with some that are totally new and interesting. Discuss cost prohibitive cleanup efforts and other real world considerations.

C. Study a feather carefully. Notice its structure, coloring, and feel. Dip the feather into the oil-polluted water and inspect it. Compare the feather to one that was not dipped. Study a small piece of string carefully. Dip the string into oil polluted water and inspect it. Compare the string from Step 8 with a piece that was not dipped. (Notice that the oil coats whatever it touches. This is one of the ways in which oil spills destroy both plant and animal life. Baby sea turtles have been found off Mexico's Pacific Coast choked to death by globs of oil stuck in their mouths and nostrils. Birds lose their ability to fly and float.)

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Roe, Michael L., Environmental Science Activities Kit, The Center for Applied Research in Education, West Nijack, New York 10995, 1993, p. 95.

DATA TABLE

Appearance of oily water

	Before additions	After 5 minutes	After 24 hours
A			
B			
C			
D			
E			

IMPACT GOVERNMENTAL REGULATIONS ON MARINE DEBRIS - WRITE A LETTER!

9-12

OBJECTIVES

The student will do the following:

1. Identify the problem of marine debris.
2. Outline some current regulations governing waste in oceans and gulfs.
3. Compose letters to government officials expressing concern over marine debris.

SUBJECTS:

Language Arts, Science
(Environmental Science), Social
Studies (Government)

TIME:

3 class periods

MATERIALS:

student sheets
magazine and/or newspaper
articles on marine debris problem

BACKGROUND INFORMATION

Trash has been thrown into the ocean for generations; but because food, natural fibers, and paper decompose quickly in the ocean, they have not posed a major problem. Also heavy non-degradable materials sink to the bottom. However, lightweight and virtually indestructible plastic products accumulate, impact ocean life, and wash to shore.

Plastic trash from disposable diapers, bags, and banana wrap cover coral and kill the tiny Cnidaria that built the coral reefs. The coral reefs have taken hundreds of years to form and protect islands and coastlines from erosion. Plastic rings surround the feet, beaks, and heads of marine animals and cause starvation, strangulation, and suffocation. Marine animals that eat jellies (commonly called jellyfish) often mistake plastics for their food source and then die from starvation due to gastrointestinal blockage. Many of these plastics float onto the beaches making them unattractive for human recreation. It is not uncommon to find hypodermic needles on the beaches that have washed up because the plastic cylinders float. As much as one ton of litter per mile of coastline has been removed in one day on beaches during volunteer beach

cleanups.

Marine debris can come from any vessel on the water, from drilling platforms, or even as discharges from seaside industries, or from runoff from the land. An international treaty known as the MARPOL Treaty has been established to control disposal of wastes into the ocean. However, the ocean is a big place; and trying to regulate this treaty is almost impossible. Many vessels still dispose of wastes illegally in the ocean.

Terms

banana wrap: plastic that is put around bananas during shipping

Cnidaria: phylum name for a group of invertebrates that includes coral animals, jellies, sea anemones, and the hydra

gastrointestinal tract: the hollow tube that runs from the mouth to the anus in animals

MARPOL Treaty: international treaty that regulates the disposal of solid waste, including plastics

non-degradable: not capable of chemical or biological decomposition

phylum: the principal division of kingdoms. The classification system is the characterization of an organism by its Kingdom, Phylum, Class, Order, Family, Genus, and Species.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a water body; may pick up and carry a variety of pollutants

ADVANCE PREPARATION

- A. Copy Student Sheets.
- B. Obtain a copy of the MARPOL Treaty, if possible, to share with students, from the Government Printing Office, Washington, D.C.

PROCEDURE

- I. Setting the stage
 - A. Discuss Background Information and terms.

B. Assign each student to bring to class and be prepared to give a one-minute summary of one article on marine debris.

II. Activity

- A. Have students present one minute summaries on marine debris articles.
- B. Distribute Hypothetical Situation and discuss letter format and communication tips.
- C. Assign letter and give handouts.
- D. Collect letters.
- E. Discuss letters. Have students critique and note whether or not essential elements were included. **W**

III. Follow-up

Ask students to see if they can find a more effective way to communicate what John Doe saw. If they fail to find the information in the extension, share that information with the class a few days later.

IV. Extension

Let students know that a form is available for reporting to NOAA: Marine Debris Information Office Atlantic Coast and Gulf of Mexico c/o Center for Marine Conservation any dumping violation witnessed. For extra credit, have a student write the Center for Marine Conservation to obtain a copy of the report form.

NOAA: Marine Debris Information Office Atlantic Coast and Gulf Of Mexico
c/o Center for Marine Conservation
1725 DeSales Street NW
Washington, D.C. 20036

RESOURCES

Gulf of Mexico Program, Public Information Center, Building 1200, Room 103, Stennis Space Center, MS 39529-6000, (handout on Marine Debris Timeline) Phone: (601) 688-7940

Weber, Michael, Richard Townsend, and Rose Bierce, Environmental Quality in the Gulf of Mexico, Center for Marine Conservation and EPA, Washington, D.C. 20036.

Effective Communication:

1. Limit the length to one page or less; limit the subject to one topic.
2. State your position on the issue, why you hold that position, and what you want to see happen in regard to that issue.
3. If you write about a specific bill before Congress, include the bill name or number in your letter.

General Addresses:

Honorable (Senator's name)
United States Senate
Washington, D.C. 20510

Honorable (Representative's name)
House of Representatives
Washington, D.C. 20515

Student Sheet

Letter Format

Street Address (yours)
City, State, zip
Date

(skip a line)
Name of Business or Individual
Street Address
City, State, zip

Dear Sir/Madam: (use specific name if possible)

Body of letter. Skip line between each paragraph.

Skip a line between last paragraph and closing.

Sincerely,
Your Name
Title

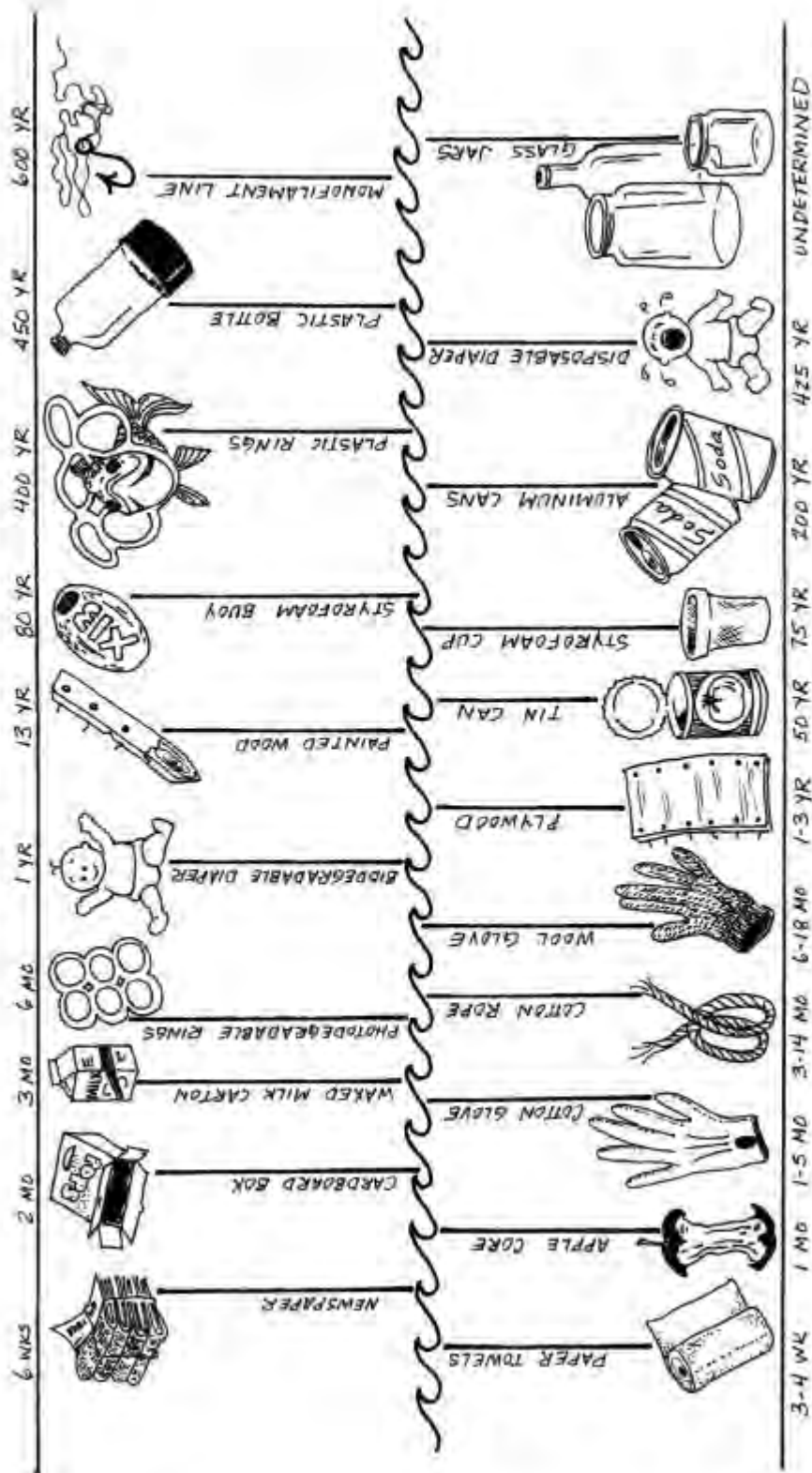
Student Sheet

HYPOTHETICAL SITUATION

John Doe was fishing one mile off the coast in a traffic area for cruise ships. He saw some plastic bags thrown off the ship; one floated near his boat. He hooked the bag, tore the top, and looked inside to find aluminum cans (recyclable), plastic rings (recyclable), and trash.

John knew it was illegal to dump garbage into the water; but he did not know what to do about it. He decided to write his Congressperson to protest the action he had witnessed. He quickly recorded the name of the ship.

MARINE DEBRIS TIMELINE



“HOW WATER PROCESSES MOVE SAND”

9-12

OBJECTIVES

The student will do the following:

1. Define longshore current.
2. Explain littoral drift.
3. Demonstrate longshore current and littoral drift.
4. Name six barrier islands in the Gulf of Mexico created by these two processes.

BACKGROUND INFORMATION

Water affects our whole life. But water affects us in ways that we do not realize until it is pointed out to us. We all enjoy going to the beach and walking, lying, or playing in the sand.

We do not think about the fact that it was water’s special capabilities that created the sandy beach we all enjoy and formed many barrier islands that are places of refuge for humans and habitats for wild animals of all kinds.

This activity explores the water processes, such as currents, tides, and wave action, that work to create the sandy coasts of the world. The islands and beaches of the Gulf of Mexico are used as examples, but sandy beaches and sandy barrier islands in any location can be profiled with this activity.

Sandy beaches and sandy barrier islands, such as the beaches and barrier islands found in the Gulf of Mexico, were not created so that humans could have fun in the sand and sun! However, sandy beaches and barrier islands do provide the first line of defense from damage due to storms and wave action. The islands and beaches take the brunt of the attack of waves and storms. They keep freshwater loaded with sediments and nutrients from completely spilling into the ocean. They

SUBJECTS:

Science (Physical Science, Earth Science, Physics), Social Studies (Geography)

TIME:

1 class period

MATERIALS:

5 gallons of sand
large wet table or equivalent outdoor area
hose with access to water
graph paper
pencils
rulers or measuring tapes
string to line off area used
map of barrier islands of the Gulf of Mexico (or equivalent)
shallows pans
¼ - ½ inch plastic tubing
small funnels to fit on tubing

maintain the integrity of the valuable estuaries behind them. And—they are a neat place to visit. They were created by water's ability to dissolve and move other substances. (Note: Sandy beaches and bars also occur along rivers, creeks, and lakes.)

Beaches have piles of sand, or sand dunes, that were brought there by the tides, waves, and currents in the oceans. Sand bars are underwater sand hills that were also deposited by ocean currents, waves, and tides. Both the beaches and the bars are very dynamic areas and are subject to removal or growth according to the action of the water's waves, tides, and currents. Sometimes the sand bars become so large that they rise above the water surface. They may then become stabilized with vegetation and may become known as barrier islands. It is important to remember that it was water that deposited these sandy beaches and bars.

In the Gulf of Mexico, the sand was originally deposited by river discharge from erosion of the Appalachian Mountains and the Rockies. Once the sand reached the Gulf, the tide, wave, and current energy took over movement of the sand particles. In the eastern Gulf of Mexico, the longshore current (the current that moves parallel with the shore) moves basically north along the lower part of Florida and then turns westward at the panhandle. As the water moves along the shore, it creates what is called the littoral drift. Littoral drift is the movement of sand in the direction of the prevailing longshore current. This process has been going on for tens of thousands of years and has shaped and changed the geography of the land it affects.

The beaches of Florida, Mississippi, and Alabama are known for their white sand shores and sandy swimming areas along these shores. The littoral drift created by the longshore current, tides, and wave action can be demonstrated in the classroom and interesting extensions can be assigned that will incorporate geography, geology, and even art into the lesson. Barrier islands, such as Petit Bois, Dauphin, Santa Rosa, Casey Key, and farther west off Texas - Montagorda and Padre Islands, are actually large ridges or bars of sand that have been deposited by river discharge, wave action, and tides. The island will slowly move in the direction of the prevailing winds and current (littoral drift). One end of the island may erode while the other end of this island grows! It is the capacity of water to move substances that students can explore and demonstrate.

Terms

accretion: the process of growing by being added to

adhesion: the act of sticking (surface attraction) or the state of being stuck together

barrier island: a ridge of sand and gravel thrown up parallel to a coastline by the waves and tides with a lagoon behind it

cohesion: the force by which the molecules of a substance are held together

current: a flow of water or air, especially when strong or swift, in a definite direction; specifically a flow within a larger body of water or mass of air

deposition: a laying or putting down (settling out suspended materials in a liquid due to a decrease in velocity of the suspension)

erosion: the process of detachment, transport, and deposition of soil material

littoral drift: movement of materials along the shore

longshore current: a flow of water that runs along the shoreline that is usually strong and swift

osmotic pressure: the force per unit area exerted by a solvent passing through a semipermeable membrane in osmosis, equal to the pressure that must be applied to the solution in order to prevent passage of the solvent into it

plane of turbulence: the flat, level, or even surface in which there is violent, irregular motion or swirling agitation of water

sand bar: a ridge or narrow shoal of sand formed in a river or along a shore by the action of currents, tides, and waves

sand dune: a pile of sand on the shore that is created by wind or water movement of the sand. Most are affected by wind and water.

surface tension: a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the formation of a meniscus. It is caused by unequal molecular cohesive forces near the surface.

thixotropy: the property of certain gels and emulsions to become fluid when agitated and then settle again when left at rest

tide: the alternate rise and fall of the surface of oceans and seas, and the bays and rivers connected with them, caused by the attraction of the moon and sun. The tide occurs once or twice in each period of 24 hours and 50 minutes.

viscosity: the state or quality of having a cohesive and sticky fluid consistency; a measure of resistance to flow upon applying a force

wave: a ridge or swell moving along the surface of a fluid or body of water as a result of disturbance, as

by wind

ADVANCE PREPARATION

- A. Have graph paper on hand.
- B. Either conduct small demonstrations in groups using shallow pans, or go outside to have a larger class demonstration with a hose.
- C. Collect materials.
- D. Go over lab procedure with students.

PROCEDURE

- I. Setting the stage
 - A. Put terms and definitions on the board.
 - B. Discuss Background Information.
 - C. Hand out graph paper and other necessary material.
 - D. Divide students into groups if group work was decided upon.
- II. Activity
 - A. Create an outside “beach” by pouring the sand in a long low “dune” in the selected spot or have student groups pour about a quart of sand in a shallow pan to create a ridge or dune.
 - B. Line off the sandy area with string. Measure and mark it off in inches or millimeters.
 - C. If using pans, put plastic tubing at one end of sand ridge and insert funnel in other end of tubing. The water will be poured into the funnel and will have the same effect as the hose. You may want to tilt the pan a little.
 - D. For pans - have students put graph paper into pan before pouring in sand. Then mark the measurements on paper.

E. Turn on hose with a slow, small flow or slowly pour water through funnel and let students observe how the water affects the sand “bar.”

F. Stop the water every minute or two to record the measurements for the movement of sand. You may take measurements on the long plane or short plane across the sandbar.

G. The sand will “erode” at the hose/tube end and “accrete” at the opposite end. Sand is heavier than water, but water’s ability to move other substances will be very apparent.

III. Follow-up

A. Have students make a graph of the data they recorded about the movement of sand. Each inch could be a mile, and each minute could be a year.

B. Ask:

1. Which way was the longshore current moving?
2. How far did the dune/island move in a week? month? year?
3. When would the dune/island be totally removed by the water?
4. Where was deposition taking place?
5. Where did most of the sand accrete?
6. Where was sand eroding?
7. Did the sand erode at the same rate all along the bar? Why or why not?
8. What water processes could you tell were taking place?

IV. Extensions

- A. Plot the volumetric flow and velocity of the water that passed over the bar.
- B. Plot the volume of sand removed and/or deposited.
- C. Study a map of barrier islands and have students name them.

D. Have students do a report on one of the barrier islands in the Gulf of Mexico.

E. Find some local area of soil erosion and photograph or map it. Check it after every storm for a semester and calculate its rate of movement or change. Predict long term effects.

V. Optional Extension

Ask students to study the following questions and respond in the next class period.

A. What happens when a channel or inlet is cut through a barrier island?

1. How does that affect the sand transport?

2. How does man prevent the channel from filling up with transported sand?

3. How does this affect sand transport “downstream” from the channel?

B. What happens if a groin is constructed to trap sand transport or to prevent a developed area from storm waves? How does this affect sand transport on either side of the groin?

C. Obtain nautical charts, areal photographs, or USGS quad maps of shoreline areas with channels, jetties, or groins to examine the beach profile. Estimate direction of littoral drift.

D. Explore the “Wave Theory”

$$C=L/T$$

Where C = wave celerity (speed at which a waveform propagates)

Where L = wavelength (crest to crest or trough to trough)

Where T = wave period (time between two successive wave crests)

Students can use this equation to estimate the length of time for waves produced by the storm to reach shore.

E. Explore the horizontal velocity

$$u = H/2 \times gT/L \times 1/\cosh(2(3.14) \times (d/L))$$

Where H = wave height (trough to crest)

Where g = gravity

Where d = water depth

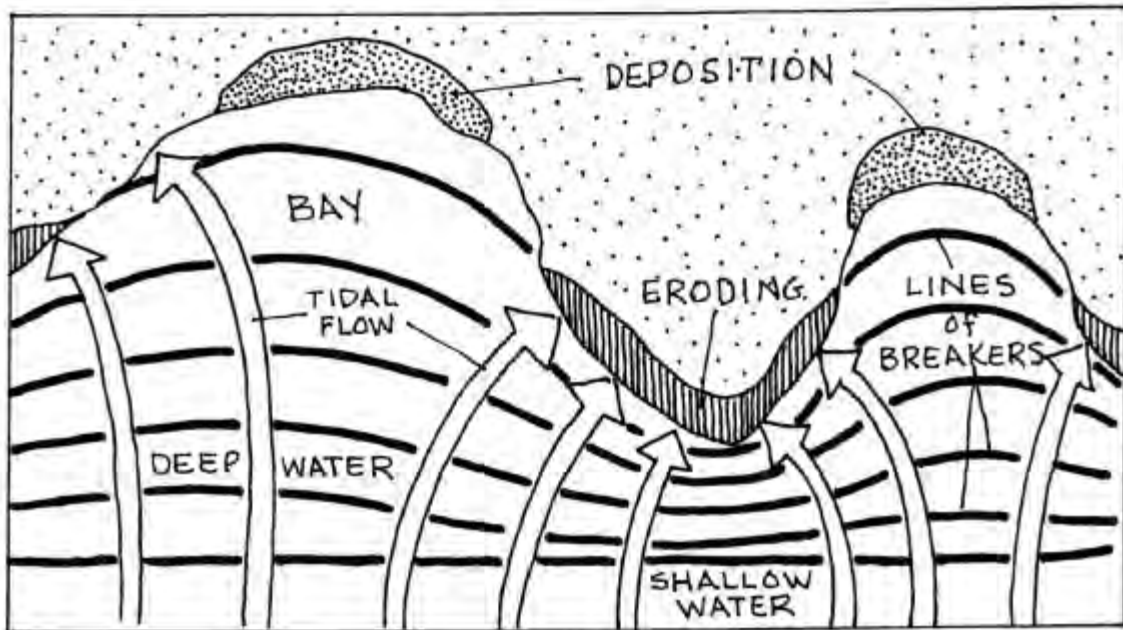
Students can measure wave heights and periods if located near a coast through simple observation. Students can estimate which waves (based on height, length, and periods) produce the greatest potential for transporting sediments. Would a storm producing long or high waves cause more erosion?

RESOURCES

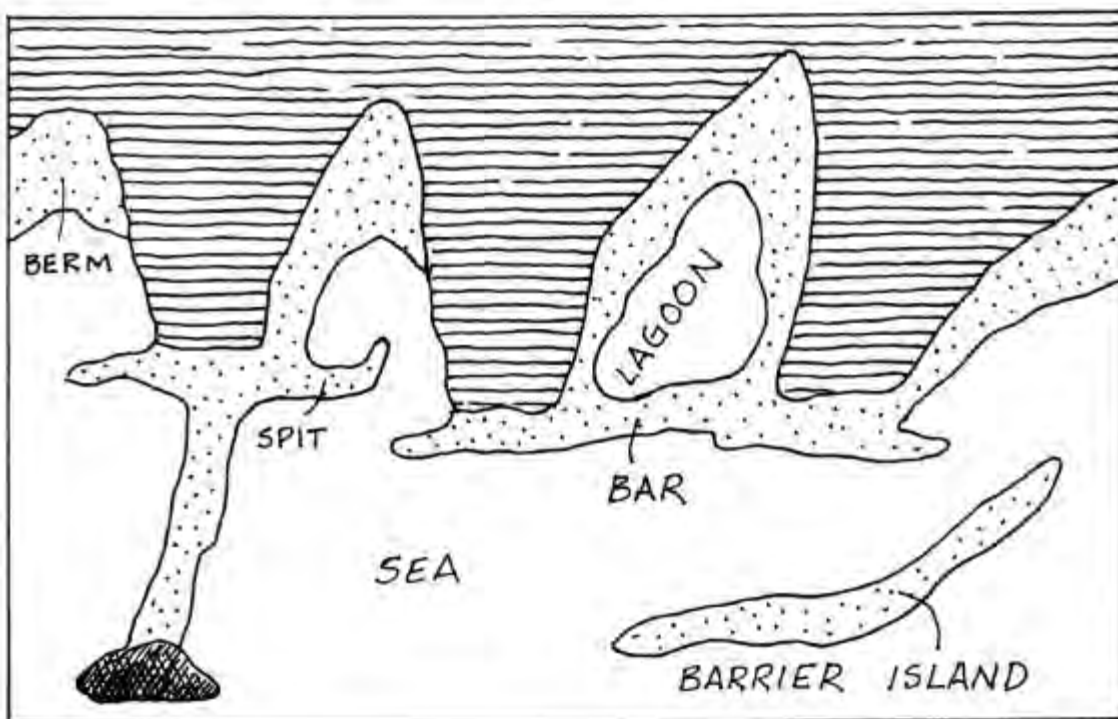
Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Gulf of Mexico Program, Public Information Center, Building 1200, Room 103, Stennis Space Center, MS 39529-6000, Phone: (601) 688-7940

TIDAL ACTION AND EROSION



ISLAND AND BAR DEPOSITION



SWEPT AWAY--OR--WHERE WILL YOU BE WHEN THE WATER COMES?

