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Air & Waste Management Association

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Environmental Resource Guide

Nonpoint Source Pollution Prevention

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Grades 9 - 12

Air & Waste Management
Association

ENVIRONMENTAL RESOURCE GUIDE

NONPOINT SOURCE POLLUTION PREVENTION

A series of classroom activities for Grades 9-12

Developed by
TENNESSEE VALLEY AUTHORITY
Environmental Education Section

Technical direction provided by
AIR & WASTE MANAGEMENT ASSOCIATION
Education Council

In Cooperation With

U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service

U.S. DEPARTMENT OF INTERIOR
Bureau of Reclamation

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Wetlands, Oceans, and Watersheds
Assessment and Watershed Protection Division

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Environmental Resource Guide - Nonpoint Source Pollution Prevention

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For information on obtaining copies of this manual, contact the Public Education Program , Air & Waste Management Association, One Gateway Center, Third Floor, Pittsburgh, Pennsylvania 15222 U.S.A., (412) 232-3444, fax (412) 232-3450.

FOREWORD

The members of the Air & Waste Management Association believe one of the best ways to achieve the goal of a clean and healthy environment is to improve the environmental literacy of our youth. As a result, the Association has established a public education program so that teachers, school children, and the public can get information they need to make responsible decisions every day about environmental issues.

As a part of this continuing program, the Association proudly presents to the educational community the second component of its Environmental Resource Guide (ERG) program - "Nonpoint Source Pollution Prevention." As with the first ERG volume on "Air Quality," this volume was developed in partnership with the Tennessee Valley Authority's (TVA's) Environmental Education Section. Using its university-based network of environmental educators, TVA identified teachers to write the activities and field test them in class settings.

Today, many pollution prevention programs focus on reducing pollutants and wastes at their source. For example, efforts are being made to install air cleaners on factories, power plants, cars, and wood stoves to trap pollutants before they get into the air and are eventually transported into water. By using such an approach to head off a problem at its earliest stage, the progression of pollution is significantly reduced.

However, because of its nature, *nonpoint source pollution* presents its own set of challenges. By definition, nonpoint source pollution cannot be traced to a specific point, but rather to many individual places. Agriculture, forestry, mining, construction, and urban activities all contribute to nonpoint source pollution.

So what can be done to prevent pollution that cannot be traced to one source? The first step is to become better educated on the subject of nonpoint source pollution—what it is, where it comes from, and what we, as individuals, can do about it.

The Environmental Resource Guide - Nonpoint Source Pollution Prevention presents basic information on the relationships between land use and water quality—specifically nonpoint source water pollution—in a series of 10 factsheets and 15 activities. This **Guide** provides elementary school teachers with a concise introduction to nonpoint source pollution issues so they can present this basic information to their students. The material is "teacher friendly" and can easily be integrated into existing science, social studies, and language arts curricula.

We hope you will find the volume helpful, and we welcome your comments to improve future editions.

Education Council
Air & Waste Management Association

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We would like to acknowledge the generous contributions of our sections and chapters to this Environmental Resource Guide. Their overwhelming support of this project and the Association's Public Education Program enables environmental professionals to reach out and share their expertise with young people, our hope for the future.

Alabama Chapter
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Indiana Chapter
Kentucky Chapter
Lake Michigan States Section
Louisiana Section
New England Section
Niagara Frontier Section
Northern Ohio Chapter
Puget Sound Chapter
South Atlantic Section
Southern Section
Southwest Ohio Chapter

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INTRODUCTION

Nonpoint water pollution now comprises the largest source of water pollution. Most nonpoint sources are related to land use activities. For example, rainwater washes over farmlands and carries topsoil and residues from farm chemicals into nearby streams. Primary nonpoint sources of water pollution include runoff from agriculture, urban areas, mining, forestry, and construction activities. Pollution prevention, as it applies to nonpoint source pollution, starts with understanding how human activities affect the quality of air, land, and water and the natural interrelationships that exist between these components of the environment. Nonpoint sources contribute 65 percent of all contaminants in water bodies as compared with 9 percent from industrial sources and 17 percent from municipal sources. For years we have concentrated on reducing point sources of pollution, pollution that can be traced to a single source, only to find that our waters were not free from contamination. Nonpoint sources of pollution were often overlooked because they come from many diffuse sources and are often difficult to pinpoint and control.

This 9-12 grade activity guide has been developed to educate students about nonpoint source water pollution. Activities in the guide fall into three broad categories: (1) What is it; (2) Where does it come from; and (3) What can we do about it. Some activities may focus on one or more of these questions. For example, a single activity may focus on a specific source of nonpoint pollution and also address ways to reduce the source.

The guide contains activities on agricultural, mining, forestry, and urban sources of nonpoint pollution. Activities focus on the four main types of water pollutants—sediment, nutrients, bacteria, and toxics—and best management practices to control nonpoint source pollution. Wherever possible, special emphasis is placed on acceptable pollution prevention alternatives.

All of the activities are "hands-on" and designed to blend with existing curricula in the areas of general science, life science, physical science, earth science, chemistry, biology, physics, ecology, algebra, geometry, and agriculture. Each activity contains (1) objectives, (2) subject(s), (3) time, (4) materials, (5) background, (6) follow-up, (7) extension, and (8) resources. Factsheets and a glossary section included at the end of the guide contain concepts and words used in the text which may be unfamiliar.

Achieving future clean water goals will require an informed citizenry capable of understanding the complex issues surrounding water management, and motivated to take action. It is our goal that wherever possible, students not only understand these issues but are given an opportunity to take action now. For this reason, we have provided suggestions on ways individuals can reduce nonpoint source pollution in their daily lives. It is the ultimate goal of this program to assure that the decision makers of tomorrow are equipped with a basic understanding of nonpoint pollution problems and can use this information to make knowledgeable judgments on the difficult water-related issues that we as a global society will inevitably face.

Organization of Individual Activities

Each activity is organized in the same way, detailing objectives, materials needed, background information, and procedures. Following is a brief summary of what you should expect to find in each activity.

OBJECTIVES: Describes what the student should be able to do when the activity is completed.

SUBJECT: The general subject(s) to which the activity applies: earth science, general science, life science, physical science, biology, chemistry, physics, ecology, algebra, geometry, and agriculture.

TIME: The approximate number of class periods (45-minute sessions) needed to complete the primary exercise(s). More time may be needed for the follow-up exercises. Some activities or follow-ups may require collecting data over several days/weeks, but will only need full class periods at the beginning and end of the activity to explain, present information, and reach conclusions.

MATERIALS: List of materials needed to complete the primary activity. Alternatives and optional materials are listed where appropriate. Occasionally, when simple but specialized equipment must be ordered, an address is given. This equipment can usually be reused by other classes or in other years. If the basic materials are not immediately available in your classroom, they can often be borrowed from other areas in the school or from a local college or university science department.

BACKGROUND INFORMATION: Background information needed for the specific activity. This material is suggested as a basis for teacher lecture and/or student discussion when the activity is introduced. (More general background information can be found in the factsheets located in the back of the guide.)

ADVANCED PREPARATION: Directions for the teacher and/or students to prepare materials in advance.

PROCEDURE: Complete directions to conduct the entire activity including follow-up and extension ideas. Includes overhead masters, student sheets, quizzes, and teacher keys.

Setting the Stage Introduction of the activity to the students. This section uses both student discussion questions/topics and sharing of pertinent background information.

Activity Step-by-step description of how to do the activity. This ends with questions to demonstrate that the students understand what they have done.

Follow-Up Conclusion of the activity by summarizing the information and drawing conclusions if applicable.

Extension Suggestions for extending the activity and/or suggestions for other related, non-laboratory activities.

Resources Reference materials either used in developing the activity or to provide additional information and addresses for ordering materials used in the activity.

These special notations appear within some activities.

CAUTION: Special care is needed for this step/procedure.

NOTE: Further explanation about a procedure, used to clarify or reemphasize important directions.

OPTIONAL: Optional procedure or materials that may enhance part of the activity.

Activity Preparation

Once you have decided on the activity(ies) you will be doing, check the materials list. You will need to take into account the number of students or student teams in your class(es). Many materials are readily available, but some may need to be borrowed or purchased ahead of time. Prepare copies of all the needed student handouts and/or transparencies or other materials for your use. If you plan to have the students do part or all of the Extension suggestions, you will want to add additional materials to your list. You may also need to locate other sources of information or telephone numbers to complete the Extension. Some Extensions can be started simultaneously with the regular activity.

As you read through the activity, highlight any CAUTION or NOTE and decide whether you will do OPTIONAL suggestions. Check the suggested time for completion of the activity and add time needed to do any extension activities. The time needed may vary from class to class. These activities have all been field-tested in high school classrooms. However, you might want to do a trial run of the activity yourself to evaluate the time needed and identify areas where minor problems might occur. It is also a good idea to mark points in the text where natural breaks can be taken to divide the activity into class periods.

The factsheets included at the end of the guide and the background material included in each activity should provide information necessary for your preparation. Further reading on the subject can be found in the lists of resources at the conclusion of each activity. If these are not readily available, you may want to check other books on environmental concerns.

TOPICS	ACTIVITIES	FACTSHEETS
Water Pollution Sources	Lingo Bingo Watershed Woes Pollution P.I.	Water Water Quality Factors Water Pollution Land Use and Water Quality
Point vs. Nonpoint	Lingo Bingo Watershed Woes Pollution P.I.	Water Water Quality Water Quality Factors Land Use and Water Quality
Sediment Pollution	It's Sedimentary, My Dear Watson Breathtaking Slip Slidin' Away	Water Pollution Land Use and Water Quality Sediment Water Pollution
Nutrient Pollution	Fed Up Breathtaking	Water Pollution Land Use and Water Quality Nutrient Water Pollution
Bacterial Pollution	Wasted Waters	Water Pollution Land Use and Water Quality Bacterial Water Pollution
Toxic Pollution	All Messed Up and No Place To Go Mined Over Water Lethal Lots	Water Pollution Land Use and Water Quality Toxic Water Pollution
Agricultural Sources	Fed Up It's Sedimentary, My Dear Watson Breathtaking Slip Slidin' Away Wasted Waters The Grass is Always Cleaner Eee-Aye-E.I.S.	Water Pollution Land Use and Water Quality Best Management Practices

TOPICS	ACTIVITIES	FACTSHEETS
Urban Sources	Fed Up It's Sedimentary, My Dear Watson Breathtaking Wasted Waters All Messed Up and No Place To Go R.I.P. Rain Lethal Lots Home Is Where The Hazard Is The Grass Is Always Cleaner	Water Pollution Land Use and Water Quality Best Management Practices Individual Actions
Mining Sources	It's Sedimentary, My Dear Watson Slip Slidin' Away Mined Over Water The Grass Is Always Cleaner	Water Pollution Land Use and Water Quality Best Management Practices
Forestry Sources	It's Sedimentary, My Dear Watson Slip Slidin' Away The Grass is Always Cleaner	Water Pollution Land Use and Water Quality Best Management Practices
Industrial Sources	Lingo Bingo Pollution P.I. R.I.P. Rain	Water Pollution Land Use and Water Quality Best Management Practices
Best Management Practices	Watershed Woes Slip Slidin' Away Mined Over Water R.I.P. Rain Home Is Where the Hazard Is The Grass is Always Cleaner Eee-Aye-E.I.S.	Land Use and Water Quality Best Management Practices Individual Actions

LINGO BINGO

OBJECTIVES

The students will do the following:

1. Define vocabulary words needed to understand nonpoint source pollution.
2. Discuss the difficulties in identifying and controlling sources of nonpoint pollution.

SUBJECTS:
General Science, Earth Science, Life Science, Physical Science, Ecology, Chemistry, Biology, Physics

TIME:
2 class periods

MATERIALS:
vocabulary list handout (included)
blank game board handout (included)
large sheets of newsprint (optional)
cover pieces (e.g., pennies, poker chips, beans; 16 per student)
Lingo Bingo Quiz (optional; included)

BACKGROUND INFORMATION

Water pollution is generally defined as any contamination of water which reduces its usefulness to humans and other organisms in nature. [See glossary for distinction between water pollution (human-caused) and water contamination (nature-caused).] If the source of pollution comes from a clearly defined location or can be traced to a single point, such as a factory or municipal wastewater treatment plant discharge pipe, then it is called point source pollution. Point sources can usually be regulated or treated before discharge. Pollution that does not enter waterways at a single point or originate from a single location is called nonpoint source pollution.

The terminology of nonpoint source pollution is as diverse as its sources. A wide range of terms is used to describe nonpoint source pollution, its effects, and control. Understanding nonpoint source pollution requires learning vocabulary words from many subjects including chemistry, biology, and geology. A good working vocabulary is necessary to understand the concepts of nonpoint source pollution.

ADVANCED PREPARATION

Make photocopies of the vocabulary list and gameboards (one each per student), and obtain cover pieces (16 per student).

PROCEDURE

I. Setting the Stage

A. Introduce vocabulary words.

1. Ask the students to define the terms pollutant and water pollution. Discuss their ideas and try to reach a consensus on definitions.
2. Now ask them to brainstorm and develop a list of sources of water pollution. Compile a class list on the board or on large sheets of newsprint.

B. Ask the students why, if we know so much about where water pollution comes from, its sources aren't better regulated to reduce, control, or prevent it.

C. Discuss the difficulties of identifying, assessing, and regulating nonpoint source pollution with the students. Point out that the terminology of nonpoint source pollution is as diverse as the sources themselves. Thus, to understand the concepts of nonpoint source pollution, its effects, and its control, students need to learn vocabulary words used to describe nonpoint source pollution.

D. Pass out the vocabulary lists to the students. Give them a homework assignment to learn the words and their definitions.

II. Activity

A. Introduce the Lingo Bingo game.

1. Have the students get out their vocabulary lists and give each student a blank bingo game board.

2. Tell them that the object of this game is to correctly identify the vocabulary words on the list by listening to their definitions.

3. Go over the pronunciations and definitions of the vocabulary words with the students.

4. Afterwards, have the students randomly select words from the vocabulary list and write one word in each open box on their game board.

5. When they are finished, have them exchange game boards. (NOTE: You may want to number the words in the vocabulary list. Then write the numbers on buttons or small squares of paper, and draw the numbers out of a box or hat to have a more random selection of the terms.)

B. Play the Lingo Bingo game.

1. Pass out cover pieces and begin the game.

2. Define the patterns of a winning game board. Winning patterns might include 5 in a row vertically, horizontally, or diagonally.

3. Instruct the students to call out "Lingo Bingo" when they have covered spaces on the board in a winning pattern.

4. All students should cover their "Pollution Free Space" with a cover piece. This is a free space.

5. Then read aloud only the definitions of the vocabulary words. Have the students identify and cover the appropriate words on their game boards with cover pieces as you read the definitions.

6. When a student calls out "Lingo Bingo," check her/his game board to see if all the words marked were used. If not, go over the missed word and continue playing until someone wins. (NOTE: You might consider giving out small prizes to the winners, or rewards such as extra credit.)

7. Continue playing Lingo Bingo as time permits.

III. Follow-Up

Give the students the vocabulary quiz (included) and discuss the results.

IV. Extension

Review the vocabulary words with the students and play a game of "Win, Lose, or Draw."

1. Put the vocabulary words on pieces of paper and put them into a hat or box.

2. Divide the students into teams of 5 or 6.

3. Only one team at a time will play.

4. Have each team pick a person to draw first, second, third, and so on.

5. Have the first person on the first team pick a word out of the hat or box and draw a picture on the chalkboard to represent the word. NOTE: They may not use numbers, symbols (except = or + signs), or words. The other members of the team will have one minute to guess the word.

6. If the team guesses the word they get 10 points. If not, the other teams can guess. If another team guesses the word, they get 5 points.

7. The team to guess the word can earn 5 more points if they can define it correctly.

8. Rotate to the next team and repeat steps 5-7. Continue until everyone has drawn one word or the class period is finished.

RESOURCES

Local Watershed Problem Studies, Bureau of Information and Education, Department of Natural Resources, Madison, Wisconsin, June 1981.

"Waste Bingo," Waste: A Hidden Resource, Tennessee Valley Authority, 1988, pp. 222-223.

	L	I	N	G	O
B					
I					
N			**Pollution Free Space**		
G					
O					

VOCABULARY LIST

1. Acid — A substance with more hydrogen ions than hydroxide ions.
2. Acid Mine Drainage — Acidic water that forms when water contacts exposed mine wastes and ores and is carried into adjacent streams as runoff.
3. Acid Rain or Acid Precipitation — Rain with a pH of less then 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels; may cause damage to buildings, car finishes, crops, forests, and aquatic life.
4. Algae — A group of microscopic photosynthetic plants.
5. Algal Bloom — A heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from fertilizers and detergents; phosphates are also naturally occurring in rock formations.
6. Aquatic Life — All the life forms in water; ranges from invertebrates and fish to algae and larger aquatic plants.
7. Bacteria — Single-cell microscopic organisms that break down organic materials.
8. Best Management Practices (BMP) — An engineered structure or management activity, or combination of these, that eliminates or reduces adverse environmental effects of pollutants.
9. Buffer Strip or Zone — Grass or other erosion-preventive vegetation planted between a waterway and an area of intensive land use.
10. Clean Water Act of 1972 — The Federal law which sets national water quality goals and directs states to upgrade surface waters through the control of point sources of pollution. It was amended in 1977 and 1987. (NOTE: The nonpoint source program was instituted in the Water Quality Act of 1987 that amended the Clean Water Act.)
11. Coliform Bacteria — Bacteria found in the intestines of warm-blooded animals that aid in the digestion process; used as indicators of fecal contamination in water bodies.
12. Combined Sewer — A sewer system that carries both sanitary sewage and stormwater runoff.
13. Contour Farming — Field operations such as plowing, planting, cultivating, and harvesting, conducted following the contours of a slope.
14. Contour Strip Cropping — Farming operations performed on the contour with crops planted in narrow strips, alternating between row crops and close-growing forage crops.
15. Conventional Tillage — Standard method of preparing a seedbed by completely inverting the soil and incorporating the residue with a plow.
16. Crop Rotation — A planned sequence of a variety of crops planted in a regular succession on the same area of land to reduce depletion of soil nutrients as opposed to the growing of one crop, year after year.
17. Dissolved Oxygen (DO) — Oxygen gas (O_2) dissolved in water.
18. Diversion — A best management practice (BMP) used to divert water across or away from a hillside, exposed soil, or other potential sources of contaminants.
19. Effluent — Waste material (i.e., smoke, sewage, etc.) discharged into the environment.
20. Endangered Species — A plant or animal in serious danger of becoming extinct.
21. Erosion — The wearing away of the earth's surface by running water, wind, ice, or other geological agents.
22. Eutrophication — Naturally occurring changes that take place after a water body receives inputs of nutrients, mostly nitrates and phosphates, from erosion and runoff of surrounding lands; this proccess can be accelerated by human activities.
23. Grassed Waterway — A natural or constructed waterway covered with grasses used to trap sediment and prevent erosion.
24. Groundwater — Water that infiltrates into and is stored in the soil and rock below the earth's surface.
25. Gully — A channel caused by the concentrated flow of water over unprotected erodible land.
26. Heavy Metals — Metals present in industrial, municipal, and urban runoff including copper, cadmium, zinc, nickel, mercury, and chromium; they are usually poisonous to humans and animals.

VOCABULARY LIST
(continued)

27. Hydrologic Cycle (Water Cycle) — The movement of water from the atmosphere to the earth and back to the atmosphere through precipitation, runoff, infiltration, percolation, storage, evaporation, and transpiration.
28. Hydroseeding — The process of sowing seed using a machine to disperse seed, water, and fertilizer together in a high pressure stream of water; used primarily to seed steep banks.
29. Impervious — Resistant to penetration by water or plant roots.
30. Infiltration — The gradual downward flow of water from the surface of the earth into the subsoil.
31. Limiting Factor — A factor whose absence exerts influence upon a population; may be responsible for no growth, limited growth (decline), or rapid growth.
32. Mulch — Any material such as straw, sawdust, leaves, plastic film, or pine bark that is spread upon the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting, freezing, and evaporation.
33. Municipal Sewage — Sewage from a community; may be composed of domestic sewage, industrial wastes, or both.
34. Nitrogen (N) — One of the major elements required for the growth of plants; present in water usually as organic nitrogen, ammonia, nitrate, and forms of nitrite; excess nitrogen causes accelerated eutrophication in water bodies.
35. Nonpoint Source (NPS) Pollution — Pollution that cannot be traced to a single point because it comes from many individual places or from one widespread area (e.g., urban and agricultural).
36. No-Till or Zero Tillage — A method of planting crops that involves no land disturbance other than opening the soil for the purpose of placing seeds at an intended depth.
37. Nutrient — An element or compound, such as nitrogen, potassium, and phosphorus, that is necessary for plant growth.
38. Organic Materials — Carbon-containing substances found in plants, animals, and their remains.
39. Parts Per Million (ppm) — The number of "parts" by weight of a substance per million parts of liquid. For example, one gram of salt in one million grams of water equals one ppm of salt.
40. Pathogenic — Capable of causing disease.
41. Percolation — The downward movement of water through the subsurface soil layers to groundwater.
42. Pesticides — Any chemical or biological agent used to kill plant or animal pests; herbicides, insecticides, fungicides, rodenticides, etc., are all types of pesticides.
43. Phosphorus (P) — One of the major elements required for the growth of plants; one of the ingredients used in the production of detergents and phosphate-containing fertilizers; excess phosphates causes accelerated eutrophication in water bodies.
44. Point Source Pollution — Pollution that can be traced to a single point such as a pipe or culvert (e.g., industrial and wastewater treatment plant discharges).
45. Pollutant — Any substance which causes pollution.
46. Polychlorinated Biphenyls (PCBs) — A group of stable human-made industrial chemicals used as insulation fluids in electrical transformers and capacitors; PCBs are harmful because they do not break down, and can bioaccumulate in humans and animals.
47. Reduced Tillage or Conservation Tillage — Any tillage practice which involves less soil disturbance and retains more plant residues on the soil's surface than conventional tillage.
48. Riprap — Large rocks placed along the bank of a waterway to prevent erosion.
49. Runoff — The portion of rainfall, melted snow, or irrigation (e.g., lawn sprinkler) water that flows across the land's surface, does not soak into the ground, and eventually runs into water bodies.
50. Sediment — Insoluble material suspended in water that consisists mainly of particles derived from rocks, soil, or organic materials; a major nonpoint source pollutant that other pollutants may attach to.

VOCABULARY LIST
(continued)

51. Sedimentation — The transport and deposition of sediment by flowing water or wind.
52. Septic Systems — A domestic wastewater treatment system into which wastes are piped directly from the home into the ground; consists of a septic tank and drainfield; wastewater is exposed to bacteria that decompose organic waste, dead bacteria and sediment settle to the bottom of the tank, and treated effluent flows out into the ground through drainage pipes.
53. Sewage — The waste liquids or solids carried off by sewers.
54. Sewer System — An underground system of pipes used to carry off sewage and surface water runoff.
55. Storm Sewer — A sewer or pipe that usually carries surface water runoff, street waste, and snow melt from the land, directly into a nearby water body.
56. Surface Water — Precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration, and is stored in streams, lakes, wetlands, and reservoirs.
57. Suspended Solids — A mixture of fine particles dispersed in a liquid.
58. Terrace — An embankment, or combination of an embankment and channel, constructed across a slope; used to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.
59. Topography — The representation of surface features of a region on maps or charts.
60. Toxic Substances — Poisonous wastes or substances in wastewaters that may end up in water bodies; may harm fish or other aquatic life.
61. Universal Soil Loss Equation (USLE) — An equation used to predict erosion; used to design erosion control systems.
62. Wastewater Treatment — Physical and chemical processes used to remove pollutants from water before discharging it into a water body.
63. Water Pollution — Any human-caused contamination of water that reduces its usefulness to humans and other organisms in nature.
64. Water Quality Management Plan — A plan for managing water quality within a watershed that considers both point and nonpoint sources of pollution.
65. Watershed — The total land area that contributes runoff to a specific water body.

Name ______________________ Date ______________________

LINGO BINGO QUIZ

MATCHING: SELECT THE BEST ANSWER.

1. _____ An engineered structure or management activity, or combination of these, that eliminates or reduces adverse environmental effects of pollutants.

2. _____ Grass or other erosion-preventive vegetation planted between a waterway and an area of intensive land use.

3. _____ The transport and deposition of sediment by flowing water or wind.

4. _____ A factor whose absence exerts influence upon a population; may be responsible for no growth, limited growth (decline), or rapid growth.

5. _____ Physical and chemical processes used to remove pollutants from water before discharging it into a water body.

6. _____ Large rocks placed along the bank of a waterway to prevent erosion.

7. _____ Capable of causing disease.

8. _____ Any material such as straw, sawdust, leaves, plastic film, or pine bark that is spread upon the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting, freezing, and evaporation.

9. _____ Single-cell microscopic organisms which break down organic materials.

10. _____ The wearing away of the earth's surface by running water, wind, ice, or other geological agents.

11. _____ An embankment, or combination of an embankment and channel, constructed across a slope; used to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

12. _____ Poisonous wastes or substances in waste waters that may end up in natural water bodies; may harm fish or other aquatic life.

13. _____ A natural or constructed waterway covered with grasses used to trap sediment and prevent erosion.

14. _____ The Federal law which sets national water quality goals and directs states to upgrade surface waters through the control of point sources of pollution. It was amended in 1977 and 1987. The nonpoint source program was instituted in the Water Quality Act of 1987 which amended the Clean Water Act.

15. _____ The portion of rainfall, melted snow, or irrigation water (e.g., lawn sprinkler) that flows across the land's surface, does not soak into the ground, and eventually runs into streams.

LINGO BINGO QUIZ
(continued)

16. ______ All the life forms in water; ranges from invertebrates and fish to algae and large aquatic plants.

17. ______ A mixture of fine particles dispersed in a liquid.

18. ______ Acidic water that forms when water contacts exposed mine wastes and ores, and is carried into adjacent streams as runoff.

19. ______ Any chemical agent used to prevent, destroy, or repel undesirable plants or animals.

20. ______ Bacteria found in the intestines of warm blooded animals that aid in the digestion process; used as indicators of fecal contamination in water bodies.

21. ______ A best management practice (BMP) used to divert water across or away from a hillside, exposed soil, or other potential sources of contaminants.

22. ______ Rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels; may cause damage to buildings, car finishes, crops, forests, and aquatic life.

23. ______ A plant or animal in serious danger of becoming extinct.

24. ______ A plan for managing water quality within a watershed that considers both point and nonpoint sources of pollution.

25. ______ The representation of surface features of a region on maps or charts.

26. ______ A channel caused by the concentrated flow of water over unprotected erodible land.

27. ______ A heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from fertilizers and detergents; phosphates are also naturally occurring in rock formations.

28. ______ Water that infiltrates into and is stored in the soil and rock below the earth's surface.

29. ______ An equation used to predict erosion; used to design erosion control systems.

30. ______ Standard method of preparing a seedbed by completely inverting the soil and incorporating the residue with a plow.

31. ______ Carbon-containing substances found in plants, animals, and their remains.

32. ______ The downward movement of water through the subsurface soil layers to groundwater.

33. ______ The total land area that contributes runoff to a specific body of water.

34. ______ Pollution that can be traced to a single point such as a pipe or culvert (e.g., industrial and wastewater treatment plant discharges).

LINGO BINGO QUIZ
(continued)

35. ______ Insoluble material suspended in water that consists mainly of particles derived from rocks, soil, or organic material.

36. ______ Pollution that cannot be traced to a single point, because it comes from many individual places or from one widespread area (e.g., urban and agricultural).

37. ______ Oxygen gas dissolved in water.

38. ______ Farming operations performed on the contour with crops planted in narrow strips, alternating between row crops and close-growing forage crops.

39. ______ Any tillage practice which involves less soil disturbance and retains more plant residues on the soil's surface than conventional tillage.

40. ______ The gradual downard flow of water from the surface of the earth into the subsoil.

41. ______ A method of planting crops that involves no land disturbance other than opening the soil for the purpose of placing the seeds at an intended depth.

42. ______ Sewage from a community; may be composed of domestic sewage, industrial wastes, or both.

43. ______ The process of sowing seed using a machine to disperse seed, water, and fertilizer together in a high pressure stream of water; used primarily to seed steep banks.

44. ______ Metals present in industrial, municipal, and urban runoff including copper, cadmium, nickel, zinc, mercury, and chromium; they are usually poisonous to humans and animals.

45. ______ Naturally occurring changes that take place after a water body receives inputs of nutrients, mostly nitrates and phosphates, from erosion and runoff of surrounding lands; this process can be accelerated by human activities.

46. ______ A group of microscopic photosynthetic plants.

47. ______ The number of "parts" by weight of a substance per million parts of water.

48. ______ Resistant to penetration by water or plant roots.

49. ______ Any substance that causes pollution.

50. ______ Any human-caused contamination of water that reduces its usefulness to humans and other organisms in nature.

LINGO BINGO QUIZ
(continued)

A. Acid Mine Drainage
B. Acid Rain
C. Algae
D. Algal Bloom
E. Aquatic Life
F. Bacteria
G. Best Management Practices (BMPs)
H. Buffer Strip or Zone
I. Clean Water Act of 1972
J. Coliform Bacteria
K. Contour Strip Cropping
L. Conventional Tillage
M. Dissolved Oxygen
N. Diversion
O. Endangered Species
P. Erosion
Q. Eutrophication
R. Grassed Waterways
S. Groundwater
T. Gully
U. Heavy Metals
V. Hydroseeding
W. Impervious
X. Infiltration
Y. Limiting Factor
Z. Mulch
AA. Municipal Sewage
BB. Nonpoint Source Pollution
CC. No-Till or Zero Tillage
DD. Organic Materials
EE. Pathogenic
FF. Parts Per Million
GG. Percolation
HH. Pesticides
II. Point Source Pollution
JJ. Pollutant
kk. Reduced Tillage or Conservation Tillage
LL. Riprap
MM. Runoff
NN. Sediment
OO. Sedimentation
PP. Suspended Solids
QQ. Terrace
RR. Topography
SS. Toxic Substances
TT. Universal Soil Loss Equation
UU. Wastewater Treatment
VV. Water Quality Management Plan
WW. Water Pollution
XX. Watershed

LINGO BINGO QUIZ
ANSWER KEY

MATCHING: SELECT THE BEST ANSWER.

1. __H__ An engineered structure or management activity, or combination of these, that eliminates or reduces adverse environmental effects of pollutants.

2. __I__ Grass or other erosion-preventive vegetation planted between a waterway and an area of intensive land use.

3. __OO__ The transport and deposition of sediment by flowing water or wind.

4. __Y__ A factor whose absence exerts influence upon a population; may be responsible for no growth, limited growth (decline), or rapid growth.

5. __UU__ Physical and chemical processes used to remove pollutants from water before discharging it into a water body.

6. __LL__ Large rocks placed along the bank of a waterway to prevent erosion.

7. __EE__ Capable of causing disease.

8. __Z__ Any material such as straw, sawdust, leaves, plastic film, or pine bark that is spread upon the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting, freezing, and evaporation.

9. __F__ Single-cell microscopic organisms which break down organic materials.

10. __P__ The wearing away of the earth's surface by running water, wind, ice, or other geological agents.

11. __QQ__ An embankment, or combination of an embankment and channel, constructed across a slope; used to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

12. __SS__ Poisonous wastes or substances in waste waters that may end up in natural water bodies; may harm fish or other aquatic life.

13. __R__ A natural or constructed waterway covered with grasses used to trap sediment and prevent erosion.

14. __I__ The Federal law which sets national water quality goals and directs states to upgrade surface waters through the control of point sources of pollution. It was amended in 1977 and 1987. The nonpoint source program was instituted in the Water Quality Act of 1987 which amended the Clean Water Act.

15. __MM__ The portion of rainfall, melted snow, or irrigation water (e.g., lawn sprinkler) that flows across the land's surface, does not soak into the ground, and eventually runs into streams.

LINGO BINGO QUIZ
ANSWER KEY
(continued)

16. ___E___ All the life forms in water; ranges from invertebrates and fish to algae and large aquatic plants.

17. ___PP___ A mixture of fine particles dispersed in a liquid.

18. ___A___ Acidic water that forms when water contacts exposed mine wastes and ores, and is carried into adjacent streams as runoff.

19. ___HH___ Any chemical agent used to prevent, destroy, or repel undesirable plants or animals.

20. ___J___ Bacteria found in the intestines of warm blooded animals that aid in the digestion process; used as indicators of fecal contamination in water bodies.

21. ___N___ A best management practice (BMP) used to divert water across or away from a hillside, exposed soil, or other potential sources of contaminants.

22. ___B___ Rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels; may cause damage to buildings, car finishes, crops, forests, and aquatic life.

23. ___O___ A plant or animal in serious danger of becoming extinct.

24. ___VV___ A plan for managing water quality within a watershed that considers both point and nonpoint sources of pollution.

25. ___RR___ The representation of surface features of a region on maps or charts.

26. ___T___ A channel caused by the concentrated flow of water over unprotected erodible land.

27. ___D___ A heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from fertilizers and detergents; phosphates are also naturally occurring in rock formations.

28. ___S___ Water that infiltrates into and is stored in the soil and rock below the earth's surface.

29. ___TT___ An equation used to predict erosion; used to design erosion control systems.

30. ___L___ Standard method of preparing a seedbed by completely inverting the soil and incorporating the residue with a plow.

31. ___DD___ Carbon-containing substances found in plants, animals, and their remains.

32. ___GG___ The downward movement of water through the subsurface soil layers to groundwater.

33. ___XX___ The total land area that contributes runoff to a specific body of water.

34. ___II___ Pollution that can be traced to a single point such as a pipe or culvert (e.g., industrial and wastewater treatment plant discharges).