9-12

OBJECTIVES

The student will do the following:

1. Read "Swept Away" by Lodi L. Jacobson.
2. Cooperatively compile a vocabulary list.
3. Discuss the facts and the predictions listed in M s . Jacobson's article.
4. Write a science fiction-style story of 500-800 words set in one of the locations mentioned in "Swept Away"

SUBJECTS:

Language Arts, Social Studies
(Geography, Political Science)

TIME:

2-3 days of class time
1 week of outside work

MATERIALS:

copies of "Swept Away" (see Resources)

BACKGROUND INFORMATION

Students retain vocabulary better when they actually use the words themselves. Cooperatively compiling a vocabulary list from "Swept Away" will allow them to do this.

Many students are intimidated by a creative writing project; but with the facts and predictions in "Swept Away," they have a basis for building a story. This kind of creative work personalizes the problems that are caused by global warming, causing the students to internalize and to think seriously about a very real problem.

Terms

cartographer: a person whose work is making maps or charts

channel: (1) a body of water joining two larger bodies of water; (2) a channel could also be the physical dimensions of a stream or river

channeling: to make a channel or channels in

fossil fuels: hydrocarbon fuels, such as petroleum, derived from living things of a previous geologic time

sedimentation: the process of depositing sediment, or the addition of soils to lakes that is part of the natural aging process

ADVANCE PREPARATION

- A. Obtain from the library and photocopy “Swept Away” for each student.
- B. Review the list of possible vocabulary words (see Teacher Sheet).
- C. The teacher may also want to write a story and share it with students.

PROCEDURE

I. Setting the stage

- A. Discuss with the students some popular works of science fiction (Star Trek, Star Wars, 1984, Brave New World). Science fiction usually takes facts and predictions and puts “flesh” on them, creating situations and characters that make us think about ourselves.
- B. Divide the class into groups of four to work on vocabulary
 - 1. Each student should read “Swept Away,” underlining every word he/she does not know.
 - 2. Each group member should share his/her list with other group members. Those in the group who know what a word means should explain it to the rest of the group. The words left over--the ones no one knows--will be recorded and given to the teacher for a master list.
 - 3. A compilation of the words from each group will be the vocabulary list for this lesson.

II. Activity

- A. Give students the enclosed Instruction Sheet.

B. Students should re-read “Swept Away,” this time paying special attention to facts and predictions.

C. Each student should choose a location mentioned in “Swept Away” for a setting for his/her science fiction story. He/she should create characters and situations that would be appropriate for that location. The time setting should be anytime from 2050 to 2150.

D. Each student should use the facts and predictions in “Swept Away” as a springboard for his/her story.

III. Follow-up

A. Evaluation--Grading criteria should include:

1.Characters appropriate to setting	20%
2.Facts incorporated into story	20%
3.Cohesiveness of story from beginning to end	20%
4.Creativity	40%

B. You may have two English teachers read the stories and choose the top three. For these, give the “Luke Skywalker Science Fiction Award.”

IV. Extensions

A. Ask students to research the concept of global warming and write a brief report on their findings.

B. Find out how much water scientists believe is stored in the polar ice caps. What could this do to coastal regions if it all melted?

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX 1996

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. And Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm.

C. Brown Publishers, Dubuque, IA, 1997.

Enger, Eldon D. And Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishes, Dubuque, IA, 1983

Jacobson, Jodi L., "Swept Away," World Watch, January/February, 1989, pp. 20-26

Nebel, Bernard J. And Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

POSSIBLE VOCABULARY FOR “SWEPT AWAY”

1. aquifer
2. hydrologic
3. insidious
4. inundation
5. infrastructure
6. subsidence
7. accretion
8. tectonic
9. compaction
10. equilibrium
11. confluence
12. exacerbate
13. prodigious
14. extrapolate
15. encroachment

INSTRUCTIONS SHEET FOR “SWEPT AWAY”

1. Re-read “Swept Away.” This time, pay special attention to facts and predictions.
2. You should choose a location mentioned in the article as a setting for your science fiction story.
3. You should create characters and situations in your story that would be appropriate for that location and time.
4. Use the facts and predictions you have noted as a springboard for the plot development of your story.
5. The time setting of your story should be sometime between 2050 and 2150.

6. Your story should be 500-800 words long.

CORRELATION - CHAPTER 1

	The Hydrologic Cycle, 1-1	Surveying The Properties of Water, 1-11	Clearly H ₂ O, 1-21	Water, Water Everywhere, 1-29	A Global View of the Wet Earth, 1-41	Water Whiz - A Board Game, 1-55	Water: Poetic, Prosaic, Mosaic, 1-71	How Would We Say It Without Water?, 1-79	Water Careers, 1-85	Water: More Priceless Than Gold, 1-91	Water You Doing About This?, 1-97	Environmental Controversy: Class Project, 1-105	"pH - The First Clue to Water Quality", 1-109
MATHEMATICS													
Basic					X				X	X	X	X	
Advanced									X			X	
SCIENCE													
Biology	X	X				X			X			X	
Chemistry	X		X						X			X	X
Earth Science	X								X		X	X	X
Ecology/Environmental Science			X						X			X	X
Physical Science/Physics		X	X	X	X	X			X	X	X	X	
LANGUAGE ARTS							X	X	X			X	
SOCIAL STUDIES													
Economics/Political Science/Government					X	X			X	X	X	X	
Geography					X			X	X			X	
History									X	X		X	
RELATED ARTS													
Art					X				X			X	
Health									X		X	X	

CORRELATION - CHAPTER 1

[illegible]

CORRELATION - CHAPTER 2

CORRELATION - CHAPTER 2

CORRELATION - CHAPTER 3

	Biography of a River, 3-1	Catch Me If You Can - (Two Ways to...), 3-7	Help! Lake Overturning, 3-15	The Aging of Lakes, 3-25	Biodiversity = Water Quality, 3-29	Floods, 3-37	Best Management Practices for Forestry, 3-43	Simple Test For Microbial Contamination, 3-49	Pollutants: How Much Total or How..., 3-53	Ethical Dilemmas - What's A Body To Do?, 3-59	What Are Fecal Coliforms and How..., 3-63	Turbidity, 3-71	Clean Clothes - Clean Environment? Phosphates, 3-79
MATHEMATICS													
Basic		X							X				X
Advanced													
SCIENCE													
Biology			X	X	X		X	X			X		X
Chemistry									X			X	X
Earth Science	X		X	X		X				X		X	
Ecology/Environmental Science			X		X		X	X			X	X	
Physical Science/Physics	X	X				X							
LANGUAGE ARTS	X									X			
SOCIAL STUDIES													
Economics/Political Science/Government	X									X			X
Geography	X	X				X							
History	X					X							
RELATED ARTS													
Art													
Health							X	X			X		

CORRELATION - CHAPTER 3

[illegible]

CORRELATION - CHAPTER 4

	Groundwater Basics, 4-1	From Ground to Water, 4-11	What's the Level, 4-19	What Goes On Down Under?, 4-27	Do You Drink It?, 4-37	Hydraulic Head, 4-51	Flow Nets, 4-61	Groundwater: Cleaning Up, 4-67	What is Groundwater Pollution Doing..., 4-77	Radon In Water, 4-85	Landfills and the Potential for Groundwater..., 4-97	Leaking Underground Storage Tanks, 4-107	
MATHEMATICS													
Basic						X				X	X	X	
Advanced	X												
SCIENCE													
Biology													
Chemistry											X		
Earth Science		X		X	X			X					
Ecology/Environmental Science			X	X	X			X	X	X	X	X	
Physical Science/Physics	X	X	X	X	X	X	X	X					
LANGUAGE ARTS		X											
SOCIAL STUDIES													
Economics/Political Science/Government							X	X				X	
Geography					X				X	X			
History													
RELATED ARTS													
Art			X										
Health									X				

[illegible]

**CORRELATION OF NATIONAL SCIENCE STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY ACTIVITY)

Activity	Standard	Relation
CHAPTER 1- INTRODUCTION TO WATER		
THE HYDROLOGIC (WATER) CYCLE	Unifying Concepts and Processes: Systems, order, and organization	3
	Unifying Concepts and Processes: Evidence, models, and explanation	3
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Physical Science: develop an understanding of interactions of energy and matter	1
	Life Science: develop understanding of matter, energy, and organization in living systems	3
	Earth and Space Science: develop understanding of energy in the earth	1
	Earth and Space Science: develop understanding of geochemical cycles	2
SURVEYING THE PROPERTIES OF WATER	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of structure and properties of matter	3
	Physical Science: develop an understanding of chemical reactions	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
CLEARLY H ₂ O	Unifying Concepts and Processes: Evidence, models, and explanation	3
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of structure and properties of matter	2
	Physical Science: develop an understanding of chemical reactions	2
	Physical Science: develop an understanding of interactions of energy and matter	1
WATER, WATER EVERYWHERE	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

**CORRELATION OF NATIONAL SCIENCE STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY ACTIVITY)

Activity	Standard	Relation
WATER, WATER EVERYWHERE (CON'T)	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Earth and Space Science: develop understanding of geochemical cycles	1
	Science and Technology: develop abilities of technological design	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
A GLOBAL VIEW OF THE WET EARTH	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Earth and Space Science: develop understanding of energy in the earth	1
	Earth and Space Science: develop understanding of geochemical cycles	1
	Science and Technology: develop abilities of technological design	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
WATER WHIZ - A BOARD GAME	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Science and Technology: develop understandings about science and technology	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
WATER: POETIC, PROSAIC, MOSAIC	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12) (BY ACTIVITY)

Activity	Standard	Relation
HOW WOULD WE SAY IT WITHOUT WATER?	History and Nature of Science: develop understanding of history of science Science in Personal and Social Perspectives: develop understanding of natural resources	1 2
WATER CAREERS	History and Nature of Science: develop understanding of science as a human endeavor History and Nature of Science: develop understanding of nature of science History and Nature of Science: develop understanding of history of science Science and Technology: develop understandings about science and technology Science in Personal and Social Perspectives: develop understanding of natural resources Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2 1 1 2 2 2
WATER: MORE PRICELESS THAN GOLD	Unifying Concepts and Processes: Systems, order, and organization Unifying Concepts and Processes: Evidence, models, and explanation Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop understanding about scientific enquiry Science in Personal and Social Perspectives: develop understanding of personal and community health Science in Personal and Social Perspectives: develop understanding of population growth Science in Personal and Social Perspectives: develop understanding of natural resources Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2 2 2 2 1 1 3 2
WATER YOU DOING ABOUT THIS?	Unifying Concepts and Processes: Systems, order, and organization Unifying Concepts and Processes: Evidence, models, and explanation Science as Inquiry: develop abilities necessary to do scientific inquiry	2 2 2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

**CORRELATION OF NATIONAL SCIENCE STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY ACTIVITY)

Activity	Standard	Relation
	Science as Inquiry: develop understanding about scientific enquiry	1
	Science in Personal and Social Perspectives: develop understanding of personal and community health	1
WATER YOU DOING ABOUT THIS?(CON'T)	Science in Personal and Social Perspectives: develop understanding of population growth	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	History and Nature of Science: develop understanding of science as a human endeavor	1
	Science and Technology: develop understandings about science and technology	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
"pH - THE FIRST CLUE TO WATER QUALITY"	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	3
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of chemical reactions	3
	Physical Science: develop an understanding of conservation of energy and increase in disorder	3

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Earth and Space Science: develop understanding of geochemical cycles	2
WHAT'S IN A BOTTLE OF WATER?	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Science as Inquiry: develop understanding about scientific enquiry	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
WHAT'S IN A BOTTLE OF WATER? (CON'T)	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
KEEP OUR COMMUNITY BEAUTIFUL!	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Science as Inquiry: develop understanding about scientific enquiry	1
	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	(No correlation to this activity)	
INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	Unifying Concepts and Processes: Evidence, models, and explanation	2
	History and Nature of Science: develop understanding of science as a human endeavor	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Science as Inquiry: develop understanding about scientific enquiry	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
ENVIRONMENTAL INFRASTRUCTURE FINANCING	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Science as Inquiry: develop understanding about scientific enquiry	1
ENVIRONMENTAL INFRASTRUCTURE FINANCING (CON'T)	Science and Technology: develop understandings about science and technology	1
	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3
THERE "OUGHTA" BE A LAW	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	3
	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Science as Inquiry: develop understanding about scientific enquiry	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
UNCLE SAM SAYS, "KEEP IT CLEAN!"	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science as Inquiry: develop understanding about scientific enquiry	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12) (BY ACTIVITY)

Activity	Standard	Relation
WATER CHEMISTRY CHECKUP	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Science as Inquiry: develop understanding about scientific enquiry	2
	Physical Science: develop an understanding of chemical reactions	2
	Earth and Space Science: develop understanding of geochemical cycles	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3
HOW HARD IS WATER?	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop understanding about scientific enquiry	3
	Physical Science: develop an understanding of structure and properties of matter	2
	Physical Science: develop an understanding of chemical reactions	2
	Earth and Space Science: develop understanding of geochemical cycles	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3
IS YOUR WATER WELL FOR DRINKING?	Unifying Concepts and Processes: Evidence, models, and explanation	2
	History and Nature of Science: develop understanding of science as a human endeavor	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Physical Science: develop an understanding of structure and properties of matter Earth and Space Science: develop understanding of energy in the earth Earth and Space Science: develop understanding of geochemical cycles	2 1 2
IS YOUR WATER WELL FOR DRINKING? (CON'T)	Science and Technology: develop understandings about science and technology Science in Personal and Social Perspectives: develop understanding of natural resources Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2 1 2
CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT		
WATER WORKS	Unifying Concepts and Processes: Systems, order, and organization Unifying Concepts and Processes: Evidence, models, and explanation Science as Inquiry: develop abilities necessary to do scientific inquiry Physical Science: develop an understanding of structure and properties of matter Physical Science: develop an understanding of chemical reactions Science and Technology: develop abilities of technological design Science and Technology: develop understandings about science and technology	2 2 3 1 2 1 3
CARBON TREATMENT FOR WATER POLLUTION CONTROL	Unifying Concepts and Processes: Evidence, models, and explanation Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop understanding about scientific enquiry Physical Science: develop an understanding of structure and properties of matter Physical Science: develop an understanding of chemical reactions Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2 3 1 2 3 1
CHLORINATION FOR DISINFECTION	Unifying Concepts and Processes: Evidence, models, and explanation	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop understanding about scientific enquiry Physical Science: develop an understanding of structure and properties of matter Physical Science: develop an understanding of chemical reactions	3 1 2 3
CHLORINATION FOR DISINFECTION (CON'T)	Science in Personal and Social Perspectives: develop understanding of personal and community health Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1 2 1
DRINKING WATER JEOPARDY	Unifying Concepts and Processes: Evidence, models, and explanation Physical Science: develop an understanding of structure and properties of matter Science in Personal and Social Perspectives: develop understanding of natural resources Science in Personal and Social Perspectives: develop understanding of environmental quality Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	1 1 2 3 1
SOURCE WATER PROTECTION: Surface Water Sources	Unifying Concepts and Processes: Systems, order, and organization Unifying Concepts and Processes: Evidence, models, and explanation Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop understanding about scientific enquiry Physical Science: develop an understanding of chemical reactions Earth and Space Science: develop understanding of energy in the earth Science and Technology: develop understandings about science and technology	2 2 3 2 2 1 1 2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of personal and community health	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
SOURCE WATER PROTECTION: Groundwater Sources	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Science as Inquiry: develop understanding about scientific enquiry	1
	Earth and Space Science: develop understanding of energy in the earth	1
	Science and Technology: develop abilities of technological design	3
	Science and Technology: develop understandings about science and technology	2
	Science in Personal and Social Perspectives: develop understanding of personal and community health	3
	Science in Personal and Social Perspectives: develop understanding of natural resources	3
HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Unifying Concepts and Processes: Evolution and equilibrium	1
METAL POLLUTION REDUCTION	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of motions and forces	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of structure and properties of matter	1
	Physical Science: develop an understanding of chemical reactions	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Physical Science: develop an understanding of interactions of energy and matter	1
METAL POLLUTION REDUCTION (CON'T)	Science and Technology: develop abilities of technological design	3
	Science in Personal and Social Perspectives: develop understanding of natural resources	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
WHAT IS IN SOURCE WATER?	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Life Science: develop understanding of biological evolution	1
	Life Science: develop an understanding of interdependence of organisms	2
	Life Science: develop understanding of behavior of organisms	1
WASTEWATER TREATMENT	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Science as Inquiry: develop understanding about scientific enquiry	2
	Physical Science: develop an understanding of chemical reactions	1
	Science and Technology: develop abilities of technological design	3
	Science and Technology: develop understandings about science and technology	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2

RELATIONSHIP:

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**CORRELATION OF NATIONAL SCIENCE STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY ACTIVITY)

Activity	Standard	Relation
THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of structure and properties of matter	2
	Physical Science: develop an understanding of chemical reactions	2
	Physical Science: develop an understanding of interactions of energy and matter	1
	Life Science: develop an understanding of interdependence of organisms	2
	Life Science: develop understanding of matter, energy, and organization in living systems	1
	Life Science: develop understanding of behavior of organisms	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	1
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
HOME RECYCLING OF GRAYWATER	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Science as Inquiry: develop understanding about scientific enquiry	1
	Physical Science: develop an understanding of chemical reactions	1
	Life Science: develop an understanding of interdependence of organisms	1
	Science and Technology: develop abilities of technological design	3
	Science in Personal and Social Perspectives: develop understanding of personal and community health	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
DO SEPTIC TANKS DO THE JOB?	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of chemical reactions	2
	Physical Science: develop an understanding of motions and forces	1
	Physical Science: develop an understanding of interactions of energy and matter	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
	Science and Technology: develop abilities of technological design	3
	Science in Personal and Social Perspectives: develop understanding of personal and community health	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
LAND APPLICATIONS OF WASTEWATER SOLIDS	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	1
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Science as Inquiry: develop understanding about scientific enquiry	1
	Physical Science: develop an understanding of structure and properties of matter	1
	Physical Science: develop an understanding of chemical reactions	1
	Physical Science: develop an understanding of interactions of energy and matter	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Life Science: develop understanding of matter, energy, and organization in living systems Earth and Space Science: develop understanding of geochemical cycles Science and Technology: develop abilities of technological design	1 1 2
LAND APPLICATIONS OF WASTEWATER SOLIDS (CON'T)	Science and Technology: develop understandings about science and technology Science in Personal and Social Perspectives: develop understanding of natural resources Science in Personal and Social Perspectives: develop understanding of environmental quality Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1 1 2 1
STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	Unifying Concepts and Processes: Systems, order, and organization Unifying Concepts and Processes: Evidence, models, and explanation Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop understanding about scientific enquiry Physical Science: develop an understanding of chemical reactions Physical Science: develop an understanding of motions and forces Physical Science: develop an understanding of interactions of energy and matter Life Science: develop understanding of matter, energy, and organization in living systems Earth and Space Science: develop understanding of geochemical cycles Science and Technology: develop abilities of technological design Science in Personal and Social Perspectives: develop understanding of personal and community health Science in Personal and Social Perspectives: develop understanding of natural resources	1 1 3 2 2 1 1 1 1 1 3 1 2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
CHAPTER 3- SURFACE WATER RESOURCES		
BIOGRAPHY OF A RIVER	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Physical Science: develop an understanding of motions and forces	2
	Physical Science: develop an understanding of interactions of energy and matter	1
	Earth and Space Science: develop understanding of energy in the earth	2
CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of motions and forces	2
	Physical Science: develop an understanding of interactions of energy and matter	2
	Earth and Space Science: develop understanding of energy in the earth	2
	Earth and Space Science: develop understanding of geochemical cycles	1
HELP! LAKE OVERTURNING!	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Unifying Concepts and Processes: Evolution and equilibrium	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of chemical reactions	2
	Physical Science: develop an understanding of motions and forces	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
HELP! LAKE OVERTURNING! (CON'T)	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Physical Science: develop an understanding of interactions of energy and matter	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
	Earth and Space Science: develop understanding of energy in the earth	1
	Earth and Space Science: develop understanding of geochemical cycles	1
THE AGING OF LAKES	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of structure and properties of matter	1
	Physical Science: develop an understanding of chemical reactions	2
	Physical Science: develop an understanding of interactions of energy and matter	1
	Life Science: develop an understanding of interdependence of organisms	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
BIODIVERSITY = WATER QUALITY	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
	Life Science: develop understanding of behavior of organisms	2
FLOODS	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
FLOODS (CON'T)	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Physical Science: develop an understanding of motions and forces	2
	Physical Science: develop an understanding of interactions of energy and matter	2
	Earth and Space Science: develop understanding of energy in the earth	2
BEST MANAGEMENT PRACTICES FOR FORESTRY	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	History and Nature of Science: develop understanding of science as a human endeavor	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Science as Inquiry: develop understanding about scientific enquiry	1
	Physical Science: develop an understanding of interactions of energy and matter	1
	Life Science: develop understanding of matter, energy, and organization in living systems	2
	Earth and Space Science: develop understanding of energy in the earth	1
	Science and Technology: develop abilities of technological design	2
	Science and Technology: develop understandings about science and technology	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
SIMPLE TEST FOR MICROBIAL CONTAMINATION	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Life Science: develop understanding of behavior of organisms	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of structure and properties of matter	2
	Physical Science: develop an understanding of chemical reactions	2
ETHICAL DILEMMAS WHAT'S A BODY TO DO?	(No correlation to this activity.)	
WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of chemical reactions	1
	Life Science: develop an understanding of interdependence of organisms	1
	Life Science: develop understanding of matter, energy, and organization in living systems	1
	Life Science: develop understanding of behavior of organisms	2
	Science in Personal and Social Perspectives: develop understanding of personal and community health	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
TURBIDITY	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
TURBIDITY (CON'T)	Physical Science: develop an understanding of interactions of energy and matter	1
	Earth and Space Science: develop understanding of geochemical cycles	1
CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science in Personal and Social Perspectives: develop understanding of personal and community health	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
WHAT TURNED THE CREEK ORANGE?	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Physical Science: develop an understanding of chemical reactions	2
	Earth and Space Science: develop understanding of energy in the earth	1
	Earth and Space Science: develop understanding of geochemical cycles	2
THERMAL POLLUTION	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of motions and forces	1
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Physical Science: develop an understanding of interactions of energy and matter	1
	Earth and Space Science: develop understanding of energy in the earth	2
CHAPTER 4- GROUNDWATER RESOURCES		
GROUNDWATER BASIC	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Physical Science: develop an understanding of interactions of energy and matter	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12) (BY ACTIVITY)

Activity	Standard	Relation
FROM GROUND TO WATER	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Physical Science: develop an understanding of motions and forces	1
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Earth and Space Science: develop understanding of energy in the earth	2
	Earth and Space Science: develop an understanding of origin and evolution of the universe	2
WHAT'S THE LEVEL?	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Physical Science: develop an understanding of motions and forces	1
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Earth and Space Science: develop understanding of energy in the earth	2
	Earth and Space Science: develop an understanding of origin and evolution of the universe	2
WHAT GOES ON DOWN UNDER?	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Physical Science: develop an understanding of motions and forces	1
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Earth and Space Science: develop understanding of energy in the earth	2
DO YOU DRINK IT?	Earth and Space Science: develop an understanding of origin and evolution of the universe	2
	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	History and Nature of Science: develop understanding of science as a human endeavor	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Physical Science: develop an understanding of motions and forces	2
	Physical Science: develop an understanding of interactions of energy and matter	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
DO YOU DRINK IT? (CON'T)	Earth and Space Science: develop understanding of energy in the earth	1
	Science and Technology: develop abilities of technological design	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
HYDRAULIC HEAD	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Physical Science: develop an understanding of interactions of energy and matter	1
	Earth and Space Science: develop understanding of energy in the earth	2
	Earth and Space Science: develop understanding of geochemical cycles	2
FLOW NETS	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	3
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Physical Science: develop an understanding of interactions of energy and matter	1
	Earth and Space Science: develop understanding of energy in the earth	2
	Earth and Space Science: develop understanding of geochemical cycles	2
	Science and Technology: develop abilities of technological design	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
GROUNDWATER: CLEANING UP	Unifying Concepts and Processes: Systems, order, and organization	1
	History and Nature of Science: develop understanding of science as a human endeavor	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
RADON IN WATER	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
	Unifying Concepts and Processes: Systems, order, and organization	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	2
	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	3
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Physical Science: develop an understanding of chemical reactions	1
	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	3
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2
LEAKING UNDERGROUND STORAGE TANKS	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Physical Science: develop an understanding of motions and forces	1
	Science and Technology: develop understandings about science and technology	2
	Science in Personal and Social Perspectives: develop understanding of personal and community health	2
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
CHAPTER 5- WETLANDS AND COASTAL WATERS		
AN ALTERNATIVE TO THE "WHAT I DID ON SUMMER VACATION-"WHAT I CAN DO ON SUMMER VACATION"	(No correlation to this activity)	
UNDERSTANDING MARINE RESOURCES	Unifying Concepts and Processes: Systems, order, and organization	1
	Life Science: develop understanding of matter, energy, and organization in living systems	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	2
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
RIVER INPUT INTO THE GULF OF MEXICO	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Life Science: develop understanding of matter, energy, and organization in living systems	1
	Earth and Space Science: develop understanding of energy in the earth	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
WETLANDS, USA - MORE THAN SWAMPS!	Unifying Concepts and Processes: Systems, order, and organization	2
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Life Science: develop an understanding of interdependence of organisms	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
KNOW YOUR GULF	(No correlation to this activity)	
SEA MARGIN DIVERSITY	Unifying Concepts and Processes: Systems, order, and organization	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12) (BY ACTIVITY)

Activity	Standard	Relation
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Life Science: develop an understanding of the cell	1
SEA MARGIN DIVERSITY (CON'T)	Life Science: develop an understanding of interdependence of organisms	2
	Life Science: develop understanding of matter, energy, and organization in living systems	2
ESTUARIES: INTERFACE BETWEEN SEA AND LAND	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Life Science: develop an understanding of interdependence of organisms	2
	Life Science: develop understanding of matter, energy, and organization in living systems	1
	Life Science: develop understanding of behavior of organisms	1
	Earth and Space Science: develop understanding of energy in the earth	1
EROSION KILL THE HABITATS THAT FEED YOU!	Unifying Concepts and Processes: Systems, order, and organization	1
	Unifying Concepts and Processes: Evidence, models, and explanation	2
	Unifying Concepts and Processes: Constancy, change, and measurement	1
	Science as Inquiry: develop abilities necessary to do scientific inquiry	1
	Physical Science: develop an understanding of motions and forces	2
	Physical Science: develop an understanding of conservation of energy and increase in disorder	1
	Earth and Space Science: develop understanding of energy in the earth	2
	Earth and Space Science: develop understanding of geochemical cycles	1
	Science in Personal and Social Perspectives: develop understanding of natural resources	1
	Science in Personal and Social Perspectives: develop understanding of environmental quality	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	1
OIL SPILLS	Unifying Concepts and Processes: Evidence, models, and explanation Unifying Concepts and Processes: Constancy, change, and measurement History and Nature of Science: develop understanding of science as a human endeavor	2 1 1
OIL SPILLS (CON'T)	Science as Inquiry: develop abilities necessary to do scientific inquiry Science as Inquiry: develop understanding about scientific enquiry Physical Science: develop an understanding of structure and properties of matter Physical Science: develop an understanding of chemical reactions Physical Science: develop an understanding of interactions of energy and matter Science and Technology: develop abilities of technological design Science and Technology: develop understandings about science and technology Science in Personal and Social Perspectives: develop understanding of natural resources Science in Personal and Social Perspectives: develop understanding of environmental quality Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	2 1 1 2 1 3 2 2 3 2 2
IMPACT GOVERNMENTAL REGULATIONS ON MARINE DEBRIS - WRITE A LETTER!	(No correlation to this activity)	
"HOW WATER PROCESSES MOVE SAND"	Unifying Concepts and Processes: Systems, order, and organization Unifying Concepts and Processes: Evidence, models, and explanation Physical Science: develop an understanding of motions and forces	2 2 2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY ACTIVITY)

Activity	Standard	Relation
	Physical Science: develop an understanding of interactions of energy and matter	2
	Earth and Space Science: develop understanding of energy in the earth	2
SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	(No correlation to this activity)	

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Unifying Concepts and Processes: Systems, order, and organization	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	3
	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	1
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	2
	THERE "OUGHTA" BE A LAW	1
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	1
	WATER CHEMISTRY CHECKUP	2
	HOW HARD IS WATER?	2
	CHAPTER 2-DRINKING WATER AND WASTEWATER TREATMENT	
	WATER WORKS	2
	SOURCE WATER PROTECTION:	2
	Surface Water Sources	
	SOURCE WATER PROTECTION:	2
	Groundwater Sources	
	WHAT IS IN SOURCE WATER?	2
	WASTEWATER TREATMENT	2
	THE WORLD OF BIOLOGICAL	1
	WASTEWATER TREATMENT	
	HOME RECYCLING OF GRAYWATER	1
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF	1
	WASTEWATER SOLIDS	
	STORM WATER: BEST	1
	MANAGEMENT PRACTICES AND	
	POLLUTION PREVENTION	
	CHAPTER 3- SURFACE WATER RESOURCES	
	BIOGRAPHY OF A RIVER	1
	CATCH ME IF YOU CAN -- (TWO	1
	WAYS TO MEASURE STREAM	
	FLOW)	
	HELP! LAKE OVERTURNING!	2
	THE AGING OF LAKES	2
	BIODIVERSITY = WATER QUALITY	2
	FLOODS	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Unifying Concepts and Processes: Systems, order, and organization (con't)	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	SIMPLE TEST FOR MICROBIAL CONTAMINATION	1
	POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	1
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	DO YOU DRINK IT?	2
	HYDRAULIC HEAD	2
	FLOW NETS	2
	GROUNDWATER: CLEANING UP	1
	RADON IN WATER	1
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	UNDERSTANDING MARINE RESOURCES	1
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	1
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1
	EROSION KILL THE HABITATS THAT FEED YOU!	1
	"HOW WATER PROCESSES MOVE SAND"	2
Unifying Concepts and Processes: Evidence, models, and explanation	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	3
	SURVEYING THE PROPERTIES OF WATER	2
	CLEARLY H ₂ O	3
	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	1
	WATER WHIZ - A BOARD GAME	2
	WATER: MORE PRICELESS THAN GOLD	2
Unifying Concepts and Processes: Evidence, models, and explanation (con't)	WATER YOU DOING ABOUT THIS?	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	2
	"pH - THE FIRST CLUE TO WATER QUALITY"	2
	WHAT'S IN A BOTTLE OF WATER?	1
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	2
	THERE "OUGHTA" BE A LAW	1
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	1
	WATER CHEMISTRY CHECKUP	2
	HOW HARD IS WATER?	2
	IS YOUR WATER WELL FOR DRINKING?	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WATER WORKS	2
	CARBON TREATMENT FOR WATER	2
	POLLUTION CONTROL	
	CHLORINATION FOR DISINFECTION	2
	DRINKING WATER JEOPARDY	1
	SOURCE WATER PROTECTION:	2
	Surface Water Sources	
	SOURCE WATER PROTECTION:	2
	Groundwater Sources	
	HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	2
	METAL POLLUTION REDUCTION	2
	WHAT IS IN SOURCE WATER?	2
	WASTEWATER TREATMENT	2
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	2
	HOME RECYCLING OF GRAYWATER	2
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Unifying Concepts and Processes: Evidence, models, and explanation (con't)	CHAPTER 3- SURFACE WATER RESOURCES	
	BIOGRAPHY OF A RIVER	1
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	HELP! LAKE OVERTURNING!	1
	HELP! LAKE OVERTURNING!	2
	THE AGING OF LAKES	1
	BIODIVERSITY = WATER QUALITY	2
	FLOODS	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	SIMPLE TEST FOR MICROBIAL CONTAMINATION	2
	POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	1
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	1
	TURBIDITY	1
	CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	1
	WHAT TURNED THE CREEK ORANGE?	1
	THERMAL POLLUTION	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	FROM GROUND TO WATER	1
	WHAT'S THE LEVEL?	1
	WHAT GOES ON DOWN UNDER?	1
	DO YOU DRINK IT?	2
	HYDRAULIC HEAD	2
	FLOW NETS	2
	WHAT IS GROUNDWATER	1
	POLLUTION DOING TO THE NEIGHBORHOOD?	
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	RIVER INPUT INTO THE GULF OF MEXICO	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Unifying Concepts and Processes: Evidence, models, and explanation (con't)	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	OIL SPILLS	2
	"HOW WATER PROCESSES MOVE SAND"	2
Unifying Concepts and Processes: Constancy, change, and measurement	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	2
	SURVEYING THE PROPERTIES OF WATER	2
	CLEARLY H ₂ O	2
	WATER, WATER EVERYWHERE	1
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	"pH - THE FIRST CLUE TO WATER QUALITY"	2
	WATER CHEMISTRY CHECKUP	2
	HOW HARD IS WATER?	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	2
	METAL POLLUTION REDUCTION	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	1
	HELP! LAKE OVERTURNING!	1
	THE AGING OF LAKES	1
	FLOODS	1
	SIMPLE TEST FOR MICROBIAL CONTAMINATION	2
	POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	2
	THERMAL POLLUTION	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	GROUNDWATER BASIC	2
	WHAT GOES ON DOWN UNDER?	1
	HYDRAULIC HEAD	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Unifying Concepts and Processes: Constancy, change, and measurement (con't)	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	EROSION KILL THE HABITATS THAT FEED YOU!	1
	OIL SPILLS	1
Unifying Concepts and Processes: Evolution and equilibrium	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	1
	CHAPTER 3- SURFACE WATER RESOURCES	
Science as Inquiry: develop abilities necessary to do scientific inquiry	HELP! LAKE OVERTURNING!	1
	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	3
	SURVEYING THE PROPERTIES OF WATER	3
	WATER WHIZ - A BOARD GAME	1
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	SOURCE WATER PROTECTION: Surface Water Sources	3
	WATER WORKS	3
	CHAPTER 3- SURFACE WATER RESOURCES	
	HELP! LAKE OVERTURNING!	2
History and Nature of Science: develop understanding of science as a human endeavor	CHAPTER 1- INTRODUCTION TO WATER	
	WATER CAREERS	2
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	1
	IS YOUR WATER WELL FOR DRINKING?	2
	CHAPTER 3- SURFACE WATER RESOURCES	
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	DO YOU DRINK IT?	1
	GROUNDWATER: CLEANING UP	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

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Standard	Activity	Relation
History and Nature of Science: develop understanding of nature of science	CHAPTER 1- INTRODUCTION TO WATER	
	WATER CAREERS	1
History and Nature of Science: develop understanding of history of science	CHAPTER 1- INTRODUCTION TO WATER	
	HOW WOULD WE SAY IT WITHOUT WATER?	1
	WATER CAREERS	1
Science as Inquiry: develop abilities necessary to do scientific inquiry	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	2
	CLEARLY H ₂ O	3
	A GLOBAL VIEW OF THE WET EARTH	1
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	2
	"pH - THE FIRST CLUE TO WATER QUALITY"	3
	WHAT'S IN A BOTTLE OF WATER?	2
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	1
	THERE "OUGHTA" BE A LAW	1
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	1
	WATER CHEMISTRY CHECKUP	3
	HOW HARD IS WATER?	3
	IS YOUR WATER WELL FOR DRINKING?	1
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	CARBON TREATMENT FOR WATER POLLUTION CONTROL	3
	CHLORINATION FOR DISINFECTION	3
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	3
	METAL POLLUTION REDUCTION	3

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science as Inquiry: develop abilities necessary to do scientific inquiry (con't)	WHAT IS IN SOURCE WATER?	2
	WASTEWATER TREATMENT	3
	THE WORLD OF BIOLOGICAL	2
	WASTEWATER TREATMENT	
	HOME RECYCLING OF GRAYWATER	3
	DO SEPTIC TANKS DO THE JOB?	3
	LAND APPLICATIONS OF	3
	WASTEWATER SOLIDS	
	STORM WATER: BEST	3
	MANAGEMENT PRACTICES AND	
	POLLUTION PREVENTION	
	CHAPTER 3- SURFACE WATER RESOURCES	
	BIOGRAPHY OF A RIVER	1
	CATCH ME IF YOU CAN -- (TWO	2
	WAYS TO MEASURE STREAM	
	FLOW)	
	THE AGING OF LAKES	2
	BIODIVERSITY = WATER QUALITY	2
	FLOODS	1
	BEST MANAGEMENT PRACTICES	2
	FOR FORESTRY	
	SIMPLE TEST FOR MICROBIAL	2
	CONTAMINATION	
	POLLUTANTS: HOW MUCH TOTAL	2
	OR HOW MUCH PER UNIT OF	
	WATER?	
	WHAT ARE FECAL COLIFORMS AND	2
	HOW ARE THEY RELATED TO	
	WATER QUALITY?	
	TURBIDITY	2
	WHAT TURNED THE CREEK	1
	ORANGE?	
	THERMAL POLLUTION	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	DO YOU DRINK IT?	1
	HYDRAULIC HEAD	2
	FLOW NETS	3
	RADON IN WATER	2
	LEAKING UNDERGROUND	1
	STORAGE TANKS	

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science as Inquiry: develop abilities necessary to do scientific inquiry (con't)	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	RIVER INPUT INTO THE GULF OF MEXICO	1
	WETLANDS, USA - MORE THAN SWAMPS!	1
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1
	EROSION KILL THE HABITATS THAT FEED YOU!	1
	OIL SPILLS	2
	CHAPTER 1- INTRODUCTION TO WATER	
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	1
	WHAT'S IN A BOTTLE OF WATER?	2
Science as Inquiry: develop understanding about scientific enquiry	KEEP OUR COMMUNITY BEAUTIFUL!	1
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	1
	THERE "OUGHTA" BE A LAW	1
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	1
	WATER CHEMISTRY CHECKUP	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	CARBON TREATMENT FOR WATER POLLUTION CONTROL	1
	CHLORINATION FOR DISINFECTION	1
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	1
	WASTEWATER TREATMENT	2
	HOME RECYCLING OF GRAYWATER	1
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science as Inquiry: develop understanding about scientific enquiry (con't)	CHAPTER 3- SURFACE WATER RESOURCES	
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	1
Physical Science: develop an understanding of structure and properties of matter	CHAPTER 1- INTRODUCTION TO WATER	
	SURVEYING THE PROPERTIES OF WATER	3
	CLEARLY H ₂ O	2
	HOW HARD IS WATER?	2
	IS YOUR WATER WELL FOR DRINKING?	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WATER WORKS	1
	CARBON TREATMENT FOR WATER POLLUTION CONTROL	2
	CHLORINATION FOR DISINFECTION	2
	DRINKING WATER JEOPARDY	1
	METAL POLLUTION REDUCTION	1
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	THE AGING OF LAKES	1
	POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	1
Physical Science: develop an understanding of chemical reactions	CHAPTER 1- INTRODUCTION TO WATER	
	SURVEYING THE PROPERTIES OF WATER	2
	CLEARLY H ₂ O	2
	"pH - THE FIRST CLUE TO WATER QUALITY"	3
	WATER CHEMISTRY CHECKUP	2
	HOW HARD IS WATER?	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Physical Science: develop an understanding of chemical reactions	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WATER WORKS	2
	CARBON TREATMENT FOR WATER POLLUTION CONTROL	3
	CHLORINATION FOR DISINFECTION	3
	SOURCE WATER PROTECTION: Surface Water Sources	1
	METAL POLLUTION REDUCTION	2
	WASTEWATER TREATMENT	1
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	2
	HOME RECYCLING OF GRAYWATER	1
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	2
	CHAPTER 3- SURFACE WATER RESOURCES	
	HELP! LAKE OVERTURNING!	2
	THE AGING OF LAKES	2
	POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	2
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	1
	WHAT TURNED THE CREEK ORANGE?	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	2
Physical Science: develop an understanding of motions and forces	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	2
	DO SEPTIC TANKS DO THE JOB?	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	1

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Physical Science: develop an understanding of motions and forces	CHAPTER 3- SURFACE WATER RESOURCES	
	BIOGRAPHY OF A RIVER	2
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	HELP! LAKE OVERTURNING!	2
	FLOODS	2
	THERMAL POLLUTION	1
	FROM GROUND TO WATER	1
	WHAT'S THE LEVEL?	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	WHAT GOES ON DOWN UNDER?	1
	DO YOU DRINK IT?	2
	LEAKING UNDERGROUND STORAGE TANKS	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	"HOW WATER PROCESSES MOVE SAND"	2
Physical Science: develop an understanding of conservation of energy and increase in disorder	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	1
	"pH - THE FIRST CLUE TO WATER QUALITY"	3
	CHAPTER 3- SURFACE WATER RESOURCES	
	HELP! LAKE OVERTURNING!	1
	THERMAL POLLUTION	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	FROM GROUND TO WATER	1
	WHAT'S THE LEVEL?	1
	WHAT GOES ON DOWN UNDER?	1
	HYDRAULIC HEAD	1
	FLOW NETS	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	EROSION KILL THE HABITATS THAT FEED YOU!	1
Physical Science: develop an understanding of interactions of energy and matter	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	1
	CLEARLY H ₂ O	1

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Physical Science: develop an understanding of interactions of energy and matter	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	METAL POLLUTION REDUCTION	1
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	1
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	BIOGRAPHY OF A RIVER	1
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	HELP! LAKE OVERTURNING!	2
	THE AGING OF LAKES	1
	FLOODS	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	TURBIDITY	1
	THERMAL POLLUTION	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	GROUNDWATER BASIC	1
	DO YOU DRINK IT?	1
	HYDRAULIC HEAD	1
	FLOW NETS	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	1
	"HOW WATER PROCESSES MOVE SAND"	2
Life Science: develop understanding of biological evolution	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT WHAT IS IN SOURCE WATER?	1
Life Science: develop an understanding of interdependence of organisms	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WHAT IS IN SOURCE WATER?	2
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	2
	HOME RECYCLING OF GRAYWATER	1

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Life Science: develop an understanding of interdependence of organisms	CHAPTER 3- SURFACE WATER RESOURCES	
	THE AGING OF LAKES	2
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	3
	SURVEYING THE PROPERTIES OF WATER	2
Life Science: develop understanding of matter, energy, and organization in living systems	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	1
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	HELP! LAKE OVERTURNING!	2
	THE AGING OF LAKES	2
	BIODIVERSITY = WATER QUALITY	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	UNDERSTANDING MARINE RESOURCES	1
	RIVER INPUT INTO THE GULF OF MEXICO	1
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Life Science: develop understanding of behavior of organisms	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WHAT IS IN SOURCE WATER?	1
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	1
	BIODIVERSITY = WATER QUALITY	2
	SIMPLE TEST FOR MICROBIAL CONTAMINATION	2
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1
Earth and Space Science: develop understanding of energy in the earth	CHAPTER 1- INTRODUCTION TO WATER	
	THE HYDROLOGIC (WATER) CYCLE	1
	A GLOBAL VIEW OF THE WET EARTH	1
	IS YOUR WATER WELL FOR DRINKING?	1
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	SOURCE WATER PROTECTION: Surface Water Sources	1
	SOURCE WATER PROTECTION: Groundwater Sources	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	BIOGRAPHY OF A RIVER	2
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	HELP! LAKE OVERTURNING!	1
	FLOODS	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	WHAT TURNED THE CREEK ORANGE?	1
	THERMAL POLLUTION	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	FROM GROUND TO WATER	2
	WHAT'S THE LEVEL?	2
	WHAT GOES ON DOWN UNDER?	2
	DO YOU DRINK IT?	1
	HYDRAULIC HEAD	2
	FLOW NETS	2

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Earth and Space Science: develop understanding of energy in the earth (con't)	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	RIVER INPUT INTO THE GULF OF MEXICO	1
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	"HOW WATER PROCESSES MOVE SAND"	2
	THE HYDROLOGIC (WATER) CYCLE	2
Earth and Space Science: develop an understanding of geochemical cycles	CHAPTER 1- INTRODUCTION TO WATER	
	WATER, WATER EVERYWHERE	1
	A GLOBAL VIEW OF THE WET EARTH	1
	"pH - THE FIRST CLUE TO WATER QUALITY"	2
	WATER CHEMISTRY CHECKUP	1
	HOW HARD IS WATER?	1
	IS YOUR WATER WELL FOR DRINKING?	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	1
	HELP! LAKE OVERTURNING!	1
	TURBIDITY	1
	WHAT TURNED THE CREEK ORANGE?	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	HYDRAULIC HEAD	2
	FLOW NETS	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	EROSION KILL THE HABITATS THAT FEED YOU!	1