LINGO BINGO QUIZ
ANSWER KEY
(continued)

35. NN Insoluble material suspended in water that consists mainly of particles derived from rocks, soil, or organic material.

36. BB Pollution that cannot be traced to a single point , because it comes from many individual places or from one widespread area (e.g., urban and agricultural).

37. M Oxygen gas dissolved in water.

38. K Farming operation performed on the contour with crops planted in narrow strips, alternating between row crops and close growing forage crops.

39. KK Any tillage practice which involves less soil disturbance and retains more plant residues on the soil's surface than conventional tillage.

40. X The gradual downard flow of water from the surface of the earth into the subsoil.

41. CC A method of planting crops that involves no land disturbance other than opening the soil for the purpose of placing the seeds at an intended depth.

42. AA Sewage from a community; may be composed of domestic sewage, industrial wastes, or both.

43. V The process of sowing seed using a machine to disperse seed, water, and fertilizer together in a high pressure stream of water; used primarily to seed steep banks.

44. U Metals present in industrial, municipal, and urban runoff including copper, cadmium, nickel, zinc, mercury, and chromium; they are usually poisonous to humans and animals.

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47. FF The number of "parts" by weight of a substance per million parts of water.

48. W Resistant to penetration by water or plant roots.

49. JJ Any substance that causes pollution.

50. WW Any human-caused contamination of water that reduces its usefulness to humans and other organisms in nature.

WATERSHED WOES

OBJECTIVES

The students will do the following:

1. Describe the characteristics of a watershed by interpreting topographic maps.
2. Calculate the area of a watershed and the amount of potential runoff using acreage grids.
3. Explain how human activities and land use practices contribute to nonpoint source water pollution and how they can adversely affect water quality and the plants and animals within a watershed area.
4. Explain the need for regulating and monitoring land use in a watershed area.
5. Give examples of how a watershed can be protected.

SUBJECTS:
General Science, Earth Science, Life Science, Physical Science, Ecology, Geology, Algebra

TIME:
2-3 class periods

MATERIALS:
topographic maps, road maps, and city maps representing the same area (see Resources to order or purchase from local bookstore)
USGS map acreage grid (some libraries have these for loan or they may be purchased from USGS—sample included)
index cards
acetate sheets
alcohol or mineral spirits (to clean acetate sheets)
transparency markers or grease pencils (in a variety of colors)
calculators (optional)
Watershed Woes Exercise (included)
"Topographic Map Symbols" brochure (see Resources to order)
Properties of Contours handout (included)
Contour Line Basics handout (included)
Dot Grid handout (included)
Watershed Woes Quizzes (optional; included)

BACKGROUND INFORMATION

The total land area that contributes runoff to a specific body of water is called a watershed. Precipitation from rain and snow becomes either surface water or groundwater. Surface water is water that runs off from a land area and flows into a specific water body. Groundwater is water that soaks into the ground, moves through the earth, and eventually surfaces in a specific water body. Pollutants from anywhere in the watershed may eventually show up in the water body. All plant and animal life is dependent upon and, thus, affected by the quality of water within the boundaries of a watershed. Human activities and land use practices in a watershed that adversely affect water quality may be sources of nonpoint pollution. Mining, forest practices, agriculture, construction, landfills, urban runoff, and septic systems may negatively affect water quality. To reduce pollution and protect water quality, nonpoint sources of pollution need to be identified, regulated, monitored, and controlled.

A topographic map can be used to determine the boundaries of a watershed, identify some land use practices, and plan best management programs to prevent or reduce pollution. To effectively use topographic maps, it is necessary to understand the information depicted.

Map scale is the relationship of distance on a map to the actual distance on the ground. Scale is expressed as a ratio and is graphically represented by a bar scale. For example, 1: 24,000 is the scale of the most widely available topographic maps. This means that one inch on the map is equivalent to 24,000 inches of the actual area. For most purposes, it is best to try and relate the scale to an easily understood distance because 24,000 inches means very little to most people. To do this, divide it into feet. For example, 24,000 inches is 2,000 feet—not quite half a mile. (When working in centimeters, 24,000 centimeters equals 240 meters or almost one quarter kilometer). In Canada, maps with map scales of 1: 25,000 and 1: 50,000 are common.

Colors are used to indicate particular features on a topographic map. Cultural or human-made features are black. Water is blue; vegetation is green. Red indicates roads and the U.S. Public Land Survey System. Brown is used for contour lines indicating changes in elevation. Purple is used to indicate revisions.

Symbols are standardized and used to represent surface features, boundaries, and structures. For example, a house is a square, black block. A church would be a block with a cross on top. A school is indicated by a block with a flag on it. Railroads are marked by lines with little tick marks across them. Telephone lines are shown by long dashed lines. Marshes are indicated with regularly spaced clumps of grass. Most symbols are fairly obvious and easy to understand.

Topographic maps show the shape of the earth's surface using contour lines. Contours are imaginary lines that trace the land's surface at a particular elevation. Elevation is important in analyzing water flow patterns. Intervals between contour lines are indicated on the map scale. A typical interval is 20 feet or 20 meters, showing an elevation change of 20 feet (meters). Occassionally a broken contour line is used to indicate a half-interval, perhaps 10 feet (meters). For example, a larger (20-100 feet or meters) contour interval is used for steep areas like mountainous regions and a small (5-10 feet or meters) interval is used for relatively flat areas. In steep areas, the contour lines appear close together and on flat areas the contour lines are far apart. (See "Properties of Contours" handout.)

Concentric circles, ovals, or ellipses indicate a knob or a hill. One not so obvious feature, but important to water studies, is a sinkhole. A sinkhole is an area where the ground is lower than the surrounding area and it drains inward instead of outward. It is indicated by contour lines forming a circle, oval, or ellipse, but with tick marks pointing to the center to indicate downward slope.

Contour lines and elevation changes are helpful in establishing watershed boundaries. By marking hilltops and ridges, it's possible to create a good outline of the complete watershed because water flows downhill, perpendicular to contours. An acetate sheet and a marker can be used over a map to trace watershed boundaries. Start with the mouth of a stream or other easily identifiable point. Then mark other obvious points like peaks and ridges that separate adjacent streams. Ask yourself, "Which way would water flow from this point?" Draw arrows to show drainage patterns. The picture of the watershed gets clearer and clearer as more points are identified, and it becomes easier to establish the boundaries of the watershed.

ADVANCED PREPARATION

A. Order or purchase topographic maps, road maps, and city maps representing the same area.

B. Order the "Topographic Map Symbols" brochures (1 per student) and topographic maps (1 per team).

C. Make acetate overhead of "Properties of Contours," "Contour Line Basics," and "Watershed Woes Exercise."

D. Make acetate dot grids for acreage estimation (1 per team).

E. Make photocopies of "Watershed Woes Exercise" (1 per team) and "Properties of Contours" and "Contour Line Basics" handouts (1 per student, included).

F. Obtain transparency markers, grease pencils, and index cards.

PROCEDURE

I. Setting the Stage

A. If the students are unfamiliar with topographic maps, pass out copies of "Topographic Map Symbols" brochure and introduce the following concepts:

1. Map scales

   a. Spread out a road map, city map, and topographic map on the table or the floor. Look for a bar graph on each map that represents the scale of the map. Try to use three maps with either conventional (miles and feet) or metric scales.

   b. Using index cards, copy the scale of each map onto a single card.

   c. When you finish transposing the scale, take a ruler and measure one inch or one centimeter on each scale. How many miles or meters are equal to one inch or centimeter on the different map scales?

   d. Now look for two landmarks, such as cities or where two roads cross that are common to each map. Using the scales you made on the index cards, measure the distance between the two points on each map. The distances should be about the same. Which scale was easier to use?

   e. Practice measuring the distance between other points on the different maps.

2. Contours

   a. Find the brown parallel lines on the topographic map. These are contour lines. The darker lines are contour interval lines.

   b. Look for a number located in a darker brown line. This number is the elevation above sea level.

   c. Look for the next darker contour interval line either inside or outside the first contour interval. Subtract the lesser elevation from the greater elevation marked on the darker brown lines; the difference is the number of feet or meters between two contour intervals.

   d. Several lighter brown lines occur between the darker lines. Count the number of these lines and divide it into the difference between contour intervals, and the difference is the number of feet or meters between any two contour lines.

   e. Now scan the topographic map and look for the highest and lowest points.

   f. You may find contour lines with additional lines pointing inward at right angles. These are sinkholes. Try to locate a sinkhole on your map.

3. Symbols

   a. Go over common symbols used on a map.

   b. Have the students locate the following features:

      1) Surface features: woods, stream, lake, waterfall, swamp, cave, well, or spring

2) Boundaries and roads: state line, county line, city limits, park, primary highway, secondary highway, light-duty road, gravel road, trail

3) Buildings and structures: house, church, school, transmission lines, railroad, bridge, campground

B. Ask the students what they think a watershed is and then discuss the definition of a watershed with them.

C. Ask the students what role a watershed plays in nonpoint source pollution.

D. Explain to the students that topographic maps are useful tools in determining how a stream may be affected by activities within its watershed.

E. Using topographic maps, the students should be able to determine size of a watershed and some of the potential nonpoint sources of pollution.

II. Activity

A. Review topographic maps and symbols used on their maps. (NOTE: Exercise is more meaningful if the students work with local maps, preferably one with their school or another locally prominent feature on it.)

1. Divide the class into teams of 2 to 3 students. Give each student a "Topographic Map Symbols" brochure, "Properties of Contours" handout, and "Contour Line Basics" handout.

2. Distribute topographic maps, "Watershed Woes Exercise" handouts, acetate sheets, colored overhead pens or grease pencils, and acreage grids to each team.

3. Have the students select a small stream system (watershed) on the topographic map which has some land use activities occurring nearby. (NOTE: Since the students will be mapping their stream system's watershed onto the acetate sheet, they should select one that is approximately half the size of the acetate sheet.)

4. Go over "Properties of Contours" and "Contour Line Basics" handouts and the "Topographic Map Symbols" brochure briefly with the students.

a. Ask each team to locate a hill, ridge, and stream.

b. Ask them to determine which way the stream they selected is flowing.

5. Go over the "Watershed Woes Exercise" handout.

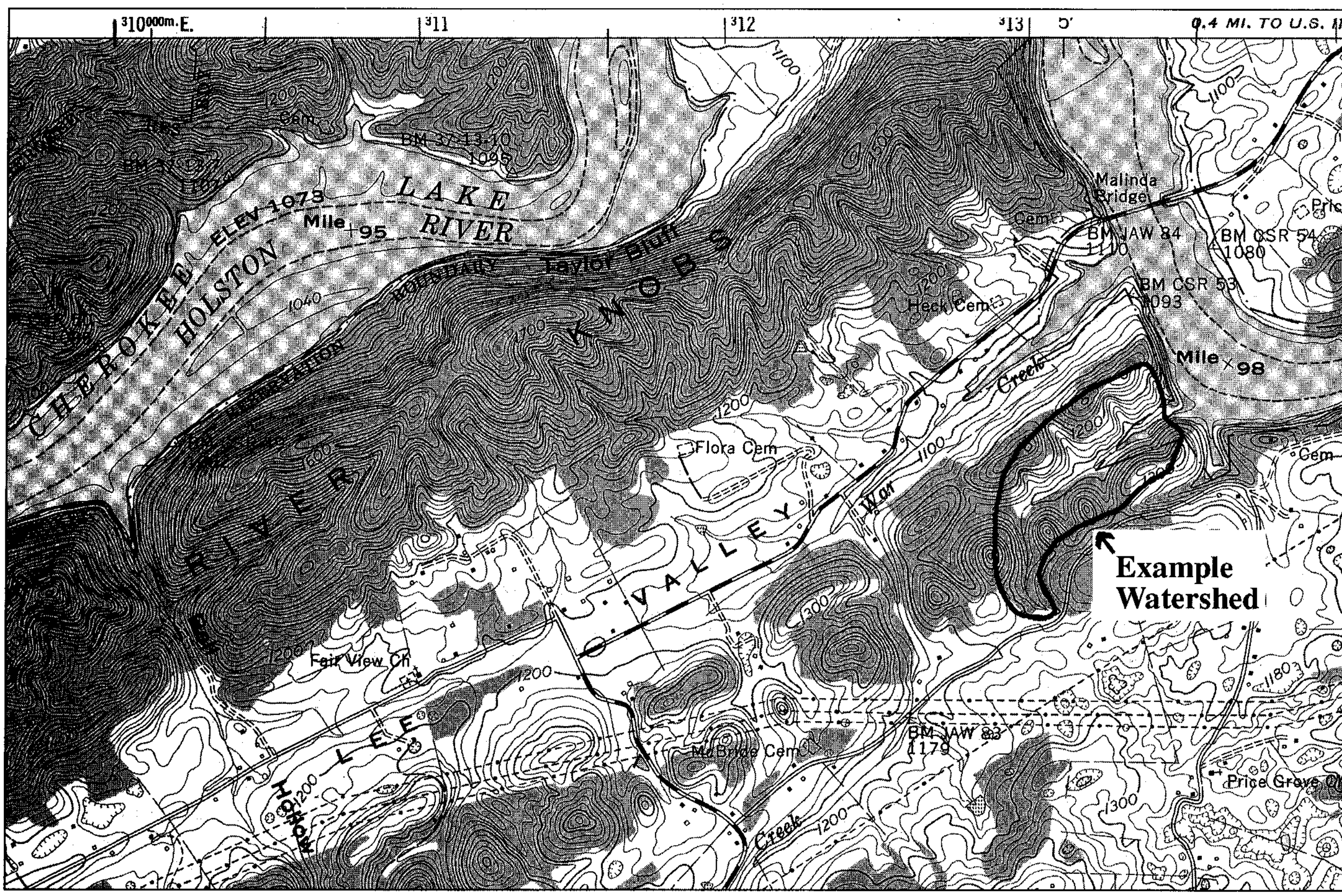
B. Map a watershed.

1. Have the teams follow the stream they selected to its origin. The point where the stream originates is called the headwaters. Beginning at the headwaters, have them follow the stream down to where it empties into the next stream. The stream they followed is a first order stream. Streams which empty into other streams are called tributaries of that stream. Next, have them follow the second stream to the next intersection. This stream is a second order stream. Then have them follow the third stream until it meets another stream, and so on, until they reach a major river or the ocean. The branching network of streams and the drainage area surrounding it that empties into a river or ocean is called a watershed.

2. Next, have them look at the contour lines which touch a stream. They should be forming a "v" with the stream in the center. (NOTE: Remember that streams always flow from higher to lower elevations.)

3. To map the drainage area for an individual tributary, have the teams examine the contour lines around the stream. Have them find the highest points on either side of the stream and above the point where the stream begins. Have them place their acetate sheet over the watershed area and mark these points with dots. Then have them connect the dots with a line. The line should form a "u" shape and will end where the stream meets another stream. They have just marked the tributary's drainage area or watershed. This is the map of the watershed boundaries for their selected stream. (See sample illustration.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



4. Now, using different colored markers, have the teams mark the areas within the watershed boundaries that are potential nonpoint sources of pollution using a key such as:

Yellow	=	Mining
Black	=	Urban Runoff
Brown	=	Agriculture
Green	=	Forestry
Red	=	Landfills

5. They might also note the critical areas of the watershed. Critical areas are places such as steep slopes with little or no ground cover that are particularly vulnerable to erosion. Land use activities in these areas often result in nonpoint source pollution. Are there significant activities occurring in these areas, such as construction, or agriculture?

6. Have the teams construct a data table. The table should include (1) name and/or location of the stream system; (2) scale of map; (3) possible point and nonpoint sources of pollution; (4) pollutant types (sediment, nutrients, bacteria, and toxics); (5) ground cover types; and (6) area of watershed.

C. Determine watershed area.

1. To determine the area of the watershed, have teams place their acetate sheet with the watershed traced on it over an acreage grid.

2. Have them count the number of dots (as instructed on the grid) and determine the conversion factor (acreage represented by each dot) from the map scale.

3. Then have them multiply the number of dots by the converting factor to determine the area of the watershed in acres.

4. Have the teams record the area in the data table.

5. Finally, have the teams write a summary of their findings from the data table to present to the class later.

D. Use data to predict potential nonpoint source pollution problems.

1. Discuss the teams' findings with them. What were some of the possible nonpoint sources of pollution in their watersheds?

2. How large were their watersheds? What does the size of the watershed represent with respect to runoff and nonpoint source pollution?

3. How does the presence and nature of the ground cover affect the amount of runoff? What types of ground cover are indicated in the teams' watershed study areas? How might the different types affect the amount of pollutants entering the water? Why?

4. Have the teams write answers to the discussion questions based on their watershed and add this to the data table and written summary prepared earlier.

5. Have the teams present their findings to the class using their acetate sheet to display their watershed map on an overhead projector.

III. Follow-Up

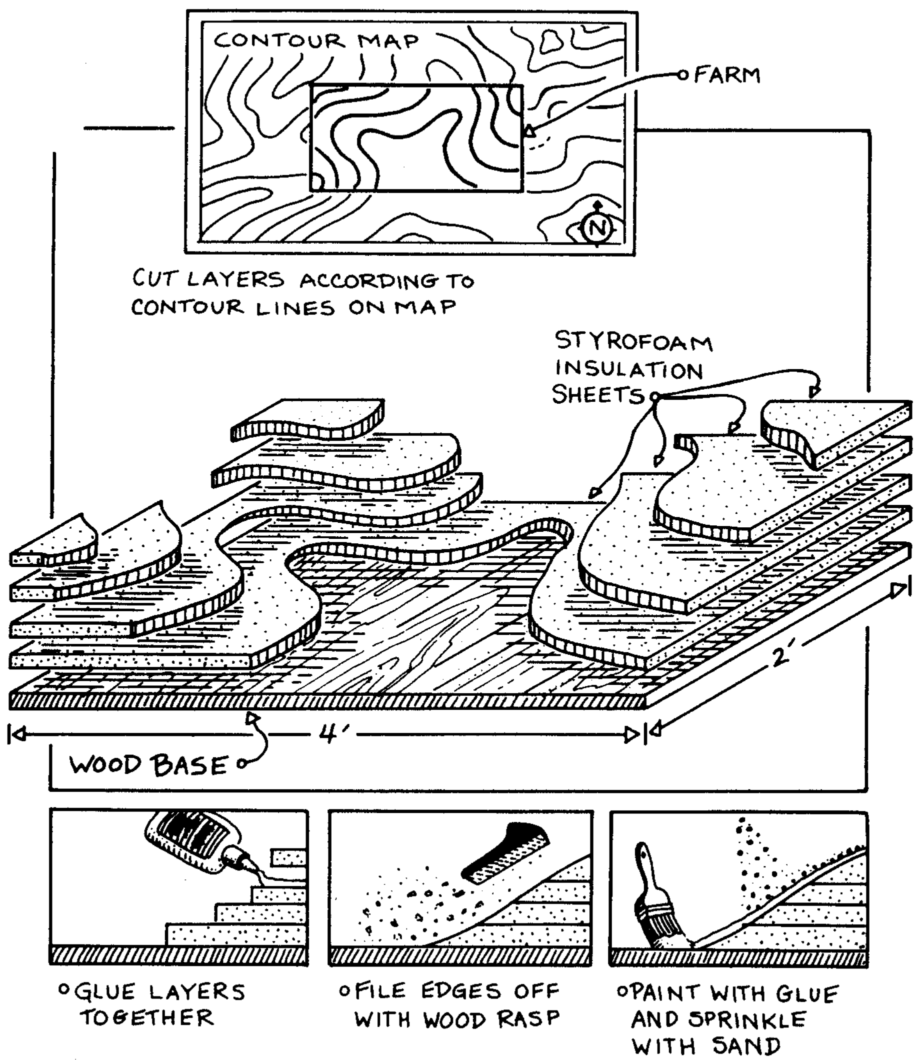
A. Give the students the Watershed Woes Quiz 1 or 2 (included). You may want to enlarge the map of the Camden Quadrangle and copy onto an overhead transparency. The class could then discuss their answers.

B. Have the students locate their home, church, school, and friends' homes on a topographic map which includes their community. Have them draw routes from their home to these points on acetate sheets and use the map scale to measure the distance. Have them locate the town water source on the map and mark the watershed boundary for the community's water supply.

IV. Extension

A. Find out the average annual rainfall in your area or for the areas depicted on the topographic maps used, if more appropriate. Ask the students, what determines the amount of actual runoff? How do rainfall and percolation rates affect runoff? Have students determine the potential volume of runoff from their watershed areas. They will need to convert acres to square feet (1 acre = 43,560 ft^2) or hectares to square meters (1 hectare = 10,000 m^2). Next, they will convert inches of rainfall to feet (or centimeters of rainfall to meters). Then multiply these together to determine the potential volume of runoff in cubic feet (or cubic meters). To make this more meaningful, convert cubic feet to gallons (cubic meters to liters). One cubic foot equals 7.2827 gallons (1 m^3 = 10,001).

B. Have students make relief sculptures of their watershed areas using cardboard, plywood, modeling clay, or papier mache and label those areas of concern marked on their watershed maps (see illustration).



C. You might also arrange a trip to the local office of the USGS in the United States to see how maps are made or visit the Canadian equivalent.

RESOURCES

Adapted from Fall Workshop Teacher Guide, TVA Water Quality Monitoring Network, Tennessee Valley Authority, Norris, Tennessee, 1992.

Clark, B. W. and J.K. Wallace, Canada, Land of Diversity, 2d ed., Prentice Hall, Canada Inc., 1989.

"How Topographic Maps Are Made," Tennessee Valley Authority Mapping Services Branch; order from Map Information and Records Unit, Mapping Services Branch, Tennessee Valley Authority, 100 Haney Building, Chattanooga, TN 37402-2801.

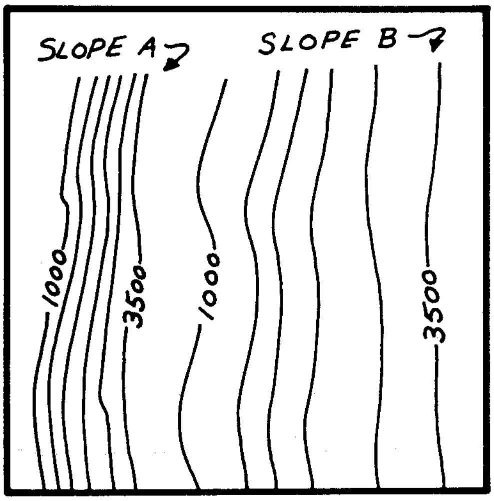
"Topographic Maps;" order from U.S. Geological Survey, Box 25286, Denver Federal Center, Denver, Colorado 80225.

"Topographic Map Symbols;" order from U.S. Department of the Interior, Geological Survey, National Mapping Division; order from Eastern Distribution Branch, U.S. Geological Survey, 1200 South Ends Street, Arlington, VA 22202.

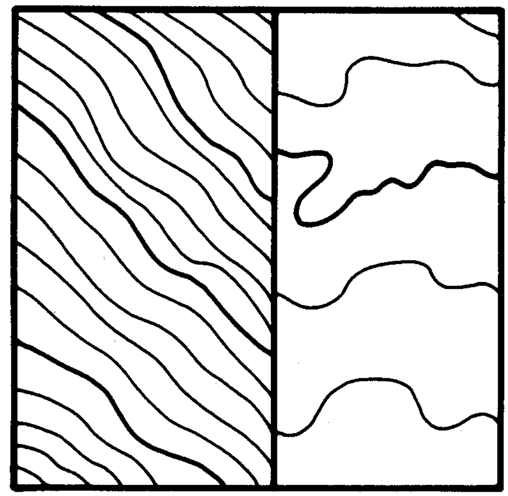
"Watershed," Aquatic Wild, Western Regional Environmental Education Council (WREEC), 1987, pp. 163-167.

PROPERTIES OF CONTOURS

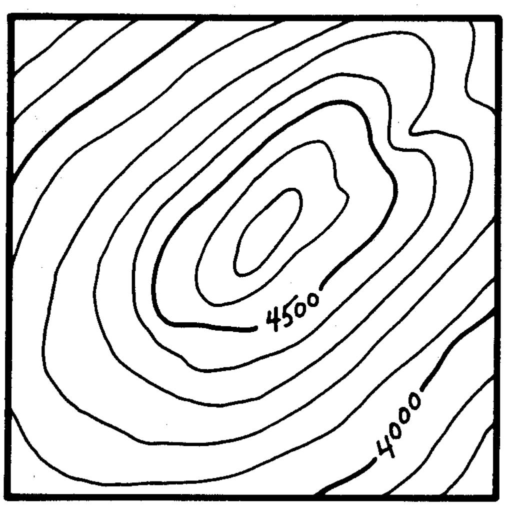
1. Contours are perpendicular to the direction of maximum slope.



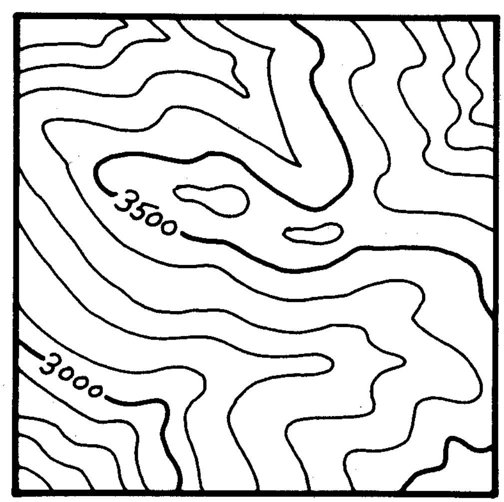
2. The distance between contours indicates the steepness of a slope; close spacing denotes steep slopes; wide spacing denotes gentle slope.



3. Concentric closed contours which increase in elevation represent hills.

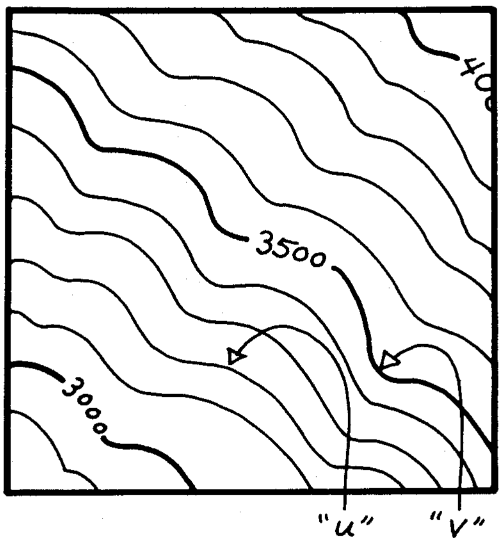


4. Irregular contours signify rough, rugged country. Smooth lines designate gradual slopes and changes.

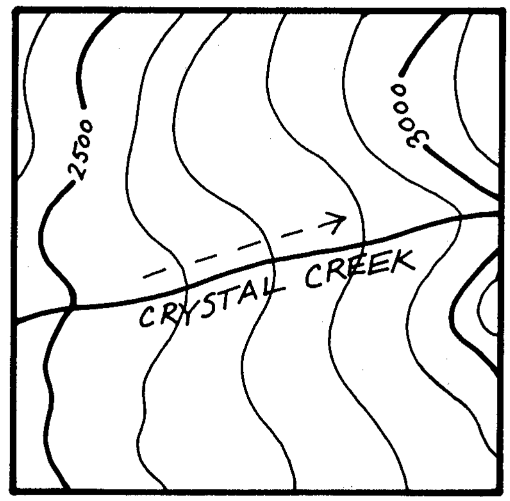


PROPERTIES OF CONTOURS (continued)

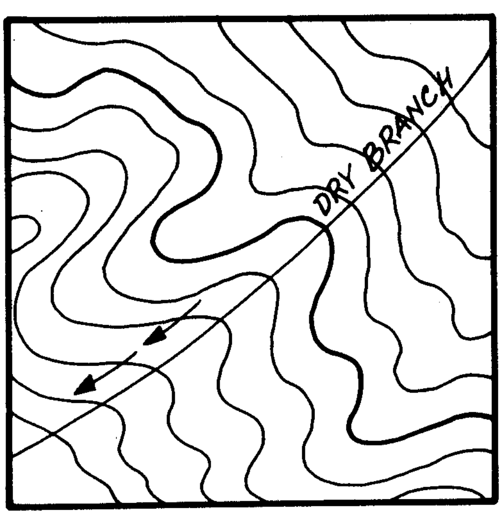
5. Valleys are usually characterized by V-shaped contours, and ridges by U-shaped contours.



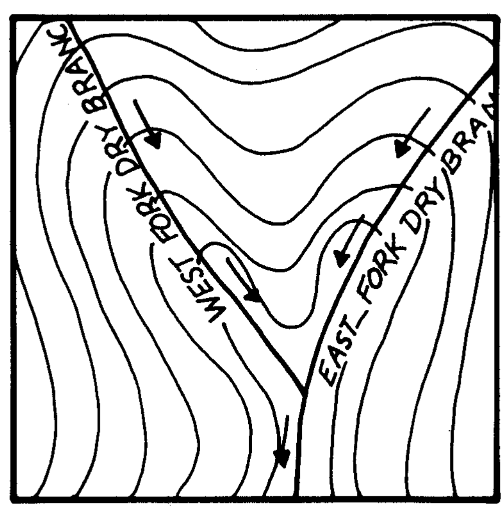
6. The V's formed by contours crossing a stream point upstream.

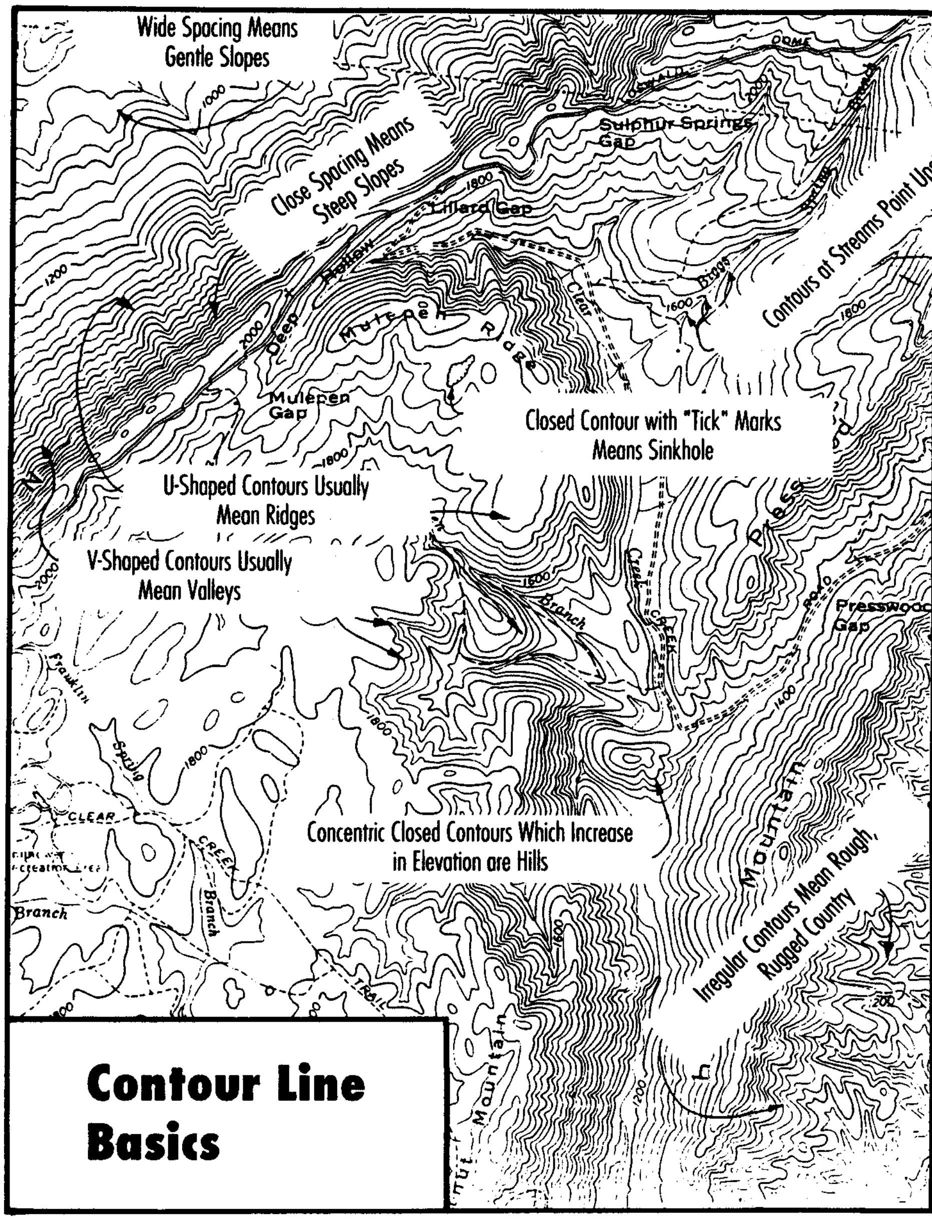


7. The U's made by contours crossing ridge lines point down the stream.

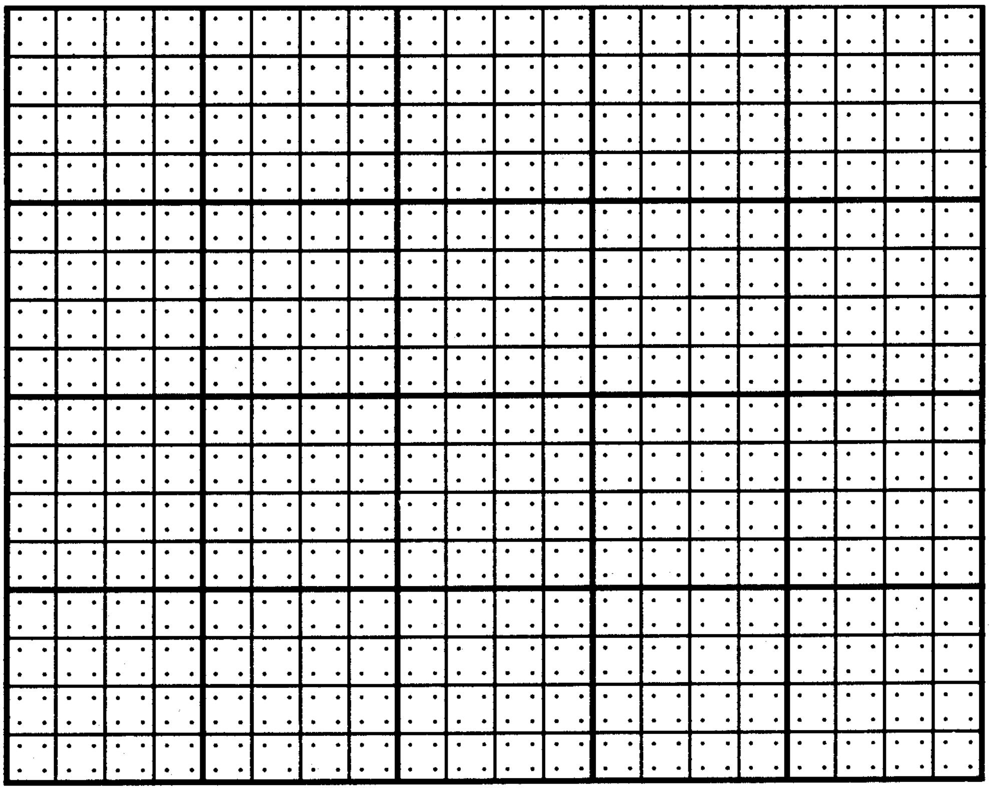


8. Contours tend to parallel streams and have an M-shape just above stream junctions.




Wide Spacing Means Gentle Slopes
Close Spacing Means Steep Slopes
Contours at Streams Point Upstream
Closed Contour with "Tick" Marks Means Sinkhole
U-Shaped Contours Usually Mean Ridges
V-Shaped Contours Usually Mean Valleys
Concentric Closed Contours Which Increase in Elevation are Hills
Irregular Contours Mean Rough, Rugged Country
Sulphur Springs Gap
Lillard Gap
Deep Hollow
Mulepen Ridge
Mulepen Gap
Presswood Gap
Clear Creek
Branch
Mountain
Contour Line Basics

DOT GRID



Map scales and equivalents

Fractional Scale	Acres Per Square Inch	Acres Per Dot
1: 24,000 (1 inch = 2,000 ft)	91.8	1.43
1: 100,000 (1 inch = 8,333 ft)	1594.0	24.9

1. Clearly draw line around area to be estimated.
2. Place dot grid randomly over area to be estimated.
3. Count all dots fully within the area plus every other dot that falls on the line around the area.
4. Record the total number of dots.
5. Repeat three times, randomly placing grid each time.
6. Take average of dot counts.
7. Multiply by appropriate acres/dot factor.