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Earth and Space Science: develop an understanding of origin and evolution of the universe	CHAPTER 4- GROUNDWATER RESOURCES	
	FROM GROUND TO WATER	2
	WHAT'S THE LEVEL?	2
	WHAT GOES ON DOWN UNDER?	2
Science and Technology: develop abilities of technological design	CHAPTER 1- INTRODUCTION TO WATER	
	WATER, WATER EVERYWHERE	1
	A GLOBAL VIEW OF THE WET EARTH	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WATER WORKS	1
	SOURCE WATER PROTECTION: Groundwater Sources	3
	METAL POLLUTION REDUCTION	3
	WASTEWATER TREATMENT	3
	HOME RECYCLING OF GRAYWATER	3
	DO SEPTIC TANKS DO THE JOB?	3
	LAND APPLICATIONS OF WASTEWATER SOLIDS	2
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	3
	CHAPTER 3- SURFACE WATER RESOURCES	
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	DO YOU DRINK IT?	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	FLOW NETS	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	3
Science and Technology: develop understandings about science and technology	CHAPTER 1- INTRODUCTION TO WATER	
	WATER WHIZ - A BOARD GAME	2
	WATER CAREERS	2
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	1
	IS YOUR WATER WELL FOR DRINKING?	2

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science and Technology: develop understandings about science and technology (con't)	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	WATER WORKS	3
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	WASTEWATER TREATMENT	1
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	LEAKING UNDERGROUND STORAGE TANKS	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	2
Science in Personal and Social Perspectives: develop understanding of personal and community health	CHAPTER 1- INTRODUCTION TO WATER	
	WATER: MORE PRICELESS THAN GOLD	1
	WATER YOU DOING ABOUT THIS?	1
	WHAT'S IN A BOTTLE OF WATER?	2
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	CHLORINATION FOR DISINFECTION	1
	SOURCE WATER PROTECTION: Surface Water Sources	1
	SOURCE WATER PROTECTION: Groundwater Sources	3
	HOME RECYCLING OF GRAYWATER	1
	DO SEPTIC TANKS DO THE JOB?	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	1
	CHAPTER 3- SURFACE WATER RESOURCES	
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	1

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science in Personal and Social Perspectives: develop understanding of personal and community health	CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	1
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
Science in Personal and Social Perspectives: develop understanding of population growth	CHAPTER 1- INTRODUCTION TO WATER	
	WATER: MORE PRICELESS THAN GOLD	1
	WATER YOU DOING ABOUT THIS?	1
Science in Personal and Social Perspectives: develop understanding of natural resources	CHAPTER 1- INTRODUCTION TO WATER	
	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	3
	WATER WHIZ - A BOARD GAME	3
	HOW WOULD WE SAY IT WITHOUT WATER?	2
	WATER CAREERS	2
	WATER: MORE PRICELESS THAN GOLD	3
	WATER YOU DOING ABOUT THIS?	3
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	3
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	3
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	3
	THERE "OUGHTA" BE A LAW	3
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	3
	WATER CHEMISTRY CHECKUP	2
	HOW HARD IS WATER?	2
	IS YOUR WATER WELL FOR DRINKING?	1

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science in Personal and Social Perspectives: develop understanding of natural resources (con't)	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	DRINKING WATER JEOPARDY	2
	SOURCE WATER PROTECTION: Surface Water Sources	3
	SOURCE WATER PROTECTION: Groundwater Sources	3
	METAL POLLUTION REDUCTION	1
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	2
	CHAPTER 3- SURFACE WATER RESOURCES	
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	DO YOU DRINK IT?	2
	GROUNDWATER: CLEANING UP	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	UNDERSTANDING MARINE RESOURCES	2
	RIVER INPUT INTO THE GULF OF MEXICO	1
	EROSION KILL THE HABITATS THAT FEED YOU!	1
	OIL SPILLS	2
Science in Personal and Social Perspectives: develop understanding of environmental quality	CHAPTER 1- INTRODUCTION TO WATER	
	WATER WHIZ - A BOARD GAME	2
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	2

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science in Personal and Social Perspectives: develop understanding of environmental quality (con't)	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	3
	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
	WATER CHEMISTRY CHECKUP	3
	HOW HARD IS WATER?	3
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	DRINKING WATER JEOPARDY	3
	SOURCE WATER PROTECTION: Groundwater Sources	2
	METAL POLLUTION REDUCTION	2
	WASTEWATER TREATMENT	3
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	1
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	2
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	3
	CHAPTER 3- SURFACE WATER RESOURCES	
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	2
	CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	DO YOU DRINK IT?	2
	GROUNDWATER: CLEANING UP	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	3
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	3
	LEAKING UNDERGROUND STORAGE TANKS	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	UNDERSTANDING MARINE RESOURCES	2
	RIVER INPUT INTO THE GULF OF MEXICO	2

RELATIONSHIP:

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CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science in Personal and Social Perspectives: develop understanding of environmental quality (con't)	EROSION KILL THE HABITATS THAT FEED YOU!	2
	OIL SPILLS	3
Science in Personal and Social Perspectives: develop understanding of natural and human-induced hazards	CHAPTER 1- INTRODUCTION TO WATER	
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	2
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	CHLORINATION FOR DISINFECTION	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	DRINKING WATER JEOPARDY	1
	METAL POLLUTION REDUCTION	2
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	2
	DO SEPTIC TANKS DO THE JOB?	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	2
	CHAPTER 3- SURFACE WATER RESOURCES	
	WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	2
	CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	2
	CHAPTER 4- GROUNDWATER RESOURCES	
	GROUNDWATER: CLEANING UP	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	3
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	OIL SPILLS	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	CHAPTER 1- INTRODUCTION TO WATER	
	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	1
	WATER WHIZ - A BOARD GAME	2
	WATER CAREERS	2
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	2
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	3
	WHAT'S IN A BOTTLE OF WATER?	1
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	1
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	3
	THERE "OUGHTA" BE A LAW	1
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	1
	IS YOUR WATER WELL FOR DRINKING?	2
	CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT	
	CARBON TREATMENT FOR WATER POLLUTION CONTROL	1
	CHLORINATION FOR DISINFECTION	1
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	1
	METAL POLLUTION REDUCTION	2
	WASTEWATER TREATMENT	2
	THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	2
	HOME RECYCLING OF GRAYWATER	1
	DO SEPTIC TANKS DO THE JOB?	2
	LAND APPLICATIONS OF WASTEWATER SOLIDS	1
	STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF NATIONAL SCIENCE STANDARDS TO WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Science in Personal and Social Perspectives: develop understanding of science and technology in local, national, and global challenges	CHAPTER 3- SURFACE WATER RESOURCES	
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	DO YOU DRINK IT?	1
	FLOW NETS	1
	CHAPTER 4- GROUNDWATER RESOURCES	
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	1
	RADON IN WATER	1
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	1
	CHAPTER 5- WETLANDS AND COASTAL WATERS	
	RIVER INPUT INTO THE GULF OF MEXICO	1
	EROSION KILL THE HABITATS THAT FEED YOU!	1
	OIL SPILLS	2
	WATER: POETIC, PROSAIC, MOSAIC	

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
CHAPTER 1- INTRODUCTION TO WATER		
THE HYDROLOGIC (WATER) CYCLE	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	3
SURVEYING THE PROPERTIES OF WATER	(No correlation to this activity.)	
CLEARLY H ₂ O	(No correlation to this activity.)	
WATER, WATER EVERYWHERE	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	2
	Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	2
	Science, Technology, & Society: make judgments about how science and technology have transformed the physical world and human society and our understanding of time, space, place, and human-environment interactions	2
	Global Connections: explain conditions and motivations that contribute to conflict, cooperation, and interdependence among groups, societies, and nations	2
	Global Connections: analyze the causes, consequences, and possible solutions to persistent, contemporary, and emerging global issues, such as health, security, resource allocation, economic development, and environmental quality	2
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

Social Studies (9-2) by Objective 1

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
A GLOBAL VIEW OF THE WET EARTH	Culture: analyze and explain the ways groups, societies, and cultures address human needs and concerns	3
	People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth , such as maps, globes, and photographs	2
	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2
	People, Places, & Environments: describe and compare how people create places that reflect culture, human needs, government policy, and current values and ideals as they design and build specialized buildings, neighborhoods, shopping centers, urban centers, industrial parks, and the like	2
	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
	People, Places, & Environments: analyze and evaluate social and economic effects of environmental changes and crises resulting from phenomena such as floods, storms, and droughts	2
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2
WATER WHIZ - A BOARD GAME	Culture: analyze and explain the ways groups, societies, and cultures address human needs and concerns	1
	Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	2
	Production, Distribution, & Consumption: consider the costs and benefits to society of allocating goods and services through private and public sectors	2
WATER: POETIC, PROSAIC, MOSAIC	(No correlation to this activity.)	
HOW WOULD WE SAY IT WITHOUT WATER?	(No correlation to this activity.)	

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
WATER CAREERS	Production, Distribution, & Consumption: analyze the role of specialization and exchange in economic processes	3

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
WATER: MORE PRICELESS THAN GOLD	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	3
	Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	1
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2
	Civic Ideals & Practices: analyze and evaluate the influence of various forms of citizen action on public policy	2
WATER: MORE PRICELESS THAN GOLD (CON'T)	Civic Ideals & Practices: evaluate the effectiveness of public opinion in influencing and shaping public policy development and decision-making	2
	Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	2
	Civic Ideals & Practices: participate in activities to strengthen the "common good," based upon careful evaluation of possible options for citizen action	2
WATER YOU DOING ABOUT THIS?	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	2
	Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	1
	Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	1
ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	Individual Development & Identity: work independently and cooperatively within groups and institutions to accomplish goals	3
	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	3

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
ENVIRONMENTAL CONTROVERSY: CLASS PROJECT (CON'T)	Power, Authority, & Governance: analyze and evaluate conditions, actions, and motivations that contribute to conflict and cooperation within and among nations	3
	Power, Authority, & Governance: prepare a public policy paper and present and defend it before an appropriate forum in school or community	1
	Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	1
"pH - THE FIRST CLUE TO WATER QUALITY"	(No correlation to this activity.)	
WHAT'S IN A BOTTLE OF WATER?	Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	2
	Production, Distribution, & Consumption: compare how values and beliefs influence economic decisions in different societies	1
KEEP OUR COMMUNITY BEAUTIFUL!	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2
	Individual Development & Identity: work independently and cooperatively within groups and institutions to accomplish goals	2
	Individuals, Groups, & Institutions: explain and apply ideas and modes of inquiry drawn from behavioral science and social theory in the examination of persistent issues and social problems	1
RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	Individual Development & Identity: analyze the role of perceptions, attitudes, values, and beliefs in the development of personal identity	2
	Individuals, Groups, & Institutions: identify and analyze examples of tensions between expressions of individuality and efforts used to promote social conformity by groups and institutions	2

RELATIONSHIP:

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE? (CON'T)	Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	2
	Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	1
INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	Culture: analyze and explain the ways groups, societies, and cultures address human needs and concerns	2
	Individual Development & Identity: work independently and cooperatively within groups and institutions to accomplish goals	3
	Individuals, Groups, & Institutions: explain and apply ideas and modes of inquiry drawn from behavioral science and social theory in the examination of persistent issues and social problems	1
	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	2
	Power, Authority, & Governance: analyze and evaluate conditions, actions, and motivations that contribute to conflict and cooperation within and among nations	2
	Global Connections: analyze the causes, consequences, and possible solutions to persistent, contemporary, and emerging global issues, such as health, security, resource allocation, economic development, and environmental quality	1
	Global Connections: analyze the relationships and tensions between national sovereignty and global interests, in such matters as territory, economic development, nuclear and other weapons, use of natural resources, and human concerns	2
	Global Connections: illustrate how individual behaviors and decisions connect with global systems	1
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2

RELATIONSHIP:

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
ENVIRONMENTAL INFRASTRUCTURE FINANCING	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	1
	Science, Technology, & Society: make judgments about how science and technology have transformed the physical world and human society and our understanding of time, space, place, and human-environment interactions	1
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2
	Civic Ideals & Practices: evaluate the effectiveness of public opinion in influencing and shaping public policy development and decision-making	1
	Civic Ideals & Practices: participate in activities to strengthen the "common good," based upon careful evaluation of possible options for citizen action	2
THERE "OUGHTA" BE A LAW	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2
	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	2
	Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	2
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2
	Civic Ideals & Practices: analyze and evaluate the influence of various forms of citizen action on public policy	2

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
	Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	1

RELATIONSHIP:

- 3-performance objective main focus of activity, direct relation to objective
- 2-objective supported or addressed in activity
- 1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
UNCLE SAM SAYS, "KEEP IT CLEAN!"	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2
	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	2
	Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	2
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2
	Civic Ideals & Practices: analyze and evaluate the influence of various forms of citizen action on public policy	2
	Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	1
WATER CHEMISTRY CHECKUP	(No correlation to this activity.)	
HOW HARD IS WATER?	(No correlation to this activity.)	
IS YOUR WATER WELL FOR DRINKING?	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	1
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2
	Civic Ideals & Practices: evaluate the effectiveness of public opinion in influencing and shaping public policy development and decision-making	1

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT		
WATER WORKS	(No correlation to this activity.)	
CARBON TREATMENT FOR WATER POLLUTION CONTROL	(No correlation to this activity.)	
CHLORINATION FOR DISINFECTION	(No correlation to this activity.)	
DRINKING WATER JEOPARDY	(No correlation to this activity.)	
SOURCE WATER PROTECTION: Surface Water Sources	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	1
SOURCE WATER PROTECTION: Surface Water Sources	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
SOURCE WATER PROTECTION: Surface Water Sources	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	1
	Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	2
	Civic Ideals & Practices: participate in activities to strengthen the "common good," based upon careful evaluation of possible options for citizen action	1
SOURCE WATER PROTECTION: Groundwater Sources	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	1
	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	1

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
SOURCE WATER PROTECTION: Groundwater Sources (CON'T)	Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	2
	Civic Ideals & Practices: participate in activities to strengthen the "common good," based upon careful evaluation of possible options for citizen action	1
HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	(No correlation to this activity.)	
METAL POLLUTION REDUCTION	(No correlation to this activity.)	
WHAT IS IN SOURCE WATER?	(No correlation to this activity.)	
WASTEWATER TREATMENT	(No correlation to this activity.)	
THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	(No correlation to this activity.)	
HOME RECYCLING OF GRAYWATER	(No correlation to this activity.)	
DO SEPTIC TANKS DO THE JOB?	(No correlation to this activity.)	
LAND APPLICATIONS OF WASTEWATER SOLIDS	(No correlation to this activity.)	
STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	(No correlation to this activity.)	
CHAPTER 3- SURFACE WATER RESOURCES		
BIOGRAPHY OF A RIVER	Time, Continuity, & Change: apply key concepts such as time, chronology, causality, change, conflict, and complexity to explain, analyze, and show connections among patterns of historical change and continuity	1
	People, Places, & Environments: refine mental maps of locales, regions, and the world that demonstrate understanding of relative location, direction, size, and shape	1
	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2

RELATIONSHIP:

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2-objective supported or addressed in activity

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
	People, Places, & Environments: describe and compare how people create places that reflect culture, human needs, government policy, and current values and ideals as they design and build specialized buildings, neighborhoods, shopping centers, urban centers, industrial parks, and the like	3
BIOGRAPHY OF A RIVER (CON'T)	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	3
	People, Places, & Environments: analyze and evaluate social and economic effects of environmental changes and crises resulting from phenomena such as floods, storms, and droughts	1
CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth , such as maps, globes, and photographs	2
	People, Places, & Environments: use appropriate resources, data sources, and geographic tools such as aerial photographs, satellite mages, geographic information systems (GIS), map projections, and cartography to generate, manipulate, and interpret information such as atlases, data bases, grid systems, charts, graphs, and maps	2
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	2
HELP! LAKE OVERTURNING!	(No correlation to this activity.)	
THE AGING OF LAKES	(No correlation to this activity.)	
BIODIVERSITY = WATER QUALITY	(No correlation to this activity.)	
FLOODS	People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth , such as maps, globes, and photographs	2
	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	1
	People, Places, & Environments: analyze and evaluate social and economic effects of environmental changes and crises resulting from phenomena such as floods, storms, and droughts	3
BEST MANAGEMENT PRACTICES FOR FORESTRY	(No correlation to this activity.)	
SIMPLE TEST FOR MICROBIAL CONTAMINATION	(No correlation to this activity.)	
POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	(No correlation to this activity.)	
ETHICAL DILEMMAS WHAT'S A BODY TO DO?	Individual Development & Identity: analyze the role of perceptions, attitudes, values, and beliefs in the development of personal identity	2
	Individuals, Groups, & Institutions: analyze group and institutional influences on people, events, and elements of culture in both historical and contemporary settings	1
	Individuals, Groups, & Institutions: identify and analyze examples of tensions between expressions of individuality and efforts used to promote social conformity by groups and institutions	2
	Individuals, Groups, & Institutions: explain and apply ideas and modes of inquiry drawn from behavioral science and social theory in the examination of persistent issues and social problems	2
WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	(No correlation to this activity.)	
TURBIDITY	(No correlation to this activity.)	
CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	(No correlation to this activity.)	
WHAT TURNED THE CREEK ORANGE?	(No correlation to this activity.)	
THERMAL POLLUTION	(No correlation to this activity.)	
CHAPTER 4- GROUNDWATER RESOURCES		
GROUNDWATER BASIC	(No correlation to this activity.)	
FROM GROUND TO WATER	(No correlation to this activity.)	
WHAT'S THE LEVEL?	(No correlation to this activity.)	

RELATIONSHIP:

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
WHAT GOES ON DOWN UNDER?	(No correlation to this activity.)	
DO YOU DRINK IT?	(No correlation to this activity.)	
HYDRAULIC HEAD	(No correlation to this activity.)	
FLOW NETS	People, Places, & Environments: refine mental maps of locales, regions, and the world that demonstrate understanding of relative location, direction, size, and shape	2
	People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth, such as maps, globes, and photographs	3
FLOW NETS (CON'T)	People, Places, & Environments: use appropriate resources, data sources, and geographic tools such as aerial photographs, satellite images, geographic information systems (GIS), map projections, and cartography to generate, manipulate, and interpret information such as atlases, data bases, grid systems, charts, graphs, and maps	2
	People, Places, & Environments: calculate distance, scale, area, and density, and distinguish spatial distribution patterns	3
	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2
GROUNDWATER: CLEANING UP	(No correlation to this activity.)	
WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	(No correlation to this activity.)	
RADON IN WATER	(No correlation to this activity.)	
LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	(No correlation to this activity.)	
LEAKING UNDERGROUND STORAGE TANKS	Individual Development & Identity: work independently and cooperatively within groups and institutions to accomplish goals	2
	Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	2

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
	Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	2
	Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	1

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
CHAPTER 5- WETLANDS AND COASTAL WATERS		
An Alternative to the "What I Did on Summer Vacation - What I Can Do on Summer Vacation."	(No correlation to this activity.)	
UNDERSTANDING MARINE RESOURCES	Culture: analyze and explain the ways groups, societies, and cultures address human needs and concerns	2
	Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	1
RIVER INPUT INTO THE GULF OF MEXICO	People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth , such as maps, globes, and photographs	1
	People, Places, & Environments: use appropriate resources, data sources, and geographic tools such as aerial photographs, satellite mages, geographic information systems (GIS), map projections, and cartography to generate, manipulate, and interpret information such as atlases, data bases, grid systems, charts, graphs, and maps	1
	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	2
	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
WETLANDS, USA - MORE THAN SWAMPS!	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	3
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	2

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
WETLANDS, USA - MORE THAN SWAMPS! (CON'T)	People, Places, & Environments: describe and compare how people create places that reflect culture, human needs, government policy, and current values and ideals as they design and build specialized buildings, neighborhoods, shopping centers, urban centers, industrial parks, and the like	1
	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
KNOW YOUR GULF	(No correlation to this activity.)	
SEA MARGIN DIVERSITY	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	2
ESTUARIES: INTERFACE BETWEEN SEA AND LAND	People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	2
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	2
	People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	2
EROSION KILL THE HABITATS THAT FEED YOU!	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	2
	People, Places, & Environments: analyze and evaluate social and economic effects of environmental changes and crises resulting from phenomena such as floods, storms, and droughts	2
	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2

RELATIONSHIP:

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CORRELATION OF SOCIAL STUDIES STANDARDS TO WATER SOURCEBOOK

(BY ACTIVITY)

Activity	Performance Objective	Relation
OIL SPILLS	(No correlation to this activity.)	
IMPACT GOVERNMENTAL REGULATIONS ON MARINE DEBRIS - WRITE A LETTER!	People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	2
	Power, Authority, & Governance: analyze and evaluate conditions, actions, and motivations that contribute to conflict and cooperation within and among nations	2
"HOW WATER PROCESSES MOVE SAND"	People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth , such as maps, globes, and photographs	1
	People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	1
SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	(No correlation to this activity.)	

RELATIONSHIP:

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of the focus of activity

**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
Culture- Social studies programs should include experiences that provide for the study of <i>culture and cultural diversity</i> , so that the learner can:		
Culture: analyze and explain the ways groups, societies, and cultures address human needs and concerns	A GLOBAL VIEW OF THE WET EARTH	3
	WATER WHIZ - A BOARD GAME	1
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	UNDERSTANDING MARINE RESOURCES	2
Time, Continuity, & Change- Social studies programs should include experiences that provide for the study of <i>the ways human beings view themselves in ad over time</i> , so that the learner can:		
Time, Continuity, & Change: apply key concepts such as time, chronology, causality, change, conflict, and complexity to explain, analyze, and show connections among patterns of historical change and continuity	BIOGRAPHY OF A RIVER	1
People, Places, & Environments- Social studies programs should include experiences that provide for the study of <i>people, places, and environments</i> , so that the learner can:		
People, Places, & Environments: refine mental maps of locales, regions, and the world that demonstrate understanding of relative location, direction, size, and shape	BIOGRAPHY OF A RIVER	1
	FLOW NETS	2
People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth , such as maps, globes, and photographs	A GLOBAL VIEW OF THE WET EARTH	2
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	FLOODS	2
	FLOW NETS	3

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of focus of activity

**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
People, Places, & Environments: create, interpret, use, and synthesize information from various representations of the earth, such as maps, globes, and photographs (con't)	RIVER INPUT INTO THE GULF OF MEXICO	1
	"HOW WATER PROCESSES MOVE SAND"	1
People, Places, & Environments: use appropriate resources, data sources, and geographic tools such as aerial photographs, satellite images, geographic information systems (GIS), map projections, and cartography to generate, manipulate, and interpret information such as atlases, data bases, grid systems, charts, graphs, and maps	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	FLOW NETS	2
	RIVER INPUT INTO THE GULF OF MEXICO	1
People, Places, & Environments: calculate distance, scale, area, and density, and distinguish spatial distribution patterns	FLOW NETS	3
People, Places, & Environments: describe, differentiate, and explain the relationships among various regional and global patterns of geographic phenomena such as landforms, soils, climate, vegetation, natural resources, and population	A GLOBAL VIEW OF THE WET EARTH	2
	SOURCE WATER PROTECTION: Surface Water Sources	1
	SOURCE WATER PROTECTION: Groundwater Sources	1
	BIOGRAPHY OF A RIVER	2
	FLOODS	2
	FLOW NETS	2
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	3
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena	THE HYDROLOGIC (WATER) CYCLE	3
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of focus of activity

**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
People, Places, & Environments: use knowledge of physical system changes such as seasons, climate and weather, and the water cycle to explain geographic phenomena (con't)	FLOODS	1
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	"HOW WATER PROCESSES MOVE SAND"	1
	A GLOBAL VIEW OF THE WET EARTH	2
	BIOGRAPHY OF A RIVER	3
	WETLANDS, USA - MORE THAN SWAMPS!	1
People, Places, & Environments: examine, interpret, and analyze physical and cultural patterns and their interactions, such as land use, settlement patterns, cultural transmission of customs and ideas, and ecosystem changes	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	2
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	BIOGRAPHY OF A RIVER	3
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

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**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
People, Places, & Environments: analyze and evaluate social and economic effects of environmental changes and crises resulting from phenomena such as floods, storms, and droughts	A GLOBAL VIEW OF THE WET EARTH	2
People, Places, & Environments: analyze and evaluate...(con't)	BIOGRAPHY OF A RIVER	1
	FLOODS	3
	EROSION KILL THE HABITATS THAT FEED YOU!	2
People, Places, & Environments: propose, compare, and evaluate alternative policies for the use of land and other resources in communities, regions, nations, and the world	A GLOBAL VIEW OF THE WET EARTH	2
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	2
	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
	SOURCE WATER PROTECTION: Surface Water Sources	1
	SOURCE WATER PROTECTION: Groundwater Sources	1
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	IMPACT GOVERNMENTAL REGULATIONS ON MARINE DEBRIS - WRITE A LETTER!	2
Individual Development & Identity- Social studies programs should include experiences that provide for the study of <i>individual development and identity</i> , so that the learner can:		
Individual Development & Identity: analyze the role of perceptions, attitudes, values, and beliefs in the development of personal identity	RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	2
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	2
Individual Development & Identity: work independently and cooperatively within groups and institutions to accomplish goals	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	3
	KEEP OUR COMMUNITY BEAUTIFUL!	2

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

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**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
Individual Development & Identity: work independently and cooperatively within groups and institutions to accomplish goals (con't)	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	3
	LEAKING UNDERGROUND STORAGE TANKS	2
<i>Individuals, Groups, & Institutions-</i> Social studies programs should include experiences that provide for the study of <i>interactions among individuals, groups, and institutions</i> so that the learner can:		
Individuals, Groups, & Institutions: analyze group and institutional influences on people, events, and elements of culture in both historical and contemporary settings	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	1
Individuals, Groups, & Institutions: identify and analyze examples of tensions between expressions of individuality and efforts used to promote social conformity by groups and institutions	RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	2
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	2
Individuals, Groups, & Institutions: explain and apply ideas and modes of inquiry drawn from behavioral science and social theory in the examination of persistent issues and social problems	KEEP OUR COMMUNITY BEAUTIFUL!	1
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	1
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	2
<i>Power, Authority, & Governance-</i> Social studies programs should include experiences that provide for the study of <i>how people create and change structures of power, authority, and governance</i> , so that the learner can:		
Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	WATER, WATER EVERYWHERE	2
	WATER: MORE PRICELESS THAN GOLD	3

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of focus of activity

**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society	WATER YOU DOING ABOUT THIS?	2
Power, Authority, & Governance: analyze and explain ideas and mechanisms to meet needs and wants of citizens, regulate territory, manage conflict, establish order and security, and balance competing conceptions of a just society (con't)	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	3
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	1
	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
	IS YOUR WATER WELL FOR DRINKING?	1
	LEAKING UNDERGROUND STORAGE TANKS	2
Power, Authority, & Governance: analyze and evaluate conditions, actions, and motivations that contribute to conflict and cooperation within and among nations	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	3
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	IMPACT GOVERNMENTAL REGULATIONS ON MARINE DEBRIS - WRITE A LETTER!	2
Power, Authority, & Governance: prepare a public policy paper and present and defend it before an appropriate forum in school or community	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

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**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
<i>Production, Distribution, & Consumption-</i> Social studies programs should include experiences that provide for the study of <i>how people organize for the production, distribution, and consumption of goods and services</i> , so that the learner can:		
Production, Distribution, & Consumption: analyze the role that supply and demand, prices, incentives, and profits play in determining what is produced and distributed in a competitive market system	WATER WHIZ - A BOARD GAME	2
	WATER YOU DOING ABOUT THIS?	1
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	WHAT'S IN A BOTTLE OF WATER?	2
	RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	2
	UNDERSTANDING MARINE RESOURCES	1
Production, Distribution, & Consumption: consider the costs and benefits to society of allocating goods and services through private and public sectors	WATER WHIZ - A BOARD GAME	2
Production, Distribution, & Consumption: analyze the role of specialization and exchange in economic processes	WATER CAREERS	3
Production, Distribution, & Consumption: compare how values and beliefs influence economic decisions in different societies	WHAT'S IN A BOTTLE OF WATER?	1
Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	WATER, WATER EVERYWHERE	2
	WATER: MORE PRICELESS THAN GOLD	1
	WATER YOU DOING ABOUT THIS?	1
	RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	1

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

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**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
Production, Distribution, & Consumption: apply knowledge of economic concepts in developing a response to a current local economic issue, such as how to reduce the flow of trash into a rapidly filling landfill	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
Science, Technology, & Society- social studies programs should include experiences that provide for the study of <i>relationships among science, technology, and society</i> , so that the learner can:		
Science, Technology, & Society: make judgments about how science and technology have transformed the physical world and human society and our understanding of time, space, place, and human-environment interactions	WATER, WATER EVERYWHERE	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	1
Global Connections- Social studies programs should include experiences that provide for the study of <i>global connections and interdependence</i> so that the learner can:		
Global Connections: explain conditions and motivations that contribute to conflict, cooperation, and interdependence among groups, societies, and nations	WATER, WATER EVERYWHERE	2
Global Connections: analyze the causes, consequences, and possible solutions to persistent, contemporary, and emerging global issues, such as health, security, resource allocation, economic development, and environmental quality	WATER, WATER EVERYWHERE	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	1
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
Global Connections: illustrate how individual behaviors and decisions connect with global systems	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	1

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

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1-objective is part of focus of activity

**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
<i>Civic Ideals & Practices-</i> Social studies programs should include experiences that provide for the study of <i>the ideals, principles, and practices of citizenship in a democratic republic</i> , so that the learner can:		
Civic Ideals & Practices: locate, access, analyze, organize, synthesize, evaluate, and apply information about selected public issues - identifying, describing, and evaluating multiple points of view	WATER, WATER EVERYWHERE	2
	WATER: MORE PRICELESS THAN GOLD	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	2
	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
	IS YOUR WATER WELL FOR DRINKING?	2
	LEAKING UNDERGROUND STORAGE TANKS	2
Civic Ideals & Practices: analyze and evaluate the influence of various forms of citizen action on public policy	WATER: MORE PRICELESS THAN GOLD	2
	THERE "OUGHTA" BE A LAW UNCLE SAM SAYS, "KEEP IT CLEAN!"	2 2
Civic Ideals & Practices: evaluate the effectiveness of public opinion in influencing and shaping public policy development and decision-making	WATER: MORE PRICELESS THAN GOLD	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	1
	IS YOUR WATER WELL FOR DRINKING?	1
Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	WATER: MORE PRICELESS THAN GOLD	2
	THERE "OUGHTA" BE A LAW	1
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	1
	SOURCE WATER PROTECTION: Surface Water Sources	2

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of focus of activity

**CORRECTION OF NATIONAL SOCIAL STUDIES STANDARDS TO
WATER SOURCEBOOK (9-12)**
(BY PERFORMANCE OBJECTIVE)

Performance Objective	Activity	Relation
Civic Ideals & Practices: construct a policy statement and an action plan to achieve one or more goals related to an issue of public concern	SOURCE WATER PROTECTION: Groundwater Sources	2
	LEAKING UNDERGROUND STORAGE TANKS	1
Civic Ideals & Practices: participate in activities to strengthen the "common good," based upon careful evaluation of possible options for citizen action	WATER: MORE PRICELESS THAN GOLD	2
	ENVIRONMENTAL INFRASTRUCTURE FINANCING	2
	SOURCE WATER PROTECTION: Surface Water Sources	1
	SOURCE WATER PROTECTION: Groundwater Sources	1

NOTE: NOT ALL PERFORMANCE EXPECTATIONS ARE MET.

3-performance objective main focus of activity, direct relation to objective

2-objective supported or addressed in activity

1-objective is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
CHAPTER 1- INTRODUCTION TO WATER		
THE HYDROLOGIC (WATER) CYCLE	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the interaction of Earth's physical systems	2
SURVEYING THE PROPERTIES OF WATER	(No correlation to this activity.)	
CLEARLY H ₂ O	(No correlation to this activity.)	
WATER, WATER EVERYWHERE	The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions	2
	The World in Spatial Terms: understand how mental maps influence spatial and environmental decision-making	2
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the interaction of Earth's physical systems	2
	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	1
	Environment and Society: understand strategies to respond to constraints placed on human systems by the physical environment	1
	Environment and Society: understand how the spatial distribution of resources affects patterns of human settlement	1
	Environment and Society: understand how resource development and use change over time	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	3
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
A GLOBAL VIEW OF THE WET EARTH	The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	2
	The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions	1
	Places and Regions: understand the meaning and significance of place	2
	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	2
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the distribution and characteristics of ecosystems	2
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	2
	Environment and Society: understand strategies to respond to constraints placed on human systems by the physical environment	2
	Environment and Society: understand how the spatial distribution of resources affects patterns of human settlement	2
	Environment and Society: understand how resource development and use change over time	2
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
WATER WHIZ - A BOARD GAME	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	1
	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
WATER WHIZ - A BOARD GAME (CON'T)	Environment and Society: understand how resource development and use change over time	2
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
WATER: POETIC, PROSAIC, MOSAIC	(No correlation to this activity.)	
HOW WOULD WE SAY IT WITHOUT WATER?	(No correlation to this activity.)	
WATER CAREERS	(No correlation to this activity.)	
WATER: MORE PRICELESS THAN GOLD	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	1
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	3
	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	2
	Environment and Society: understand strategies to respond to constraints placed on human systems by the physical environment	2
	Environment and Society: understand how the spatial distribution of resources affects patterns of human settlement	2
	Environment and Society: understand how resource development and use change over time	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	3
	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	1
	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
WATER: MORE PRICELESS THAN GOLD (CON'T)	Environment and Society: understand how resource development and use change over time	1
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
	The Uses of Geography: understands contemporary issues in the context of spatial and environmental perspectives	2
	The Uses of Geography: understands how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions.	3
ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	1
	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	2
	Environment and Society: understand how resource development and use change over time	1
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
"pH - THE FIRST CLUE TO WATER QUALITY"	(No correlation to this activity.)	
WHAT'S IN A BOTTLE OF WATER?	(No correlation to this activity.)	
KEEP OUR COMMUNITY BEAUTIFUL!	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	2
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	1
RISK ASSESSMENT: HOW MUCH RISK ARE YOU WILLING TO TAKE?	(No correlation to this activity.)	
INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	2
	The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR! (CON'T)	The World in Spatial Terms: understand how mental maps influence spatial and environmental decision-making	2
	Human Systems: understand the increasing economic interdependence of the world's countries	1
	Human Systems: understand why and how cooperation and conflict are involved in shaping the distribution of social, political, and economic spaces on Earth at different scales	2
	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	3
ENVIRONMENTAL INFRASTRUCTURE FINANCING	(No correlation to this activity.)	
THERE "OUGHTA" BE A LAW	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	2
	Environment and Society: understand strategies to respond to constraints placed on human systems by the physical environment	1
	Environment and Society: understand how resource development and use change over time	2
UNCLE SAM SAYS, "KEEP IT CLEAN!"	Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	2
	Environment and Society: understand strategies to respond to constraints placed on human systems by the physical environment	1
	Environment and Society: understand how resource development and use change over time	2
HOW HARD IS WATER?	(No correlation to this activity.)	
IS YOUR WATER WELL FOR DRINKING?	(No correlation to this activity.)	
WATER CHEMISTRY CHECKUP	(No correlation to this activity.)	
CHAPTER 2- DRINKING WATER AND WASTEWATER TREATMENT		
WATER WORKS	(No correlation to this activity.)	
CARBON TREATMENT FOR WATER POLLUTION CONTROL	(No correlation to this activity.)	
CHLORINATION FOR DISINFECTION	(No correlation to this activity.)	
DRINKING WATER JEOPARDY	(No correlation to this activity.)	
SOURCE WATER PROTECTION: Surface Water Sources	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

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1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
SOURCE WATER PROTECTION: Surface Water Sources	Environment and Society: understand the role of technology in the capacity of the physical environment to accommodate human modification	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand how resource development and use change over time	1
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
SOURCE WATER PROTECTION: Groundwater Sources	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Environment and Society: understand the role of technology in the capacity of the physical environment to accommodate human modification	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand how resource development and use change over time	1
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?	(No correlation to this activity.)	
METAL POLLUTION REDUCTION	(No correlation to this activity.)	
WHAT IS IN SOURCE WATER?	(No correlation to this activity.)	
WASTEWATER TREATMENT	(No correlation to this activity.)	
THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT	(No correlation to this activity.)	
HOME RECYCLING OF GRAYWATER	(No correlation to this activity.)	
DO SEPTIC TANKS DO THE JOB?	(No correlation to this activity.)	

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

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1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
LAND APPLICATIONS OF WASTEWATER SOLIDS	(No correlation to this activity.)	
STORM WATER: BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION	(No correlation to this activity.)	

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
CHAPTER 3- SURFACE WATER RESOURCES		
BIOGRAPHY OF A RIVER	Places and Regions: understand the meaning and significance of place Places and Regions: understand the changing physical and human characteristics of places Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere Physical Systems: understand the distribution and characteristics of ecosystems Physical Systems: understand the BIODIVERSITY and productivity of ecosystems	2 1 2 1 2
CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	The World in Spatial Terms: understand how to use technologies to represent and interpret Earth's physical and human systems The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions Places and Regions: understand the changing physical and human characteristics of places Physical Systems: understand the spatial variations in the consequences of physical processes across Earth's surface The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2 2 2 2 1 2
HELP! LAKE OVERTURNING!	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere Physical Systems: understand the interaction of Earth's physical systems	2 2
HELP! LAKE OVERTURNING! (CON'T)	Physical Systems: understand the distribution and characteristics of ecosystems Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	1 2
THE AGING OF LAKES	(No correlation to this activity.)	
BIODIVERSITY = WATER QUALITY	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere Physical Systems: understand the distribution and characteristics of ecosystems	1 2

RELATIONSHIP:

3-standard main focus of activity, direct relation to standard

2-standard supported or addressed in activity

1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
BIODIVERSITY = WATER QUALITY (CON'T)	Physical Systems: understand the BIODIVERSITY and productivity of ecosystems	2
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
FLOODS	Places and Regions: understand the changing physical and human characteristics of places	2
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the spatial variations in the consequences of physical processes across Earth's surface	3
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
BEST MANAGEMENT PRACTICES FOR FORESTRY	Places and Regions: understand the meaning and significance of place	1
	Places and Regions: understand the changing physical and human characteristics of places	2
	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	1
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the spatial variations in the consequences of physical processes across Earth's surface	2
	Physical Systems: understand the BIODIVERSITY and productivity of ecosystems	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	3
		2
	Environment and Society: understand the role of technology in the capacity of the physical environment to accommodate human modification	
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	3
	Environment and Society: understand how resource development and use change over time	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
BEST MANAGEMENT PRACTICES FOR FORESTRY (CON'T)	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
SIMPLE TEST FOR MICROBIAL CONTAMINATION	(No correlation to this activity.)	
POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?	(No correlation to this activity.)	
ETHICAL DILEMMAS WHAT'S A BODY TO DO?	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	1
	Environment and Society: understand strategies to respond to constraints placed on human systems by the physical environment	3
	Environment and Society: understand how resource development and use change over time	2
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	3
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
WHAT ARE FECAL COLIFORMS AND HOW ARE THEY RELATED TO WATER QUALITY?	(No correlation to this activity.)	
TURBIDITY	(No correlation to this activity.)	
CLEAN CLOTHES - CLEAN ENVIRONMENT? PHOSPHATES	(No correlation to this activity.)	
WHAT TURNED THE CREEK ORANGE?	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the interaction of Earth's physical systems	2
	Environment and Society: understand the role of technology in the capacity of the physical environment to accommodate human modification	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2

RELATIONSHIP:

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
WHAT TURNED THE CREEK ORANGE? (CON'T)	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	1
CHAPTER 4- GROUNDWATER RESOURCES		
THERMAL POLLUTION	(No correlation to this activity.)	
GROUNDWATER BASIC	(No correlation to this activity.)	
FROM GROUND TO WATER	(No correlation to this activity.)	
WHAT'S THE LEVEL?	(No correlation to this activity.)	
WHAT GOES ON DOWN UNDER?	(No correlation to this activity.)	
DO YOU DRINK IT?	The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	2
	The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions	2
	The World in Spatial Terms: understand how mental maps influence spatial and environmental decision-making	2
	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	2
DO YOU DRINK IT? (CON'T)	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the interaction of Earth's physical systems	2
HYDRAULIC HEAD	(No correlation to this activity.)	
FLOW NETS	The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	2
	The World in Spatial Terms: understand how to use technologies to represent and interpret Earth's physical and human systems	2
	The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
FLOW NETS (CON'T)	The World in Spatial Terms: understand how mental maps influence spatial and environmental decision-making	3
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the spatial variations in the consequences of physical processes across Earth's surface	2
	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	2
	Environment and Society: understand how resource development and use change over time	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
GROUNDWATER: CLEANING UP	Places and Regions: understand the changing physical and human characteristics of places	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand how resource development and use change over time	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	Places and Regions: understand the changing physical and human characteristics of places	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand how resource development and use change over time	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD? (CON'T)	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
RADON IN WATER	Places and Regions: understand the changing physical and human characteristics of places	1
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand how resource development and use change over time	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions	1
	Places and Regions: understand the changing physical and human characteristics of places	2
	Physical Systems: understand the interaction of Earth's physical systems	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
LEAKING UNDERGROUND STORAGE TANKS	Places and Regions: understand the changing physical and human characteristics of places	2
	Physical Systems: understand the interaction of Earth's physical systems	1
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
LEAKING UNDERGROUND STORAGE TANKS (CON'T)	Environment and Society: understand the geographic results of policies and programs for resource use and management The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2 2
CHAPTER 5- WETLANDS AND COASTAL WATERS		
An Alternative to the "What I Did on Summer Vacation - What I Can Do on Summer Vacation."	(No correlation to this activity.)	
UNDERSTANDING MARINE RESOURCES	Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity Physical Systems: understand the BIODIVERSITY and productivity of ecosystems Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues Environment and Society: understand how to apply appropriate models and information to understand environmental problems Environment and Society: understand how the spatial distribution of resources affects patterns of human settlement Environment and Society: understand how resource development and use change over time Environment and Society: understand the geographic results of policies and programs for resource use and management The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources The Uses of Geography: understand contemporary issues in the context of spatial and environmental perspectives The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2 1 2 2 2 2 2 3 2 2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
RIVER INPUT INTO THE GULF OF MEXICO	The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	2
	The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	2
	The World in Spatial Terms: understand how mental maps influence spatial and environmental decision-making	2
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the distribution and characteristics of ecosystems	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	3
	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	1
	The Uses of Geography: understand contemporary issues in the context of spatial and environmental perspectives	2
WETLANDS, USA - MORE THAN SWAMPS!	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the interaction of Earth's physical systems	1
	Physical Systems: understand the distribution and characteristics of ecosystems	2
	Physical Systems: understand the BIODIVERSITY and productivity of ecosystems	2
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
WETLANDS, USA - MORE THAN SWAMPS! (CON'T)	The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	2
	The Uses of Geography: understand contemporary issues in the context of spatial and environmental perspectives	1
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2
KNOW YOUR GULF	(No correlation to this activity.)	
SEA MARGIN DIVERSITY	The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	1
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the distribution and characteristics of ecosystems	2
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
ESTUARIES: INTERFACE BETWEEN SEA AND LAND	The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	1
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the distribution and characteristics of ecosystems	2
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2
EROSION KILL THE HABITATS THAT FEED YOU!	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	1
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the distribution and characteristics of ecosystems	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
EROSION KILL THE HABITATS THAT FEED YOU! (CON'T)	Environment and Society: understand how the spatial distribution of resources affects patterns of human settlement	2
	Environment and Society: understand how resource development and use change over time	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
OIL SPILLS	(No correlation to this activity.)	
IMPACT GOVERNMENTAL REGULATIONS ON MARINE DEBRIS - WRITE A LETTER!	(No correlation to this activity.)	
"HOW WATER PROCESSES MOVE SAND"	The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	2
	The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	2
	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the spatial variations in the consequences of physical processes across Earth's surface	2
	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	2
	Environment and Society: understand the geographic results of policies and programs for resource use and management	1
SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	2
	Physical Systems: understand the interaction of Earth's physical systems	2
	Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	1
	Environment and Society: understand how to apply appropriate models and information to understand environmental problems	2
	Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

Activity	Standard	Relation
SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES? (CON'T)	Environment and Society: understand the geographic results of policies and programs for resource use and management	2
	The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Essential Element 1. The World in Spatial Terms -Standard 1) How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective; 2) How to use mental maps to organize information about people, places, and environments in a spatial context; 3) How to analyze the spatial organization fo people, places, and environments on Earth's surface.		
The World in Spatial Terms: understand how to use maps and other graphic presentations to depict geographic problems	A GLOBAL VIEW OF THE WET EARTH	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	DO YOU DRINK IT?	2
	FLOW NETS	2
	RIVER INPUT INTO THE GULF OF MEXICO	2
	"HOW WATER PROCESSES MOVE SAND"	2
The World in Spatial Terms: understand how to use technologies to represent and interpret Earth's physical and human systems	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	FLOW NETS	2
The World in Spatial Terms: understand how to use geographic representations and tools to analyze, explain, and solve geographic problems	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	FLOW NETS	2
	RIVER INPUT INTO THE GULF OF MEXICO	2
	SEA MARGIN DIVERSITY	1
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1
	"HOW WATER PROCESSES MOVE SAND"	2
The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	1
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
The World in Spatial Terms: understand how to use mental maps of physical and human features of the world to answer complex geographical questions (con't)	DO YOU DRINK IT?	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	1
The World in Spatial Terms: understand how mental maps influence spatial and environmental decision-making	WATER, WATER EVERYWHERE	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
	DO YOU DRINK IT?	2
	FLOW NETS	3
	RIVER INPUT INTO THE GULF OF MEXICO	2
Essential Element 2. Places and Regions- Standard 4) The physical and human characteristics of places; 5) That people create regions to interpret Earth's complexity; 6) How culture and experience influence people's perceptions of places and regions.		
Places and Regions: understand the meaning and significance of place	A GLOBAL VIEW OF THE WET EARTH	2
	BIOGRAPHY OF A RIVER	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
Places and Regions: understand the changing physical and human characteristics of places	BIOGRAPHY OF A RIVER	1
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	FLOODS	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	GROUNDWATER: CLEANING UP	1
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	1
	RADON IN WATER	1
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
Places and Regions: understand how relationships between humans and the physical environment lead to the formation of places and to a sense of personal and community identity	A GLOBAL VIEW OF THE WET EARTH	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	WATER WHIZ - A BOARD GAME	1
	WATER: MORE PRICELESS THAN GOLD	1
	WATER YOU DOING ABOUT THIS?	1
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	DO YOU DRINK IT?	2
	UNDERSTANDING MARINE RESOURCES	2
Essential Element 3. Physical Systems- Standard 7) The physical processes that shape the patterns of Earth's surface; 8) The characteristics and spatial distribution of ecosystems on Earth's surface.		
Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere	THE HYDROLOGIC (WATER) CYCLE	2
	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	1
	WATER: MORE PRICELESS THAN GOLD	1
	SOURCE WATER PROTECTION: Surface Water Sources	1
	SOURCE WATER PROTECTION: Groundwater Sources	1
	BIOGRAPHY OF A RIVER	2
	HELP! LAKE OVERTURNING!	2
	BIODIVERSITY = WATER QUALITY	1
	FLOODS	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	WHAT TURNED THE CREEK ORANGE?	1
	DO YOU DRINK IT?	1
	FLOW NETS	2
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	1
	SEA MARGIN DIVERSITY	1
Physical Systems: understand the dynamics of the four basic components of Earth's physical systems: the atmosphere, biosphere, lithospheres, and hydrosphere(con't)	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	1