NOTE: Areas larger than dot grid may be estimated by breaking them down into smaller areas, then totaling the number of dots in each area.

Names ______________________ Date ______________

WATERSHED WOES EXERCISE

Procedure:

1. Define the term watershed.

2. Select the watershed of a small stream (try to find one that can be traced onto approximately one half of the acetate sheet).

3. To map the watershed, locate the highest point next to the stream on either side and above the point where the stream system starts. The watershed ends where the stream system joins another stream. Place the acetate sheet on the map so that the watershed boundaries will fit on the sheet. Mark the highest points (ridge tops) on either side and above the stream system with dots and connect the dots along the ridges, ending where the stream system joins another stream. These are the watershed boundaries.

4. Which way is the stream flowing (i.e., north, south, etc.)? Mark direction with an arrow on the acetate sheet.

5. Locate the ridge(s) associated with your watershed. Label them on the acetate sheet.

6. Using colored markers on the acetate sheet, mark the areas within the watershed boundaries that are potential nonpoint sources of pollution:

Yellow	=	mining
Black	=	urban runoff
Brown	=	agriculture
Green	=	forestry
Red	=	landfills

7. Are there critical areas vulnerable to erosion or where significant activities are occuring? Label them on the acetate sheet.

8. Construct a data table to include the following:
   a. name and/or location of the stream system
   b. scale of map
   c. possible point and nonpoint sources of pollution
   d. pollutant types
   e. ground cover types
   f. area in acres

9. To estimate the area (acres) of the watershed, place the acetate sheet of the watershed area over the dot grid. Count the number of dots fully within the area and every other one that falls on the line around the area. Repeat this procedure two more times, randomly placing the watershed area over dot grid. Compute the average of dot counts by dividing the sum total by three. Determine the conversion factor to be used with your map. Multiply the average number of dots by the conversion factor to estimate the area of the watershed in acres.

10. Write a summary of your findings from the data table on a separate sheet of paper. Present your findings to the class and discuss their significance.

Name _______________ Date _______________

WATERSHED WOES QUIZ 1

1. Contour lines closely spaced means (steep, gentle) slopes _______________.

2. Irregular contour lines mean _______________.

3. V-shaped contour lines mean _______________.

4. Concentric closed contour lines which increase in elevation are _______________.

5. Contour lines at streams point (upstream, downstream) _______________.

6. U-shaped contour lines usually mean _______________.

7. The symbol for a power transmission line is _______________.

8. Blue color indicates _______________.

9. The symbol for a single railroad track is _______________.

10. What does the purple color on the maps indicate? _______________

On Camden Quandrangle, label the following on the map provided and draw the map symbol below in the space provided.

1. _______ An unimproved road
2. _______ A railroad
3. _______ A primary highway
4. _______ The highest elevation
5. _______ The direction of flow of Cypress Creek

WATERSHED WOES QUIZ 1
(continued)

6. _______ An area of flat land

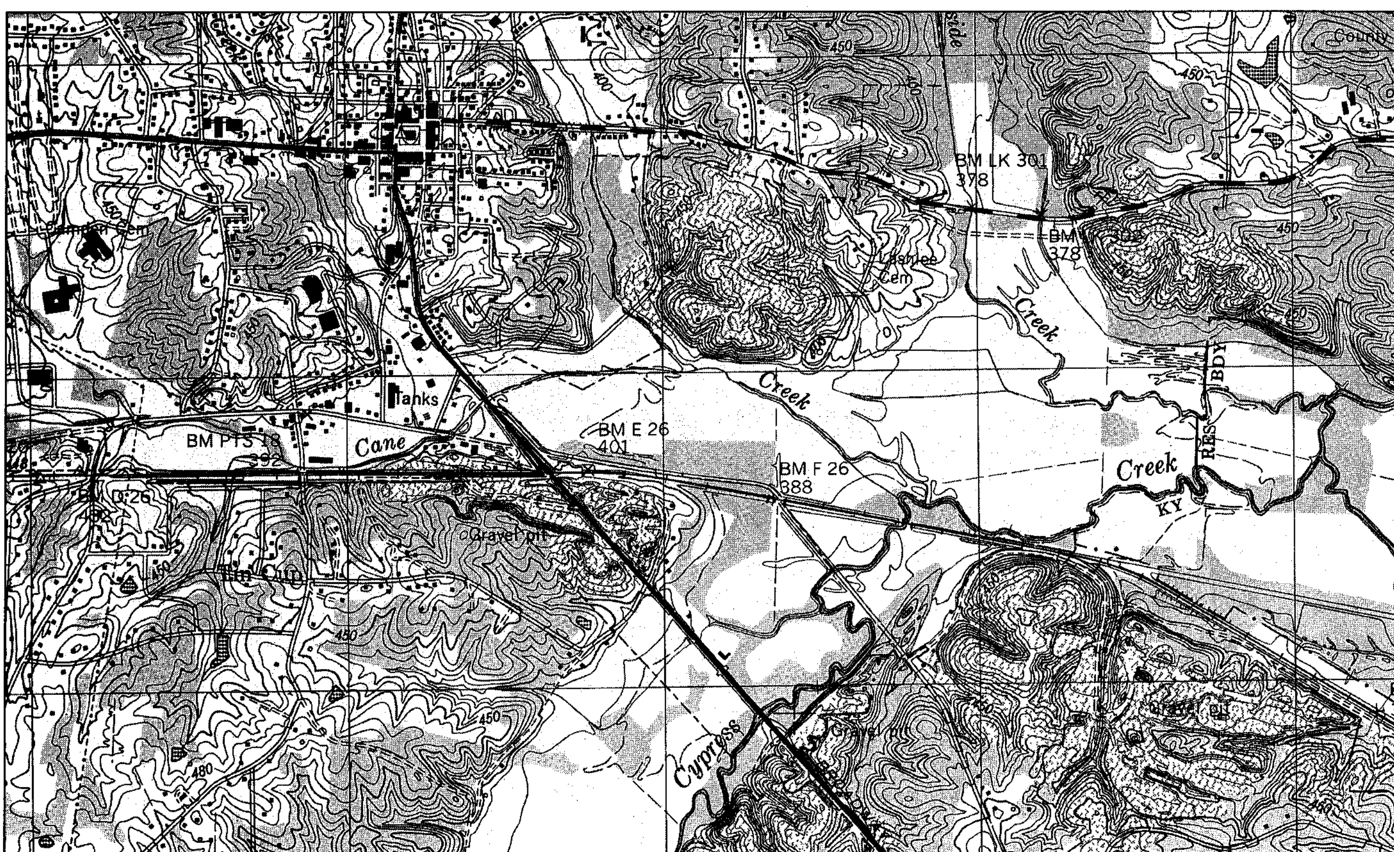
7. _______ A secondary highway

8. _______ Camden Central High School

9. _______ A power transmission line

10. _______ A house

CAMDEN QUADRANGLE



WATERSHED WOES QUIZ 1
ANSWER KEY

1. Contour lines closely spaced means (steep, gentle) slopes. steep

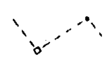
2. Irregular contour lines mean rough, rugged country.

3. V-shaped contour lines mean valleys.

4. Concentric closed contour lines which increase in elevation are hills.

5. Contour lines at streams point (upstream, downstream) upstream

6. U-shaped contour lines usually mean ridges.

7. The symbol for a power transmission line is  ________.

8. Blue color indicates water.

9. The symbol for a single railroad track is ________.

10. What does the purple color on the maps indicate? revisions

On Camden Quandrangle, label the following on the map provided and draw the map symbol below in the space provided.

1. ===== An unimproved road
2. A railroad
3. ____ A primary highway
4. 540 The highest elevation
5. NE A direction of flow of Cypress Creek

WATERSHED WOES QUIZ 1
ANSWER KEY
(continued)

6. ________ An area of flat land

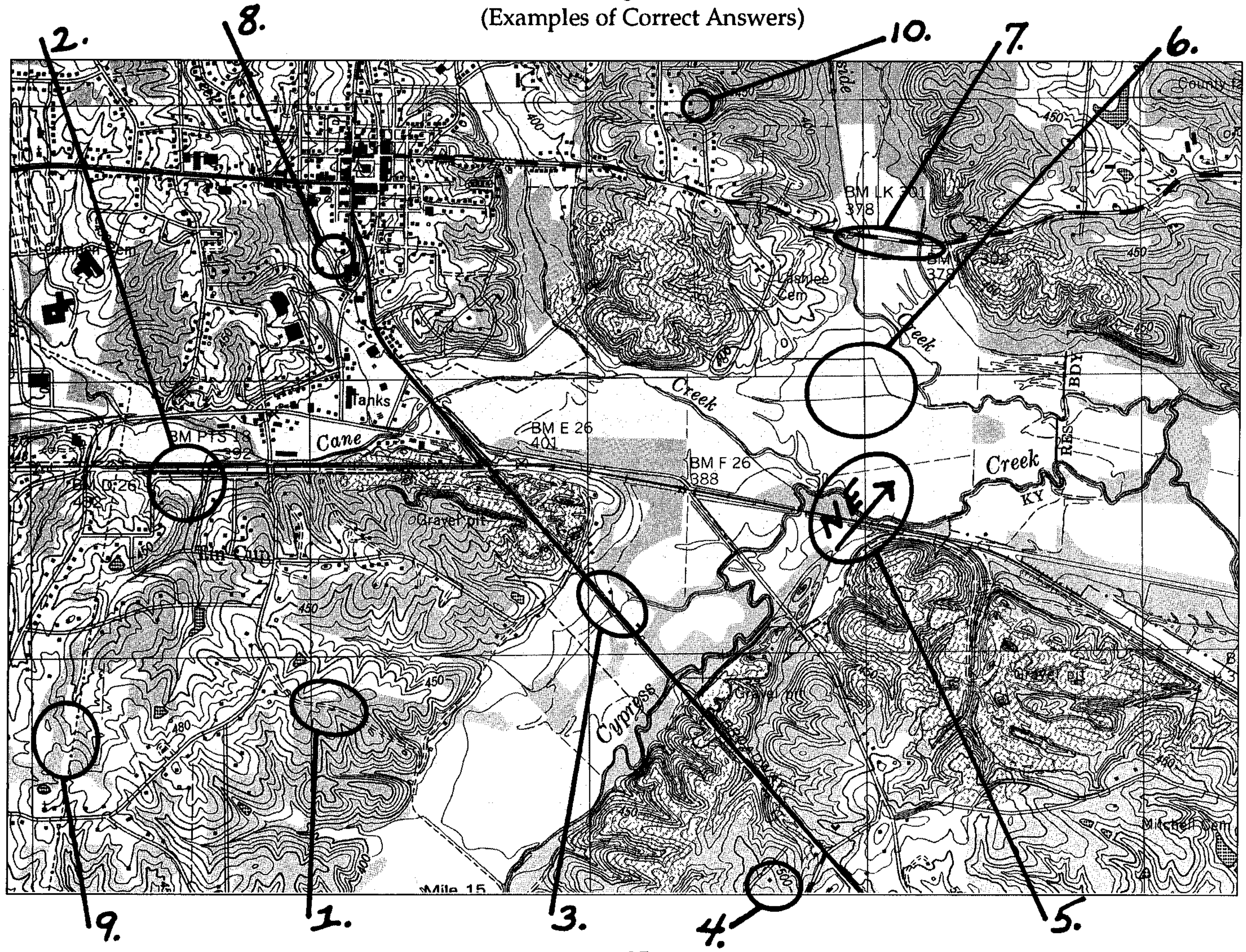
7. ________ A secondary highway

8. ________ Camden Central High School

9. ________ A power transmission line

10. ________ A house

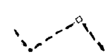
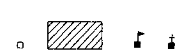
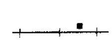
CAMDEN QUADRANGLE
(Examples of Correct Answers)



Name ______________________ Date ______________________

WATERSHED WOES QUIZ 2

Matching: Select the best answer.

1. ______	Blue color	A.	downstream
2. ______	Primary road	B.	steep slopes
3. ______	Sinkhole	C.	upstream
4. ______	Purple color	D.	water
5. ______	Power transmission lines	E.	gravel, sand, open area
6. ______	Closely spaced contour lines	F.	valleys
7. ______	V-shaped contour lines	G.	revisions
8. ______	Unimproved road	H.	rough, rugged country
9. ______	Building	I.	
10. ______	Green color	J.	forests
11. ______	Brown color	K.	ridges
12. ______	U-shaped contour lines	L.	
13. ______	V's formed by contour lines crossing a stream point ___	M.	
14. ______	Secondary highway	N.	
15. ______	Irregular contour lines	O.	
16. ______	Railroad track	P.	
17. ______	Light duty road	Q.	
18. ______	Hill	R.	
		S.	

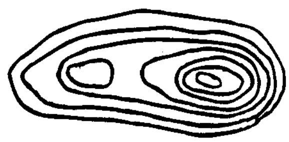
Complete:

19. Determine highest possible elevation for the illustration below if the contour interval is 100 feet: ____________________.

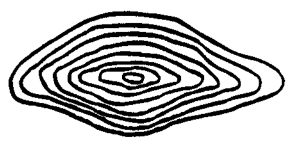
WATERSHED WOES QUIZ 2
(continued)

20. What is a watershed?

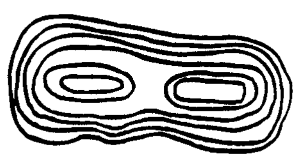
Match the following:

21. ____ 

A. 

22. ____ 

B. 

23. ____ 

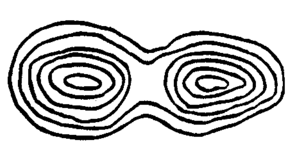
C. 

24. ____ 

D. 

25. ____ 

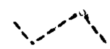
E. 

26. ____ 

F. 

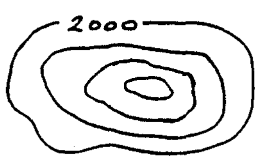
WATERSHED WOES QUIZ 2
ANSWER KEY

Matching: Select the best answer.

1.	D	Blue color	A.	downstream
2.	Q	Primary road	B.	steep slopes
3.	L	Sink hole	C.	upstream
4.	G	Purple color	D.	water
5.	I	Power transmission lines	E.	gravel, sand, open area
6.	B	Closely spaced contour lines	F.	valleys
7.	F	V-shaped contours	G.	revisions
8.	M	Unimproved road	H.	rough, rugged country
9.	N	Building	I.	
10.	J	Green color	J.	forests
11.	E	Brown color	K.	ridges
12.	K	U-shaped contour lines	L.	
13.	C	V's formed by contour lines crossing a stream point ___	M.	
14.	O	Secondary highway	N.	
15.	H	Irregular contour lines	O.	
16.	P	Railroad track	P.	
17.	R	Light duty road	Q.	
18.	S	Hill	R.	
			S.	

Complete:

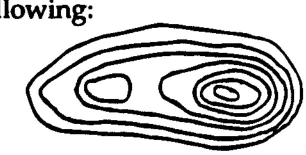
19. Determine highest possible elevation for the illustration below if the contour interval is 100 feet: 2300 feet+ .

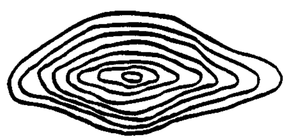


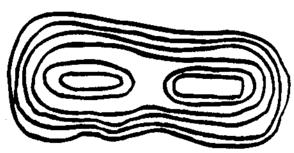
WATERSHED WOES QUIZ 2
ANSWER KEY
(continued)

20. What is a watershed? The total land area that contributes runoff to a specific body of water.

Match the following:

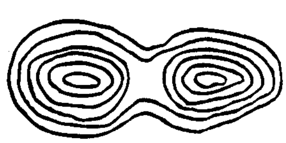
21. B  A. 

22. E  B. 

23. D  C. 

24. C  D. 

25. F  E. 

26. A  F. 

POLLUTION P.I.

OBJECTIVES

The students will do the following:

1. Use information gathered to match a station number on the map to the station name using a map of Anywhere, USA, the hypothetical study area.
2. Use raw data to determine the extent of nonpoint source pollution in the Broad River.
3. Make a data chart or table to organize data.
4. Use data tables to make logical decisions about possible sources of nonpoint pollution using a map of Anywhere, USA, the hypothetical study area.

SUBJECTS:
General Science, Life Science, Earth Science, Physical Science, Ecology, Chemistry, Biology, Physics

TIME:
2 class periods

MATERIALS:
Anywhere USA map (included)
Pollution P.I. Exercise (included)
24 envelopes
overheads of Introduction, Anywhere USA map, and Pollution P.I. Exercise (included)
transparency markers
clue cards (included)
acetate sheets

BACKGROUND INFORMATION

Nonpoint source pollution (NPS) enters water bodies from many diffuse sources and is often difficult to pinpoint and control. It happens when runoff from rainfall or snowmelt picks up and carries natural contaminants and human-made pollutants into lakes, rivers, wetlands, coastal waters, and underground water resources.

All land uses contribute to NPS in some way. Major sources of NPS include improper land use practices in agriculture, forestry, and mining; inadequate control of growth and development in cities; and storm sewers. Pollutants include: (1) excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; (2) oil, grease, and harmful chemicals from urban runoff, energy production, and manufacturing processes; (3) sediment from improperly managed construction sites, crop and forest lands, mining operations, and eroding stream banks; (4) salt from de-icing practices; (5) acid drainage from abandoned mines; and (6) bacteria and nutrients from livestock, pet wastes, and faulty septic systems.

Soil erosion causes nonpoint pollution by adding silt and sand (called sediment) to a body of water, such as a river. Sediment is the largest single nonpoint source pollutant. Sediment particles can also carry many other pollutants such as chemicals into water bodies.

Land use practices affect how much sediment is washed into water bodies. For example, erosion rates on construction sites can be as much as 2,000 times that in an undisturbed forest area of similar terrain. Once construction ceases, the surface is stabilized, and gardens and lawns are created, the rate of erosion on vegetated areas usually decreases. Poorly managed farmland can also increase sediment load from erosion, as much as 200 times that of undisturbed forestland. Grass and rangeland follow farmland in increased sediment loads. When overgrazed or poorly managed, erosion rates can reach upwards of 10 times that of similar terrain covered with undisturbed forest.

Sediment pollution can have profound effects on humans, other organisms, the environment, and the economy:

(1) Agriculture - Poor farming practices or farming highly erodable lands can cause severe erosion. Excess fertilizer can get washed into lakes, bays, and rivers causing excessive growth of algae and underwater weeds. Pesticides can have long-term effects on wildlife and human health by accumulating in the food chain (bioaccumulation). Overgrazing, particularly in the western U.S., and poorly managed livestock operations can both accelerate sediment loading of water bodies.

(2) Forestry - Erosion from improper logging practices or the construction of temporary roads to remove logs can contribute to the filling in of streams with sediment which can smother spawning areas for fish.

(3) Mining - Acid drainage from strip mining and deep shaft mining can both cause water quality problems. The construction of temporary roads to remove minerals can also cause erosion.

(4) Urban - Stormwater runoff containing road salt, soil, lawn and garden chemicals, and pet wastes can travel via street and storm drains to nearby rivers, lakes, and estuaries and degrade drinking water supplies, recreational areas, and wildlife habitat. Household and automotive products like oil, grease, gasoline, paints, fertilizers, pesticides, and other household chemicals carelessly disposed of in back-yards, on streets, and in storm sewers can end up in our surface waters. These substances can harm aquatic life, degrade water supplies, and, in severe cases, fish consumption may be banned to protect public health.

ADVANCED PREPARATION

A. Make copies of "Anywhere USA" handout and student sheets; one per student (included).

B. Make two copies of the clue cards (included). Label envelopes with the letter and station name. Cut cards apart and place three clue cards of the same letter in the appropriate envelope.

C. Make overheads of "Introduction," student sheet, and map (included).

D. Make copies of the "Pollution P.I. Exercise"; one per team (included).

PROCEDURE

I. Setting the Stage

A. Define nonpoint source pollution and discuss possible nonpoint sources using the "Introduction" overhead.

B. Tell the students this activity will introduce them to nonpoint source pollution by examining how various nonpoint pollution sources enter a water body and what changes they cause.

C. Using the "Anywhere USA" map overhead, explain to the students that water quality in the Broad River was tested by taking samples at the six stations listed on the map. Water was sampled at several sites across the width of the river and at different depths at each collection station.

D. Explain that water collected at Station 1 would represent water upstream from the site. Water collected at Station 2 would represent water coming into the river between Station 2 and Station 1, and would also include water upstream from Station 1. Tell them that they will be trying to determine which set of data goes with which site.

E. Each envelope contains important data for each site. The more information they have, the easier it will be to identify the collection site. For clarity, you might run through one envelope of cards with the whole class. Start a sample data table on the board (included), placing the station name across the top and pollution type down the side. Explain that their objective is to match all the collection site names to those listed on the map by number.

II. Activity

A. Divide the class into teams of 3 or 4. Give each student copies of "Pollution P.I. Exercise" and the map of "Anywhere USA."

1. Give each team two envelopes with a station name clearly marked on the front.

2. When the teams finish with one envelope, tell them to exchange it with you for another. (NOTE: Each team is only permitted to have two envelopes at once.) Explain to them that time is always a factor in any investigation and they may not have all the time they need to complete their investigation. Tell them to do the best they can.

3. All the students will record data in the tables in the "Pollution P.I. Exercise."

4. Each team needs data on all six collection sites, so encourage them to do as many envelopes as possible.

5. When a team thinks they have the answer, have them consult with you to check their work.

B. When the teams have discovered the correct answers, they should brainstorm within their group to determine the possible improper practices going on in each location and determine corrective procedures. For example, how could the pollution be controlled or prevented in Stampede Valley? Have them record this in the exercise.

C. When everyone finishes, discuss their answers.

1. What are the problems?

2. What are some possible solutions?

3. Ask students where on the map they would want to live?

III. Follow-Up

A. Site maps are often color coded to focus on specific problem areas. These maps are often used to plan corrective actions. Distribute colored pencils or crayons and have the students color code the maps using the chart below:

Water Type	Temp.	Sulfates	pH
1 (blue)	73-79°F (23-26°C)	50-150 mg/l	7.1 - 7.5
2 (yellow)	80-86°F (27-30°C)	151-250 mg/l	6.6 - 7.0
3 (red)	87-93°F (31-34°C)	251-350 mg/l	6.1 - 6.5
4 (brown)	94-100°F (35-38°C)	351-450 mg/l	5.5 - 6.0

Have each person on a team select one variable to color code on their map of Anywhere USA. For example, have one person color code only temperature on their map, another would color code only sufates, and a third only pH. Also, have everyone use colored dots and dashes to indicate agricultural, industrial, and municipal areas on the map and put a key on the map. Discuss ways to use these maps to plan solutions to NPS pollution problems.

B. Ask the students to re-examine the solutions they proposed earlier from different perspectives such as economic, political, social, public health, and environmental. How do the actions of one community affect the lives of people living in a different community downstream?

IV. Extension

Divide the students into groups, have them gather similiar data at six different sites, make their own clue cards, and develop their own Pollution P.I. game.

RESOURCES

Goodie, A., The Nature of the Environment, Basil Blackwell, Inc., Oxford, England, 1984.

"Fowl Play," The Class Project, National Wildlife Federation, Washington, DC, 1982, pp. 101-106.

McKenzie, G. D., W. A. Pettyjohn, and R. O. Utgard, Investigations in Environmental Geoscience, "Surface Water Contamination," Burgess Publishing Company, Minneapolis, Minnesota, 1978.

INTRODUCTION

Pollution P.I.

What are some sources of NPS?

- Agricultural
- Urban runoff
- Energy production
- Construction
- Mining
- Highways
- Irrigation
- Sewage/septic tanks
- Forestry

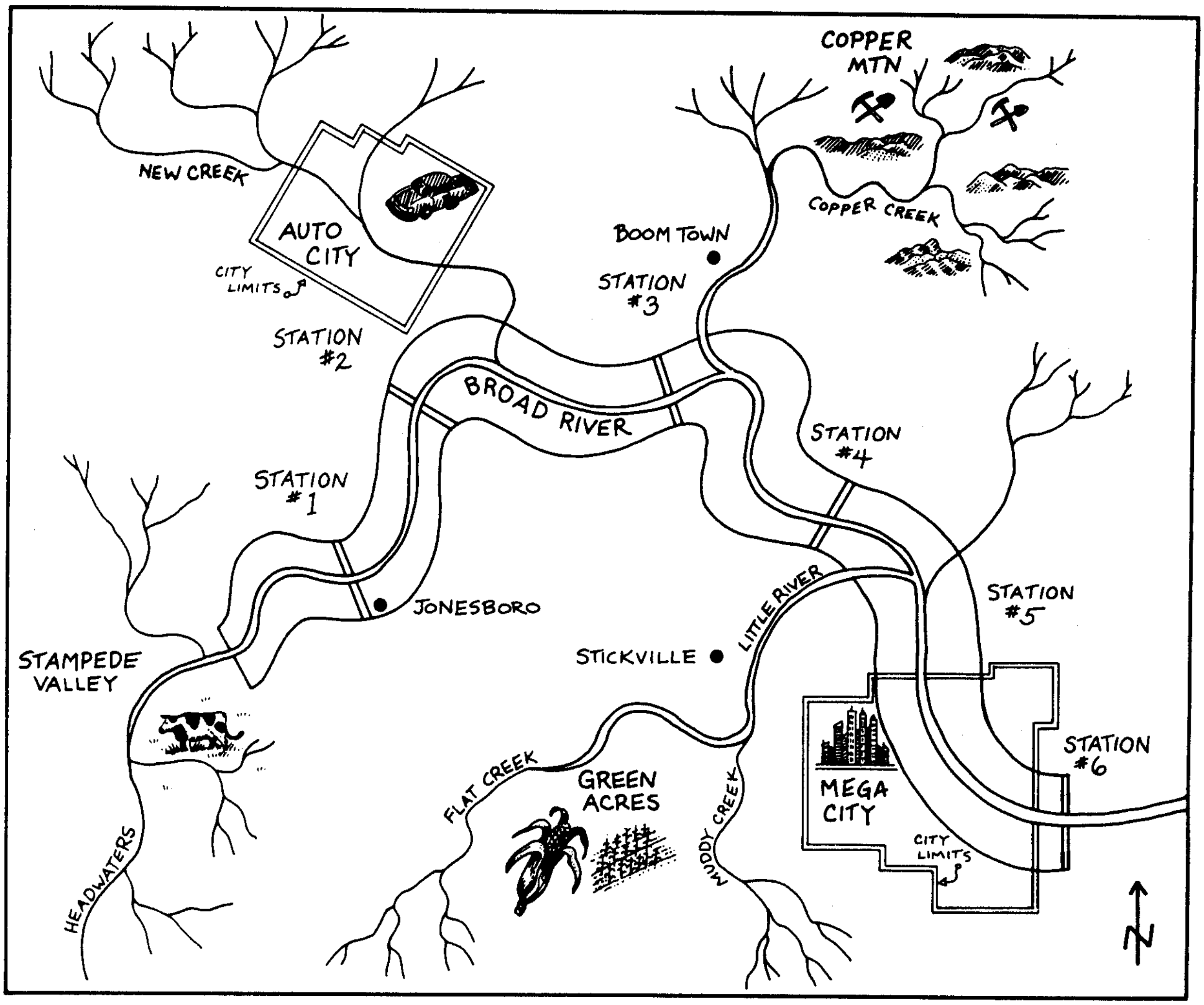
What are some of the ways nonpoint source pollution enters the water?

- Runoff
- Flooding
- Seeping into groundwater
- Tides
- Sewage overflow
- Trash dumps
- Air transport

Changes caused by NPS:

- Erosion
- Sedimentation
- Eutrophication
- Contaminate food and water supply
- Stress (or kill) aquatic plants and animals

ANYWHERE USA



Copper Mountain - Top of a mountainous region to the north that has been extensively mined for copper and iron from Boomtown, up Copper Creek, and along its tributaries.

Stampede Valley - Major cattle ranching district between Cattle Creek and the headwaters of Broad River (due to economic difficulties, range land is overgrazed in some valleys).

Green Acres - Large farming area upriver from Stickville, between Flat Creek and Muddy Creek.

Auto City - Old established city where the majority of the population relies heavily on the auto/steel industry which is the economic base for the city.

Mega City - A new, rapidly growing city with major construction constantly going on, including a wide variety of industry and business.

Jonesboro - Oldest town in state with little or no growth and a small population.

Clue Cards

Harrison Collection Station, Envelope C Analysis shows high levels of coliform bacteria due to livestock waste entering streams.	**Harrison Collection Station, Envelope D** Herbicide (plant-killing chemicals) residues were present in this analysis in medium amounts.	**K-L Collection Station Envelope A** Analysis showed only medium levels of coliform bacteria at this station.	**K-L Collection Station Envelope B** Suspended sediments at this station was 5 times that of similar terrain covered with undisturbed forests.
Harrison Collection Station, Envelope C Suspended sediments at this station were 10 times that of similar terrain covered with undisturbed forest.	**Harrison Collection Station, Envelope D** Analysis showed pH levels were acceptable at 7.1-7.5.	**K-L Collection Station Envelope A** Water temperatures of the samples collected at this station ranged from 73-79°F (23-26°C).	**K-L Collection Station Envelope B** Analysis showed pH levels were acceptable at 7.1-7.5.
Harrison Collection Station, Envelope C Water temperatures of the samples collected at this station ranged from 73-79°F (23-26°C).	**Harrison Collection Station, Envelope D** Concentrations of metals and sulfides were not discovered in the water analysis.	**K-L Collection Station Envelope A** Low or only trace amounts of herbicides were found in the water quality analysis at this station.	**K-L Collection Station Envelope B** Concentrations of metals and sulfides were not discovered in this water analysis.
M-B Collection Station Envelope F Water temperatures of the samples collected at this station ranged from 80-86°F (27-30°C).	**M-B Collection Station Envelope G** High concentrations of chloride and sulfide were discovered in the water quality analysis.	**C-D Collection Station Envelope E** Water analysis showed pH levels much more acidic than normal at 5.9 (Normal = 6.5-8.5)	**C-D Collection Station Envelope H** High concentrations of sulfates were discovered in the water quality analysis.