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	EROSION KILL THE HABITATS THAT FEED YOU!	1
	"HOW WATER PROCESSES MOVE SAND"	2
	SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	2
Physical Systems: understand the interaction of Earth's physical systems	THE HYDROLOGIC (WATER) CYCLE	2
	WATER, WATER EVERYWHERE	2
	HELP! LAKE OVERTURNING!	2
	FLOODS	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	WHAT TURNED THE CREEK ORANGE?	2
	DO YOU DRINK IT?	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	1
	WETLANDS, USA - MORE THAN SWAMPS!	1
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	"HOW WATER PROCESSES MOVE SAND"	2
	SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	2
Physical Systems: understand the spatial variations in the consequences of physical processes across Earth's surface	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	1
	FLOODS	3
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	FLOW NETS	2
	"HOW WATER PROCESSES MOVE SAND"	2
Physical Systems: understand the distribution and characteristics of ecosystems	A GLOBAL VIEW OF THE WET EARTH	2
Physical Systems: understand the distribution and characteristics of ecosystems (con't)	BIOGRAPHY OF A RIVER	1

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	HELP! LAKE OVERTURNING!	1
	BIODIVERSITY = WATER QUALITY	2
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	2
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
Physical Systems: understand the BIODIVERSITY and productivity of ecosystems	BIOGRAPHY OF A RIVER	2
	BIODIVERSITY = WATER QUALITY	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	1
	UNDERSTANDING MARINE RESOURCES	1
	WETLANDS, USA - MORE THAN SWAMPS!	2
Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues	A GLOBAL VIEW OF THE WET EARTH	2
	WATER: MORE PRICELESS THAN GOLD	3
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	HELP! LAKE OVERTURNING!	2
	BIODIVERSITY = WATER QUALITY	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	3
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	1
	GROUNDWATER: CLEANING UP	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	2
Physical Systems: understand the importance of ecosystems in people's understanding of environmental issues (con't)	UNDERSTANDING MARINE RESOURCES	2
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SEA MARGIN DIVERSITY	2

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1-standard is part of focus of activity

CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	ESTUARIES: INTERFACE BETWEEN SEA AND LAND	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
	SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	1
Essential Element 4. Human Systems- Standard 9) The characteristics, distribution, and migration of human populations on Earth's surface; 10) The characteristics, distribution, and complexity of Earth's cultural mosaics, 11) The patterns and networks of economic interdependence on Earth's surface.		
Human Systems: understand the increasing economic interdependence of the world's countries	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	1
Human Systems: understand why and how cooperation and conflict are involved in shaping the distribution of social, political, and economic spaces on Earth at different scales	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	2
Human Systems: understand how differing points of view and self-interests play a role in conflict over territory and resources	WATER WHIZ - A BOARD GAME	2
	WATER YOU DOING ABOUT THIS?	2
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	2
	KEEP OUR COMMUNITY BEAUTIFUL!	2
	INTERNATIONAL WATER DISPUTES: YOU BE THE NEGOTIATOR!	3
	THERE "OUGHTA" BE A LAW	2
	UNCLE SAM SAYS, "KEEP IT CLEAN!"	2
Essential Element 5. Environment and Society- Standard 14) How human actions modify the physical environment; 15) How physical systems affect human systems; 16) The changes that occur in the meaning, use, distribution, and importance of resources.		
Environment and Society: understand the role of technology in the capacity of the physical environment to accommodate human modification	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
Environment and Society: understand the role of technology in the capacity of the physical environment to accommodate human modification (con't)	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	WHAT TURNED THE CREEK ORANGE?	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
Environment and Society: understand how to apply appropriate models and information to understand environmental problems	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	3
	WHAT TURNED THE CREEK ORANGE?	2
	GROUNDWATER: CLEANING UP WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2 2
	RADON IN WATER	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
	UNDERSTANDING MARINE RESOURCES	2
	RIVER INPUT INTO THE GULF OF MEXICO	3
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	2
Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity	WATER, WATER EVERYWHERE	1
	A GLOBAL VIEW OF THE WET EARTH	2
	WATER: MORE PRICELESS THAN GOLD	2
	WHAT TURNED THE CREEK ORANGE?	2
	FLOW NETS	2
	"HOW WATER PROCESSES MOVE SAND"	2
Environment and Society: understand how changes in the physical environment can diminish its capacity to support human activity (con't)	WATER, WATER EVERYWHERE	1
	A GLOBAL VIEW OF THE WET EARTH	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	WATER: MORE PRICELESS THAN GOLD	2
	WHAT TURNED THE CREEK ORANGE?	2
	FLOW NETS	2
	"HOW WATER PROCESSES MOVE SAND"	2
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	3
Environment and Society: understand the geographic results of policies and programs for resource use and management	FLOODS	2
	WHAT TURNED THE CREEK ORANGE?	1
	"HOW WATER PROCESSES MOVE SAND"	1
	SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	2
Environment and Society: understand how the spatial distribution of resources affects patterns of human settlement	WATER, WATER EVERYWHERE	1
	A GLOBAL VIEW OF THE WET EARTH	2
	WATER: MORE PRICELESS THAN GOLD	2
	UNDERSTANDING MARINE RESOURCES	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
Environment and Society: understand how resource development and use change over time	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	2
	WATER WHIZ - A BOARD GAME	2
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	1
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	THERE "OUGHTA" BE A LAW	2
Environment and Society: understand how resource development and use change over time (con't)	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	2
	WATER WHIZ - A BOARD GAME	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	1
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	1
	THERE "OUGHTA" BE A LAW	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	2
	UNDERSTANDING MARINE RESOURCES	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
Environment and Society: understand the geographic results of policies and programs for resource use and management	WATER, WATER EVERYWHERE	3
	WATER: MORE PRICELESS THAN GOLD	3
	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	FLOW NETS	2
	GROUNDWATER: CLEANING UP	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
	UNDERSTANDING MARINE RESOURCES	2
	EROSION KILL THE HABITATS THAT FEED YOU!	2
Essential Element 6. The Uses of Geography- Standard 17) How to apply geography to interpret the past; 18) How to apply geography to interpret the present and plan for the future.		
The Uses of Geography: understand how different points of view influence the development of policies designed to use and manage Earth's resources	WATER, WATER EVERYWHERE	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	A GLOBAL VIEW OF THE WET EARTH	2
	WATER WHIZ - A BOARD GAME	2
	WATER: MORE PRICELESS THAN GOLD	2
	WATER YOU DOING ABOUT THIS?	2
	ENVIRONMENTAL CONTROVERSY: CLASS PROJECT	2
	KEEP OUR COMMUNITY BEAUTIFUL!	1
	CATCH ME IF YOU CAN -- (TWO WAYS TO MEASURE STREAM FLOW)	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	3
	UNDERSTANDING MARINE RESOURCES	3
	RIVER INPUT INTO THE GULF OF MEXICO	1
	WETLANDS, USA - MORE THAN SWAMPS!	2
The Uses of Geography: contemporary issues in the context of spatial and environmental perspectives	WATER: MORE PRICELESS THAN GOLD	2
	UNDERSTANDING MARINE RESOURCES	2
	RIVER INPUT INTO THE GULF OF MEXICO	2
	WETLANDS, USA - MORE THAN SWAMPS!	1
The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions	WATER, WATER EVERYWHERE	2
	A GLOBAL VIEW OF THE WET EARTH	2
	WATER: MORE PRICELESS THAN GOLD	3
The Uses of Geography: understand how to use geographic knowledge, skills, and perspectives to analyze problems and make decisions (con't)	SOURCE WATER PROTECTION: Surface Water Sources	2
	SOURCE WATER PROTECTION: Groundwater Sources	2
	BEST MANAGEMENT PRACTICES FOR FORESTRY	2

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CORRELATION OF NATIONAL GEOGRAPHY STANDARDS TO THE WATER SOURCEBOOK (9-12)

(BY STANDARD)

Standard	Activity	Relation
	ETHICAL DILEMMAS WHAT'S A BODY TO DO?	2
	GROUNDWATER: CLEANING UP	2
	WHAT IS GROUNDWATER POLLUTION DOING TO THE NEIGHBORHOOD?	2
	RADON IN WATER	2
	LANDFILLS AND THE POTENTIAL FOR GROUNDWATER CONTAMINATION	2
	LEAKING UNDERGROUND STORAGE TANKS	2
	UNDERSTANDING MARINE RESOURCES	2
	WETLANDS, USA - MORE THAN SWAMPS!	2
	SWEPT AWAY -- OR -- WHERE WILL YOU BE WHEN THE WATER COMES?	2

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QCC CORRELATIONS BY SUBJECT (Grades 9-12)
Quality Core Curriculum (QCC)

Subject	Activity	QCC Correlation	Relationship to Local Curriculum
Chemistry	Clearly H ₂ O pg. 1-21	6, 11, 15	Chemical Bonding - Covalent Bonding and Molecular Compounds; pH of solutions; liquids
	pH - The First Clue to Water Quality pg. 1-109	11	Concept of pH
	Water Chemistry Checkup	11	Concept of pH, acids, and bases
	Metals Pollution Reduction pg. 2-59	8, 11, 15	Metallic bonding in metals, concept of pH, and properties of liquids
AP Chemistry	Clearly H ₂ O pg. 1-21	1, 8, 11, 16	Bonding and Shapes of Molecules Properties of solutions: Freezing Point Depression Boiling Point Elevation
	pH - The First Clue to Water Quality pg. 1-109	1, 10, 11	Solution Equilibrium Acid/Base Titration Ionization Constant of Water
	Pollutants: How Much Total Or How Much Per Unit of Water pg. 3-53	1, 16	Concentration of Solutions Serial Dilution
Biology	What Are Fecal Coliforms And How Are They Related To Water? 3-63 to 3-70	29.1, 29.2, 29.3, 29.4, 29.5	Unit on the Digestive System
	Surveying The Properties Of Water 1-11 to 1-20	4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6	Unit on Chemistry and Biochemistry
	Clearly Water 1-21 to 1-27	4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6	Unit on Chemistry and Biochemistry
	Risk Assessment: How Much Risk Are You Willing To Take? 1-133 to 1-145	24.1, 24.2, 24.3, 24.4	Unit on Personal Health/Disease
	Simple Test For Microbial Contamination 3-49 to 3-52	24.1, 24.2, 24.3, 24.4	Unit on Personal Health/Disease

	Chlorination For Disinfectant 2-15 to 2-32	24.1, 24.2, 24.3, 24.4	Unit on Personal Health/Disease
	Carbon Treatment For Water Pollution Control 2-9 to 2-14	24.1, 24.2, 24.3, 24.4	Unit on Personal Health/Disease
	The Hydrologic Cycle 1-1	1, 5, 19, 25	Ecology Unit: The Water Cycle and Homeostasis Botany Unit: Plan Transpiration
	Water Whiz: A Board Game 1-55	1, 27	Ecology Unit: Acid Rain, Pollution
	Drinking Water Jeopardy 2-21	1, 16, 20	Diversity of Life: Waterborne Diseases and the Impact Upon Living Organisms
	What is in Source Water 2-65	1, 16, 20	Diversity of Life: Observations of Protists and Microinvertebrates in a Pond Ecosystem
	Simple Test for Microbial Contamination 3-49	1, 15, 16, 17	Diversity of Life: Growth of Virus, Bacteria, Protozoa, and Fungi in Water Samples
	Wetlands - USA - More than Swamps 5-52	1, 26	Ecology Unit: Freshwater Aquatic Biomes
	Estuaries: Interface Between Sea and Land 5-53	1, 26	Ecology: Aquatic Biome
Applied Biology	Clearly H ₂ O 1-21	N/A	Waterbook. Subunit 4
	Water Careers 1-85	N/A	Waterbook. Subunit 1
	Water: More Precious Than Gold 1-91	N/A	Waterbook. Subunit 1
	Water Works 2-1	N/A	Waterbook. Subunit 5
	Groundwater Basics 4-1	N/A	Waterbook. Subunit 2
	Do You Drink It? 4-37	N/A	Waterbook. Subunit 3
	What is Groundwater Pollution Doing to our Neighborhood? 4-77	N/A	Disease and Wellness. Subunit 3
Ecology	Simple Test for Microbial Contamination	1, 35	Water Pollution Unit

	Water Whiz: A Board Game	36	Ground Water Unit
	Water, Water Everywhere	36	Surface Water Unit
	Wetlands, USA	18	Wetlands Unit
	Do You Drink It?	36	Aquifer Unit
Physics	Water Careers 1-85	1.1 - 1.4	Physics Careers
	Environmental Controversy: Class Project 1-105	1.1 - 1.4; 2.1 - 2.6	Science Process and Reasoning Skills
	How are Detection Limits Set for Water Pollutants? 2-55	1.1 - 1.4; 2.1 - 2.6	Mechanics and Limits
Physical Science	Clearly H ₂ O Pg. 1-21	4, 5, 9	Matter: Structure and Properties
	Surveying the Properties of Water Pg. 1-11	4, 5	Matter: Structure and Properties
	Waterwise: A Board Game Pg. 1-55	12	Energy
	pH - The First Clue to Water Quality Pg. 1-109	1, 4, 10	Chemical Reactions Acids and Bases
	Water Quality Checkup Pg. 1-185	1, 4, 5	Solutions, Families of Elements
	Water Works Pg. 2-1	4, 5	Matter: Structure and Properties
	Carbon Treatment for Water Pollution Control Pg. 2-9	9	Atomic Theory and Patters of Relativity
	The World of Biological Wastewater Treatment Pg. 2-83	10, 11	Chemical Reactions, Organic, and Biochemistry
	Chlorination for Disinfection Pg. 2-215	1, 4, 5	Solutions, Halogens
	How are Detention Limits Set for Water Pollutants	1, 5, 13, 15	Accuracy in Measurements, Inclined plans/Simple Machines
	Radon in Water Pg. 4-85	7, 8	Atomic Theory and Patters for Reactivity
	Oil Spills Pg. 5-659	11	Organic and Biochemistry
Geology	Water Careers Pg. 1-85	1, 2, 21, 22,, 25, 26, 28, 29, 30, 31	Resources and Our Environment Chapter 6 Unit 1

	The Hydrologic Cycle or The Ocean Pg. 1-1	1, 10, 14, 30, 31	Water Moving Underground (The never-ending movement of water) Unit 2 Chapter 9
	A Global View of the Wet Earth Pg. 1-41	1, 10, 13, 22, 23, 26, 30, 31	The Ocean: Unit 4 Earth - The Water Plant Chapter 17
	Floods Pg. 3-37	1, 12, 14, 30, 31	Forces that Attack the Surface Unit 2 Running Water Chapter 10
	Water You Doing About This? Pg. 1-97	1, 2, 22, 23, 25, 28, 29, 30, 31	Resources and Our Environment Unit 1 Environmental Problems and Solutions Chapter 6

GLOSSARY

above ground storage tanks (ASTs): any type of container used above the surface to store products. Regulated ASTs include those containing 660 or more gallons (in one container) or 1320 gallons (in more than one container) of oil of any kind and which pose a potential discharge to surface waters.

absorption field (drainfield): area where effluent from a septic tank is discharged

accretion: the process of growing by being added to

accuracy: the closeness of a measurement to the true or accepted value

acid mine drainage: acidic waters that are formed in mine areas from water coming into increased contact with sulfate and sulfide minerals. This forms sulfuric acid.

acidic: having a pH value of less than 7; acidic liquids are corrosive and sour **(DO NOT TASTE!)**

acidity: (1) a characteristic of substances with a pH less than 7; (2) tending to form an acid

acid rain: rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels or from volcanic activity; may cause damage to buildings, monuments, car finishes, crops, forests, wildlife habitats, and aquatic life

activated sludge: sludge particles produced by the growth of microorganisms in aerated tanks as a part of the activated sludge process to treat wastewater

activated carbon (charcoal): material made from coal by driving off hydrocarbons under heat without oxygen, leaving a tremendous surface area on which many chemicals can be adsorbed

acute (toxic) effects: adverse health effects which are observed rather quickly after exposure to a toxin; illness with rapid onset caused by a toxin

adage: an old saying; a phrase passed down through the years

adhere: to stick fast; stay attached to another substance

adhesion: the act of sticking (surface attraction) or the state of being stuck together

adsorption: phenomenon by which molecules in a fluid phase are attracted to a solid surface (e.g., activated carbon) and held there by physical or weak chemical bonds

advanced treatment: any level of treatment beyond secondary treatment that includes secondary treatment plus nutrient removal. Advanced treatment generally removes greater than 85% of BOD and TSS; typically required when the waters receiving effluent from a treatment plant do not provide adequate dilution. It is generally very expensive to construct and maintain advanced treatment facilities.

aeration: exposing to circulating air; addition of oxygen to wastewater or water, as in first step of both activated sludge wastewater treatment process and drinking water treatment

aerobic: with oxygen; needing oxygen for cellular respiration

aesthetic: (1) drinking water - refers to water characteristics such as taste, odor, color, and appearance that reduce the quality but do not necessarily result in adverse health effects;
(2) of or relating to the sense of the beautiful; artistic quality or appearance

AF: (acre foot) - volume of any substance required to cover one acre of a surface to the depth of 1 ft ($43,560 \text{ ft}^3$) or (1232.75 m^3)

agriculture: science of cultivating the soil, producing crops, and raising livestock; farming

air sparging: injecting air into groundwater to help remove contaminants

algae: any various, primitive, chiefly aquatic, one-celled or multicellular plants that lack true stems, roots, and leaves, but usually contain chlorophyll. Algae are divided into three groups: chlorophyta (green), phaeophyta (brown), and rhodophyta (red), typically grow in sunlit waters in proportion to the amount of nutrients available, and serve as food for fish and small aquatic animals.

algal bloom: a sudden increase in the amount of algae, usually causing large, floating masses to form. Algal blooms can affect water quality by lowering DO content and decreasing sunlight penetration, are usually caused by excessive nutrient addition, and can be characteristic of a eutrophic lake.

alkaline: having a pH greater than 7; alkaline liquids are caustic and bitter **(DO NOT TASTE!)**

alkalinity: (1) a characteristic of substances with a pH greater than 7; (2) the capacity of water to

neutralize acids, imparted primarily by the water's content of carbonates, bicarbonates, and hydroxides (expressed in mg/l of CaCO_3)

allegory: a story in which symbols are used to present moral truths

alliteration: repetition of an initial sound, usually of a consonant or cluster, in two or more words of a phrase or line of poetry

alum: aluminum salt (typically, aluminum sulfate) used as a flocculant

anaerobic: in the absence of oxygen; able to live and grow where there is no air or free oxygen, as certain bacteria

anhydrite: a white to grayish or reddish mineral of anhydrous (free from water) calcium sulfate (CaSO_4) occurring as layers in gypsum deposits

anthropomorphize (personify): to take something inanimate or subhuman and give it human characteristics

aqueous: of, pertaining to, or dissolved in water

aquiclude: a low-permeability unit that forms either the upper or lower boundary of a groundwater flow system

aquifer: porous, water-bearing layer of sand, gravel, and rock below the Earth's surface; reservoir for groundwater

aquifer recharge: the addition of water by any means to an aquifer

aquitard: a low-permeability layer of rock or clay that can store water but transmits it very slowly one aquifer to another

arid: lacking enough water for adequate growth; dry and barren

artesian well: a well that produces water without need for pumping due to pressure exerted by confining layers of soil

artesian aquifer: an aquifer that is sandwiched between two layers of impermeable materials and is under great pressure, forcing the water to rise without pumping. Springs often surface from artesian aquifers.

aseptic: free or protected from disease-producing or putrefying microorganisms

assessment: a fact-based evaluation or judgment

atmospheric pressure: the pressure or force per unit area, exerted by the atmosphere on any surface beneath or within it

atmospheric water: water found in vapor form in the atmosphere

atom: any of the smallest particles of an element that combine with similar atomic particles of other elements to produce molecules; made up of electrons, neutrons, and protons

attenuation: dilution or lessening in severity

bacteria: typically one-celled, non-photosynthetic microorganisms that multiply by simple division. They occur in three main forms: spherical (cocci), rod-shaped (bacilli), and spiral (spirilla).

banana wrap: plastic that is put around bananas during shipping

bar-built estuary: type of estuary formed by a series of bars or islands created from offshore depositing sand, washed down by rivers or in from deep water. The sand works up the continental shelf and stabilizes. A bar-built estuary is usually laterally extended along the shore, and is long, narrow, and low.

barrier island: a ridge of sand and gravel thrown up parallel to a coastline by the waves and tides with a lagoon behind it

barrier reef: a rock or coral reef, aligned roughly parallel to a shore and separated from it by a lagoon

bathymetry: the measurement of the depth of the ocean

bay: a body of water partly enclosed by land but with a wide outlet to the sea

bedrock: the solid rock that underlies all soil, sand, clay, gravel, and loose material on the Earth's surface; the bottom layer

benefit: help or reward; positive factors to consider

benthic: living on the bottom of a lake or sea; pertaining to the ocean bottom

benzene: (1) a clear, inflammable, poisonous, aromatic liquid, C_6H_6 , obtained by scrubbing coal gas with oil and by the fractional distillation of coal tar. It is used as a solvent for fats and in making lacquers, varnishes, many dyes, and other organic compounds; (2) a structural unit in the molecules of organic aromatic compounds.