Clue Cards
(continued)

M-B Collection Station Envelope F Suspended sediment at lowest level of all collection points possibly due to high runoff of old established city or little erosion of well established plant cover.	**M-B Collection Station Envelope G** Coliform bacteria levels were acceptable, but high concentrations of miscellaneous solids were observed at this station, i.e., paper, rags, plastic.	**C-D Collection Station Envelope E** Water temperatures of all samples collected at this station ranged from 80-86°F (27-30°C).	**C-D Collection Station Envelope H** Coliform bacteria levels were very low. Some miscellaneous organic solids were observed to be at this station, i.e., paper, rags.
M-B Collection Station Envelope F Analysis showed pH levels to be 6.6-7.0, more acidic than the normal	**M-B Collection Station Envelope G** High concentrations of iron and other metals were discovered in this water quality analysis.	**C-D Collection Station Envelope E** Suspended sediment at level 5 times that of similar terrain with undisturbed forest cover.	**C-D Collection Station Envelope H** High concentrations of iron and other metals were discovered in the water quality analysis.
ST-S Collection Station Envelope L Sediment load at significant levels, as much as 100 times that of water draining a similar terrain with undisturbed forest cover.	**ST-S Collection Station Envelope M** Analysis showed a pH level of 6.4, more acidic than normal.	**NERAK Collection Station, Envelope J** Water temperatures of the water samples collected at this station ranged from 94-100°F (35-38°C).	**NERAK Collection Station, Envelope I** Sediment load was obvious by site. River looked muddy with suspended sediment at level 500 times that of similar terrain with undisturbed forest cover.
ST-S Collection Station Envelope L Water temperatures of the water samples collected at this station ranged from 80-86°F (27-30°C).	**ST-S Collection Station Envelope M** Coliform bacteria levels were acceptable.	**NERAK Collection Station, Envelope J** Highest level of coliform bacteria count and undecomposed organic matter indicative of a poor or inadequate sewage system.	**NERAK Collection Station, Envelope I** High concentrations of sulfides and metals were discovered in the water quality analysis.
ST-S Collection Station Envelope L Significant levels of salts were found in the water quality analysis.	**ST-S Collection Station Envelope M** Residues of fertilizers and pesticides were discovered in the water quality analysis.	**NERAK Collection Station, Envelope J** Significant amounts of toxic chemicals including oil, grease, pesticide, herbicides, were discovered in this water quality analysis.	**NERAK Collection Station, Envelope I** Water quality anaylsis showed pH to be at a level 6.1, more acidic than normal.

Name ______________________ Date ______________________

POLLUTION P.I. EXERCISE

Procedure:

1. Examine the map of "Anywhere U.S.A."

2. How many stations are located on Broad River?

3. What does the water at Station 1 represent? Station 2?

4. Water samples were taken from several sites across the width of the river and at different depths at each collection station. Use the clues to match the station number with the station name of all six stations. Use as many envelopes as possible.

5. Use the data table below to collect information.

Station #						
Station Name						
Temperature						
pH						
Sediment Load						
Toxic Chemicals						
Coliform Bacteria						
Fertilizers						
Pesticides						
Salts (Chlorides, Sulfides, or Sulfates)						
Metals						

6. Use the data to determine the extent of nonpoint source pollution in Broad River.

POLLUTION P.I. EXERCISE
(continued; Follow-Up)

7. Identify the problems associated with each station and possible solutions to those problems.

8. Color the map according to the chart and instructions below.

Water Type	Temp.	Sulfates	pH
1(blue)	73-79°F (23-26°C)	50-150 mg/l	7.1 - 7.5
2(yellow)	80-86°F (27-30°C)	151-250 mg/l	6.6 - 7.0
3(red)	87-93°F (31-34°C)	251-350 mg/l	6.1 - 6.5
4(brown)	94-100°F (35-38°C)	351-450 mg/l	5.5 - 6.0

Have each person on a team select one stream variable to color code on the map of Anywhere USA. For example, have one person color code only temperature on their map, another would color code only sulfates, and a third only pH. Also, have everyone use colored dots and dashes to indicate agricultural, industrial, and municipal areas on the map. Discuss ways to use these maps to plan solutions to NPS pollution problems.

POLLUTION P.I. EXERCISE
TEACHER KEY

Procedure:

1. Examine the map of "Anywhere U.S.A."

2. How many stations are located on Broad River? 6

3. What does the water at Station 1 represent? Station 2? Water upstream of Station 1. Water coming into the river between Station 2 and Station 1, and would also include water upstream from Station 1.

4. Water samples were taken from several sites across the width of the river and at different depths at each collection station. Use the clues to match the station number with the station name of all six stations. Use as many envelopes as possible.

5. Use the data table below to collect information.

Station #	1	2	3	4	5	6
Station Name	Harrison	K-L	M-B	C-D	ST-S	NERAK
Temperature	73-79°F (23-26°C)	73-79°F (23-26°C)	80-86°F (27-30°C)	80-86°F (27-30°C)	80-86°F (27-30°C)	94-100°F (35-38°C)
pH	7.1-7.5	7.1-7.5	6.6-7.0	5.9	6.4	6.1
Sediment Load	10x higher	5x higher	lowest, misc solids, paper, rags, plastic	5x higher, misc solids, paper, rags	100x higher	500x higher undecomposed organic matter
Toxic Chemicals	no info	no info	no info	no info	no info	significant amounts
Coliform Bacteria	high	medium	acceptable but high	very low	acceptable	highest count
Fertilizers	no info	no info	no info	no info	residues	significant amounts
Pesticides	medium	low or trace	no info	no info	residues	no info
Salts (Chlorides, Sulfides, or Sulfates)	not discovered	not discovered	high chloride & sulfide	high sulfates	significant salts	high sulfides
Metals	not discovered	not discovered	high iron & other metals	high iron & other metals	no info	high metals

6. Use the data to determine the extent of nonpoint source pollution in Broad River. Possible pollution sources include copper and iron mining, cattle ranching, row cropping, auto/steel industry, Auto City, Mega City, and Jonesboro.

POLLUTION P.I. EXERCISE
(continued; Follow-Up)
TEACHER KEY

7. Identify the problems associated with each station and possible solutions to those problems.

Copper Mountain - Abandoned and active copper and iron mines: Use proper mining and reclamation practices; restrict mining adjacent to streams; use buffer strips to minimize mining impact on stream; cover and/or remove tailing piles to prevent runoff into streams; locate haul roads away from streams; design, maintain, and close roads following best management practice guidelines; and reclaim abandoned mine sites.

Stampede Valley - Cattle Farming: Restrict pasturing on steep slopes and sensitive soils, restrict cattle access to stream; provide alternative water sources; use best management practice guidelines to determine the appropriate number of animals per acre; divide pastures and practice rotational grazing; and rotate forage crops to maintain soil fertility.

Green Acres - Row Cropping: Use conservation tillage, contour plowing and terracing practices on slopes; minimize use of fertilizers and pesticides and time applications to reduce runoff; and use manure when possible as a fertilizer and soil conditioner.

Auto City - (1) Auto/Steel Industry: Discharges from factories are point source and fall under NPDES permit laws in the U.S.; possible NPS at plants include accidential spills and runoff from exposed piles of coal and other ores used in processing; implement spill prevention programs and cover piles of ores or other materials which might dissolve and enter runoff; plants can minimize problems best by reducing and recycling materials used to produce their products; (2) Urban area: reduce litter, maintain septic tanks, reduce use of hazardous home chemicals by substituting safer products; properly dispose of home waste, reduce use of fertilizers and pesticides, and provide for recycling of petroleum products and home hazardous wastes.

Mega City - (1) Urban: See Auto City; (2) Construction: Use silt screens, hay bales, and other methods to prevent silt from entering streams, use straw and other mulches to protect soil, use diversion ditches and sediment basins to divert runoff and collect sediment laden water, provide receptacles to collect spent solvents, and properly dispose of all chemicals, chemical containers, and other construction waste.

Jonesboro - Urban: See Auto City.

TEACHER ANSWER KEY BY STATION

Station #1 -Harrison Collection Station

- Water temperature of the samples collected at this station ranged from 73-79°F (23-26°C).
- Analysis showed that pH levels were acceptable at 7.1-7.5.
- Suspended sediment (sediment load) at this site was 10 times that of similar terrain with cover of undisturbed forests.
- Analysis showed high levels of coliform bacteria due to livestock waste entering streams.
- Herbicide (plant killing chemicals) residues were present in this analysis in medium amounts.
- Concentrations of metals and sulfides were not discovered in the water analysis.

Station #2 - K-L Collection Station

- Water temperature of samples collected at this station ranged from 73-79°F (23-26°C).
- Analysis showed that pH levels were acceptable at 7.1-7.5.
- Suspended sediments (sediment load) were 5 times that of similar terrain covered with undisturbed forests.
- Analysis showed only medium levels of coliform bacteria at this station.
- Low or only trace amounts of herbicides were found in the water quality analysis at this station.
- Concentrations of metals and sulfides were not discovered in this water quality analysis.

Station #3 - M-B Collection Station

- Water temperature of the samples collected at this station ranged from 80-86°F (27-30°C).
- Analysis showed pH levels were at 6.6-7.0, more acidic than the normal.
- Suspended sediment levels (sediment load) at lowest level of all collection points.
- Coliform bacteria levels were acceptable, but high concentrations of solids were observed at this station, i.e., paper, rags, plastic.
- High concentrations of chloride and sulfide were discovered in this water quality analysis.
- High concentrations of iron and other metals were discovered in the water quality analysis.

Station #4 - C-D Collection Station

- Water temperature of the samples collected at this station ranged from 80-86°F (27-30°C).
- Water analysis showed pH levels much more acidic than normal at 5.9. (Normal ranges for natural waters is 6.5-8.5.)
- Suspended sediment (sediment load) was 5 times that of similar terrain with undisturbed forest cover.
- Coliform bacteria levels were very low. Some miscellaneous organic solids were observed at this station, i.e., paper, rags.
- High concentrations of sulfates were discovered in the water quality analysis.
- High concentrations of iron and other metals were discovered in this water quality analysis.

Station #5 - ST-S Collection Station

- Water temperature of the samples collected at this station ranged from 80-86°F (27-30°C).
- Analysis showed pH level at 6.4, more acidic than normal.
- Sediment load was at significant levels, as much as 100 times that of water draining a similar terrain with undisturbed forest cover.
- Coliform bacteria were at an acceptable level.
- Residues of fertilizers and pesticides were discovered in the water quality analysis.
- Significant levels of salts were found in the water quality analysis.

TEACHER ANSWER KEY
(continued)

Station #6 - NERAK Collection Station

- Water temperature of the samples collected at this station ranged from 94-100°F (35-38°C).
- Water quality analysis showed pH to be at a level 6.1, more acidic than normal.
- Sediment load was obvious by sight. The river looked muddy with suspended sediment at a level 500 times that of similar terrain with undisturbed forest cover.
- Significant amounts of toxic chemicals including oil, grease, pesticides, and herbicides were found.
- Tests revealed the highest coliform bacteria count of all the stations and solid matter indicated poor or inadequate sewage system.
- High concentrations of sulfides and metals were discovered in water quality tests.

FED UP

OBJECTIVES

The students will do the following:

1. Perform a controlled experiment examining changes in pond water due to phosphate and nitrate enrichment over a 10-day period.
2. Explain what eutrophication is and how excessive nutrients affect water quality.
3. Explain the role of phosphorous and nitrogen compounds in the eutrophication of water systems.
4. Identify nonpoint sources of nutrient enrichment.

SUBJECTS:
General Science, Life Science, Earth Science, Physical Science, Ecology, Biology, Chemistry, Physics

TIME:
2 class periods

MATERIALS:
class set of LAB-AIDS®: Pollutant effects of phosphates and nitrates kit. (See references.)
"Collecting a Water Sample" handout (included)
data sheets (included)
100 ml graduated cylinders (one per team of 6)
compound microscopes and commercially prepared algal slides (optional)
dissolved oxygen test kit (optional)
algae identification charts (optional; included)
safety goggles
sun lamp or grow light (optional)
marking pens
"Fed Up Quiz" (optional; included)
7 150 ml clear plastic cups/team (optional)
3 150 ml beakers (optional)
3 1 ml pipettes (optional)
high nitrate/low phosphate granulated fertilizer (optional)
high phosphate/low nitrate granulated fertilizer (optional)
permanent ink pens (optional)
waders (optional)
adhesive labels (optional)
collecting bottles (optional)
ice chest with ice (optional)
plastic wading pools (optional)
maps of sampling sites (optional)

BACKGROUND INFORMATION

The population of aerobic (oxygen-dependent) life in a pond, lake, or stream depends in part on the amount of dissolved nutrients in the water. Too little of any single non-living factor can limit or prevent growth of a population of plants or animals even if all the other factors within the ecosystem are at or near their most desirable range. Factors which limit growth are called limiting factors. Water low in nutrients is called oligotrophic while water high in nutrients is called eutrophic. The nutrients of greatest concern in eutrophication are nitrogen and phosphorous. Phosphorous is usually the least available or limiting nutrient in freshwater ecosystems followed by nitrogen. In saltwater ecosystems, nitrogen is the limiting nutrient.

Eutrophication is a gradual natural process of nutrient enrichment in waterways. The impact of a discharge on a receiving water body is based on the ability of those waters to assimilate or break down the wastes. Additions of excess phosphorous and nitrogen compounds accelerate eutrophication by enhancing aquatic plant growth. When aquatic plants die and decompose over time, they fill in water bodies with organic material. Human activities can greatly increase the rate at which this happens. Eutrophication and the filling in of a water body can reduce flood storage capacity and hydroelectric power potential, and change the ecology of the water body which may affect fish and recreational activities.

Nonpoint sources of nutrient enrichment include agricultural fertilizers, livestock wastes, pet feces, failing septic tanks, and eroded soil. Phosphate detergents can enter waterways through storm drains, from improperly treated wastewater, and from failing septic tanks. Phosphate and nitrate fertilizer used on crops and lawns can also become major nonpoint pollutants when they wash into water bodies. When it rains, runoff carries soil and nutrients into water bodies. (Phosphates usually travel into water bodies attached to soil. Nitrate fertilizers are water soluble; they can dissolve directly in water and don't always travel to water bodies attached to soil particles.)

Livestock waste can be another nonpoint source of nutrient enrichment since cattle can produce 15-25 times as much wet manure (solid and liquid wastes) as people. For example, untreated wastes from a 10,000 head cattle feedlot can cause water quality problems approximately equal to those of a city of 150,000 people. However, it is difficult to make a real comparison between municipal sewage which is diverted by pipes to waste water treatment plants and livestock wastes which are usually stored and then land applied. If animal wastes are not properly stored and applied to land, they can create serious water quality problems. Animal feedlots are a major source of ammonia (a by-product of the decomposition of fecal matter), uric acid, and urea in urine. Ammonia is oxidized by bacteria to form nitrous and nitric acids or ammonium salts in a process called nitrification. Because this process uses oxygen, nitrification can reduce the amount of oxygen available for aquatic animals and may cause fish kills.

Excessive nutrients entering waterways can cause rapid growth of blue-green or other algae. This is called an "algal bloom." Algal blooms can produce thick surface mats, turn the water green, stain boats, cause a skin rash on swimmers, and may be toxic to animals that drink the water. When the excess nutrients are used up the algal blooms die. The break down or decaying of the dead algae uses oxygen which reduces the amount available for use by aquatic animals. This also can cause fish kills.

ADVANCED PREPARATION

A. Order the LAB-AID® kit. (Address in Reference Section.) One kit supplies 35 tests.

B. Alternatives to LAB-AID® kits:

1. Use 150 ml beakers to mix solutions. To make the phosphate solution, add 100 mg (0.1 g) potassium phosphate to 100 ml water. To make the nitrate solution, add 100 mg (0.1 g) potassium nitrate to 100 ml water. To make the nitrate and phosphate solution, add 100 mg (0.1 g) potassium phosphate and 100 mg (0.1 g) potassium nitrate to 100 ml water. Substitute these solutions for the LAB-AID® solutions. Add 0.5 ml for 9 drops and 1 ml for 18 drops of each solution to the test containers as described in the Procedure section.

2. Use 150 ml beakers to mix solutions. Get three types of granulated fertilizers from a garden supply store—(1) high in nitrates and low in phosphates, (2) high in phosphates and low in nitrates, and (3) equal in nitrate and phosphate concentration. Substitute these solutions for those in the LAB-AID® kit by adding 1 granule of fertilizer for the 9 drops test solution and 3 granules for the 18 drops test solution as described in the Procedure section. (NOTE: With this alternative, nitrogen and phosphorus can not be isolated. In one set of test solutions, nitrogen will be in greater concentration, in another, phosphorus will be greater, and in the third, both will be equal.)

C. Within a few days prior to the experiment, obtain several liters of pond or stream water (depending on class or group size) and store in a cool place until ready for use.

D. Make photocopies (1 per student) of the Student Data and Collecting a Water Sample handouts (included).

PROCEDURE

I. Setting the Stage

A. Discuss eutrophication and how this process can be accelerated by human activity.

B. Explain to the students that they will view the effects of various levels of nutrient enrichment in this experiment.

II. Activity

A. Prepare water samples.

1. Divide the class into teams of seven and give each student a data sheet.

2. Each student per team will be responsible for setting up one test container and everyone will be responsible for monitoring all of the containers.

3. Give each team seven clean testing containers. Label each by numbering them from one to seven. Container #1 will be the control.

4. Place 90 ml of water sample (from a pond or stream) into each test container.

5. Have the students record the date the experiment was prepared and location of where the water sample was collected on their data sheet.

B. Prepare test solutions.

1. If using the LAB-AID® kit, have the students read the directions provided. If not, explain how you prepared the test solutions.

2. Then have the students add the nitrate and the phosphate "pollutants" from the LAB-AID® kit or alternative test solutions daily, as described below. (CAUTION: Students should use safety goggles whenever they are handling chemicals. NOTE: Nitrates and phosphates can stain clothing and skin.)

Container #	Solutions (added daily)
1	0 drops control
2	9 drops phosphate solution
3	18 drops phosphate solution
4	9 drops nitrate solution
5	18 drops nitrate solution
6	9 drops nitrate and phosphate solution
7	18 drops nitrate and phosphate solution

C. Place a piece of paper towel over each test container and place them in a sunny location so that each container receives the same amount of light. (NOTE: Use a sun lamp or grow light if sunlight is unavailable.)

D. Use the data sheet provided to record daily observations for all seven containers. Data collected should include observations on color, clarity, and odor of the water.

E. When the experiment is completed, have the students answer the following questions based upon their observations:

1. How long did it take before changes in the algae content of the control and in each of the test containers were observed? (Answers will vary.)

2. After five days, how did the contents compare of tests containers #2 to #3; #4 to #5; and #6 to #7? (Greater concentrations should result in increased algal growth.)

3. After ten days, how did the contents compare of test container #2 to the control; #4 to the control; #6 to the control; and #6 to #2 and #6 to #4. (The test containers will have greater concentrations of algae.)

4. How do you explain these observations? (Phosphates and nitrates increase algae growth.)

F. Discuss the following:

1. What happens to the amount of dissolved oxygen in the water following an algal bloom? (Decreases.)

2. How might this affect aquatic animal life? (Animals can't breathe.)

3. What can or should be done to control nonpoint sources of phosphate and nitrate compounds in runoff? [Apply best management practices (BMPs).]

III. Follow-Up

A. Have the students identify the type(s) of algae that grew using copies of the algae identification charts, microscopes, slides, and commerically prepared algal slides. Compare the actual source of your water sample to the charts provided. Do they correspond? What factors in the area are contributing to increased nutrient levels and algal growth? What could be done to prevent this? Recommend changes to the local landowner and monitor algae growth. Is there an observable change? Why or why not?

B. Have the students perform dissolved oxygen (DO) tests on the samples. Is there a correlation between DO and algal growth? (Yes, algae also require DO.)

C. Perform a larger-scale study on the effects of nutrient enrichment using plastic wading pools as artificial ponds. Add different amounts of nitrate and phosphate fertilizers, manure, phosphate detergents, grass cuttings, etc. Be sure to leave one pond as a control. Have students answer the questions above. Have the students compare what goes on in these "ponds" to what happens in local lakes or farm ponds.

D. Check the students' understanding of material by giving them the "Fed Up" quiz (included).

IV. Extension

A. Obtain water samples from a variety of water systems. Take some samples from waters that appear to be eutrophic and at least one from water that appears to be oligotrophic or from areas you suspect may be impacted despite their appearance.

1. Use a grease pencil or pencil and masking tape to label each sample. Include date, time of day, and sampling location.

2. Record sampling locations on a map or make a sketch and describe each sampling site.

3. Survey the area and note possible nonpoint sources of pollution.

4. Test each sample for nitrate and phosphate levels using commercial kits.

5. Compare the results of the tests to your observations from each sampling site.

B. Compare the different sites.

1. Draw, or use, a local land use map to show locations of possible nonpoint sources of phosphate and nitrogen compound effluent.

2. Develop an action plan to address any significant problems you found.

RESOURCES

Hansin, J.W. Chris, Global Science: Energy, Resources, Environment Laboratory Manual and Teacher's Guide, 2nd Edition, "The Effects of Phosphate and Nitrate Pollutants on Pond Water," Kendall Hunt Publishing Company, Dubuque, Iowa, 1981, pp. 209-212.

"Industry Facts: Water," Beef Handbook, The National Cattlemen's Association, September 1990.

LAB AIDS® Kit: Pollutant Effects of Phosphates and Nitrates, Hubbard Scientific or LAB-AIDS, Inc., 130 Wilbur Place, Bohemia, NY 11716.

Needham, Paul R., Freshwater Biology, Holden-Day Inc., San Francisco, California, 1962.

Oxygen, phosphorous, or nitrogen test kits, Carolina Biological Supply Company , Burlington, North Carolina 27215.

Oxygen, phosphorous, or nitrogen test kits, LaMotte Chemical Products Company, P.O. Box 329, Chestertown, Maryland 21620.

Oxygen, phosphorous, or nitrogen test kits, Hach Equipment Company, P.O. Box 389, Loveland, Colorado 80539.

Palmer, C. Mervin, Algae in Water Supplies, An Illustrated Manual on the Identification, Significance, and Control of Algae in Water Supplies, U.S. Department of Health, Education, and Welfare, Public Health Service Publication No. 657, Washington, DC, 1962.

Prepared algal slides, Carolina Biological Supply Company, Burlington, North Carolina 27215.

Prescott, G. W., How to Know the Freshwater Algae, William C. Brown Company, Dubuque, Iowa, 1970.

Schmidt, James C., editor, How to Identify and Control Water Weeds and Algae, Applied Biochemists, Inc., Mequon, Wisconsin, 1976.

Terrell, Charles R. and Dr. Patricia Bytnar Perfetti, Water Quality Indicators Guide: Surface Waters, (SCS-TP-161), United States Department of Agriculture, Soil Conservation Service, 1988. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402.

COLLECTING A WATER SAMPLE

Collecting Container:

Any container (glass or plastic bottle) can be used to collect a water sample. Before use, wash the bottle (use non-phosphate soap) and rinse all soap from container using distilled water. When doing a dissolved oxygen (DO) test, use only the special bottle provided with your test kit to collect the sample.

Labeling Bottle:

Label the top and side of the clean, dry collection bottle, using adhesive labels and permanent ink pen. Include date, time, and collection site on each label.

Sampling Technique:

Select a representative site, preferably at the midpoint of the main flow channel. Avoid sampling in shallow water near the shore or in stagnant water. Rinse out the sampling bottle several times using the water you are going to sample. Next, plunge the container with the lid on mid-way between the surface and bottom of stream. Remove the lid, allow the container to fill with water, and replace the lid. Then remove the sample from the water.

Preservation of Water Sample:

It is best to run tests on water samples immediately after collection. However, if this is not possible, store sample in a cooler with ice to transport to the lab. Most water quality samples can be held on ice and tests run at a later time, with the exception of the DO test which should be performed immediately when the water is collected.

Name ______________________ Date ______________________

DATA SHEET

WATER SAMPLE

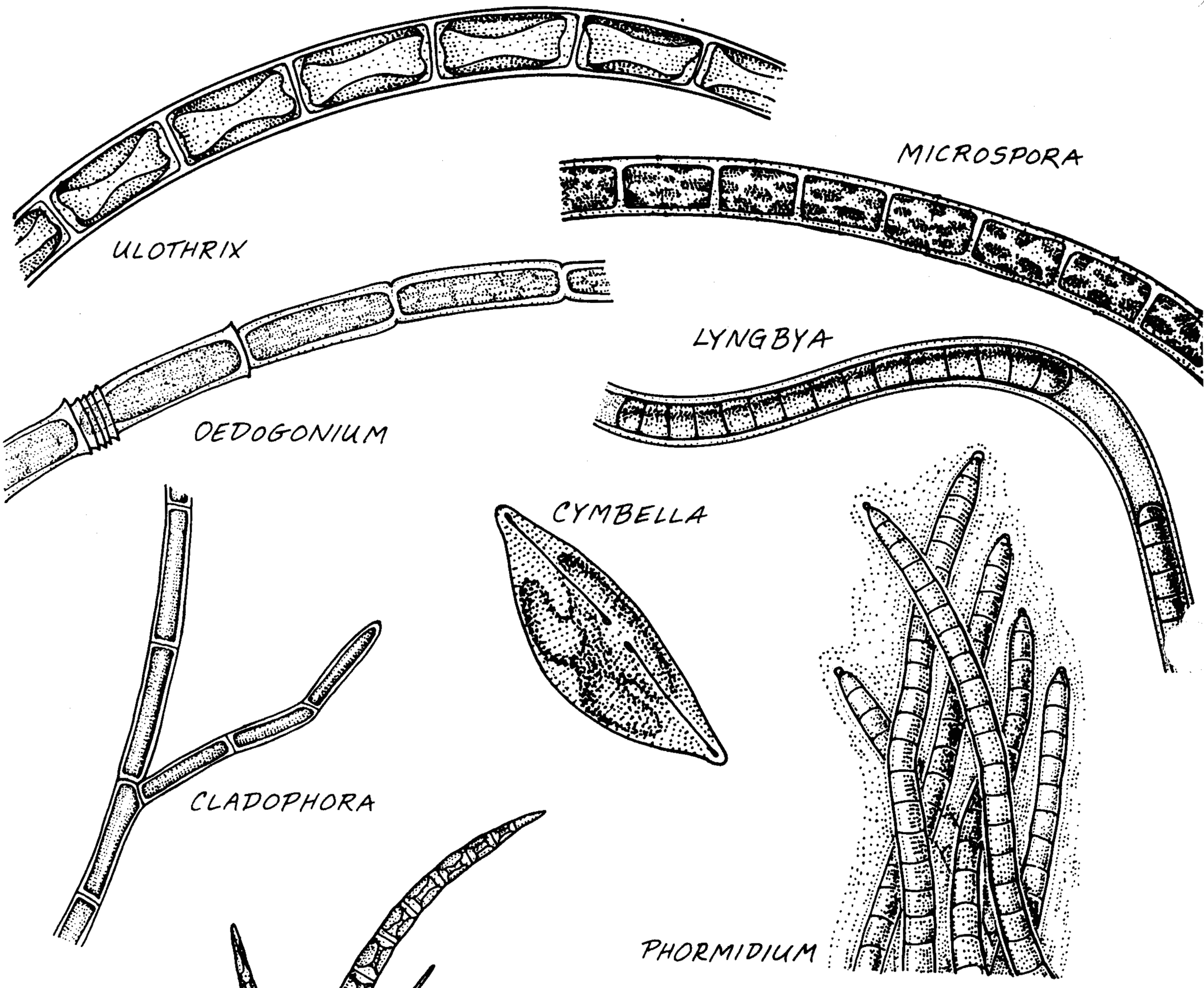
Date collected ______________ Location collected ______________________

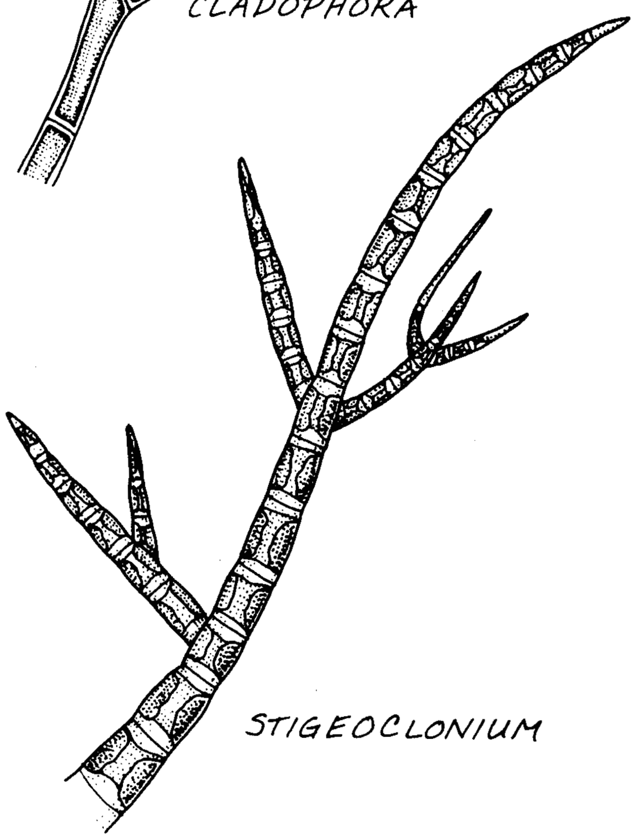
Color and general appearance of sample ______________________________

OBSERVATIONS

Day	SAMPLE NUMBER						
	#1 (control)	#2	#3	#4	#5	#6	#7
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

ATTACHED ALGAE

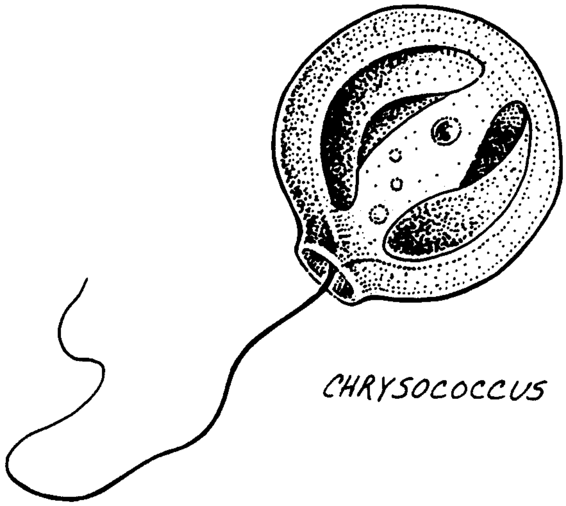




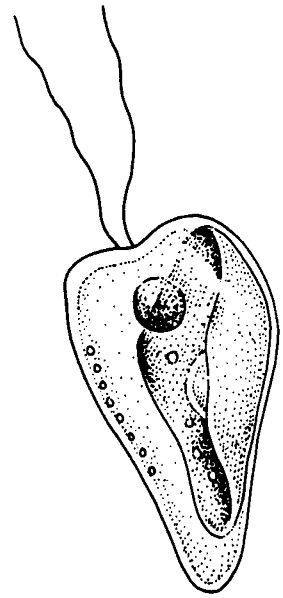
OTHER IMPORTANT SPECIES ARE:

ACHNANTHES
AUDOUINELLA
BATRACHOSPERMUM
BULBOCHAETE
CHAETOPHORA
CHARA
COMPSOPOGON
DRAPARNALDIA
GOMPHONEMA
PHYTOCONIS
TETRASPORA
TOLYPOTHRIX
VAUCHERIA