Bernoulli Principle: the statement in hydraulics that, under conditions of uniform steady flow of water in a conduit or stream channel, the sum of the velocity head, the pressure head, and the head due to elevation at any given point is equal to the sum of these heads at any other point plus or minus the losses in head between the two points due to friction or other causes

best management practices (BMPs): techniques that are determined to be currently effective, practical means of preventing or reducing pollutants from point or nonpoint sources in order to protect water quality. BMPs include, but are not limited to: structural and nonstructural controls, operation and maintenance procedures, and other practices. Usually, BMPs are applied as a system of practices rather than as a single practice.

bicarbonate: an acid salt of carbonic acid containing the radical HCO_3^-

bioaccumulate: to accumulate larger and larger amounts of a toxin within the tissues of organisms at each successive trophic level

bioaccumulation: the process by which a substance is taken up by an (aquatic) organism both from water and through food

bioassessment: an evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters

biochemical oxygen demand (BOD): a laboratory measurement of wastewater that is one of the main indicators of the quantity of pollutants present; a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material

biodegradable: capable of being decomposed (broken down) by natural biological processes

biodegradation: the breakdown of materials by living things into simpler chemicals

biodiversity: the number of different varieties of life forms in a given area, or an index derived from this number

biological treatment: treatment of wastewater using microorganisms to decompose undesirable

organic compounds in an aqueous waste stream

biological magnification (biomagnification): bioaccumulation occurring through several levels of a food chain; process by which certain substances (such as pesticides or heavy metals) are deposited into a waterway, are eaten by aquatic organisms which are in turn eaten by large birds, animals, or humans, and become concentrated in tissues or internal organs as they move up the food chain.

biomes: area or groups of ecosystems with similar climates, soils, and communities

bioremediation: a biologically mediated corrective process that occurs naturally over time; humans may speed up this process through technology (see in-situ bioremediation)

biosolids: wastewater solids that meet government criteria for beneficial use

biota: the plant and animal life of a region

biotic: living or derived from living things

blackwater: domestic wastewater containing human or animal waste or other sources of pathogens

“bloom” (algal bloom): a sudden excessive growth of algae that can affect water quality adversely; large floating masses of algae; characteristic of a eutrophic lake

blowouts: when an oil well blows its top and spews crude oil into the air

“blue baby” syndrome (methemoglobinemia): pathological condition where the skin of infants (or other sensitive groups) turns blue due to nitrates bonding with red blood cells, which prevent the transport of oxygen throughout the body; can be caused by nitrate contamination in drinking water

BOD (Biochemical Oxygen Demand): a laboratory measurement of wastewater that is one of the main indicators of quantity of pollutants present

bog: freshwater marsh with build-up of peat and high acidity, that typically supports mosses adapted to acidic soil conditions (particularly, sphagnum); many are located in colder regions

boiling point (BP): the temperature at which a liquid starts to bubble up and vaporize by being heated

bottled water: water that is sealed in food grade bottles and is intended for human consumption

bottomlands: lowlands along streams and rivers that are typically flooded

brackish water: water that is a mixture of fresh and salt water

buffer zone: an area between the water supply source and the possible contamination sources where no contamination activities are likely to occur

calcium carbonate: one of the most stable, common, and widely dispersed materials on Earth; occurs naturally in oyster shells, calcite, limestone, marble, chalk, and other forms; used to express hardness and alkalinity (mg/l of CaCO_3)

capillary action: the action by which the surface of a liquid where it is in contact with a solid (as in a capillary tube) is elevated or depressed depending on the relative attraction of the molecules of the liquid for each other and for those of the solid

carbon column: compressed activated carbon in a tube; used for adsorption processes

carbonate aquifer: underground layer of limestone that is saturated with usable amounts of water

carbon dioxide: colorless, odorless gas made of carbon and oxygen (CO_2); exhaled by animals, and humans, utilized by plants in photosynthesis and contained in automobile exhaust

carbonic acid: substance formed by combining water (H_2O) and carbon dioxide (CO_2); chemical formula H_2CO_3

carcinogen: cancer-causing agent

career: a chosen pursuit or life's work; a job or profession one is trained to do

cartographer: a person whose work is making maps or charts

channel: (1) a body of water joining two larger bodies of water; (2) a channel could also be the physical dimensions of a stream or river

channeling: to make a channel or channels in

channelization: the straightening and sometimes deepening of stream or river channels to speed water flow and reduce flooding. A waterway so treated is said to be channelized. However, channelization can cause unstable situations and may cause adverse environmental impacts.

chemical oxidation: a means of destroying dissolved organic contaminants in water using ultraviolet (UV) radiation, hydrogen peroxide, or other processes

chemical water pollution: introduction of chemicals into a waterbody

chlorination: the addition of chlorine to water to destroy microorganisms especially for disinfection

chlorine: a chemical compound used as disinfectant in wastewater treatment and drinking water treatment processes; symbol Cl_2

chronic (toxic) effects: adverse health effects that are either the result of long-term (chronic) use or those that are permanent or long-lasting (e.g., cancer)

cinquain: a poem of five lines as follows:

First line	One word, giving title
Second line	Two words, describing title
Third line	Three words, expressing an action
Fourth line	Four words, expressing a feeling
Fifth line	One word, a synonym for the title

clarifier (settling tank or sedimentation tank): a vessel in which solids settle out of water by gravity during drinking water or wastewater treatment processes

Clean Water Act (CWA): water pollution control law passed to restore and maintain the nation's waters; the nation's primary source of federal legislation that specifies the methods to be used in determining how much treatment is required for discharges (effluents) from publicly owned treatment works (POTWs)

club soda: same as soda water; water charged under pressure with carbon dioxide gas

Cnidaria: phylum name for a group of invertebrates that includes coral animals, jellies, sea anemones and the hydra

coagulant: a substance added to a mixture that will cause precipitates (flocs) to form; also called "flocculant"

coagulation: the process by which dirt and other small suspended solid particles are chemically bound, forming flocs using a coagulant (flocculant) so they can be removed from the water (the second step in drinking water treatment)

cohere: to be united by molecular cohesion; to stick to the same substance

cohesion: the force by which the molecules of a substance are held together

colloid: a solid, liquid, or gaseous substance made up of very small, insoluble, nondiffusible particles that remain in suspension in a surrounding solid, liquid, or gaseous medium of different matter

commensal relationship: a relationship between two organisms in which one is benefited by the relationship and the other is neither benefited nor harmed

common law: the law of a country or state based on custom, usage, and the decisions and opinions of law courts

community: assemblage of populations of species living together and interacting with each other within a certain area

compound: a substance formed by the bonding of two or more atoms or ions that share electrons (covalent compounds) or transfer electrons (ionic compounds)

con: against; in opposition; negative consideration

concentration: strength or density, as of a solution, as in amount of solute per volume of solution

condensation: (1) the process of changing from a vapor to a liquid; (2) a liquid obtained by the coming together of a gas or vapor

confined aquifer: an artesian aquifer

conservation: act of using the resources only when needed for the purpose of protecting from waste or loss of resources

contaminant: an impurity that causes air, soil, or water to be harmful to human health or the environment; something that makes a substance impure, infected, corrupted, or polluted

continental shelf: a shallow, submarine plain of varying width, forming a border to a continent and typically ending in a steep slope to the oceanic abyss

contour: (1) imaginary line on the surface of the Earth connecting points of the same elevation; (2) a way of shaping the surface of the land in a particular form, commonly used to prevent erosion and control water flow

conversion: a physical transformation from one material state to another

coral reef: erosion-resistant marine ridge or mound built slowly over thousands of years by coral polyps (tiny animals) bound together with algal material and biochemically deposited carbonates

corrosion: a substance formed or an action of wearing away by chemicals; formed by deterioration

cost: price; practical factors to consider

covalent bond: bond formed between two atoms when they share pairs of electrons

crude oil: unrefined petroleum; a mixture of many different hydrocarbons

cryptosporidiosis: acute, highly infectious disease caused by the protozoan *Cryptosporidium parvum* that can be transmitted by contaminated food or water

current: a flow of water or air, especially when strong or swift, in a definite direction; specifically, such a flow within a larger body of water or mass of air

cypress domes: small, depressional swamps, typically with tall cypress trees at center characterized by subsurface hardpan overlain by organic matter

dam: man-made or animal-made barrier across a stream that holds and regulates flow of water

decomposition: the process of breaking down into constituent parts or elements

deltaic estuary: type of estuary formed by a delta

delta: a deposit of sand and soil, usually triangular, formed at the mouth of some rivers

density: the ratio of mass of an object to its volume

deposition: a laying or putting down (settling out suspended materials in a liquid due to a decrease in velocity of the suspension)

detritus: decomposed or disintegrated organic matter (found in water and on land) and associated microbial elements

diatomic molecule: molecule made of two atoms

digested solids: sewage solids that have been broken down by microorganisms

digestion: the process of sewage treatment by the decomposition of organic matter; decomposition of organic waste materials by the action of microbes

dike: elevated structure alongside of stream or perpendicular that acts as a barrier to floodwaters

discharge: (1) the outflow of groundwater from a flowing artesian well, ditch, or spring; (2) the release or emittance of a substance.

discharge area: an area where groundwater flowing toward the surface escapes as a spring, seep baseflow, or by evaporation and transpiration

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in water; used in both wastewater and drinking water treatment

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water

distributary: a branch of a river that flows away from the main stream

diversions/channeling: altering the course of a river or stream causing the stream to change its direction

dolomite: a mineral $[CaMg(CO_3)_2]$ consisting of a calcium magnesium carbonate found in crystals and in extensive beds as a compact rock

domestic wastewater: wastewater that comes primarily from individuals and does not generally include industrial or agricultural wastewater

dowsing: to search for a source of water or minerals with a divining rod

drawdown: the lowering of the water table as water is removed from an aquifer

drinking water standard: maximum contaminant level or treatment technique requirement

drowned river valley: type of estuary that is wider than deep and triangular in shape

eddy: a current (of water or air) running contrary to the main current

effluent: treated wastewater, flowing from a lagoon, tank, treatment process, or treatment plant

electron: any of the negatively charged particles that form a part of all atoms; exists outside the nucleus; involved in bond formation

element: natural substances that cannot be broken into anything simpler by ordinary chemical means

elevation head: the elevation of the point at which the hydrostatic pressure is measured, above or below an arbitrary horizontal datum

emergent: rising from a surrounding liquid

Environmental Protection Agency (EPA): the U.S. agency responsible for efforts to control air, land, and water pollution, radiation, and pesticide hazards, and to promote ecological research, pollution prevention, and proper solid waste disposal

epidemic diseases: diseases that spread rapidly by infection among many individuals in an area

epilimnion: one of three temperature or thermal zones located at the top of a thermally stratified lake; varies in size and temperature characteristics based on a seasonal cycle

epitaph: a short composition in prose or verse, written as a tribute to a dead person

equator: a great circle of the Earth that is everywhere equally distant from the two poles ~~and divides~~ the Earth's surface into the northern and southern hemispheres

equipotential line: a line in a two-dimensional groundwater flow field such that the total hydraulic head is the same for all points along the line

erosion: the process of detachment, transport, and deposition of soil material

escarpment: a long cliff or steep slope separating two comparatively level or more gently sloping surfaces

estuarine: formed or deposited in an estuary; of or having the characteristics of an estuary

estuary: a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouths of rivers, and includes bays, lagoons, sounds, and marshes.

ethics: the study of the general nature of values and of the specific moral choices to be made by the individual in relationships with others and his/her environment

eutrophic: refers to a body of water characterized by nutrient-rich water supporting abundant growth of algae and/or other aquatic plants at the surface

eutrophic lake: a lake containing a high concentration of dissolved nutrients; often shallow, with periods of oxygen deficiency

eutrophication: the process in which a body of water becomes oxygen deficient, nutrient-rich and supports an abundant growth of surface aquatic plants and algae; natural aging cycle of lakes, normally taking centuries, but it can be rapidly accelerated when outside sources of nutrients are added, such as wastewater, fertilizer, or feed lot runoff

evaporate: to pass off in vapor or in invisible minute particles (to cause evaporation)

evaporation: the process of changing from a liquid to a vapor

facultative anaerobic: describes an organism that can use another electron accepting molecule other than oxygen for cellular respiration, if oxygen is not present

fault: a fracture in the Earth's crust accompanied by displacement of one side of the fracture with respect to the other

fecal coliform bacteria: a type of coliform bacteria found in the intestines of humans and warm-blooded animals that aids in the digestion process and is used as an indicator of fecal contamination and/or possible presence of pathogens

feed lots: confined areas where livestock is kept

ferment: to break down sugars only partially, producing a gas (usually CO₂) and alcohol

fertilizer: natural and synthetic materials including manure, nitrogen, phosphorus and treated with sludge that are worked into the soil to provide nutrients and increase its fertility

filter strip: area of land that infiltrates surface runoff and traps sediment and associated pollutants

filtration: the process of passing a liquid or gas through a porous article or mass (e.g. paper, membrane, sand) to separate out matter in suspension, used in both wastewater and drinking water treatment

fjord: narrow, deep valleys carved by glaciers and flooded by the sea

fjord-drowned glacial valley: type of estuary usually found in arctic and polar regions, U-shaped, deeper than wide, that has a small river discharge and a large tidal volume; important to

shipping

flocculant: a substance added to a mixture that will cause precipitates (flocs) to form; also called “coagulant”

flocculation: physical process of growing of flocs from smaller flocs or particles

flocs: lumpy or fluffy masses of particles agglomerated by a flocculant or coagulant

floodplain: relatively flat area on either side of a river that may be under water during a flood

flow line: the line of flow of groundwater

flow net: the set of intersecting equipotential lines and flow lines representing two-dimensional steady flow through porous media

fluid: a substance, as a liquid or gas, that is capable of flowing and that changes its shape at a steady rate when acted upon by a force

fluid pressure: the mechanical energy per unit mass of a fluid, at any given point in space and time, with respect to an arbitrary state and datum (fluid potential)

fluoride: a binary compound of fluorine added to drinking water to help prevent tooth decay

fluvial: found in, produced by, or relating to a river

forested wetland: wetland dominated by trees. “Trees” (for the purpose of this definition) are defined as woody vegetation with diameter greater than 3 inches at breast height (approximately 4 feet from ground level).

fossil fuels: hydrocarbon fuels, such as petroleum, derived from living things of a previous geologic time

fracture: a break in rock that may be caused by compressional or tensional forces

freezing point (FP): the temperature at which a liquid begins to precipitate crystals

freshwater marsh: a wetland frequently or continually inundated by freshwater, characterized by herbaceous vegetation

gastrointestinal tract: the hollow tube that runs from the mouth to the anus in animals

geologic map: a map of the Earth's surface with surface geologic formations superimposed over existing features such as roads, streams, lakes, and other features

geological formation: a body of rock identified by lithic characteristics and stratigraphic position; the fundamental unit in lithostratigraphic classification

geology: a science that deals with the structure and history of the Earth and its life, especially as recorded in rocks

glacier: a large mass of ice formed on land by compacted snow

gradient: change of elevation, velocity, pressure, or other characteristics per unit length; slope

gram negative: the result of a certain laboratory test done on microorganisms to divided into two groups (either gram negative or gram positive). Gram negative bacteria have a cell membrane composed of lipopolysaccharide and protein.

graywater: wastewater from households which does not come into contact with sewage

grit chamber: a chamber or tank used in primary treatment where wastewater slows down and heavy, large solids (grit) settle out and are removed

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

groundwater divide: a crest of the water table with flow going in opposite directions on either side

gulf: a large area of a sea or ocean partially enclosed by land

gulf stream: the oceanic current that brings warm Gulf of Mexico water up along the east coast of the U.S. and across the Atlantic to the British Isles

habitat: the place or type of site where a plant or animal naturally or normally lives and grows

haiku: 3-line poem. First line has 5 syllables, second line has 7 syllables, and third line has 5 syllables

harbor: a waterbody where wave action is reduced or dampened

hard water: water high in mineral content; water containing an abundance of Ca^{+2} and Mg^{+2} ions

hardness: a measure of all the multivalent (primarily calcium and magnesium) ions expressed as mg/l of calcium carbonate (CaCO_3)

hazardous waste: waste materials that are dangerous to human health and/or the environment

headwaters: the streams that are the sources of a river

homogeneous: (1) uniform throughout in structure or make-up (for a substance or material); (2) of the same or similar nature or kind (for a group)

hot spot: region where an unusually high number of deaths are due to cancer that might be linked to environmental contamination

hydraulic head: the height of the free surface of a body of water above a given subsurface point; the sum of elevation, pressure, and velocity components at a given point in an aquifer

hydrocarbons: a very large group of chemical compounds consisting primarily of carbon and hydrogen. The largest source of hydrocarbons is petroleum (crude oil).

hydrogen sulfide: gas emitted during organic decomposition by anaerobic bacteria which smells like rotten eggs and can cause illness in heavy concentrations (chemical formula, H_2S)

hydrologic cycle: the cyclical process of water's movement from the atmosphere, its inflow and temporary storage on and in land, and its outflow to the oceans; cycle of water from the atmosphere, by condensation and precipitation, then its return to the atmosphere by rain and transpiration.

hydrology: the study of water, its properties, distribution on Earth, and effects on the Earth's environment.

hydroxide precipitation: using the hydroxide ion (OH^-) to cause a material to come out of solution

hypolimnion: one of three temperature or thermal zones located at the bottom of a thermally stratified lake; varies in size and other characteristics based on a seasonal cycle

hypoxic: containing very little or decreased oxygen

igneous rock: rock that solidified from a hot, liquid state

impermeable (substance): a substance through which other substances are unable to pass

in-situ bioremediation: a means of degrading hydrocarbon-based contaminants at the site of contamination

incubation: the phase of development of a disease between the infection and the first appearance of symptoms

indicator organism: an organism whose presence or absence typically indicates or provides information on the certain conditions within its environment

infiltration: the flow of water downward from the land surface into and through the upper soil layers

influent: wastewater flowing into a treatment plant

ingestion: the process of taking into the body, as by swallowing

injection well: a well in which fluids, such as wastewater, saltwater, natural gas, or used chemicals, are injected in the ground for the purpose of disposal or to force adjacent fluids like oil into the vicinity of oil-producing wells

inspect: to examine in detail, especially for flaws

interstitial: of, forming, or occurring in a small or narrow space between things or parts

intertidal: of, or pertaining to a shore zone bounded by the levels of low and high tide

inventory: a detailed list of items in one's view or possession, especially a periodic survey of goods and materials

ion: an atom or molecule that has lost or gained one or more electrons

ionization constant: a comparison of the strengths of acids or bases in a given solvent, such as water, expressed by the amount of H^+ ions compared to the OH^- ions

isotropic: having physical properties, such as conductivity and elasticity, the same regardless of the direction of measurement

kinetic energy: the energy of a body resulting from its motion

kinetic movement: movement of electrons, atoms, and molecules as a result of their energy state

lactose: a type of simple sugar that can be digested by fecal coliform bacteria

lagoon: a shallow body of water, especially one separated from the sea by sandbars or coral reefs

lagoons (oxidation ponds or stabilization ponds): a wastewater treatment method that uses ponds to treat wastewater. Algae grow within the lagoons and utilize sunlight to produce oxygen, which is in turn used by microorganisms in the lagoon to break down organic material in the wastewater. Wastewater solids settle in the lagoon, resulting in effluent that is relatively well treated, although it does contain algae.

lake: a standing body of water which undergoes thermal stratification and turnover by mixing

leachate: a liquid that results from water collecting contaminants as it trickles through wastes, or soil containing agricultural pesticides or fertilizers

leaching: the removal of chemical constituents from rocks and soil by water (Leach = to leak)

leaking underground storage tank: underground storage tank which has spilled, leaked, emitted, discharged, leached, disposed, or otherwise allowed an escape of its contents into groundwater, surface water, or subsurface soils

leeward: in the direction toward which the wind blows; of the side of anything away from the wind

lentic system: surface water that is standing such as a lake or a pond

levee: an embankment, natural or artificial, built alongside a river to limit high water events from flooding bordering land

limestone: a rock that formed chiefly by accumulation of organic remains; consists mainly of calcium carbonate

limnetic zone: a zone in a lake extending over open water from the edge of one littoral zone to the other and above the profundal zone; characterized by floating vegetation and moderate to high sunlight penetration

limnology: the science that deals with the physical, chemical, and biological properties and features of fresh waters, especially lakes and ponds

liquid: fluid composed of molecules that move freely among themselves but do not tend to separate like those of gases; state of matter that has a definite volume but not a definite shape

lithic: of stone

lithostratigraphy: the arrangement of rocks in layers or strata; the branch of geology dealing with the study of the nature, distribution, and relations of the stratified rocks of the Earth's crust

littoral drift: movement of materials along the shore

littoral zone: a zone along the shore of a lake that is characterized by very shallow water, rooted vegetation, high sunlight penetration

log landing: site where logs are sorted and loaded onto trucks for hauling

longshore current: a flow of water that runs along the shoreline that is usually strong or swift

loop current: oceanic current that enters the Gulf of Mexico through the Yucatan Channel and/or exits through the Straits of Florida (Parent of the Gulf Stream)

lotic system: surface water that is flowing such as a river or stream

man-made: made by humans; artificial or synthetic

management: to effect a plan of action; to solve a problem by direction, guidance, administration, or control

mangrove swamps: tropical, wet, coastal areas dominated by mangroves (trees). Mangroves have extensive root systems which form a dense thicket, providing cover for aquatic life.