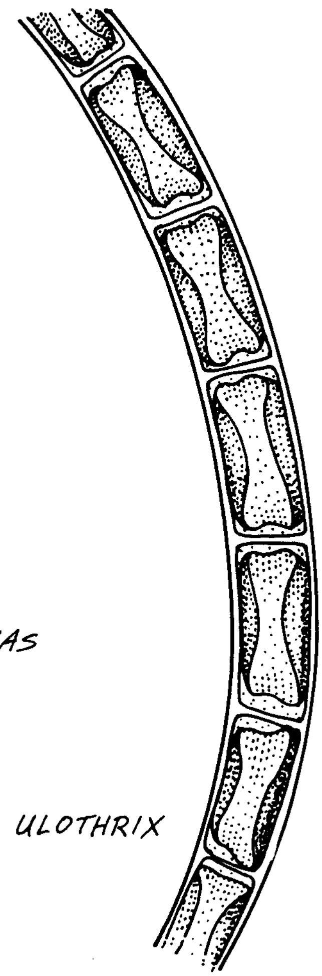
CLEAN WATER ALGAE



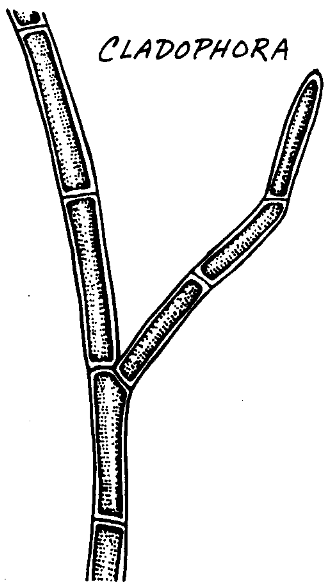
CHRYSOCOCCUS



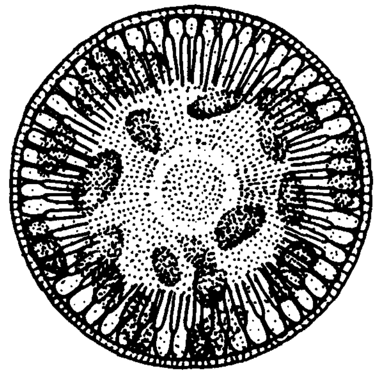
RHODOMONAS



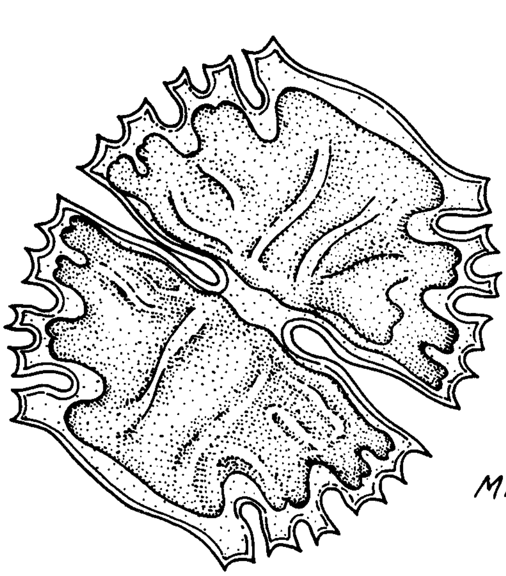
ULOTHRIX



CLADOPHORA



CYCLOTELLA

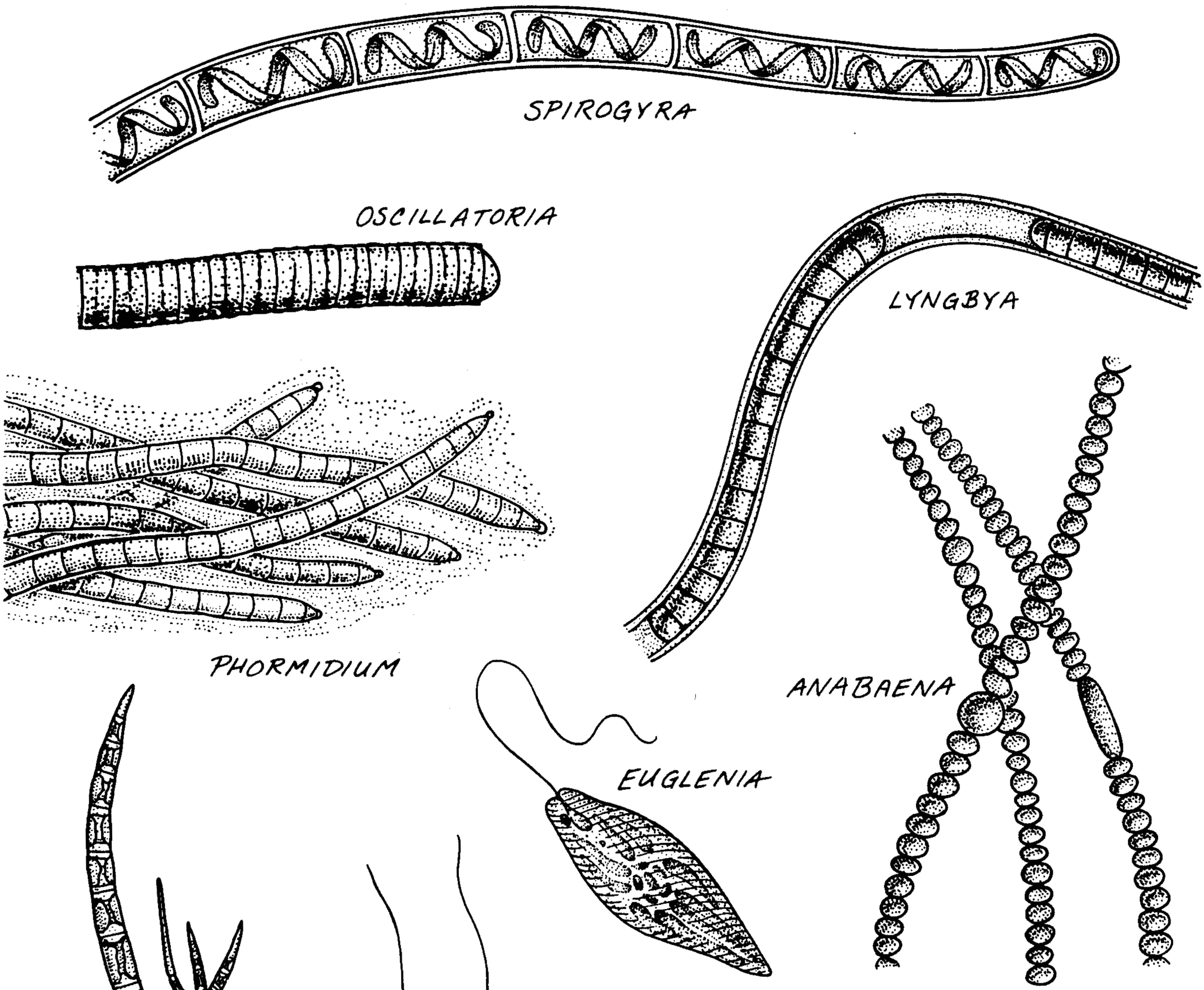


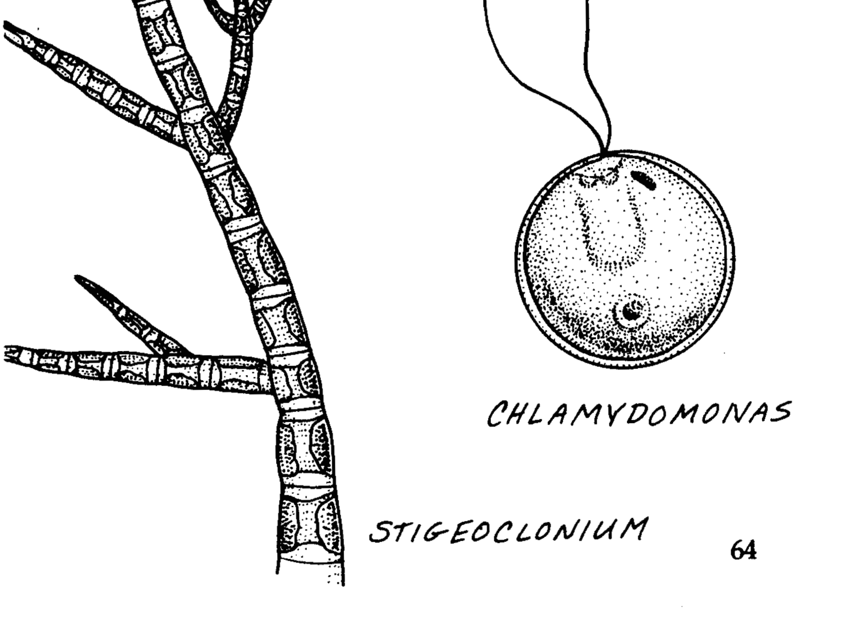
MICRASTERIAS

OTHER IMPORTANT SPECIES ARE:

AGMENELLUM
ANKISTRODESMUS
CALOTHRIX
CHROMULINA
COCCOCHORIS
COCCONEIS
ENTOPHYSALIS
HILDENBRANDIA
MERIDION
MICROCOLEUS
PHACOTUS
PINNULARIA
RHIZOCLONIUM
STAURASTRUM
SURIRELLA

FRESHWATER POLLUTION ALGAE

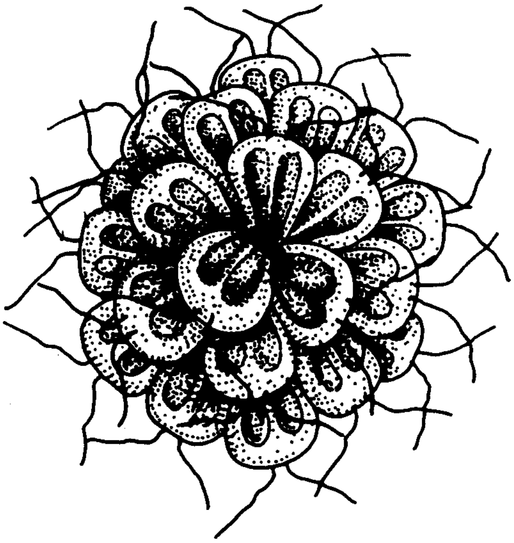




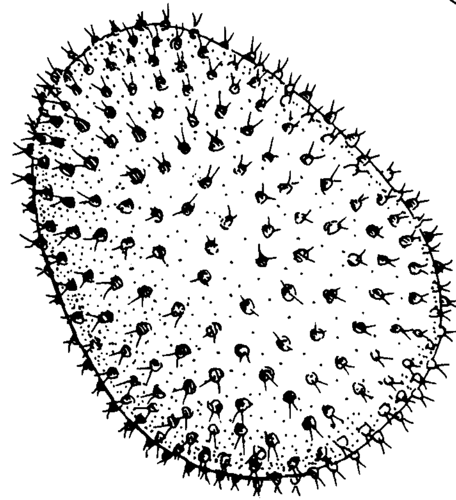
<u>OTHER</u> <u>IMPORTANT</u> <u>SPECIES</u> <u>ARE</u>:

AGMENELLUM
ANACYSTIS
ARTHROSPIRA
CARTERIA
CHLORELLA
CHLOROCOCCUM
CHLOROGONIUM
GOMPHONEMA
LEPOCINCLIS
NITZSCHIA
PYROBOTRYS
TETRAEDRON

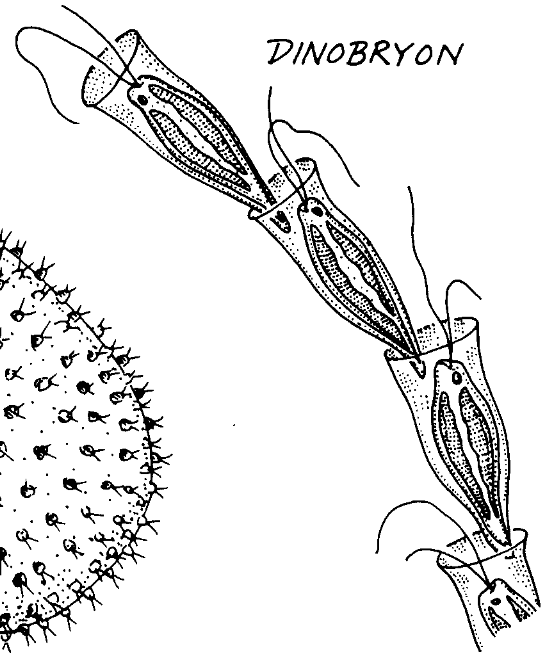
TASTE AND ODOR ALGAE



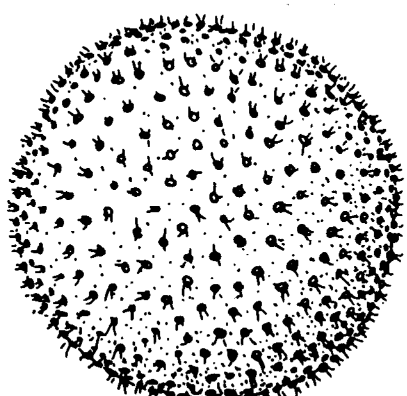
SYNURA



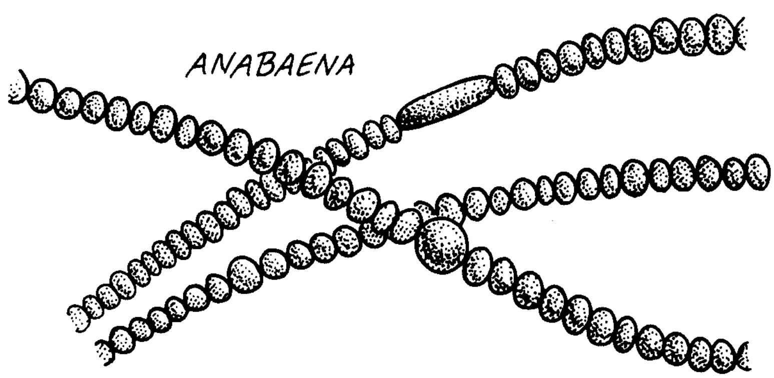
UROGLENOPSIS



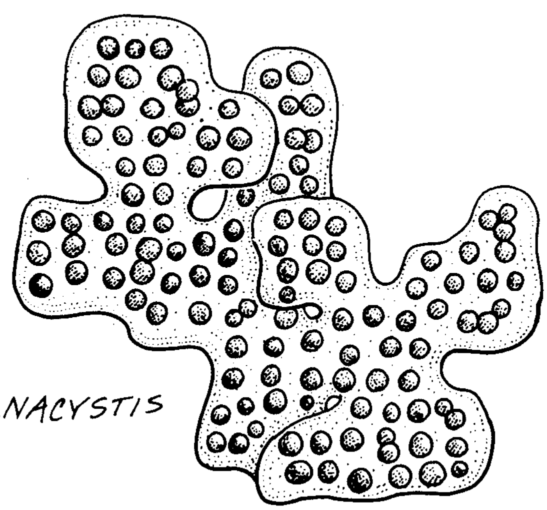
DINOBRYON



VOLVOX



ANABAENA

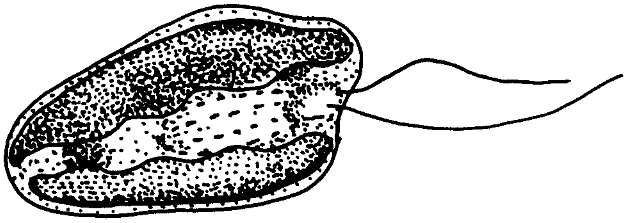


ANACYSTIS

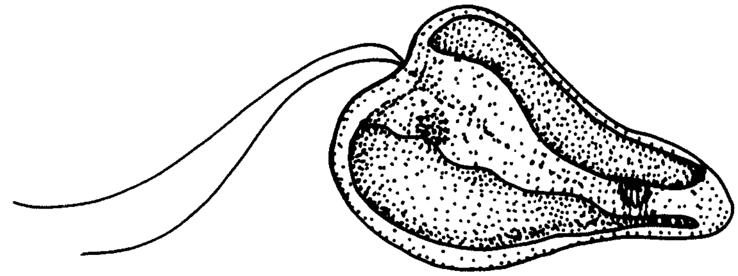
OTHER IMPORTANT SPECIES ARE:

APHANIZOMENON
ASTERIONELLA
CERATIUM
GOMPHOSPHAERIA
HYDRODICTYON
MALLOMONAS
NITELLA
PANDORINA
PERIDINIUM
STAURASTRUM
SYNEDRA
TABELLARIA

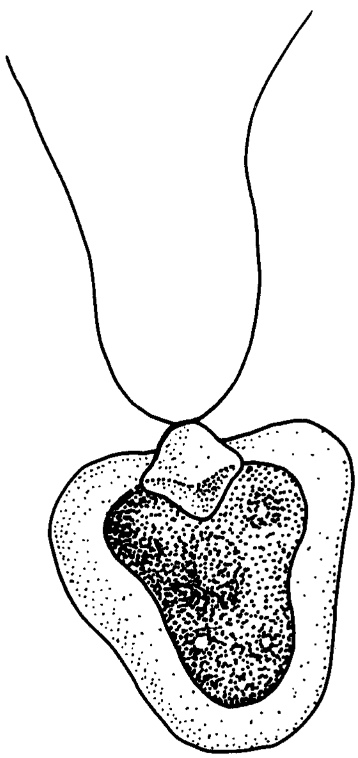
SEWAGE POND ALGAE



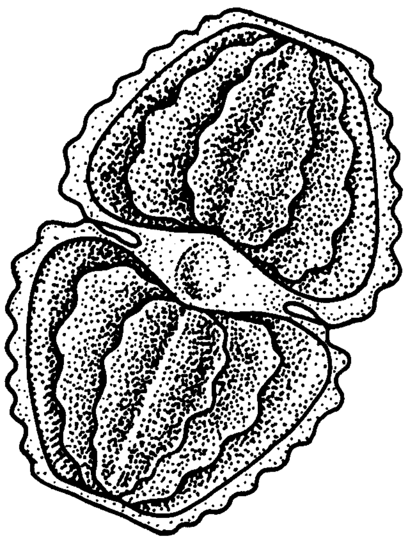
CRYPTOMONAS



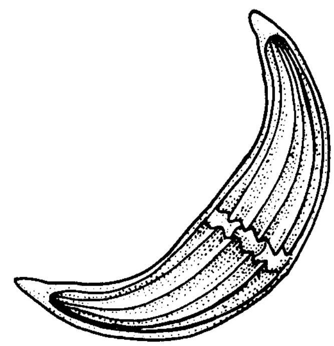
CHROOMONAS



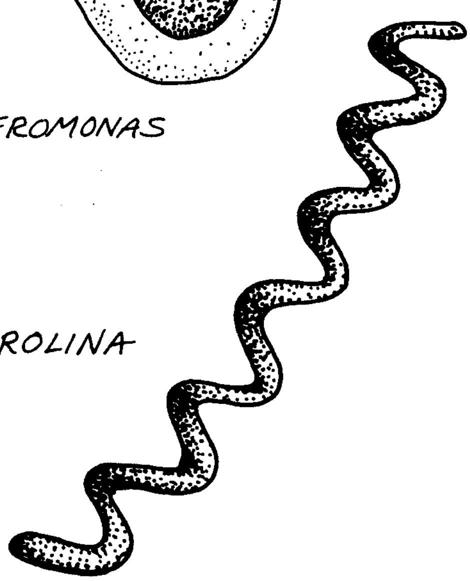
PTEROMONAS



COSMARIUS



CLOSTERIUM



SPIROLINA

OTHER IMPORTANT SPECIES ARE:

ANKISTRODESMUS
CHLAMYDOMONAS
CHODATELLA
CHROMULINA
CLOSTERIOPSIS
DICTYOSPHAERIUM
ELAKATOTHRIX
MASSARTIA
OUROCOCCUS
PLANKTOSPHAERIA
POLYEDRIOPSIS
SCENEDESMUS
SCHIZOTHRIX
SCHROEDERIA
VACUOLARIA

Name ______________________ Date ______________________

"FED UP" QUIZ

True/False:

1. ______ Dissolved oxygen content of a body of water can be lowered as a result of an algal bloom.

2. ______ Human activity can greatly accelerate the process of eutrophication.

3. ______ Nitrogen is the least available nutrient in freshwater aquatic ecosystems followed by phosphorus.

4. ______ A 10,000 head cattle feedlot can cause water quality problems approximately equal to those of a city of 150,000 people.

5. ______ The amount of life in a body of water depends on the amount of dissolved nutrients in the water.

6. ______ Nitrification can reduce the amount of oxygen available for aquatic animals and may cause fish kills.

Complete:

7-9. List 3 major nonpoint sources of nutrients in waterways.

(1) ______________________________

(2) ______________________________

(3) ______________________________

10. Define eutrophication. ______________________________

11. Water that is low in nutrients is called ______________________________

12. Water that is rich in nutrients is called ______________________________

13. What type of algae is most commonly found in an algal bloom? ______________________________

14. How may runoff from lawns contribute to the problem of excess nutrients in waterways?

____

____

____

15. Discuss the problems associated with eutrophication. ______________________________

____

____

"FED UP" TEACHER KEY

True/False:

1. True Dissolved oxygen content of a body of water can be lowered as a result of an algal bloom.

2. True Human activity can greatly accelerate the process of eutrophication.

3. False Nitrogen is the least available nutrient in freshwater aquatic ecosystems followed by phosphorus.

4. True A 10,000 head cattle feedlot can cause water quality problems approximately equal to those of a city of 150,000 people.

5. True The amount of life in a body of water depends on the amount of dissolved nutrients in the water.

6. True Nitrification can reduce the amount of oxygen available for aquatic animals and may cause fish kills.

Complete:

7-9. List 3 major nonpoint sources of nutrients in waterways.

(1) Agricultural fertilizer/urban runoff

(2) Livestock wastes

(3) Failing septic tanks

10. Define eutrophication. The nutrient enrichment of waterways with P and N compounds.

11. Water that is low in nutrients is called oligotrophic. .

12. Water that is rich in nutrients is called eutrophic. .

13. What type of algae is most commonly found in an algal bloom? blue-green

14. How may runoff from lawns contribute to the problem of excess nutrients in waterways?

Phosphate and nitrate fertilizers used on lawns attach to soil particles. When it rains, runoff carries the soil and nutrients into waterways. (NOTE: Nitrogen is water soluble and can also move independently of the soil in water.)

15. Discuss the problems associated with eutrophication. Eutrophication can cause lakes to fill in at a very rapid rate. Erosion from farming, construction, forest operations, and mining, and excess nutrients from fertilizers, detergents, and sewage both contribute to eutrophication. Solving the problem will require implementing practices that control sediment and nutrient types of pollutants.

IT'S SEDIMENTARY, MY DEAR WATSON

Air & Waste Management Association

OBJECTIVES

The students will do the following:

1. Determine the amount of solid material or sediment suspended in water samples.
2. Explain turbidity observations of water samples.
3. Explain ways in which sediment disturbs organisms.
4. Determine possible local nonpoint sources of sediment present in water samples.

SUBJECTS:
General Science, Earth Science, Ecology, Chemistry, Biology

TIME:
2-4 class periods

MATERIALS:
thermometers
local topographic map
filter paper
funnels
stirring rods
balances (electronic preferred)
shovel or spades (to collect soil, optional)
turbidimeter (optional)
clean, dry, wide-mouth collection bottles with lids (two per student or lab team)
beakers
large watch glasses
stick-on labels or masking tape
permanent ink markers or grease pencils
area land use maps
samples of water from local streams or lakes
data table (included)
cooler with ice (optional)
calculators (optional)
soil—preferably clay type (optional)
sun lamp or grow light (optional)
data sheet (optional; included)
graph paper
"Collecting a Water Sample" handout (included; see page 60)
"It's Sedimentary" Quiz (optional, included)

BACKGROUND INFORMATION

Heavy rains or snow melt can wash a variety of suspended materials or sediment into water bodies and make water cloudy or turbid. Turbidity is a measure of the amount of suspended material (cloudiness) in the water. Many other pollutants such as bacteria, nutrients, and harmful chemicals can attach to sediment particles and be transported with the sediment. While the process is natural, human activities can increase the rate faster than ecosystems can adjust. Improperly managed construction sites may cause a 2,000-fold increase in erosion rates and poorly managed farmland may cause a 200-fold increase, compared to rates of similar undisturbed forest lands. Sediment can interfere with aquatic life, commercial and recreational activities, and hydroelectric power generation. Sediment can decrease light transmission through the water, thus decreasing plant photosynthesis and reproduction. Also, sediment absorbs heat causing the temperature of the water to increase. A decrease in photosynthesis and/or an increase in water temperature can result in a decrease in the level of dissolved oxygen. Moreover, sediment can interfere with feeding and reproductive patterns of aquatic life. When sediment settles, it may create blankets which smother the aquatic plants and animals, and disrupt the food chain. Sediment can gradually fill lakes and streams. This can reduce flood storage capacity and hydroelectric power potential in reservoirs and cause navigation problems in rivers. The best way to solve nonpoint problems caused by sediment is to prevent or reduce soil erosion caused by human activities.

ADVANCED PREPARATION

A. Make copies of the student data table and/or other forms as needed.

B. Choose sampling sites.

   1. Number and mark them on a local topographic map.

   2. Assign a site to each student (or lab team) and have them collect a water sample. (NOTE: To save time, you may want to mix up some water samples in the lab which contain various amounts of sediment and assign them site numbers on a ficticious map. If you do, use a shovel or spade to collect a clay type soil. NOTE: Soils with high organic matter or peat float on water.)

C. If the students collect samples, have them complete a data table that includes date, time, site of collection, weather at time of collection, site number, description of location (including possible nonpoint sources of pollution), general observations of water sample (color, odor, appearance), and temperature of sample (data table included).

D. Instruct the students on proper water sample collection procedure.

   1. Give each student or lab team a copy of the handout "Collecting a Water Sample." (See page 60.)

   2. Give each student or lab team two clean, dry collection bottles.

   3. Have them wait until a heavy rain is forecast and tell the students to collect their samples, preferably, just after it has rained. They can also collect them while it is raining or within 30 minutes after the rain stops. Each collection bottle should be filled completely and capped tightly. (CAUTION: Hands should be washed with antibacterial soap after the sample is collected.)

   4. Have the students record site number, date, time, weather, and collector's initials at time of collection on the sample bottle.

   5. Students should put their samples in a cool, dark place (such as a cooler with ice) immediately after they collect them and bring them to the class.

PROCEDURE

I. Setting the Stage

   A. Explain that heavy rains can wash a variety of suspended materials into water bodies.

   B. Discuss what types of land use activities are most likely to result in erosion and why.

   C. Explain ways sediment can disturb aquatic ecosystems.

II. Activity

A. Make general observations of the samples. (NOTE: Shake sample first to suspend sediment.)

1. If you collected the samples, have the students make observations on the color and general appearance of their water samples and record them on the data table. (NOTE: If they collected the sample, this information should already be recorded.)

2. Distribute thermometers and have students record the room temperature. (CAUTION: Remind students to use extra caution when working with glassware and thermometers to prevent breakage. Go over lab safety procedures.)

   a. Establish a standard room temperature and have students adjust their thermometer readings to it. For example, if a student's thermometer reads one degree lower than the standard room temperature, then the student should add one degree to their temperature reading.

   b. Record the adjusted temperature on the data table.

B. Observe the effects of sediment on water temperature.

1. Have the students remove the lid from one of their two sample containers and place the uncapped samples in a sunny location so they all receive the same amount of sunlight. Be sure to include a control sample for comparison. Record the time. (NOTE: You may substitute a grow light or a sunlamp if sunny windows are not available.)

2. After about an hour, have students measure the temperature of the water sample. Explain the proper procedure for holding a thermometer. The thermometer should be suspended in the water, not touching the bottom or sides of the container. Record the time and temperature on the data table.

C. Have the students determine the percent sediment load in the water samples using the second sample collected.

1. Have them leave the lid on the collection bottle and weigh the sample. Then have them record the result in the data table. (NOTE: Make sure the outside of the bottle is clean and dry).

2. Next, have them weigh the filter paper and record this in the data table.

3. Then have them shake the sample. (NOTE: If a turbidimeter is available, use it to determine the turbidity of the water samples.)

4. Review with the students how to fold filter paper. (See the following illustration.) Then have them slowly pour the sample through the funnel lined with the filter paper into a receiving beaker. (NOTE: Students may need to gently stir the water in the funnel with a stirring rod to get the water to pass through the filter paper.)

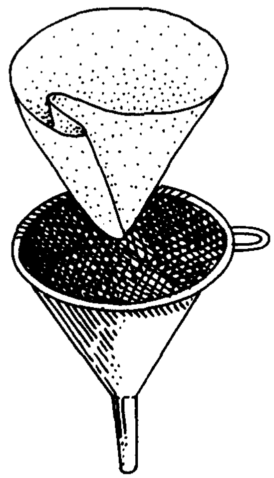
5. To make sure all of the sediment is removed from the collection bottle, have the students rinse the bottles several times with small amounts of distilled water and pour the rinse water through the filter each time.

6. Have students use a grease pencil to label a large watch glass with their initials.

7. Then have them carefully remove the filter paper from the funnel and place it unfolded, dirty-side up on the watch glass.

8. Have them set aside the watch glass with the filter paper and allow the sediment and filter paper to air dry completely.

9. Next, have them wash, dry, recap, and weigh their original collection bottle and record this weight in their data table.



10. To determine the weight of the water sample, have them subtract the weight of the bottle from that of the bottle with the water sample. Have them record the results in the data table.

11. After the filter paper (with sediment) dries, weigh it and substract the weight of the clean filter paper to get the weight of the sediment and record the result in the data table.

12. To calculate the percent sediment load, divide the weight of the sediment by the weight of the water sample and multiply by 100. Record the result in the data table.

D. Compile the class data.

1. Have the students compare the appearance of the various samples with their corresponding sediment loads and temperature readings. They may want to categorize the samples by site type, such as urban, agricultural, construction runoff, etc., or by area referring to the map and site numbers.

2. Distribute graph paper and have students plot percent sediment load versus temperature in sunlight for all the samples.

3. Fit a line to the data plotted.

E. Discuss the results.

1. Is there an apparent correlation between percent sediment load and temperature? Why or why not? (Greater sediment load, higher temperature. Sediment absorbs heat.)

2. How does sediment affect stream temperature? (More sediment absorbs more heat and causes higher stream temperature.)

3. How might temperature affect the dissolved oxygen content and aquatic life? (Higher temperature causes lower dissolved oxygen level. Organisms requiring higher DO levels will either move to a more favorable environment or perish.)

4. Which organisms are might be most affected by a temperature increase? Why? (Trout, mayflies, stoneflies, and caddisfly larvae; they require colder temperatures and higher DO to live.)

5. Have students refer to the topographic map of the sample sites and the data they collected.

   a. What are the probable sources of sediment? (Answers will vary depending on land use activities.)

   b. What other nonpoint pollutants are likely to occur in the water samples? (Answers will vary.)

   c. How could this erosion be prevented? [Apply best management practices (BMPs) associated with specific land uses.)

III. Follow-Up

A. Have students complete the quiz included and discuss the results.

B. Take the lids off the jars and allow the water samples to sit in a sunny location for about a week. Record observations daily on color, odor, algae growth, sediment, and turbidity of water on the data sheet. Some jars may begin to smell foul. Bacteria, litter, and animal waste would make a sample smell foul. Toxic chemicals would kill algae; hence the water would be clear. Fertilizers and animal wastes would foster the growth of algae. Refer to the land use map and data collected. What pollutants are the samples likely to contain that exhibit these traits? Where and what are the likely sources of these pollutants?

IV. Extension

Prepare two each of water samples with various sediment loads. Place one set of the samples in the sun, and the other set in the shade. Determine temperature differences between the different sediment loads and between those in the sun and those in the shade. Graph the results. Let sediment load be on the x-axis and temperature be on the y-axis. Connect the temperature data for the shaded samples together and those from the sunny samples together. Examine the slopes of the lines. Is there an apparent correlation between sediment load and temperature? (Yes.) Is there a gap between the lines? (Yes.) On average, how much does the lack of cover affect the temperature of the water? (Significantly.) Compare the slopes of the lines. How does the amount of cover affect the sediment load? (Answers will vary.) Is there a correlation between the three variables—cover, sediment, and temperature? (Yes.)

RESOURCE

Walesh, Stewart G., Urban Surface Water Management, Chapter 7, "Nonpoint Source Water Pollution Load Techniques," John Wiley and Sons, Inc., New York, NY, 1989, pp. 217-244.

IT'S SEDIMENTARY DATA TABLE

Name ______________________ Date ____________ Standard Room Temperature ____________

Site # & Who Collected	Date Collected	Time	Location Description	Weather Conditions	Color and Appearance	Weight of Sample	Weight of Sediment	% of Sediment Load	Temperature in Sunlight	Turbidity Reading (Optional)

Name ______________________ Date ______________________

DATA SHEET

YOUR WATER SAMPLE

Date collected____________ Location collected ____________________ Sample # ____________

Color and general appearance of initial sample ____

DAILY OBSERVATIONS
(color, odor, algae growth, sediment, and turbidty)

Day	Control	SAMPLE NUMBER						
		#1	#2	#3	#4	#5	#6	#7
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Name ______________________ Date ______________________

"IT'S SEDIMENTARY" QUIZ

True/False

1. ______Sediment is the largest contributor to nonpoint source pollution.

2. ______Poorly managed farmland may cause a 20,000-fold increase in erosion rates as compared to those of undisturbed forest land.

3. What is turbidity? ______________________

____

4. Sediment (increases,decreases) light transmission in water. ______________________

5. What does sediment consist of? ______________________

6-7. A(n) (increase, decrease) in photosynthesis and a(n) (increase, decrease) in water temperature can result in a decrease in the amount of dissolved oxygen. ______________________

8-10. List 3 types of land use practices where mismanagement may result in sediment pollution.

(1) ______________________

(2) ______________________

(3) ______________________

11. Why was it important to allow the filter paper containing sediment to dry in this experiment?

____

12-14. Use the following data to fill in the required information:

56.44 g = mass of collection bottle, lid, and water sample.
1.24 g = mass of filter paper.
2.78 g = mass of filter paper and sediment.
25.21 g = mass of collection bottle and lid.

What is the mass of sediment?______________________

What is the mass of water sample?______________________

What is the percent sediment load?______________________

"IT'S SEDIMENTARY" QUIZ
(continued)

15-20. Construct and label the graph below with the following data:

% sediment load	Temperature °C
2.5	28
4.5	29
6.5	30
8.5	31
10.5	32

"IT'S SEDIMENTARY" TEACHER KEY

True/False

1. True Sediment is the largest contributor to nonpoint source pollution.

2. False Poorly managed farmland may cause a 20,000-fold increase in erosion rates as compared to those of undisturbed forest land.

3. What is turbidity? Measure of the amount of suspended material in the water (cloudiness).

4. Sediment (increases,decreases) light transmission in water. decreases

5. What does sediment consist of? Suspended materials washed or blown from land.

6-7. A(n) (increase, decrease) in photosynthesis and a(n) (increase,decrease) in water temperature can result in a decrease in the amount of dissolved oxygen. decrease, increase

8-10. List 3 types of land use practices where mismanagement may result in sediment pollution.

(1) Agricultural or Logging

(2) Urban or Mining

(3) Construction

11. Why was it important to allow the filter paper containing sediment to dry in this experiment?

So the mass measurements would be accurate.

12-14. Use the following data to fill in the required information:

56.44 g = mass of collection bottle, lid, and water sample.
1.24 g = mass of filter paper.
2.78 g = mass of filter paper and sediment.
25.21 g = mass of collection bottle and lid.

What is the mass of sediment? 1.54 g

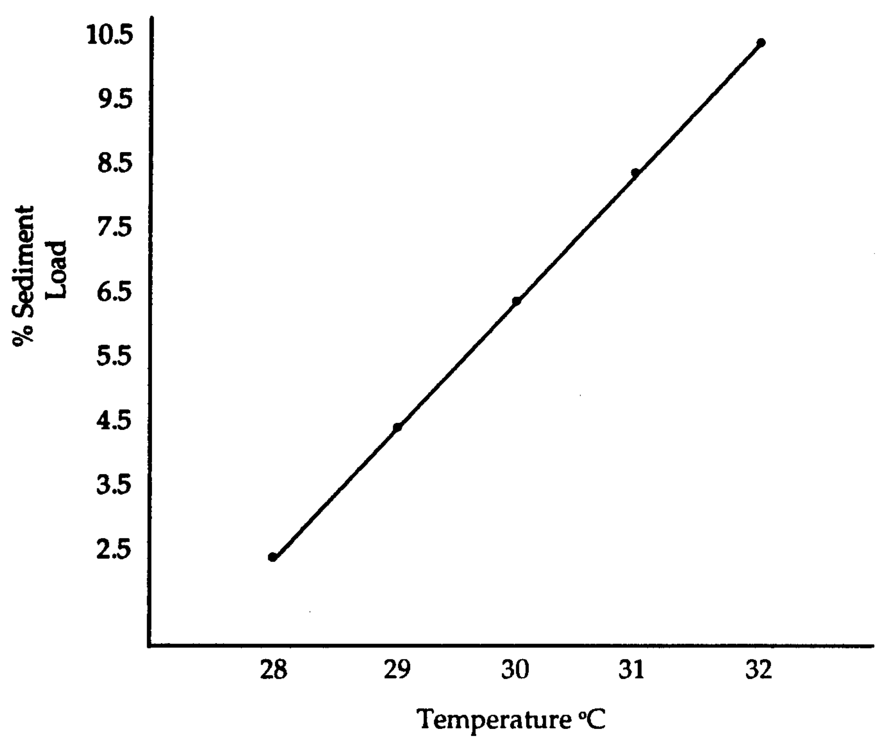
What is the mass of water sample? 31.23g

What is the precent sediment load? 4.93%

"IT'S SEDIMENTARY" TEACHER KEY
(continued)

15-20. Construct and label the graph below with the following data:

% sediment load	Temperature °C
2.5	28
4.5	29
6.5	30
8.5	31
10.5	32



BREATHTAKING

OBJECTIVES

The students will do the following:

1. Describe the importance of dissolved oxygen (DO) to the survival of aquatic plants and animals.
2. Perform a controlled experiment to determine the effects of manure, inorganic fertilizers, plant debris, and sediment on the DO content and BOD (biological oxygen demand) of a water supply.
3. Explain how inorganic nutrients and organic nonpoint source pollutants affect water quality.

SUBJECTS:
General Science, Earth Science, Life Science, Physical Science, Ecology, Biology, Chemistry, Physics

TIME:
3 class periods (over 15-day period)

MATERIALS:
10 one-quart (liter) wide-mouth glass jars (such as large mayonnaise or canning jars) with lids
20 sample bottles
access to refrigerator or cooler with ice
10 gallons (38 liters) pond or aquarium water (in suitable container(s) for dispensing)
1/2 cup (120 ml) grass clippings or leaf litter
1/2 cup (120 ml) manure (pet or livestock waste)
1/2 cup (120 ml) liquid household plant fertilizer (ready-made or mixed up from concentrate)
1/2 cup (120 ml) topsoil from a garden area or potting soil
10 measuring spoons (table or teaspoons)
10 measuring cups (100 ml graduated cylinders)
10 thermometers
10 turkey basters
stick-on labels or masking tape
permanent ink pen or grease pencil
commercial dissolved oxygen test kit with enough supplies to run 20 DO tests (addresses provided)
aluminum foil
goggles
disposable rubber gloves
anti-bacterial soap
paper towels
data chart (included)
tables 1, 2, and 3 (included)
"Collecting a Water Sample" handout (included; see page 60)
field guides (optional)
sun lamp or grow light (optional)
"Breathtaking Quiz" (optional; included)

BACKGROUND INFORMATION

Oxygen (O_2) is as important to the animals living in the water as it is to those living on land. Although oxygen does not dissolve very well in water, enough does to support a wide variety of living organisms. Oxygen dissolved in water is called dissolved oxygen or DO. Oxygen enters water by either diffusion from the atmosphere or photosynthesis by aquatic plants. Most of the DO in water comes from photosynthesis.

The solubility of oxygen in water depends on water temperature. Cool water can hold more oxygen than warmer water because gases are more soluble in cooler water.

The amount of DO may vary significantly from one place to another in aquatic habitats for a variety of reasons. The amount of DO in water depends on the mixing of water and air, the amount produced as a product of photosynthesis by aquatic plants, the amount of oxygen used by plants and animals in respiration, the amount of oxygen used for bacterial decomposition of organic wastes, and the temperature of water.

One way to measure DO is in parts per million (ppm) which is based on the weight of the oxygen versus the weight of the water. DO in aquatic environments can range from no oxygen (0 ppm) to 15 ppm: 6-10 ppm is sufficient for most aquatic animals.

Most plants and animals are adapted to specific levels of DO and become stressed if there is a significant lowering of DO. Low DO levels are often caused by human activities. One cause of low DO in aquatic environments is the addition of organic material to the water which is then decomposed by bacteria. Another is the addition of nutrients that either stimulate aquatic plant growth or require oxidation.

The amount of life in a pond, lake, or stream partly depends on the amount of dissolved nutrients in the water. Water low in nutrients is referred to as oligotrophic while water high in nutrients is eutrophic. The nutrients of greatest environmental concern are nitrogen and phosphorous. Phosphorous is the least available or limiting nutrient in most freshwater ecosystem. Nitrogen is the least available or limiting nutrient in most marine ecosystems. Excessive nutrients entering waterways can accelerate algae growth or cause an "algal bloom." Algal blooms can produce thick surface mats, turn the water green, stain boats, cause a skin rash to swimmers, and may be toxic to animals that drink the water. When algae dies, oxygen is consumed by the decaying process which reduces the amount of oxygen remaining for use by aquatic animals.

Nonpoint sources of nutrient enrichment include fertilizers, livestock wastes, leaking septic tanks, and urban runoff. Phosphate detergents may enter water bodies in surface water runoff from activities such as washing the car or from leaking septic tanks. Phosphate and nitrate fertilizers used on home gardens and lawns can also be nonpoint source pollutants. Phosphates can attach to sediment particles and flow into water bodies as surface water runoff. Phosphates can become more concentrated in runoff than they were in the place where they were applied.

Heavy rains can wash a variety of suspended materials into water bodies. Many other pollutants such as bacteria and harmful chemicals can also be transported on sediment. Sediment decreases light transmission through the water, thus decreasing plant photosynthesis. Sediment also increases the temperature of the water. A decrease in photosynthesis and/or an increase in water temperature results in a decrease in the DO content.

Livestock waste is another major nonpoint source of nutrient enrichment. A 10,000-head cattle feedlot can cause water quality problems approximately equal to those of a city of 150,000-250,000 people. However, it is difficult to make a real comparison between municipal sewage which is diverted by pipes to wastewater treatment plants and livestock wastes which are usually stored and land applied. If animal wastes are not properly stored and applied to land, they can create serious water quality problems. Animal feedlots are a major source of ammonia, a by-product of the decomposition of fecal matter, uric acid, and urea in urine. Ammonia in water undergoes nitrification (the oxidation of nitrogen in ammonia by bacteria to form nitrous and nitric acids and salts) to form nitrates with an accompanying use of oxygen, reducing the amount of oxygen available for aquatic animals.

Organic materials such as leaves, twigs, branches and other debris from trees, shrubs, and herbaceous plants enter water bodies regularly by airborne transport or as a component of surface water runoff. Other organic contaminants include dead organisms such as fish and invertebrates. Naturally occurring organic materials that enter water bodies may cause pollution, but are considered contaminants by U.S. law. Organic materials generated by human activities are called organic pollutants. Examples of organic pollutants include pet wastes, livestock wastes, improperly treated sewage, and biodegradable refuse.

Organic matter is decomposed by bacterial action. Bacteria populations increase as more food (organic materials) becomes available and actively compete with other oxygen demanding organisms in water. Bacteria decomposing organic wastes can deplete the supply of DO needed to support other aquatic life. The amount of oxygen used by bacteria to decompose organic waste is referred to as the biological oxygen demand (BOD). BOD is a quanitative measure of the oxygen-depleting capability of a given amount of organic materials. Thus, BOD is a measure of the amount of organic pollution in a body of water.

ADVANCED PREPARATION

A. Order dissolved oxygen test kits (see Resources).

B. Prior to the day of the experiment, obtain manure, top soil, houseplant fertilizer, and grass clippings or leaf litter. (CAUTION: Manure should be handled with disposable rubber gloves and stored in airtight containers prior to use. Persons handling manure should wash their hands immediately after contact with anti-bacterial soap.)

C. The morning before conducting the experiment, collect three liters of freshwater from an aquarium, pond, or stream in a large, clean container with a lid. (NOTE: You may want to have the students collect their own samples from different locations and compare.) Screw the lid on tightly and store the sealed container in a cool place such as a refrigerator or cooler with ice. (See instructions on "Collecting a Water Sample," page 60.)

D. Copy "Data Chart" (included) and student handouts (included).

PROCEDURE

I. Setting the Stage

A. Ask the class to define these terms: dissolved oxygen (DO), biological oxygen demand (BOD), oligotrophic, eutrophic, and algal bloom.

B. Explain that the amount of DO present in water depends on the following: (1) water temperature; (2) the amount of air absorbed at the surface and mixed into the water as it moves; (3) the amount of oxygen produced during photosynthesis by aquatic plants; (4) the amount of oxygen used by plants and animals in respiration; and (5) the amount of oxygen used by bacteria to decompose organic wastes.

C. Explain how these factors affect the amount of DO in water bodies:

1. DO levels in water can be reduced by nonpoint source pollutants such as sewage from leaking septic tanks, domestic animal wastes, organic/inorganic fertilizers from lawns and farming operations, erosion from disturbed areas, and organic debris such as grass clippings and leaves.

2. DO levels can be reduced when phosphates and nitrates from fertilizers enter a waterway and cause algal blooms (eutrophication).

3. Bacteria which decompose organic materials often actively compete with other oxygen-demanding organisms such as fish, and can deplete the supply of DO needed to support aquatic life (see Table 1).

II. Activity

A. Prepare the samples.

1. Divide the students into teams of two or three.

2. Distribute a clean, dry, large jar to each team.

3. Using the chart included, assign one of the ten water samples to each team and have them prepare their sample as indicated.

4. Have them swirl their samples (including controls) to simulate the natural mixing of a body of water.

5. Have the students label their sample jars with the date, sample number, and their initials.

6. Have the students measure and record the room and water temperatures and observations on the appearance of their samples in a data chart (included).

7. Place the uncapped jars in a sunny location (preferably near a window) where they will all be subject to the same temperature and lighting. (NOTE: If sunlight is unavailable, use a sun lamp or grow lights.)

WATER SAMPLE CHART

SAMPLE	TREATMENT
1 & 2	None; 3 cups (750 ml) water only
3 & 4	1/4 c (60 ml) liquid houseplant fertilizer in 3 cups (750 ml) water
5 & 6	1/4 c (60 ml) manure in 3 cups (750 ml) water
7 & 8	1/4 c (60 ml) grass clippings or leaf litter in 3 cups (750 ml) water
9 & 10	1/4 c (60 ml) top soil or potting soil in 3 cups (750 ml) water

8. Tightly cap the container with the remaining aquarium, pond, or stream water and store it in a refrigerator or cooler with ice.

B. Observe samples.

1. Have the students record observations on their water samples daily for a course of 10 days. (NOTE: You may want to shorten the activity to five days. If you do, only add 1/2 cup (120 ml) of extra water on day 3 and demonstrate the DO test near the end of the 5-day period. Conduct the BOD test on the 5th day.)

   a. Is the water cloudy?

   b. Has the color changed?

   c. Is there more algal growth?

   d. Is a film forming on the surface?

   e. What does it smell like? (CAUTION: Molds and bacteria growing in the samples may be harmful. Have the students wear disposable rubber gloves while handling the sample and wash their hands with anti-bacterial soap after handling samples.)

2. On days 3 and 7, have the students add 1/2 cup (120 ml) of the extra aquarium, pond, or stream water to their samples. Make sure the water has reached room temperature BEFORE adding it to the sample.

C. Demonstrate how to perform a DO test near the end of the 10-day period. Be sure to instruct them on all safety precautions.

D. On the tenth day, have the students measure and record the DO of their water samples, as instructed in the test kit and by your demonstration.

   1. Have the students use a turkey baster to transfer a sample of water from their jar to the DO test bottle. Demonstrate how to squeeze the bulb tightly before submerging the tip on the turkey baster into the middle layer of their water samples. Also, demonstrate how to slowly squeeze the water sample into the sampling bottle, allowing the water to gently run down the side of the container. (NOTE: Since the DO content of the upper layer of water will be greater than that for the bottom layer, the sample should be taken from the middle layer. Be sure that no air bubbles get into the sample. The sampling bottle should be slightly overfilled.)

   2. Next demonstrate how to perform the DO test using instructions from your kit.

   3. Have the students perform the DO test.

E. Determine the biological oxygen demand (BOD).

   1. Have the students wrap a new sample bottle in aluminum foil. Ask the students why they think the BOD sample bottles must be covered with foil. (To keep photosynthesis from occuring.)

   2. Have the students label these bottles with the date, sample number, and their initials.

   3. Using a turkey baster, have the students fill the wrapped bottle with water from their water samples, using the same procedure as before.

   4. Place the bottles in a dark drawer or cabinet and let them sit for five days at 68°F (20°C, room temperature). The bottles should all be stored in the dark, at the same temperature. (NOTE: Do not cap the bottles!)

   5. After five days, have the students conduct a DO test to determine the DO content of the wrapped bottles and record the results. The BOD test measures the amount of oxygen consumed by microorganisms decomposing organic matter microorganisms over a five-day period.

   6. To determine the BOD level, subtract the DO level of the wrapped bottle from that of the DO level of the unwrapped bottle. Record the result.

F. Compile the class data on the board or on an overhead transparency.

   1. All students should construct and record in a data table the class results for DO and BOD.

   2. Examine the results from the replicate samples (1 & 2, 3 & 4, 5 & 6, 7 & 8, 9 & 10). Are the values similar?

   3. Now, average the results of the replicate samples for both DO and BOD.

   4. Rank the average DO and BOD levels for the controls and treatments.

      a. Which samples had the highest DO?

b. Which samples had the lowest DO?

c. Which samples had the highest BOD?

d. Which samples had the lowest BOD?

e. How are DO and BOD related?

5. Assume that the samples were taken from actual streams. Examine tables #1 and #2 (included) and discuss the following:

   a. What types of fish and bottom animals would be likely be present in each of these streams? (NOTE: You may want to have identification guides on hand to illustrate organisms in Table 2.)

   b. What might the water and substrate be like?

   c. What are the levels of organic waste indicated by the BOD test results of each stream sample?

   d. What are the most likely nonpoint sources of organic waste pollution of the streams?

III. Follow-Up

A. Have the students complete the quiz included and discuss the results.

B. You might take initial DO readings on Day 1 of the experiment and compare these with the readings for Day 10.

C. Construct a variety of graphs using the data you collected to show other relationships. For example, graph DO and BOD at the end of the experiment for each jar or construct a bar chart of DO from Day 1 to Day 10 for each jar. Discuss the results. Pass out Table 3 and discuss impacts of BOD on aquatic life.

IV. Extension

A. Test DO upstream and downstream from a suspected nonpoint source of fertilizer or livestock waste.

   1. Does the DO content differ in these two areas?

   2. Does the stream appear different in these two areas?

   3. What factors may be responsible for these differences?

B. Perform DO tests as before on freshwater aquarium or pond/stream water containing different sediment loads.

C. Correlate DO with sediment loads and discuss the results with the students.

D. Have the students do biological sampling of their sampling site to determine if the organisms present are consistent with their DO readings (see Resources).

RE SOURCES

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Reid, George K., Pond Life, A Guide to Common Plants and Animals of North American Ponds and Lakes, Golden Press, New York, New York, 1987.

Renn, Dr. Charles E., Investigating Water Problems, LaMotte Chemical Products Company, P.O. Box 329, Chestertown, Maryland 21620, 1970.

Smith, Robert Leo, Ecology and Field Biology, 4th ed., Harper Collins Publishers, New York, New York, 1990.

DATA CHART

Name______________________________ Date (Day 1)__________

Sample #	Observations Day 1	Observations Day 3	Observations Day 7	Observations Day 10	DO		BOD
					Day 10	Day 15	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Conclusions: ______________________________

____

____

____

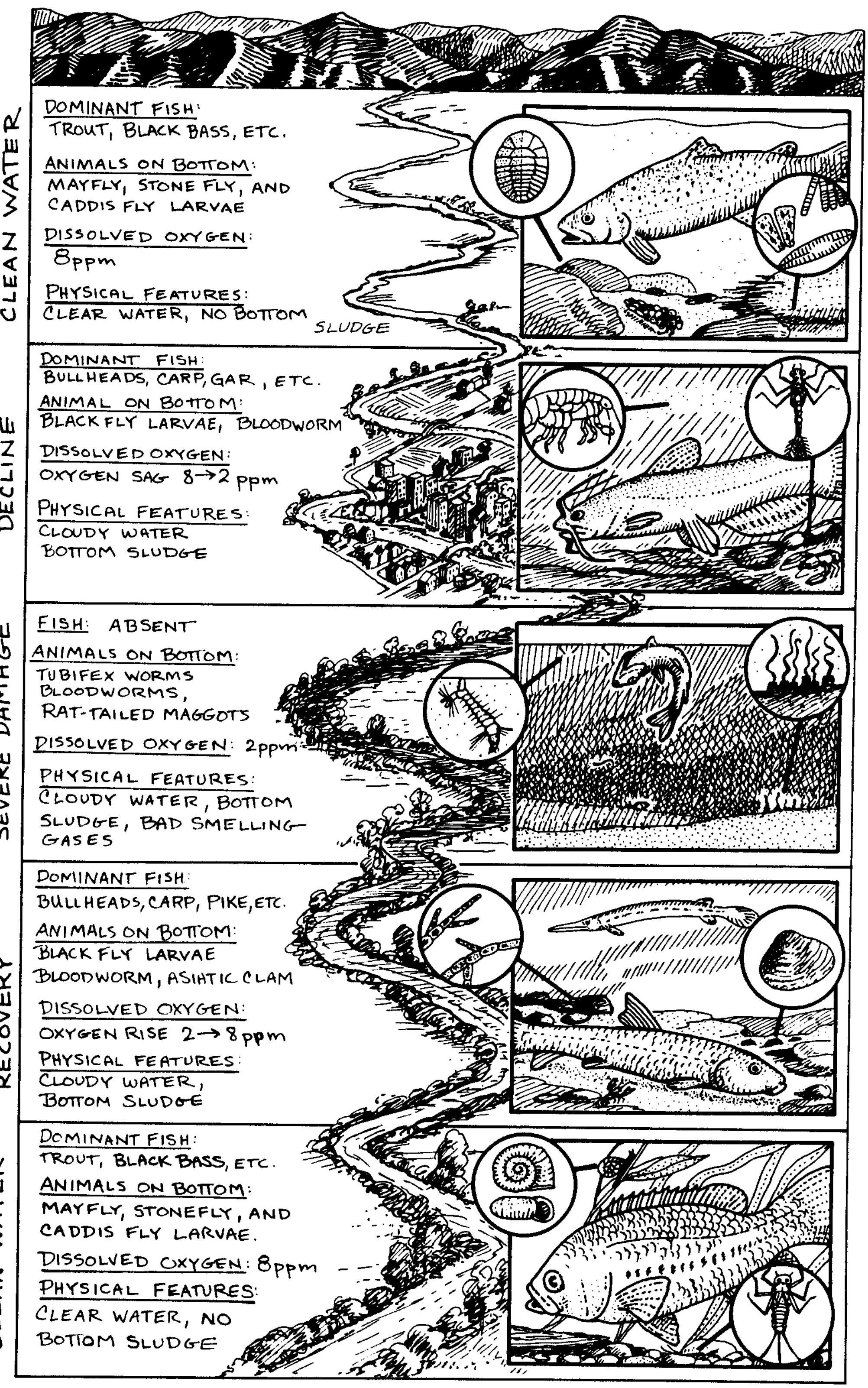
TABLE 1:
INDICATORS/EFFECT OF INORGANIC AND ORGANIC NUTRIENT POLLUTION ON OXYGEN LEVELS AND AQUATIC LIFE OF A STREAM

Amount of Pollution	Low	Medium	High
Dominant Fish	Gamefish: Trout, black bass, etc.	Non-game Fish: Bullheads, carp, gars, etc.	Fish Absent
Index Animals Present on River Bottom	Mayfly larvae Stonefly larvae Caddisfly larvae	Blackfly larvae Bloodworm	Sludge worms Bloodworms Rattailed maggots
Dissolved Oxygen (ppm)	> 8 ppm	4-8 ppm	2-4 ppm
Status of Water	Clean water	Decline	Severe damage, Decomposition
Physical Features	Clean water No bottom sludge	Cloudy water Bottom sludge	Cloudy water Bottom sludge Bad smelling gases

TABLE 2:
BIOLOGICAL OXYGEN DEMAND AND CORRESPONDING LEVELS OF ORGANIC WASTE POLLUTION

BOD (mg/l)	Indication of organic waste level
1-2	Very clean water, little organic waste
3-5	Moderately clean water, some organic waste
6-9	Polluted water, much organic waste and bacteria
10+	Very polluted

TABLE 3


CLEAN WATER
DOMINANT FISH:
TROUT, BLACK BASS, ETC.
ANIMALS ON BOTTOM:
MAYFLY, STONE FLY, AND
CADDIS FLY LARVAE
DISSOLVED OXYGEN:
8ppm
PHYSICAL FEATURES:
CLEAR WATER, NO BOTTOM
SLUDGE
DECLINE
DOMINANT FISH:
BULLHEADS, CARP, GAR, ETC.
ANIMAL ON BOTTOM:
BLACK FLY LARVAE, BLOODWORM
DISSOLVED OXYGEN:
OXYGEN SAG 8→2 ppm
PHYSICAL FEATURES:
CLOUDY WATER
BOTTOM SLUDGE
SEVERE DAMAGE
FISH: ABSENT
ANIMALS ON BOTTOM:
TUBIFEX WORMS
BLOODWORMS,
RAT-TAILED MAGGOTS
DISSOLVED OXYGEN: 2ppm
PHYSICAL FEATURES:
CLOUDY WATER, BOTTOM
SLUDGE, BAD SMELLING
GASES
RECOVERY
DOMINANT FISH:
BULLHEADS, CARP, PIKE, ETC.
ANIMALS ON BOTTOM:
BLACK FLY LARVAE
BLOODWORM, ASIATIC CLAM
DISSOLVED OXYGEN:
OXYGEN RISE 2→8 ppm
PHYSICAL FEATURES:
CLOUDY WATER,
BOTTOM SLUDGE
CLEAN WATER
DOMINANT FISH:
TROUT, BLACK BASS, ETC.
ANIMALS ON BOTTOM:
MAYFLY, STONEFLY, AND
CADDIS FLY LARVAE.
DISSOLVED OXYGEN: 8ppm
PHYSICAL FEATURES:
CLEAR WATER, NO
BOTTOM SLUDGE

Name ______________________ Date ______________________

"BREATHTAKING" QUIZ

True/False

1. ______ A 10,000-head cattle feedlot can cause water quality problems approximately equal to those of a city of 150,000 people.

2. ______ Aquatic life depends on oxygen dissolved in water.

3. ______ Most of the dissolved oxygen in water comes from photosynthesis.

4. ______ Eight ppm of dissolved oxygen would be sufficient for most animals.

5. ______ Cool water will hold more oxygen than warmer water.

6-8. List three factors that determine the amount of dissolved oxygen present in water.

(1) ______________________________

(2) ______________________________

(3) ______________________________

9-10. Water low in nutrients is called ______________________________,
while water high in nutrients is called ______________________________.

11-12. The nutrients of greatest environmental concern are ______________________________
and ______________________________.

13-14. List two nonpoint sources of nutrient enrichment.

(1) ______________________________

(2) ______________________________

15. Sediment (increases, decreases) light transmission through water. ______________

16. Sediment (increases, decreases) temperature of the water. ______________

17. What is biological oxygen demand? ______________________________

____

____

18. Oxyen diffuses more (quickly, slowly) in water than in air. ______________

19-20. A(n) (decrease, increase) in photosynthesis and a(n) (decrease, increase) in water temperature results in a decrease in the dissolved oxygen content. ______________

"BREATHTAKING" QUIZ
TEACHER KEY

True/False

1. False A 10,000-head cattle feedlot can cause water quality problems approximately equal to those of a city of 150,000 people.

2. True Aquatic life depends on oxygen dissolved in water.

3. True Most of the dissolved oxygen in water comes from photosynthesis.

4. True Eight ppm of dissolved oxygen would be sufficient for most animals.

5. True Cool water will hold more oxygen than warmer water.

6-8. List three factors that determine the amount of dissolved oxygen present in water.

(1) Mixing with air or temperature of water

(2) Photosynthesis or decomposition

(3) Respiration

9-10. Water low in nutrients is called oligotrophic, while water high in nutrients is called eutrophic.

11-12. The nutrients of greatest environmental concern are phosphorous and nitrogen.

13-14. List two nonpoint sources of nutrient enrichment.

(1) Fertilizers or leaky septic tanks

(2) Livestock wastes or urban runoff

15. Sediment (increases, decreases) light transmission through water. decreases

16. Sediment (increases, decreases) temperature of the water. increases

17. What is biological oxygen demand? The oxygen used by bacteria in decomposing organic waste is referred to as BOD. BOD is a measure of the amount of organic waste in a body of water.

18. Oxygen diffuses more (quickly, slowly) in water than in air. slowly

19-20. A(n) (decrease, increase) in photosynthesis and a(n) (decrease, increase) in water temperature results in a decrease in the dissolved oxygen content. decrease, increase

WASTED WATERS

OBJECTIVES

The students will do the following:

1. Explain why Escherichia coli and other coliform bacteria are used as indicators of fecal waste contamination.
2. Perform techniques outlined in commercial kits to test water samples for the presence of coliform bacteria.
3. Determine if water samples are safe by comparing bacteria in the samples with standards set by health agencies.
4. Identify possible nonpoint sources of fecal contamination.

SUBJECTS:
General Science, Life Science, Earth Science, Ecology, Biology, Chemistry

TIME:
1-2 class periods

MATERIALS:
coliform test kit—includes teacher's manual, student guides, and sterile collection bottles, petri dishes, absorbent pads, and media (can be ordered from a biological supply company)
water samples (collected from desired sources in sterile collection bottles)
filter units
syringe suction pump
forceps
alcohol
alcohol lamp
sterile pipettes
pipette bulb
incubator or access to one
dissecting microscope or magnifying glass
Health Department Water Quality Standards (obtain from local health department)
"Collecting a Water Sample" handout (included; see page 55)
disposable rubber gloves
anti-bacterial soap
paper towels
data sheet (included)
"Fecal Coliform Culture Procedure" handout (included)

BACKGROUND INFORMATION

Coliforms are a group of bacteria which are widely distributed in nature and can be found in water, soils, and a wide variety of both warm- and cold-blooded animals. Fecal coliform bacteria are relatively harmless bacteria found in the intestines of humans and warm-blooded animals. Disease-causing or pathogenic organisms also occur in the intestines of humans and warm-blooded animals and are almost always present in water containing fecal coliform bacteria. Pathogenic organisms include bacteria, viruses, and parasites that cause diseases and illnesses such as typhoid fever, infectious hepatitis, cholera, dysentery (a major killer in many third world countries), polio, gastroenteritis, diarrhea, and ear infections. Fecal wastes can also contaminate groundwater, causing drinking water to be unsafe for human consumption. In urban areas coliform bacteria enters water bodies when stormwater carries fecal wastes from pets, birds, rodents, and faulty sewer connections either by way of runoff or storm sewers (not connected to wastewater treatment plants) into lakes and streams. In rural areas, animal feedlots, domestic animal manure, wildlife manure, and failing septic systems are typical sources of fecal contamination.

Because coliforms are relatively easy to isolate and they normally survive longer than disease-causing organisms, fecal coliforms work well as indicator organisms. Escheria coli or E. coli are used for fecal contamination testing because (1) testing for such a wide variety of pathogens is difficult, (2) many pathogenic organisms are difficult to culture in the laboratory, and (3) studies show that pathogenic bacteria occur in relatively equal numbers to fecal coliforms. Water samples are cultured in the lab to detect the presence of E. coli and other fecal coliforms. In most cases, the absence of fecal coliforms in a water sample indicates the water is free of pathogenic organisms.

Fecal coliform standards in the United States (U.S.) are determined by the Environmental Protection Agency (EPA) and enforced by the states. General fecal coliform standards for drinking water and recreation are given below:

Drinking water—No more than 1 coliform per 100 ml of water tested.

Swimming pools—No more than 1 coliform per 100 ml of water tested.

Body-contact water recreation and swimming beaches—An average of no more than 200 fecal coliforms per 100 ml. (Some states use 1000 total coliforms per 100 ml sample.)

Boating and nonbody-contact water recreation—An average of no more than 2000 fecal coliforms per 100 ml sample. (NOTE: Total coliforms would be much higher.)

Total coliform counts include species from the genera Klebsiella, Escherichia, Citrobacter, and Enterobacter. Fecal coliforms refer to E. coli and Klebsiella species whose presence indicates recent fecal contamination. Because fecal coliforms grow at 40°C, they typically do not live long in water bodies.

ADVANCED PREPARATION

A. Order coliform test kits (see Resources).

B. Make one copy per student of the handouts "Collecting a Water Sample" (see page 60), "Fecal Coliform Culture Procedure" (included), and "Data Sheet" (included).

C. Prior to performing the tests, obtain and share information with the students on health department fecal coliform standards or invite a health department official to visit your class and share this information with the students.

D. Distribute sterile collection bottles to the students with the handout on how and where to collect the water samples.

E. Have the students collect water samples.

   1. Water samples may be collected from a variety of sources, such as home drinking water, well water, pond or stream water, or school drinking water.

   2. Stream water samples should be collected upstream and downstream from an area suspected of contributing fecal contamination to the water, such as a cow pasture, so that the samples can be compared. (CAUTION: Encourage students to wear disposable rubber gloves when collecting water samples from potentially contaminated sites and to always wash their hands with anti-bacterial soap immediately after collecting samples.)

F. Gather materials needed from materials list.

PROCEDURE

I. Setting the Stage

   A. Explain that bacterial water pollution is responsible for many human illnesses including typhoid fever, dysentery, polio, and infectious hepatitis.

B. Discuss the potential health hazards of contaminated water and that state and municipal health departments are required by law to take frequent samples of drinking water supplies to test for disease-causing organisms.

1. EPA is responsible in the U.S. for setting the water quality standards that state, local, and municipal governments must comply with.

2. Explain that the bacterial standards vary according to how the water will be used.

C. Discuss how disease-causing organisms reach water bodies.

1. Fecal coliform bacteria are found in the digestive tract of warm-blooded animals.

2. Point out that most fecal coliform bacteria are relatively harmless organisms. But because they are indicators of fecal contamination of a water supply, high levels of some fecal bacteria indicate the water will also contain pathogenic organisms.

3. The main nonpoint sources of fecal contamination are animal feedlots, domestic animal manure, and failing septic systems.

E. Discuss why E. coli is used as an indicator organism.

1. E. coli, relatively harmless intestinal coliform bacteria, are much easier to test for than a wide variety of pathogens.

2. The presence of E. coli in a water body indicates recent fecal contamination. (NOTE: Because coliform bacteria grow at 40°C, they typically do not live long in water bodies.)

3. Many diseases are due to pathogens transmitted by fecal contaminated waters (e.g., dysentery, cholera, typhoid fever).

II. Activity

A. Distribute the "Fecal Coliform Culture Procedure" handout (included) to the students. Review the basic bacteriological lab techniques and the procedure for the coliform test.

B. Perform the fecal coliform test. Have the students use the water collected to perform the coliform test.

C. Have each student record the water sample source and test results in a data table (included). Instruct them to either follow the directions included with the activity or the directions provided with the kit acquired.

1. Compile all of the students' data on the board.

   a. Which samples had the lowest count? Highest count? Why?

   b. Would it be safe to drink this water?

   c. Would it be safe to swim in it? (If contaminated no; may get ill; see Background Information.)

   d. Would it be safe to eat fish caught from this water? Why or why not? (If contaminated no; fish may be diseased and not safe to eat.)

2. Examine the land use activities in the area upstream from where each water sample was taken, and discuss the possible sources of fecal contamination.

   a. What was the possible pollution source(s)?

   b. What could be done to prevent fecal coliform contamination from occurring?

D. Discuss what drinking water standards (for coliforms) are and how different standards apply for different types of uses.

   1. For example, water which meets drinking water standards may not be suitable for industrial use (e.g., the pharmaceutical industry) and vise versa.

   2. How do the bacterial counts from the samples taken compare to the health department standards?

III. Follow-Up

A. Have the students contact the state or provincal water pollution control agency and find out what standards your state has set for fecal coliforms in drinking water, for body-contact recreation, and for nonbody-contact recreation. Are they the same as the EPA (or Canadian equivalent) guidelines or more stringent? Find out how wastewater and drinking water treatment plants are monitored in your state (or province). You may want to have the students perform coliform tests on your local wastewater plant's discharge.

B. Plan a field trip to a local drinking water or wastewater treatment facility.

IV. Extension

A. Have students conduct research to examine different methods used to control fecal contamination and answer the following questions:

   1. How are bacteria removed from well water?

   2. How do septic systems work?

   3. What do farmers do with livestock waste?

B. After their research is completed, do the following:

   1. Take the class on a field trip to your local drinking water treatment facility or invite a representative to visit your class.

   2. Invite a representative to discuss septic systems with the class.

   3. Arrange to visit a local farm to see firsthand how farmers manage livestock waste.

RESOURCES

Adapted from "Fecal Coliform Testing," TVA Teacher/Student Water Quality Monitoring Network, Tennessee Valley Authority, Norris, TN, 1989.