MARPOL Treaty: international treaty that regulates the disposal of solid waste, including plastics

marsh: wetland dominated by grasses

maximum contaminant level (MCL): maximum permissible level of a contaminant in water is delivered to any user of a public water system; drinking water standard

mechanical treatment plant: uses blowers and surface aerators to transfer oxygen into the water

metallurgy: the science of separating metals from their ores and preparing them for use by smelting, refining

metamorphic rock: rock made by heating and pressurizing preexisting rocks

metaphor: a figure of speech containing an implied comparison in which a word or phrase ordinarily and primarily used for one thing is applied to another

Method Detection Limit (MDL): the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero

microalgae: plant-like microorganisms that use chlorophyll for photosynthesis

microbe: microorganism (microbiological organism)

microbiological: referring to microscopic or ultramicroscopic organisms such as algae, bacteria, or protozoa

microbiology: study of microorganisms, a large and diverse group of organisms that exists as single cells or cell clusters

microorganisms: microscopic or ultramicroscopic organisms (e.g., bacteria, protozoa, viruses)

mineral waters: sparkling (carbonated) waters generally used as an alternative to soft drinks or cocktails

model: using simple or familiar objects to explain or demonstrate a new, unfamiliar, or complicated concept

molecule: the smallest particle of a compound that can exist in the free state and still retain the characteristics of the compound

mud flats: large estuarine expanses composed of rich muds exposed at low tides

multimedia filters: filters that contain more than one type of filtering material

multivalent (ion): ion that has lost or gained more than one electron (also called “polyvalent ion”)

municipal: of or relating to municipality (city, town, etc.). Municipal wastewater is primarily used as wastewater

natural: produced or existing in nature; not artificial or manufactured

natural water: water that comes from springs or streams and does not have any chemicals added to it

negotiations: a conferring, discussing, or bargaining to reach an agreement

NIMBY: NOT IN MY BACK YARD

nitrates: compounds containing nitrogen as nitrates (NO_3^-). In the environment, these compounds are found in animal wastes, fertilizers, and in septic tanks and untreated municipal sewage. Their primary public health hazard is the cause of methemoglobinemia or “blue baby” syndrome.

non-degradable: not capable of chemical or biological decomposition

nonendospore-forming: does not form an encapsulated nucleus resistant to most harsh environmental conditions

nonpoint source: general or collective source of contamination

nonpoint source pollution (NPS): pollution that cannot be traced to a single point (e.g., outlet or pipe) because it comes from many individual sources or a widespread area (typically, urban, rural, and agricultural runoff)

nonpolar molecule: covalent molecule that does not exhibit any partial (+) or (-) charges or fields

nonrenewable resource: a resource in a fixed amount; all minerals, coal, crude oil, and natural gas

NPDES (National Pollutant Discharge Elimination System): a program created by the Clean Water Act to ensure that water quality is maintained by dischargers of wastewater. NPDES permits require the operator of wastewater treatment plants to test and report the quality of the effluent discharged to streams. The NPDES permit specifies pollutant limitations on the effluent that prevent damage to receiving waters.

nutrients: compounds, minerals, or elements needed by living organisms to carry on their functions. Nitrogen, phosphorus, potassium, and other elements are examples of nutrients required for plant growth.

ocean: the entire body of salt water that covers about 71 percent of the Earth’s surface

oceanography: a science that deals with the oceans and includes the delineation of their extent and depth, the physics and chemistry of their waters, marine biology, and the exploration of their natural resources

oligotrophic: refers to any ecosystem that has nutrient-poor water

optimum pH: the pH condition that will produce the best results for a given purpose

organic: of, pertaining to, or derived from living organisms

organic molecule: any molecule that contains carbon and hydrogen

osmotic pressure: the force per unit area exerted by a solvent passing through a semipermeable membrane in osmosis, equal to the pressure that must be applied to the solution in order to prevent passage of the solvent into it

outcrop: the exposure of bedrock or strata projecting through the overlying cover of detritus and soil

overturning (turnover): process by which water and nutrients are circulated in a lake due to thermal processes which can occur on a seasonal basis

parts per million (ppm): a measurement of concentration of 1 unit of material dispersed in 1 million units of another (for water, same as mg/l)

pathogenic: producing disease

pathogens: disease-causing agents, especially disease-producing microorganisms

perception: one's belief, comprehension, or knowledge; may not be based on facts

percolate: to drain or seep through a porous and permeable substance; to filter such as a liquid passing through a porous body (water through soil to the aquifer)

percolation: the downward movement through the subsurface soil layers to groundwater

percometer: an instrument to measure the rate of percolation

permeability: the capacity of a porous material to transmit fluids. Permeability is a function of the sizes, shapes, and degree of connection among pore spaces, the viscosity of the fluid, and the pressure driving the fluid.

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 - 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

phosphate: an ion composed of a phosphorus atom with 4 oxygen atoms attached (PO_4^{-3}) It is an important plant nutrient.

phosphorus: an element considered the key nutrient in controlling eutrophication in lakes and ponds

phylum: the principal division of kingdoms. The classification system is the characterization of an organism by its Kingdom, Phylum, Class, Order, Family, Genus, and Species.

phytoplankton: any of the many species of plants (such as algae) that consist of single cells or small groups of cells that live and grow freely suspended in the water near the surface

picrocuries per liter (pCi/L): units for measurement of radioactive element concentration and in air

plane of turbulence: the flat, level, or even surface in which there is violent, irregular motion or swirling agitation of water

plankton: microscopic plants and animals in water which are influenced in mobility by the movement of water (i.e., as opposed to nekton (fish) which can swim)

plume: an area where a contaminant has spread out

point source: known source of contamination

point source pollution: pollution that can be traced to a single point source such as a pipe or culvert (e.g., industrial, wastewater treatment plant, and certain storm water discharges)

polar molecule: covalent molecule that has a partial (+) and partial (-) end

pollutant (water): any substance suspended or dissolved in water that builds up in sufficient quantity to impair water quality

pollution: an unwanted change in air, water, or soil (usually through the introduction of pollutants or contaminants) that can affect the health and survival of humans and other organisms

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation or increased efficiency in the use of energy, water, or other materials

pond: a still body of water smaller than a lake where mixing of nutrients and water occurs primarily through the action of wind (as opposed to turnover)

population: group of organisms of a single species living in a certain area and interbreeding (or interacting)

pore: a passage; channel; a tiny opening, usually microscopic

pore space: the volume of the open spaces in rock or soil

porosity: a description of the total volume of rock or soil not occupied by solid matter

potable water: water suitable for drinking without harmful effects

potentiometric surface: a surface that represents the level where water will rise in a tightly cased well. The water table is the potentiometric surface for an unconfined aquifer.

prairie potholes: shallow marsh-like ponds which serve as primary breeding grounds for ducks and migratory birds found in North Dakota, South Dakota, Minnesota, and Canada

precipitation: water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the Earth's surface, such as rain or snow

precision: the agreement among the numerical values of a set of measurements of the same quality made in the same way

pressure head: the height of a column of liquid supported, or capable of being supported by pressure p at a point in the liquid

pressurize: to put (gas or liquid) under a greater than normal pressure

primary productivity (producers): in an ecosystem, those organisms, mostly green plants that use light energy to construct their organic constituents from inorganic compounds

primary treatment: the first stage of wastewater treatment that removes settleable or floating solids only; generally removes 40% of the suspended solids and 30-40% of the BOD in the wastewater

Prior Appropriations Water Rights: doctrine of western states that says that "one who is first in time is first in right," or whoever occupies a location first receives the water that he/she wants or needs

privy: an outhouse; a latrine

pro: for; in support of; affirmative consideration

profundal zone: a zone in a lake extending from the bottom of the limnetic zone to the bottom of the lake; characterized by deep waters, decomposing vegetation, and little to no sunlight penetration

protozoa: mostly microscopic animals made up of a single cell or a group of more or less identical cells. Protozoa live chiefly in water, but many are parasitic.

radionuclides: types of atoms which spontaneously undergo radioactive decay; usually naturally occurring, and can contaminate water or indoor air (e.g., radon)

radon: colorless, odorless, tasteless, naturally occurring radioactive gas formed from natural deposits of uranium that can cause lung cancer. It can enter the home around plumbing pipes and/or through cracks and openings in the foundation. It can also be brought in with the home's water supply.

radon decay products: the radioactive elements that immediately follow radon-222 in the decay chain. They are ultrafine solids that tend to adhere to other solids, such as dust particles in the air, or lung tissue if inhaled.

raw/untreated solids: settleable solids, grit, and other solid material removed by the primary clarifier (not treated by microorganisms)

recharge: (1) to replenish a waterbody or an aquifer with water; (2) the replacement of any water that may have flowed out or been pumped out of the aquifer

recharge area: an area where infiltration moves downward into an aquifer

reclamation: bringing land that has been disturbed by some process back to its original condition

record: an account, as of information, set down in writing as a way of preserving data collected on a specific subject

red tide: a reddish discoloration of coastal surface waters due to concentrations of certain toxin-producing dinoflagellates. Can cause pulmonary irritations in man and can cause death of marine mammals.

reef: a strip or ridge of rocks, sand, or coral that rises to or is near the surface of a body of water

reforestation: restocking of a forest stand through natural regeneration or artificially planted or by seedlings

refractory wastewater: wastewater containing an organic or nutrient content that will not oxidize in normal treatment processes

regeneration: the process of being renewed or reconstituted

renewable resource: a resource that can be used, then grown or replenished in some manner from year to year; plants and some animals

residual: the quantity left over at the end of a process; remainder

residue: something that remains after a part is taken away

resource: natural assets: air, water, soil, oil, gas, coal, trees, minerals, land, wildlife, people; the materials needed for the satisfaction of wants and needs

respiration: the sum total of the process of oxygen being conveyed to the cells and tissue of living organisms and the process by which the products of this oxidation process, CO₂ and H₂O, are given off

riffle: fast moving area in a stream. Usually the surface is broken by small waves or rocks.; the slope of a stream bed is steeper in riffles than it is in open pools, where the water surface tends to be smoother.

riparian: of, adjacent to, or living on the bank of a river, stream, or sometimes, of a lake or pond

riparian communities: living organisms adjacent to or living on the bank of a river, lake or pond

riparian rights: water rights enjoyed by owners of land adjacent to a body of water

risk: exposure to danger; negative factors to consider

river: a large body of flowing water that receives water from other streams and/or rivers

river mouth: where the river empties into a larger body of water

river source: where the river begins

road cut: a hill, ridge, or mountain side excavated for a road right-of-way. Road cuts leave exposed strata, rock, and soil that can be viewed in their natural state if not covered or vegetated.

rod-shaped bacteria: a physical form of bacteria. These are longer than they are wide; cylindrical.

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in ; eventually enters a waterbody; may pick up and carry a variety of pollutants

Safe Drinking Water Act: a law passed by the U.S. Congress in 1974 and amended in 1986 and 1996 to help ensure safe drinking water in the United States. The Act requires that regulations be enacted to set maximum contaminant levels (MCLs) or treatment technique requirements for a variety of chemicals, metals, and pathogens in public water supplies; also requires protection of surface source waters and underground sources of drinking water.

salinity: the amount of salt dissolved in water

salt marsh: estuarine habitat submerged at high tide, but protected from direct wave action, and overgrown by salt-tolerant herbaceous vegetation; aquatic grasslands (coastal “prairies”) affected by changing tides, temperatures, and salinity

sand bar: a ridge or narrow shoal of sand formed in a river or along a shore by the action of currents, tides, and waves

sand dune: a pile of sand on the shore that is created by wind or water movement of the sand. Most are affected by wind and water.

saturated zone: a portion of the soil profile where all pores are filled with water. Aquifers are located in this zone. There may be multiple saturation zones at different soil depths separated by layers of clay or rock.

saturation: being filled to capacity; having absorbed all that can be taken up

seasonal: happening based on the yearly seasons of spring, summer, fall, and winter

Secchi disc: a black and white circular plate that is used to determine water clarity

secondary containment for above-ground fuel storage tanks: spill containment facility that will sufficiently contain 110 percent of the capacity of the largest tank located within the area of management

secondary treatment: a type of wastewater treatment used to convert dissolved and suspended

pollutants into a form that can be removed, producing a relatively highly treated effluent. Secondary treatment normally utilizes biological treatment processes (activated sludge, trickling filters, etc.) followed by settling tanks and will remove approximately 85% of the BOD and TSS in wastewater. Secondary treatment for municipal wastewater is the minimum level of treatment required by the Clean Water Act.

sediment: eroded soil material, containing primarily inorganic constituents

sedimentary rock: a rock that consists chiefly either of small pieces of rock cemented together (sandstone) or of crystals that grew from water (rock salt, limestone)

sedimentation: (1) the process of depositing sediment, or the addition of soils to lakes that is part of the natural aging process; (2) the drinking water treatment process of letting heavy particles in raw water settle out into holding ponds or basins before filtration (also called “settling”); (3) the process used in both primary and secondary wastewater treatment that takes place when gravity pulls particles to the bottom of a tank (also called “settling”)

seltzer water: natural mineral water that is effervescent

septic system: on-site equipment or system to treat wastewater, consisting of a septic tank and an absorption field

septic tank: a tank, commonly buried, to which all of the wastewaters from the home should flow and in which, primary digestion of the organic matter occurs by anaerobic bacteria; the main part of a septic system where scum and solids accumulate; derived from “sepsis”-- meaning “putrid decay” or “decay without oxygen”

settling tank (sedimentation tank or clarifier): a vessel in which solids settle out of water by gravity during wastewater or drinking water treatment process.

settling pond: usually a human-made pond that is designed to remove many of the particulates from runoff water

sewage: waste and wastewater produced by residential, commercial, and light industrial establishment; typically discharged into sewers and sometimes, into septic tanks

sewage contamination: the introduction of untreated or improperly treated sewage into a water body

silviculture: care and cultivation of forest trees; forestry

simile: a figure of speech in which one thing is likened to another dissimilar thing by the use of

words such as *like* or *as*

sinkhole: a hole caused by collapse of the land surface, commonly because underlying limestone rock has dissolved away

site preparation: the use of machines, herbicides, fire, or combinations thereof to dispose of (unmerchantable debris), improve planting conditions, and provide initial control of competing vegetation

skid: to drag logs with specialized equipment to a landing

slope: degree of deviation of a surface from the horizontal, measured in degrees

sludge: any solid, semisolid, or liquid waste that settles to the bottom of sedimentation tanks (in wastewater treatment plants or drinking water treatment plants) or septic tanks

soda water: water charged under pressure with carbon dioxide gas

soft water: water that is low in mineral content because it has flowed through soils and rocks containing minerals that react poorly. Soaps are very “sudsy” in soft waters.

soil venting: vacuum extraction or soil vapor extraction; a means of reducing concentrations of volatile chemicals in petroleum products absorbed into soils in the unsaturated zone. A vacuum is applied to the soil to create a negative pressure gradient that causes movement of vapors toward extraction wells. The volatile chemicals are then removed through the wells, treated, and discharged into the atmosphere or reinjected to the subsurface.

solubility: ability or tendency of one substance to blend uniformly with another

solution: a homogenous mixture of two substances, usually a gas or solid in a liquid

solution mining: a type of mining wherein water is injected into a well to remove a desired mineral

solvent: a substance that dissolves another to form a solution

sound: long, broad inlet of the ocean larger than a strait or channel, connecting larger bodies of water

Source Water Protection: process that involves delineating areas contributing water to a water well or surface water intake; identifying potential contaminant sources that may threaten the water supply; and using management strategies to protect the source water from contamination.

Source water protection is applied to both surface water and groundwater supply sources.

sparkling water: carbonated drinking water

specific heat: the number of calories needed to raise the temperature of one gram of a given substance 1°C, relative to the number of calories (one calorie) needed to raise the temperature of 1 gram of water 1°C

spring: a surface flow of water originating from subsurface sources (groundwater); often a source of a stream or pond

stagnation: inactivity or without change

standard deviation: a statistical value that is equal to the square root of the arithmetic average of the squares of the deviations from the mean in a frequency distribution

strait: a narrow passage of water that connects two larger bodies of water

stream gauging: the measurement of velocity of streams (stream velocity)

stream velocity: the volume of water in a stream flowing past a certain point per unit time typically measured in cubic per second (cfs)

streamside management zone (SMZ): area left along streams to protect streams from sediment and other pollutants, protect streambeds, and provide shade and woody debris for aquatic organisms

succession (lake): gradual, orderly process of changes in a lake ecosystem brought about by changes in species types and populations; occurs over long periods of (geologic) time and ultimately results in the lake reverting back to land (a terrestrial ecosystem)

suction: a force causing a fluid or solid to be drawn into interior space or to adhere to a surface due to the difference between external and internal pressures

sulfuric acid: (chemical formula, H_2SO_4) the most widely used industrial chemical; a major part of acid rain that is formed by sulfur oxides combining with atmospheric moisture

supertanker: a very large ship used to carry crude oil

surface tension: a property of liquids in which the exposed surface tends to contract to the smallest possible area, as in the formation of a meniscus. It is caused by unequal molecular cohesive forces near the surface.

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

suspended solids: small particles of solid materials in water that cause cloudiness or turbidity

suspension: a mixture whose particles are temporarily dispersed through a fluid but not dissolved in it

swamp: wetland dominated by shrubs and trees

synergistic: more than one agent working together to produce enhanced combined effects (i.e., a greater total effect than the sum of the individual effects)

tectonic estuary: type of estuary formed when the Earth's crust shifts suddenly as in an earthquake, volcanic eruption, or a tsunami; has no definite shape

temperature zones: regions characterized by different temperature characteristics

tertiary treatment: any level of treatment beyond secondary treatment, which could include filtration nutrient removal (removal of nitrogen and phosphorus), and removal of toxic chemicals or metals; also called "advanced treatment" when nutrient removal is included

thermocline: one of the three temperature or thermal zones located between the upper and lower thermally stratified zones of a lake; also called the metalimnion. The thermocline is a thin boundary layer between two layers of distinctly different temperatures. The thermocline is a place characterized by dramatic vertical temperature change.

thixotropy: the property of certain gels and emulsions to become fluid when agitated and then settle again when left at rest

tidal creeks: meandering, creek-like channels within salt marshes and mud flats, through which seawater enters and leaves as the tide rises and falls

tidal flats: flat-topped banks of sand and silt that comprise the most elevated portion of the salt marsh

tide: the alternate rise and fall of the surface of oceans, seas, and the bays, rivers, etc. connected with them, caused by the attraction of the moon and sun. The tide occurs once or twice in each period of 24 hours and 50 minutes.

time-of-travel: the time required for groundwater to move from a specific point beneath the surface to a well

tolerance: the natural or developed ability to endure or resist the harmful effects of a substance

toluene: a colorless, liquid, flammable, poisonous hydrocarbon, C_7H_8 , obtained originally from balsam of Tolu but now generally from coal tar or petroleum; used in making dyes, explosives, and as a solvent; structurally consisting of a methyl radical attached to a benzene ring

topographical map: a contour map designed to show elevation; commonly referred to as a "topo" map; scale 7.5" or 1:24,000

total suspended solids (TSS): a laboratory measurement of the quantity of solids present in water that is one of the main indicators of the quantity of pollutants present; amount of solid in suspension in water or wastewater

toxic chemical: a chemical with the potential of causing death or damage to humans, animals, plants, protists; poison

toxic: harmful to living organisms

transpiration: process in which water absorbed by the root systems of plants moves up through the plants, passes through pores (stomata) in their leaves or other parts, and then evaporates into the atmosphere as water vapor; the passage of water vapor from a living body through a membrane or pores

treatment technique: drinking water treatment requirement in lieu of a maximum contaminant level (MCL); typically used when establishing an MCL is too difficult or when compliance with an MCL would be too costly; drinking water standard.

tributary: a stream that flows into a larger stream, river, or another waterbody

trickling filter process: a biological treatment process that uses coarse media (usually rock or plastic) contained in tank that serves as a surface on which microbiological growth occurs. Wastewater trickles over the media and the microorganisms remove the pollutants (BOD and TSS). Trickling filters are followed by settling tanks to remove microorganisms that wash off or pass through the trickling filter media.

TSS (Total Suspended Solids): a laboratory measurement of the quantity of wastewater that is one of the main indicators of the quantity of pollutants present

tsunami: a huge sea wave caused by a submarine disturbance such as an earthquake or volcanic eruption

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

Tyndall effect: the scattering and polarization of a light beam caused when light is reflected from colloidal particles in a system

typhoid fever: acute, highly infectious disease caused by *Salmonella typhosa* bacteria that can be transmitted by contaminated food or water

uncertainty: lack of certainty; doubt

unconfined aquifer: an aquifer containing unpressurized groundwater, having an impermeable layer below but not above it

underground injection well: a type of well used for wastewater disposal, aquifer recharge and solution mining of minerals

underground storage tank (UST): any tank, including underground piping connected to the tank, that has at least 10 % of its volume underground and contains petroleum products or hazardous substances (except heating oil tanks and some motor fuel tanks used for farming or residential purposes)

universal solvent: water; a material that can dissolve almost any other substance

unsaturated zone: a portion of the soil profile that contains both water and air; the zone between the land surface and the water table. The soil formations do not yield usable amounts of free-flowing water. It is also called zone of aeration and vadose zone

USGS: United States Geological Survey

vadose zone: the zone of aeration between the Earth's surface and the water table; area of the soil that contains both air and water; same as unsaturated zone--zones between land surface and the water table

valence: a number representing the capacity of an atom or radical to combine with other atoms or radicals, as measured by the number of hydrogen or chlorine atoms which one radical or one atom of an element will combine with or replace (oxygen has a valence of two: one atom of oxygen combines with two hydrogen atoms to form the water molecule H_2O); the electric charge of an element or radical resulting from a change in oxidation state (that is, in the transfer or sharing of electrons)

vapor: a substance in gaseous form

variable wastewater: wastewater that comes from different sources (regular sewage, stormwater, or industrial wastewater)

variance or random error: degree of change or difference; divergence; discrepancy

velocity (linear): distance per unit time

virus: any of a group of ultramicroscopic or submicroscopic infectious agents that cause various diseases in animals, such as measles and mumps, or in plants, such as mosaic disease. Viruses are capable of multiplying only in connection with living cells.

viscosity: the state or quality of having a cohesive and sticky fluid consistency; a measure of resistance to flow upon applying a force

wants and needs: those things people desire for sustenance and quality of life

wastewater: water that has been used for domestic or industrial purposes

water analysis: series of tests to determine various chemical or physical characteristics of a sample of water

water bar: a long mound of dirt constructed across the slope to prevent soil erosion and water pollution by diverting drainage from a road or skid trail into a filter strip

waterborne diseases: diseases spread by contaminated water

waterfall: a cascade of water, as over a dam

waterlogging: condition that occurs when the water table rises too near the surface causing plants to die as a result of water filling air spaces in the soil

water quality: the condition of water with respect to its content of contaminants, natural or anthropogenic

water quality criteria: levels of water quality needed to support a designated use for a body of water, usually expressed as concentration values for specific chemicals

water rights: rights, sometimes limited, to use water from a stream, canal, etc., for general or specific purposes, such as irrigation

watershed: land area from which water drains to a particular surface waterbody

waters of the state: includes every natural or artificial watercourse, stream, river, wetland, pond, lake, coastal, ground or surface water wholly or partially in the state that is not entirely confined and retained on the property of a single landowner

water table: upper surface of the zone of saturation of groundwater

water-table aquifer: an unconfined aquifer

water treatment: a method of cleaning water for a specific purpose such as drinking

water vapor: water in a gaseous (vapor) form and diffused as in the atmosphere

wave: a ridge or swell moving along the surface of a fluid or body of water as a result of disturbance, as by wind

well: a bored, drilled, or driven shaft or dug hole. Wells range from a few feet to more than 6 miles in depth, but most water wells are between 100 and 2,000 feet in depth.

wellhead: the physical structure or device at the land surface from or through which groundwater flows or is pumped

Wellhead Protection Area: the surface and subsurface area surrounding a public water supply well through which contaminants are reasonably likely to move toward and reach such well

Wellhead Protection Program (WHPP): a groundwater-based source water protection program

wetland: areas that periodically have waterlogged soils or are covered with a shallow layer of resulting in reduced soil conditions. Wetland areas typically support plant life adapted to life wet environments.

zone of influence: area surrounding a pumping well within which the potentiometric surface has been changed due to groundwater withdrawal

zone of saturation: that region below the surface in which all voids are filled with liquid

zoning: to divide into areas determined by specific restrictions; any section or district in a city restricted by law for a particular use