"Coliform Bacteria Determination," <u>Groundwater: A Vital Resource Student Activities Guide</u>, Tennessee Valley Authority and Cedar Creek Learning Center, 1986, pp. 37-38.

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Coliform Test Supplies, Nalge Company, Box 20365, Rochester, New York 14602.

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Water Microbiology: Laboratory and Field Procedures, Millipore Corporation, Bedford, Massachusetts, 1986.

FECAL COLIFORM CULTURE PROCEDURE

1. Sanitize forceps by dipping in alcohol and burning off the alcohol using an alcohol lamp. (NOTE: Use the alcohol lamp just to ignite the alcohol on the forceps; don't hold forceps in the flame of alcohol lamp. CAUTION: Do NOT place hot forceps back into the alcohol!)

2. Use the sanitized forceps to place an absorbent pad in a sterile petri dish. (CAUTION: Do NOT touch the pad with your fingers! NOTE: You can buy petri dishes with the pads inserted.)

3. Break the neck off of an ampoule of fecal coliform medium and aseptically pour the contents over the absorbent pad. Do not allow the medium to come into contact with your hands or lab equipment and make sure there is as little contact with the air as possible. Put the lid back onto the dish immediately and label the outside of the petri dish (not the lid) with the date and location where the sample was collected, date and time of culture preparation, and your name. (NOTE: The petri dish is labeled because the contents of the sample are in the dish, not the lid. Lids can be accidentally placed on the wrong sample!)

4. Flame-sanitize the forceps again. Unscrew the upper half of the filtration system. Place a sterile membrane filter on top of the filtration system with forceps, grid side up. Be sure the filter is completely flat with no wrinkles. (NOTE: If you tear the filter, dispose of it and use another filter.) Attach the top half of the filtration system to the bottom. It is best to do this as quickly as possible to reduce the possibility of contaminating the filter. (NOTE: Preassembled, sterile, analytical filter units are available from biological supply companies.)

5. Mix the water sample by vigorously shaking for several seconds (about 30 times). (CAUTION: Avoid coming into contact with the water sample.) Place the pointed end of a sterile pipette into the water to be sampled. Lower the pipette into the water and squeeze the rubber bulb attached to the top of the pipette to obtain the desired volume. (See the following table.)

Suggested Sample Volumes for Fecal Coliform Analyses

Type of Water	Sample Volume
Drinking water	100 ml
Wells, spring	30, 100 ml
Lakes, reservoirs	10, 30, 100 ml
Water supply intake	0.1, 0.3, 1, 3, 10 ml
Bathing beaches	0.1, 0.3, 1, 3, 10 ml
River water	0.01, 0.03, 0.1, 0.3, 1 ml
Chlorinated sewage effluent	0.01, 0.03, 0.1, 0.3, 1 ml
Raw sewage	0.0003, 0.001, 0.003, 0.01, 0.03 ml

6. Place the end of the pipette into the opening on the filtration system and deposit the sample onto the filter. If the sample does not cover the entire surface of the filter, add distilled water to the filter using a new sterile pipette. This will spread the sample evenly on the filter.

7. Holding the filtration system level, use a syringe suction pump to draw all of the sample through the filter while swirling the filter system to ensure uniform mixing and even distribution of the sample on the filter. Be careful when pushing the plunger back into the syringe that the filter is not forced off of the membrane. Suction water off the filter until it appears dry.

FECAL COLIFORM CULTURE PROCEDURE
(continued)

8. Remove the top half of the filtration system and carefully remove the filter with flame-sanitized forceps. Open the top of the petri dish and lay the filter across the pad, grid side up. It is best to do this step as quickly as possible to reduce the chance of contamination. Petri dishes should be incubated within 30 minutes of filtering the sample to inhibit the growth of non-fecal coliforms. Plates should be inverted and incubated 22-24 hours at 44.5°C. (NOTE: Inverting plates in the incubator will prevent condensate from falling onto the surface of the culture during incubation.)

9. Wash your hands immediately following the procedure with anti-bacterial soap.

10. After incubation, carefully count the bacterial colonies on the filter using a dissecting microscope or magnifying glass. Fecal coliform colonies should be counted within 20 minutes after removal from the incubator to avoid color changes. When performing counts, colonies in each and every grid square are to be counted. To facilitate the counting procedure, start at the "top" of the grid system and go back and forth, left to right, from top to bottom counting one line at a time. (CAUTION: Do not open petri dishes. If you do, wash you hands with anti-bacterial soap.)

CALCULATIONS

11. To determine the number of indicator organisms in the water tested, use the following formula:

$$\frac{\text{Number of Colonies Counted X 100}}{\text{Milliliters of Sample}} = \text{Number of Indicator Organisms per 100 ml}$$

Indicator organisms in water samples are expressed as number per 100 ml. (NOTE: Each visible colony in the incubated culture developed from a single bacterial cell in the original sample.) For example, a three milliliter (3 ml) sample was added to the filtration unit which contained approximately 20 ml of sterile buffer. After filtration and incubation, 36 indicator organisms were counted. Therefore, (36 x 100)/3 = 1200 indicator organisms/100 ml. (NOTE: For statistical accuracy, and to eliminate the possibility of errors due to colony crowding or color development on the membrane, a minimum number of 20 and maximum number of 60 colonies per plate is recommended for fecal coliform tests. If less than 20 are counted, then a new sample should be collected and the test performed with a larger volume. If greater than 60 colonies are counted, perform the test with a smaller volume.)

Name ______________________ Date ______________

DATA SHEET

Sample #	Collection Location	Land Use Activities in Area	Coliform Test Results	Drinking Water Standard	Body-Contact Water Recreation Standard	Industrial Water Supply Standard

SLIP SLIDIN' AWAY

OBJECTIVES

The student will do the following:

1. Predict the amount of erosion from hypothetical sites using the Universal Soil Loss Equation (USLE).
2. Determine the effect soil type, rainfall, and topography have on soil erosion.
3. Determine what measures need to be taken to prevent soil loss from hypothetical sites.

SUBJECTS:
General Science, Earth Science, Physical Science, Ecology, Physics, Algebra

TIME:
2 class periods

MATERIALS:
site information cards (one per team; included)
overhead transparency of USLE Problem example (included)
handouts of Figures and Tables (one per team; included)
calculators (one per team)
U.S. map with state boundaries (optional)
U.S. soil map (included)

BACKGROUND INFORMATION

Erosion is the gradual weathering of the earth's surface. It is a natural process which results in soil being washed into water bodies. Human activities, however, can greatly increase the rate of erosion by removing vegetative cover and exposing bare soil to winds and rain. When this happens, heavy rains can wash a variety of suspended materials, including soil, into water bodies. This makes the water cloudy or turbid. Turbidity is a measure of the amount of suspended particles (cloudiness) in the water.

Sediment can interfere with aquatic life, commercial and recreational activities, hydroelectric power generation, and drinking water and wastewater treatment operations. Sediment can decrease light transmission through water, thus decreasing plant photosynthesis and reproduction. Also, sediment increases the amount of heat that can be absorbed and stored in water. A decrease in photosynthesis and an increase in water temperature usually results in a decrease in the dissolved oxygen (DO) content. Low DO can stress or kill aquatic organisms. Sediment can also interfere with feeding and reproductive patterns of aquatic life. When sediment settles, it can create a blanket which smothers aquatic habitat and disrupts the food chain. Sediment can gradually fill lakes and streams. This can reduce flood storage capacity, cause navigation problems, and interfere with generation of hydroelectric power. Many other pollutants such as bacteria, nutrients, and harmful chemicals can be transported attached to sediment.

What is an acceptable rate of erosion? Generally speaking, the rate of soil loss should not exceed the rate of soil formation. The accepted rate of soil formation on many agricultural soils is approximately 5 tons/acre-year (11.25 metric tons/hectare-year), and so this figure is often used as the target figure for average soil loss on those soils. Acceptable ranges vary depending upon land use and soil type.

The Universal Soil Loss Equation (USLE) has been one of the most powerful, widely used, and practical tools for (1) on-farm planning of soil conservation practices, (2) inventorying and assessing regional and national impacts of erosion, and (3) developing and implementing public policy related to soil conservation. The USLE was developed by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS), Soil Conservation Service (SCS), and Purdue University in the late 1950s. The USLE is used to predict soil loss from a specific site. The USLE estimates the amount of soil that will erode from a site (in tons or metric tons/year) based on the topography, soil type, rainfall, and other factors of the area. The USLE also incorporates the effects of soil erosion control, ground cover, and management practices. The

USLE for one acre (hectare) is E = R x K x LS x C x P, where E is the soil loss by water erosion in tons per acre (metric tons per hectare) per year; R is the rainfall factor; K is the soil erodibility factor; LS is the topographic factor; C is the management factor, and P is the erosion-control practice.

In 1993, a revised USLE (RUSLE) was released by the USDA Agricultural Research Service. The RUSLE uses the exact same equation as the USLE, but the data used for R, K, C, LS, and P values have been revised to incorporate new information derived from research, experience, and improved technology developed in the last three decades. The RUSLE estimates are more site specific than USLE estimates and should provide a more accurate picture of both soil loss and the effects of soil conservation practices to reduce erosion.

This exercise uses the old USLE and only two soil types, mollisols and non-mollisols, to demonstrate how the equation works. For more updated information on RUSLE, contact either the USDA, SCS, or the Soil and Water Conservation Society.

ADVANCED PREPARATION

A. Copy and cut apart the 16 information cards (included).

B. Copy the tables and figures included, each team will need a copy of each.

C. Make overheads of the figures, tables, and example problem (included).

PROCEDURE

I. Setting the Stage

A. Have the students define the term erosion.

B. List the land use activities that cause erosion and the negative consequences that result.

C. Explain that soil loss or erosion can be measured using a Universal Soil Loss Equation (USLE). Explain that this equation has been revised and is now called RUSLE. Explain that USLE and RUSLE are the same equation, but RUSLE uses more up-to-date information for the variables. Explain that in this activity they will see how to use the formula as a tool for planning.

D. Introduce the USLE and go over the symbols with the students. The USLE for one acre (hectare) is: E = R x K x LS x C x P, where E is the soil loss by water erosion in tons/acre/year (metric tons/hectare/year), R is the rainfall factor, which accounts for the erosive forces of rainfall and runoff in erosion index units/year; K is the soil erodibility factor of a particular soil in tons/acre/erosion index unit (metric tons/hectare/erosion index unit); LS is the topographic factor; C is the cover and management factor reflecting the influence of vegetation and mulch ; and P is the erosion-control practice factor which accounts for practices superimposed on the land surface such as contouring, sediment basins, terracing, etc. Go over example problem (included).

E. Define the terms mollic and mollisol. Explain that there are hundreds of types of soil, but for the purpose of this activity, you will be comparing two general types.

1. Mollic soils or mollisols occur in regions with moderate rainfall and are perhaps the world's most productive soils or "prime farmland."

2. Mollisols are brownish soils with high organic matter and moderate clay content in the subsoil.

II. Activity

A. Assign teams, distribute materials, and review tasks.

1. Tell the students they will be playing the roles of site assessment experts for the United States Soil Conservation Service or the Canadian equivalent.

2. The students will work in teams of two.

3. Each team will be in charge of assessing a hypothetical proposed construction site.

4. Each team will assess their site's susceptibility to erosion and recommend appropriate soil erosion control practices and management.

5. In addition to the general soil characteristics (such as silty and claylike), students will need to determine whether or not a soil is likely to be mollic. For the purposes of this activity, students will use a simplified map that shows where mollisols are located in the United States (included). If the location of their site lies within an area generally known as having mollisols, then their site's soil will be considered to be mollic. In the U.S., most of the large areas of mollisols are in the Great Plains. These areas support dense stands of grass which produce an abundance of organic matter. The decomposition of this organic matter, in the presence of calcium, leads to the formation of mollic soils.

6. Using the USLE, each team will calculate the predicted soil loss by water erosion for their site if the soil were bare and no erosion control methods were practiced.

7. Then they will determine and recommend the types and amount of cover, management, and erosion-control practices needed to reduce the amount of erosion to the recommended five tons per acre (11.25 metric tons/hectare) annually. (NOTE: Five tons per acre (11.25 metric tons/hectare) is a recommended average loss per year for agricultural soils. Acceptable ranges vary depending upon land use and soil type.)

B. Calculate soil loss.

1. Distribute to each team site information cards and a copy of each table and figure. Have each team determine the rainfall factor (R) from Figure 1. You may need to explain how to read the contour lines used in Figure 1. (For explanation of contour lines, see "Watershed Woes" activity.) Also, from figure 1, students should note if the soil is likely to be mollic (or mollisol) or not.

2. From the soil information on their cards and Table 1, the students can determine the soil erodibility factor (K) for their sites.

3. The topographic factor (LS) is determined using the slope length, percent slope, and Figure 2. To do this, locate the point at which the slope length (on the x-axis) intersects with the appropriate percent slope line within the graph. Use a straight edge to read the value of LS on the y axis.

4. The values for the cover and management factor (C) and the erosion-control practice factor (P) are given in Tables 2 and 3, respectively. Note that C and P both equal 1.0 for bare soil with no soil erosion control. Thus, to determine the amount of soil loss by water erosion for bare soil with no erosion-control practices, simply multiply R, K, and LS together. Assume the site has bare soil and you need to recommend control practices.

5. Next, determine what soil erosion-control practice, ground cover, and management practices to recommend.

6. Determine the percent (y), in decimal form, by which the amount of soil erosion must be decreased for it to be less than or equal to five tons/acre-year (11.25 metric tons/hectare/year)

   y = five tons/acre-year (11.25 metric tons/hectare-year) + E (bare without controls)

7. Now, from Tables 2 and 3, determine which values for C and P will, when multiplied together, be less than or equal to y.

   a. If a value less than or equal to y is unattainable, what is the lowest attainable value?

   b. What are the practices for C and P?

C. Discuss the results.

1. Have the students summarize and report their recommendations for their sites. Do any groups recommend not disturbing the site? How do topography, location, and soil type affect the rate of erosion, and hence, water quality?

2. Have each group present their findings to the class.

III. Follow-Up

A. Have students research the types of soil erosion-control practices used in construction and have student teams design a hypothetical construction site.

1. They should describe the characteristics of their site, such as location, soil type, acreage, slope length, percent slope, rainfall factor, distance from stream, and other information regarding the nature of the watershed and water body.

2. Have them predict the total amount of soil loss by water erosion for bare soil without erosion control and the likely affects on the water body. You may want to select sites on actual topographic maps proposed for development and have students determine the percent slope themselves.

3. Have them determine the types and amount of erosion-control practices needed.

4. Have them draw a diagram depicting the construction site, distance from a stream, and use of erosion-control practices. In addition to the erosion-control practices included in Tables 2 and 3, the students can also use sediment basins, silt screens, straw bale diversions, diversion ditches, clover, or other alternative ground covers. (See Figure 3 as a sample plan.)

B. Have students obtain permission to visit a construction site and interview the owner/site manager. What evidence of erosion is present? What is being done to reduce erosion? How long will the operation take? How far is the site from a water body? What other types of pollutants could enter the water body from the site? Sketch the site and note problem areas and corrective practices. Have students share their findings with the class.

IV. Extension

A. Have the students write letters to local developers, contractors, local or state departments of transportation, or others involved in some form of land disturbance which causes erosion and encourage them to use best management practices (BMPs) to prevent ersosion.

B. Invite a guest speaker to talk about erosion-control practices.

C. Write to the Soil and Water Conservation Society for more information on RUSLE.

RESOURCES

Foth, H.D., and L. M. Turk, Fundamentals of Soil Science, John Wiley and Sons, Inc., New York, New York, 1981, Figures 10-19.

Hudson, N., Soil Conservation, Cornell University Press, Ithaca, New York, 1971, p. 36.

Keller, Edward A., Environmental Geology, Fourth Edition, Charles E. Merrill Publishing Company, Columbus, Ohio, 1985, p. 238.

Renakd, Kenneth G., George Foster, Glenn A. Wessies, and Jeffrey P. Porter, "RUSLE Revised Universal Soil Loss Equation," Journal of Soil and Water Conservation, January/February 1991.

Revised Universal Soil Loss Equation (RUSLE), Soil and Water Conservation Society, 7515 North East Ankeny Road, Ankeny, Iowa 50021, or 1-800-THE-SOIL.

Walesh, S. G., Urban Surface Water Management, Chapter 7, "Nonpoint Source Pollution Load Techniques," John Wiley and Sons, Inc., New York, New York, 1989.

Wischmeier, Walter H., and Dwight D. Smith, Predicting Rainfall Erosion Losses: A Guide To Conservation Planning, U.S. Department of Agriculture, Washington, DC, 1978.

FIGURE 1

Rainfall factors (in inches) for use with the Universal Soil Loss Equation (USLE). (Adapted from Wischmeier and Smith, 1978 map. Locations of mollic soils in the U.S. adapted from Foth and Turk, 1981. NOTE: To convert to centimeters, multiply inches by 2.5.)

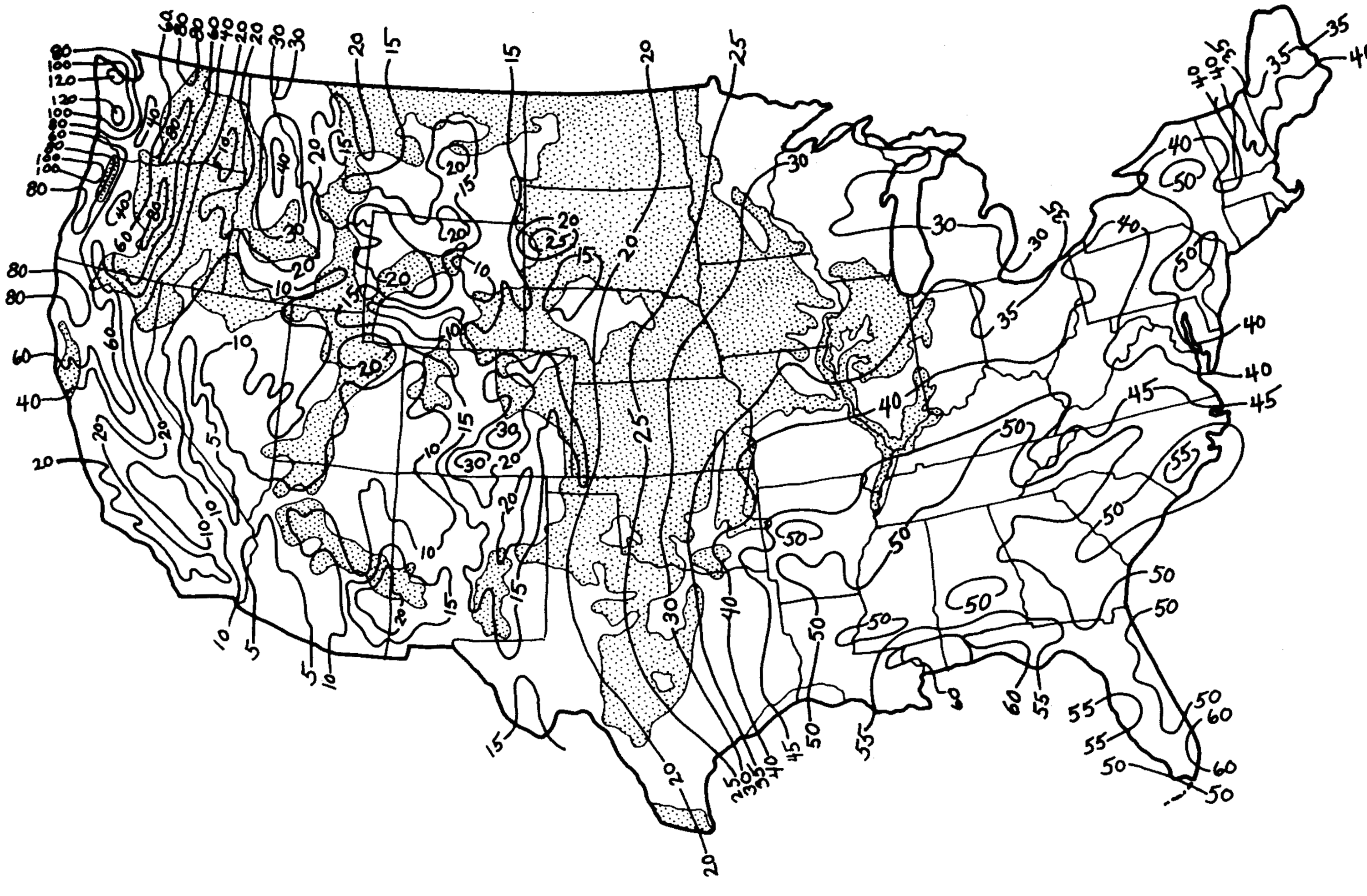


FIGURE 2

Topographic factor as a function of slope and slope length for use with the Universal Soil Loss Equation (USLE). (Adapted from Wischmeier and Smith, 1978, and Foth and Turk, 1981).

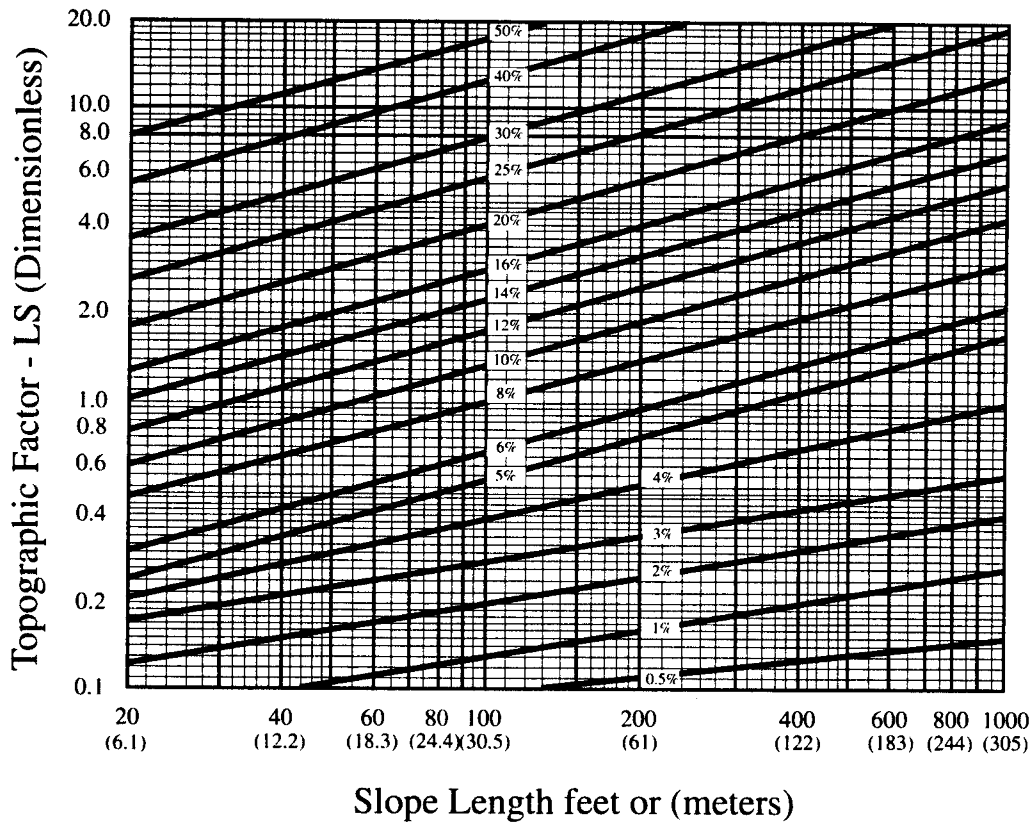


TABLE 1

Typical soil erodibility factors for use with the Universal Soil Loss Equation (USLE).

Soil	Soil Erodibility Factor (K) tons/acre or metric tons/hectare-erosion index unit
sands & gravels	0.10
loamy coarse sands, sand & fine sand	0.15
loamy fine sand & loamy sand	0.17
fine sandy loam & sandy loam, mollic	0.20
fine sandy loam & sandy loam, nonmollic	0.24
loam, clay loam & sandy clay loam, mollic	0.28
loam, clay loam & sandy clay loam, nonmollic	0.32
silt loam & silty clay loam, mollic	0.32
silt loam & silty clay loam, nonmollic	0.37
silt loam & silty clay loam, subsoil	0.43
clay & silty clay, less than 50% clay	0.32
clay & silty clay, over 50% clay	0.28

Source: Walesh, 1989.

TABLE 2

Cover and management factors for use with the Universal Soil Loss Equation (USLE).

Cover or Management Measure	Cover & Management Factor C (dimensionless)
Bare soil	1.0
Straw mulch*	
0.5 tons per acre (1.13 metric tons per hectare)	0.35
1.0 tons per acre (2.25 metric tons per hectare)	0.18
1.5 tons per acre (3.38 metric tons per hectare)	0.06
3.0 tons per acre (6.75 metric tons per hectare)	0.03
4.0 tons per acre (9.0 metric tons per hectare)	0.02
Grass	0.011

Source: Adapted Walesh, 1989.

*Mulch assumed to be anchored by means such as punching into soil with a disk or using mulch net.

TABLE 3

Erosion-control practice factor for use with the Universal Soil Loss Equation (USLE).

	Erosion-Control Practice and Resulting Factor P (dimensionless)		
Land Slope (percent)	No Erosion-Control Practice	Contouring	Terracing
1-2	1.0	0.6	0.12
3-8	1.0	0.5	0.10
9-12	1.0	0.6	0.12
13-16	1.0	0.7	0.14
17-20	1.0	0.8	0.16
21-20	1.0	0.9	0.18

Sources: Adapted from Foth and Turk, 1981, and Walesh, 1989.

SITE INFORMATION CARDS

Location: southeastern Colorado Percent Slope: 30 Slope Length: 50 ft (15.2 m) Soil: loam, clay loam, and sandy clay loam	Location: northern Texas Panhandle Percent Slope: 30 Slope Length: 100 ft (30.5 m) Soil: silt loam and silty clay loam
Location: central Michigan Percent Slope: 30 Slope Length: 200 ft (61 m) Soil: loam, clay loam, and sandy clay loam	Location: central Missouri Percent Slope: 30 Slope Length: 400 ft (122 m) Soil: silt loam, silty clay loam
Location: central Florida Percent Slope: 20 Slope Length: 50 ft (15.2 m) Soil: silt loam and silty clay loam	Location: northern Illinois Percent Slope: 20 Slope Length: 100 ft (30.5 m) Soil: fine sandy loam and sandy loam
Location: upstate Vermont Percent Slope: 20 Slope Length: 200 ft (61 m) Soil: silt loam and silty clay loam	Location: western Pennsylvania Percent Slope: 20 Slope Length: 400 ft (122 m) Soil: fine sandy loam and sandy loam
Location: northern Maine Percent Slope: 10 Slope Length: 50 ft (15.2 m) Soil: loam, clay loam, and sandy clay loam	Location: central Tennessee Percent Slope: 10 Slope Length: 100 ft (30.5 m) Soil: silt loam and silty clay loam
Location: north-central Oregon Percent Slope: 10 Slope Length: 200 ft (61 m) Soil: loam, clay loam, and sandy clay loam	Location: northeastern North Carolina Percent Slope: 10 Slope Length: 400 ft (122 m) Soil: silt loam, silty clay loam
Location: central North Dakota Percent Slope: 5 Slope Length: 50 ft (15.2 m) Soil: silt loam and silty clay loam	Location: southeastern Arizona Percent Slope: 5 Slope Length: 100 ft (30.5 m) Soil: fine sandy loam and sandy loam
Location: north-central Nebraska Percent Slope: 5 Slope Length: 200 ft (61 m) Soil: silt loam and silty clay loam	Location: central Massachusetts Percent Slope: 5 Slope Length: 400 ft (122 m) Soil: fine sandy loam and sandy loam

UNIVERSAL SOIL LOSS EQUATION (USLE)
EXAMPLE PROBLEM

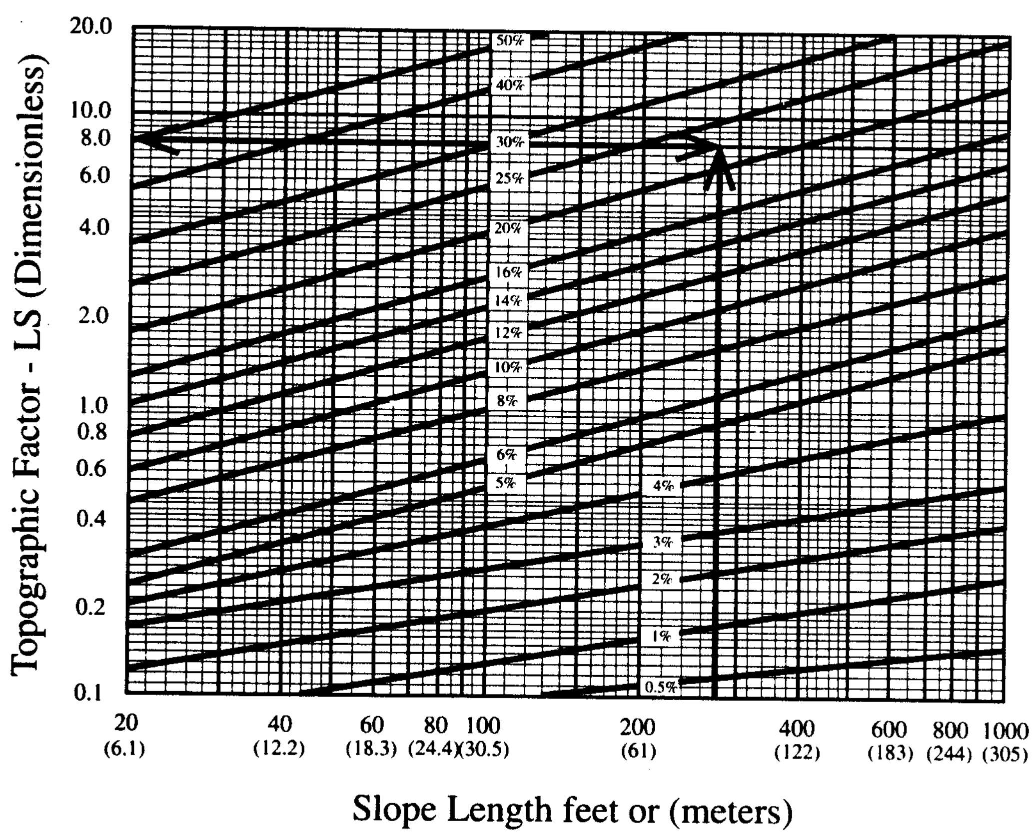
Example Card:

Location: Knoxville, TN
Percent Slope: 30
Slope Length: 300 ft (91.5 m)
Soil: Silt loam and silty clay loam, subsoil

USLE:

E = R x K x LS x C x P
where
R = 55 inches or 137.5 cm
K = 0.43
LS = 30 (percent slope) x 300 ft or 91.5 m (slope length)
therefore: LS = 8.0

To find LS:



UNIVERSAL SOIL LOSS EQUATION (USLE) EXAMPLE PROBLEM (continued)

CALCULATIONS:

C = 1

P = 1

E = 55 x 0.43 x 8.0 x 1 x 1 = 189.2 tons/acre-year
(or E = 137.5 x 0.43 x 8.0 x 1 x 1 = 473 metric tons/hectare-year)

If the site were covered with 3.0 tons per acre (6.75 metric tons per hectare) of straw mulch, the equation would be:

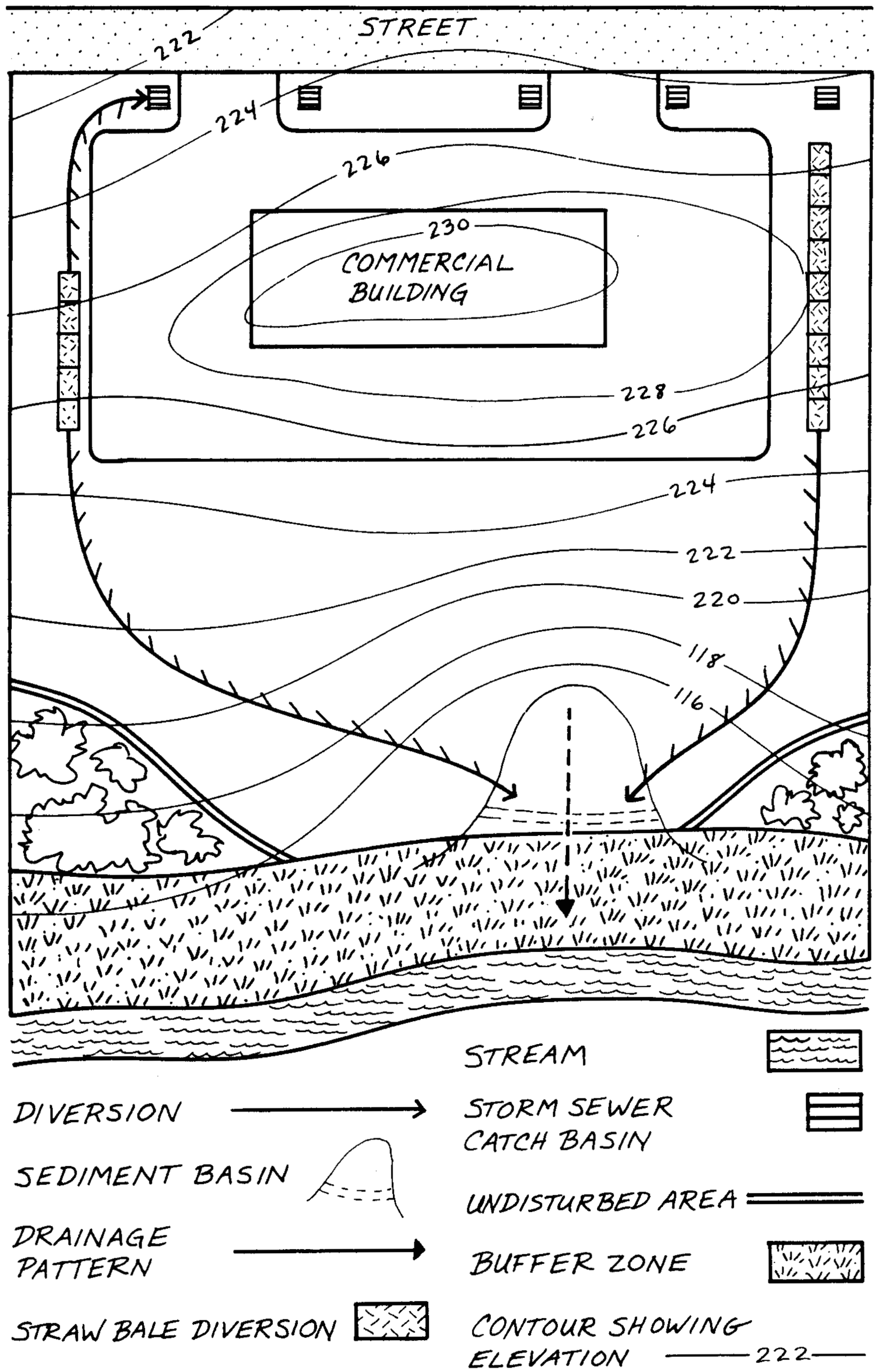
E = 55 x 0.43 x 8.0 x 0.03 x 1 = 5.7 tons/acre-year
(or E = 137.5 x 0.43 x 8.0 x 0.03 x 1 = 14.2 metric tons/hectare-year)

If the site were contoured, extrapolating the values for 30 percent land slope, the equation would be:

E = 55 x 0.43 x 8.0 x 1 x 0.9 = 170.3 tons/acre-year
(or E = 137.5 x 0.43 x 8.0 x 1 x 0.9 = 425.7 metric tons/hectare-year)

FIGURE 3

Example of a sediment- and erosion-control plan for a commercial development. (Adapted from Braxton Williams, Soil Conservation Service)



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ALL MESSED UP AND NO PLACE TO GO

OBJECTIVES

The students will do the following:

1. Map and calculate the area of the school parking lot.
2. Calculate the volume of water falling on the school parking lot.
3. Map the route surface runoff will take to the nearest water body.
4. Describe the roles that human activity and runoff play in urban nonpoint source pollution.

SUBJECTS:
General Science, Earth Science, Ecology, Life Science, Physical Science, Biology, Chemistry, Physics, Algebra, Geometry

TIME:
2 class periods

MATERIALS:
meter or yardstick
tape measure
trundlewheel (optional)*
long piece of twine (marked off in meter or foot intervals)
magnetic compasses (instrument for determing directions)
compasses (instrument for drawing circles)
writing materials
clipboards (optional)
graph paper
protractors
rulers
calculators
local rainfall data

* A trundlewheel is a simple instrument used to measure linear distance. A large wheel, attached to a handle, operates a counter or clicks as it is rolled along a surface. Each complete turn of the wheel equals one yard or meter. City road crews often use trundlewheels, so if your school does not have one, perhaps the city will loan you one.

BACKGROUND INFORMATION

Harmful chemicals can enter a water supply from many sources, including urban and rural polluted runoff, leaky landfills, improper mining, construction, farming, and forestry operations. For example, rural runoff can contain pesticides, gasoline, and other chemicals. Improper forest operations can contribute pesticides, paints, oil, gasoline, and other chemicals, such as creosote. Improper mining operations can contribute heavy metals, oils, gasoline, and other chemicals used to refine ores, including acids and bases. Urban stormwater runoff may contain sediment, debris, and harmful chemicals such as herbicides, pesticides, gasoline, oil, road salt, and heavy metals. Heavy metals from parking lot runoff, for example, might include lead, chromium, cadmium, iron, and manganese from grinding car parts.

Runoff from large areas of pavement is particularly likely to contain pollutants, since none of the water or pollutants can be absorbed through the pavement. In fact, another way in which urbanization and other development may adversely affect water quality is by increasing the volume of surface runoff while decreasing runoff times. When it rains, more water runs off at a higher speed because it is not absorbed into the ground. Hence, potential pollutants are transported more quickly from the land to the receiving water. This sometimes causes a phenomenon to occur called "shock loading." This can result in fish kills or algal blooms depending upon the type of pollutants in the runoff. Suspended materials in runoff can also absorb and store heat which increases the water temperature. Changes in water temperature can also harm aquatic life.

ADVANCED PREPARATION

A. Obtain items in materials list.

B. Make overheads of illustrations included (optional).

C. Make copies of the Procedure section for the students (optional).

PROCEDURE

I. Setting the Stage

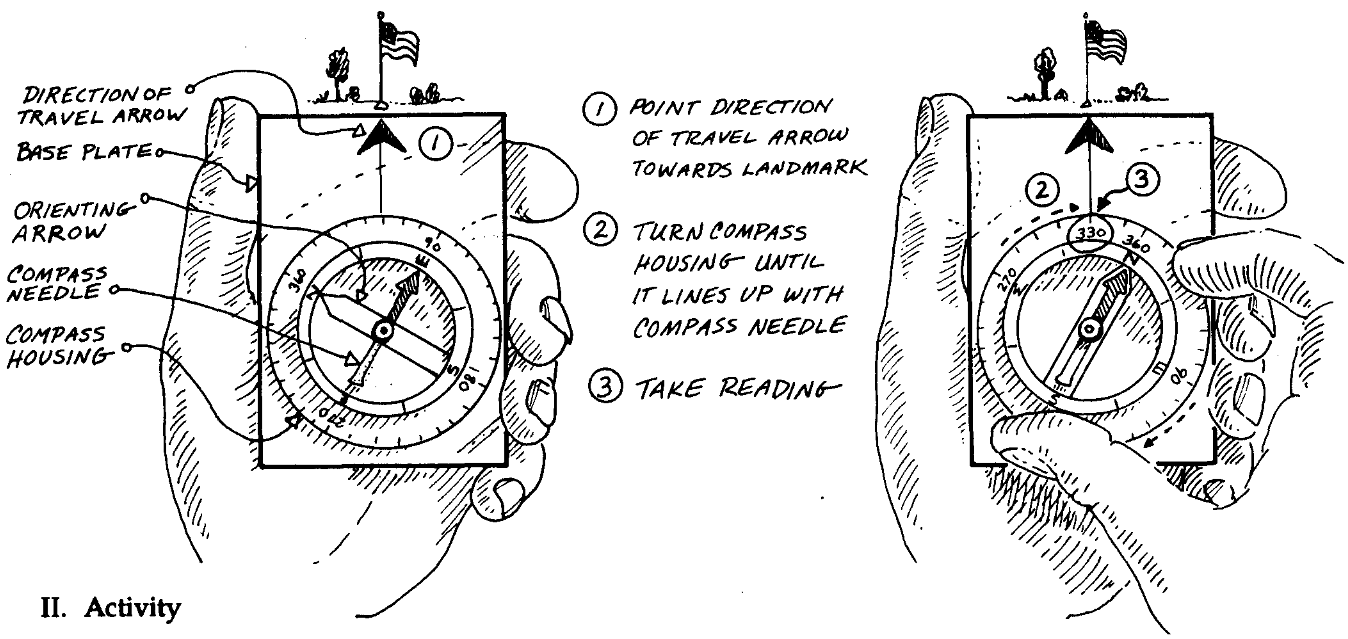
A. Explain to the students they are going to examine the impacts of runoff from the school parking lot on a neighboring stream.

B. Go over how to read a magnetic compass.

1. Hold compass level in front of you and point the direction-of-travel arrow, located on the base plate of the compass toward a landmark or reference point.

2. Next twist the compass housing (circuladial) until the compass needle (red moving arrow) lies in the orienting arrow (outline of arrow on circular dial). [NOTE: Make sure the north part of the compass needle points toward the letter N (north) on the top of the compass housing.]

3. Read the number on the compass housing where the direction of travel arrow on the base plate touches the compass housing. This is the bearing expressed in compass degrees.



II. Activity

A. Estimate the size of the school parking lot and expected runoff.

1. Have the students write down estimates of the area of the school parking lot and the annual amount of runoff.

2. Write several of these estimates on the board, including the lowest, highest, and your own estimate.

3. Which estimates does the class think are the most accurate? Compare these estimates to their final answers. (NOTE: You might take up the students' written estimates and when the activity is over, award bonus points to those students whose estimates were closest to the amounts determined in this exercise.)

B. Map the school parking lot.

1. Divide the class into teams of 3-5 students per team.

   a. Have the team members select which job they will peform. One person will be required to sketch the site and record measurements. Another person will need to operate the compass. Two-three people will be required to make site observations and take distance measurements.

   b. Instruct them on how, where, and in what units to make their measurements. (NOTE: Use either standard or metric to make measurements. Do not mix measuring units.)

   c. Depending on the size of the parking lot, you may want to assign each team a portion of the lot. If not, have all the teams measure the same parking lot.

2. Distribute a magnetic compass and measuring apparatus to each team. [NOTE: The students can determine the distances by using a 100 m or 100 ft piece of twine marked at 1 m or 1 ft intervals, respectively; or by determining a team members length of stride (how many paces does it take for the student to walk 100 m or 100 ft), and pacing off the distances; or by using a trundlewheel, if available.]

3. Have the teams make a rough sketch of the parking lot on plain paper. The measurements the students take will be recorded on this sketch for later use.

   a. First have the teams choose one central reference point such as a flag pole or other landmark which will not change over time. Their map will be drawn in relation to this point (see illustation). (NOTE: Use only one central reference point.)

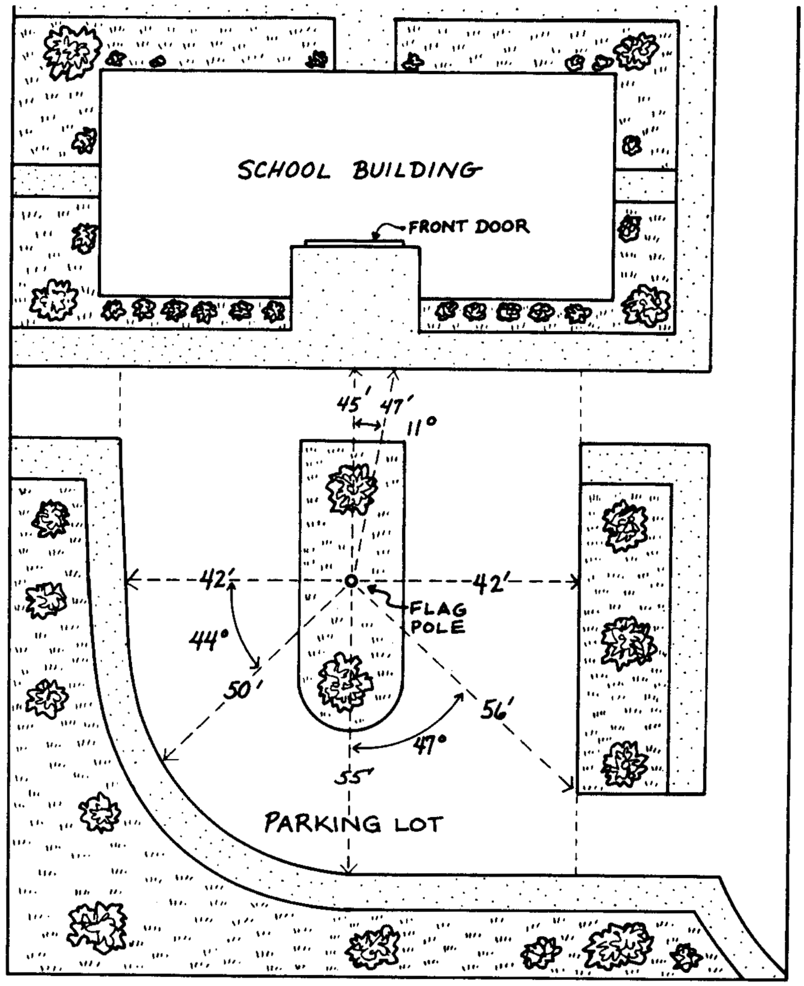
   b. Begin the sketch by locating the landmark selected in the center of the paper. Then have them use a compass to note N, S, E, and W.

   c. Then, have them locate all the prominent features and other relevant information on the sketch.

      1) For example, have each team determine the course of the runoff and distance to an aquatic habitat, if appropriate. Where does the water go from the parking lot? What route does it take? What is the nature of the route? What is the ground cover? Is it below or above ground? Have the students put arrows on their maps to show the direction of flow.

      2) Also instruct them to record any evidence of potential nonpoint source pollutants (type and approximate location).

   d. Have them identify points around the edge of the parking lot they can use later as reference points when they take their measurements. Permanent features like doors, windows, trees, or signs work well. Have them clearly mark these points on the sketch.



4. Next, have the teams determine the dimensions of the parking lot. Since many parking lots are not perfect rectangles, they will need to map the approximate shape of the parking lot by using a magnetic compass to detect directional changes.

   a. Have the team member with the magnetic compass stand next to the central point. The recorder should be standing beside him/her with a copy of the sketch.

   b. The magnetic compass will be used to determine the angles (expressed in compass degrees) between the measurements. To use the magnetic compass, point it at one of the permanent features around the periphery of the site that you have already selected and recorded on the sketch. Take a compass reading and have the recorder write this on the sketch next to that point.

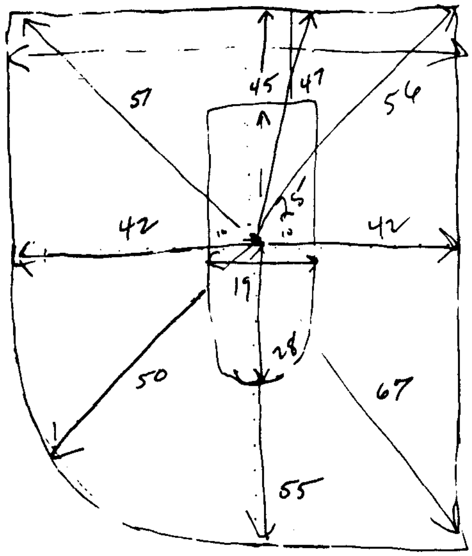
   c. Then measure the distance from the central point to the feature you just took the compass reading from and write this measurement on the sketch.

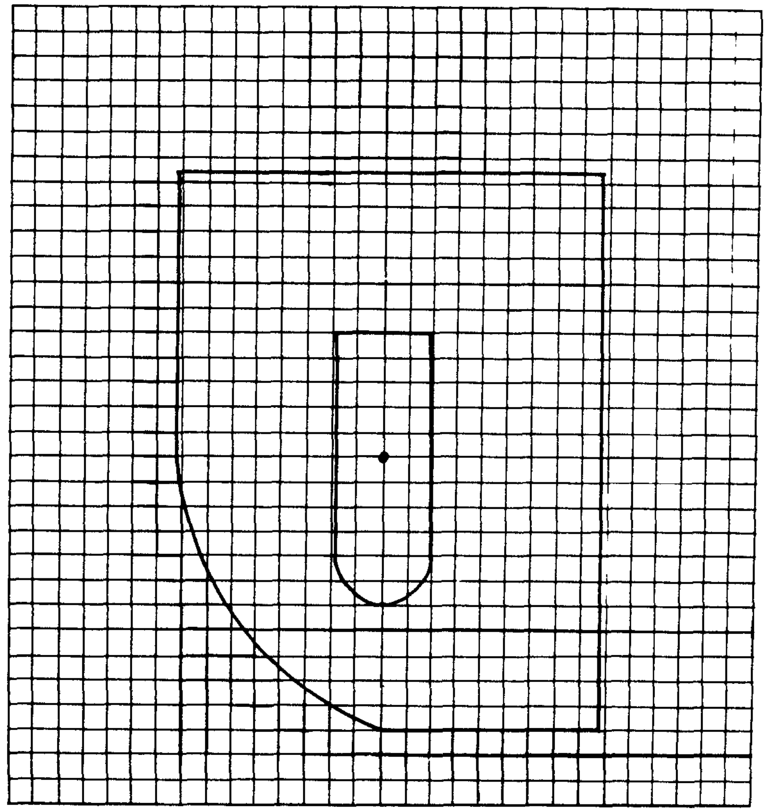
   d. Repeat this procedure by choosing another point and taking a new compass reading and measurement. To get the angle in degrees, subtract the previous compass reading from this compass reading. Continue this procedure as you make a circle either to the left or right. (NOTE: When you finish, the degrees of all the angles should total 360.) When you are done, you will have rays coming off a single central point (see illustration).

   e. You can then use this information to make a more accurate map on graph paper.

C. Determine map scale. From the largest dimension, the students will need to decide upon an appropriate map scale to use and which direction will be north. For instance, what will the side of one square equal? What will a square represent? For example, the vertical side of a square on

Student Sketch





1 SQUARE = 5'

the graph paper might equal two feet (two meters) and the horizontal side might equal two feet (two meters) or the horizontal side might equal four feet (four meters). (NOTE: Use whatever scale works best for your site, be consistent, and select a scale that will keep your map on one piece of paper. It is best to have all the teams draw their maps to the same scale and same orientation for comparison.)

D. Redraw the parking lot to scale on graph paper.

1. Have the students map the parking lot on the graph paper using a protractor and ruler. (NOTE: If the teams all measured the same site, the maps should look the same even though they may have chosen to use different points for their central landmark and permanent features.)

2. Distribute graph paper, rulers, compasses (instrument for making circles), and protractors to each team.

   a. Place the central reference point in the center of the graph paper. (NOTE: Be sure the point is located where two lines bisect.)

   b. Use the measurements on the rough sketch and the map scale choosen to determine the number of squares away from the central point each measurement should be.

   c. Use a protractor to mark the angles in degrees from the central reference point. (NOTE: Have the students lay the protractor on the central reference point and mark the angles first, then draw the lines from these points; see illustration.)

   d. After the rays are drawn, measure the distance and mark those points.

e. Then connect the dots using the ruler and compass to make smooth lines.

E. Calculate the area of the school parking lot. (NOTE: The formula for calculating is AREA = LENGTH x WIDTH or A = LW.)

1. Determine what area one square on the graph paper will represent using the map scale selected. For example if the vertcial side equals two foot (two meters) and the horizontal side equals two feet (two meters), the area would be four square feet (four square meters).

2. To find the area, simply count the number of squares contained within the perimeter of the map and multiply this by the area one square represents. (NOTE: You may want to simplfy the procedure by coming up with a workable approximation before you start; see illustration.)

   a. First, count and record only those squares completely within the boundaries of the map perimeter.

   b. Now, count the squares only partially within the boundaries, divide this number by two, and add to the number of complete squares.

   c. Next, multiply the total number of squares by the conversion factor determined by the map scale used.

   d. Have the teams record this information on a separate piece of paper.

CONVERSION FORMULA

# of complete squares + (# of partial squares + 2) = total # of squares

From map scale, 1 square = Y ft^2 (or m^2); Let Y = your choice of map scale

Thus, [total # of squares x Y ft^2 (or m^2)] = area of parking lot in ft^2 (or m^2)

F. Have the students calculate the average amount of rain that falls on the parking lot in one year. Rainfall data can be obtained using information from a variety of resource agencies, such as the Weather Bureau, local newspapers, TV weather persons, or the Soil Conservation Service or Canadian equivalent.

1. Provide the students with the necessary conversions (see conversions charts).

CONVERSION CHART

1 ft^3 = 7.2827 gallons
1 m^3 = 1000 liters
5 minute shower = 25 gallons or 95 liters
Density of water : 1 gallon = 8.34 lbs
1 liter = 1 kg

2. To determine the volume of rain falling on the parking lot annually, the students will multiply the average annual rainfall by the area of the parking lot. Volume should be recorded on their data charts in cubic feet (ft^3) or cubic meters (m^3) as these are the standard units for runoff used by professionals.

3. To be more meaningful to most students, have them convert the volume into gallons or liters, and determine how many showers they could take with this amount of water. Since a paved parking lot will not absorb any water, the volume of rainfall approximately equals the volume of runoff water. (NOTE: Some water will evaporate when rain falls on hot pavement.) Have students calculate and record on their data chart the number of five minute showers to which the annual amount of rainfall on and runoff from the parking lot is equal. Finally, if you took one shower every day, how long would it take to take this many showers? Using the conversion chart, have the students calculate the weight of the runoff. Chances are that the calculated volume and weight of runoff will impress and even surprise most students. (See Example Problem.)

G. Discuss the results.

1. Compare the students' estimates of the area of the parking lot, volume and weight of the runoff with the data the students collected. Who gave the closest estimate in each category?

2. How does runoff relate to nonpoint source pollution?

3. Review the types of pollutants that may enter a water body from parking lot runoff.

4. What kinds of pollutants did the students observe when they took their measurements?

5. What could be done to reduce nonpoint source water pollution from their school parking lot?

EXAMPLE PROBLEM (English Units):

Average annual rainfall = 100 inches and the area of the parking lot = 12,000 ft^2.

Convert the rainfall from inches to feet (12 in = 1 ft) ;
100 inches (annual rainfall) x 1 ft/12 in = 8.33 ft.

Multiply rainfall by the parking lot area to find volume of runoff;
8.33 ft (annual rainfall) x 12,000 ft^2 (area) = 99,960 ft^3 (annual runoff).

Now, convert the volume to gallons (1 ft^3 = 7.2827 gallons);
53,978 ft^3 x 7.2827 gallons/ft^3 = 727,979 gallons runoff.

Next, determine how may five minute showers could be taken with this amount of water (5 minute showers = 25 gallons);
727,979 gallons (annual runoff) ÷ 25 gallons/5 minute shower = 29,119 showers

If you took one shower every day, how long would it take to shower this many times?
29,119 showers x 1 shower/1 day x 1 year/365.25 days = 79.72 years worth of showers!

Determine the weight of the runoff (8.34 lbs/gal); 727,979 gals x 8.34 lbs/gal = 6,071,344 lbs.

EXAMPLE PROBLEM (Metric Units):

Average annual rainfall = 250 cm and the area of the parking lot = 1100 m^2.

Convert the rainfall from centimeters to meters; (100 cm = 1m) 2500 cm = 2.5 m.

Multiply rainfall by the parking lot area to find volume of runoff:
2.5 m (annual rainfall) x 1100 m^2 (area) = 2750 m^3 (annual runoff).

Now, convert the volume to liters (1 m^3 = 1000 liters);
2750 m^3 x 1000 liters/m^3 = 2,750,000 liters runoff.

Next, determine how may five minute showers could be taken with this amount of water (5 minute showers = 95 liters);
2,750,000 liters (annual runoff) ÷ 95 liters/5 minute shower = 28,947 showers

If you took one shower every day, how long would it take to shower this many times?
28,947 showers x 1 shower/1 day x 1 year/365.25 days = 79.25 years worth of showers!

Determine the weight of the runoff (1 kg/l); 2,750,000 kg.

III. Follow-Up

A. Develop best management practices for reducing nonpoint source pollution from parking lots and brainstorm on ways to implement them at your school. Publish the results of the study in the school newspaper along with general information on how to reduce urban nonpoint source pollution.

B. Collect a sample of the parking lot runoff during, or soon after, a rain storm. Following the procedure described in "It's Sedimentary," determine the percent sediment load of the runoff. Multiply the weight of the annual runoff by the percent sediment load. This value represents the number of pounds (or kilorgrams) of sediment that is transported annually in the parking lot runoff. Much of this sediment may reach an aquatic habitat and smother plant and animal life. What are the likely sources of the sediment? Are there any "barriers" such as grassed waterways to prevent the sediment from reaching an aquatic habitat? What could be done to reduce the amount of sediment in the runoff and the amount reaching a waterway?

C. Determine the amount of rainfall from a single storm using a rain gauge or local resource agencies. Repeat the procedure to find the volume of runoff. During or after the storm, have the students sketch the drainage patterns of the school parking lot and grounds and record types and sites of any nonpoint source pollution they observe.

IV. Extension

A. Collect runoff and perform water quality chemical tests on it to detect the presence and relative amounts of pollutants. Do the bioassay activity "Lethal Lots" to determine the toxicity of the runoff.

B. Determine the rate of absorption for different types of ground cover on your school grounds. To do this, pour the same volume of water on different types of cover and time how fast the water is absorbed into the ground. How does this affect the quality and amount of surface runoff?

RESOURCES

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MINED OVER WATER

OBJECTIVES:

The students will do the following:

1. Explain how sediment from mining contributes to nonpoint source pollution.
2. Describe current surface mining practices.
3. Simulate surface mining and reclamation.
4. Keep a photographic record of the effects of surface mining and reclamation and develop a presentation on the project.

SUBJECTS:
General Science, Earth Science, Physical Science, Ecology, Physics, Chemistry

TIME:
3-6 class periods over a one month period

MATERIALS:
shovels
picks
stakes
string
yard or meter sticks
grass or perennial wildflower seed
mulch (straw, grass clippings, pine needles, etc.)
cameras (instant or other type)
film

BACKGROUND INFORMATION

Sand, gravel, limestone, chert, clay, iron, mica, feldspar, phosphate, marble manganese, zinc, coal, copper, oil, and other minerals are among the many resources mined each year around the world. Mining involves the removal of minerals from either the surface or subsurface of the earth and dumping unwanted rock and other waste (spoils) somewhere else. There are two basic types of mining—surface (strip mining) and subsurface (deep shaft). Surface mining disrupts the earth's surface more than subsurface mining. However, both types of mining can cause serious environmental problems.

Over 60 percent of the coal mined in the United States is surfaced mined. Coal is usually surface mined when it lies no more than 100 to 200 feet below the earth's surface. Vegetation, rock, and soil overlying the coal (overburden) are stripped away and the coal is extracted.

The harmful environmental effects of mining depend on the type of mineral extracted, the method used, and the local topography and climate of the area. Pollutants include sediment from erosion and acids or toxic metals from oxidation and reduction reactions taking place when water reacts with exposed soil (acid mine drainage). Harmful environmental effects include siltation, increased water temperature, change in pH, low dissolved oxygen content, and toxics transported on the sediment. Sediment can smother aquatic organisms, gradually fill in aquatic habitats, interfere with navigation, and interfere with hydroelectric power generation.

Since some coal contains sulfates (SO_4), and sulfates can produce sulfuric acid (H_2SO_4) in the presence of water, acidic runoff is also a problem. In addition to lowering the pH (acidifying) of the water, acidic runoff can react with and release nutrients and toxic metals (such as aluminium, lead, iron, cadmium, and manganese) from soil into the water.

Miners have not always been required to restore mined areas by re-establishing groundcover. The abandoned mines they left behind are referred to as "orphan mines." Nature may eventually reclaim some orphan mines. Unfortunately, surface mining removes valuable topsoil and leaves behind acid-rich nutrient-poor soil. This is why natural reclamation is very slow. Because of this, bare soil will continue to erode for years, causing a variety of water quality problems.

The U.S. 1977 Surface Mining Control and Reclamation Act (SMCRA) requires miners to submit detailed mining and reclamation plans before receiving a mining permit. This law (1) defines basic reclamation; (2) establishes guidelines for constructing mine facilities and for maintaining environmental quality; and (3) protects certain lands, such as prime farmland, from mining. Reclamation means restoring the mined area to the approximate original contour, covering it with topsoil, and revegetating it. The intent of the law is for the reclaimed mining area to become as useful and productive as it was prior to being mined.

SMCRA also contains a provision for reclaiming orphan mines. Fees are collected from companies currently mining, and these funds are used to help reclaim orphan mines. While orphan mine reclamation efforts are progressing slowly, current reclamation efforts continue to assure the land will be returned to the original condition.

Best management practices (BMPs) are preventive steps taken to reduce water pollution. Many methods are available to prevent acidic runoff from mines. Waterbars and windows are earthen structures designed to channel runoff to ditches or treatment areas, such as a constructed wetland. Silt barriers are used to prevent sediment from reaching streams. Adding buffers, such as lime, help raise the pH in acidic soils and waters. Revegetating the mined site properly immediately following mining and protecting the site with mulches during mining operations are also extremely important.

ADVANCED PREPARATION

With permission from your school principal, select a small plot of land on the school grounds to be excavated or "mined" and "reclaimed." If possible, choose an area on a slope with no pre-existing erosion problems. (NOTE: This could be simulated on a smaller scale in the classroom by placing soil in a mound in a large container, like a wash tub, and planting it with grass. Use this mound to conduct the activity after the soil has settled and the grass is well established.)

PROCEDURE

I. Setting the Stage

A. Have the students research surface mining, using the library or other resources, during or outside of class time.

1. Each student (or lab team) should write a short paper describing surface mining methods (including both area and contour surface mining and the types of terrain in which these methods are used), equipment, effects on the environment, regulations, and reclamation procedures. Encourage students to use diagrams to describe different methods.

2. Use the students' research to develop an outline on the board.

B. Explain to the students that they will be simulating the effects of strip mining and demonstrating methods to reclaim strip-mined land.

II. Activity

A. Note condition of site before "mining."

1. Take several photographs of the site prior to excavation.

2. Have the students record the data and general appearance of the plot prior to "mining" in their notebooks.

3. Students should note amount and types of vegetation, and the area and approximate slope of the land. (NOTE: This may be estimated or calculated using students' measurements of the rise and run of the slope.)

B. Mine the site.

1. Have the students make several three-foot long cuts along the slope contour, one above the other. (CAUTION: Warn students to be careful when working with picks and shovels.)

2. Photograph the process step by step as you go.

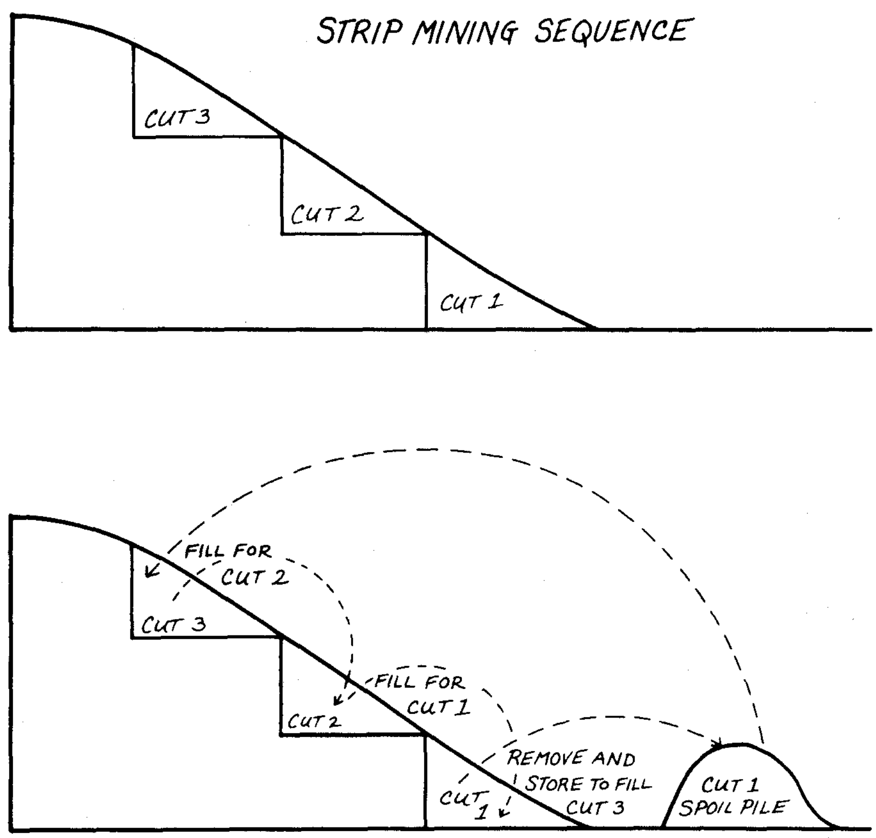
   a. The topsoil should be scraped off first and stored in a separate pile (according to reclamation requirements).

   b. The soil that is dug out with each cut represents the mine spoils.

   c. The spoils may either be deposited in the previous cut or shaped into ridges (spoil banks) two feet below the cuts. The former is a "haul back" method which helps accomplish reclamation simultaneously with mining.

3. When finished, take several photographs to record the general appearance of the freshly mined area.

4. Have the students write observations and notes describing the procedures used in their notebooks.



C. Observe the effects of unreclaimed surface mining.

1. To prevent outside disturbance, rope off the mined area using stakes and string.

2. Leave the mined area unreclaimed at least until it rains.

3. Photograph and record the effects of rainfall on the mine cuts and spoils. (NOTE: You may choose to leave the mine unreclamined for several weeks and continue to document changes in the area.)

D. Reclaim the site.

1. To reclaim the mined area, restore the area to the approximate original contour by filling in the cuts with the spoils and smooth out the soil.

2. Cover the spoil piles with the topsoil.

3. Revegetate the area by planting grass or (with approval from your principal) perennial wildflower seed to establish new plants.

4. Mulch the newly planted area with straw to prevent soil and seed loss from erosion and to retain soil moisture to facilitate plant growth.

5. Photograph the reclamation process and record observations in notebooks at regular intervals. If possible, photograph the plants at full growth.

III. Follow-Up

Develop a visual presentation of the project. Help the students prepare a posterboard display or slide presentation on the project. Assign students to work on different parts of the presentation. Share the presentation with other classes and/or parents.

IV. Extension

A. If a surface mining area is nearby, obtain permission to visit the site with your students. Interview the operator/owner and find out what mining procedures they use and how they reclaim the land. Describe the surface mining operation. How large is it? Where are the mineral deposits in the ground? How are the minerals mined, processed, and transported? Sketch a top view and a cross sectional view of the mining operation and note its geographic location. Is there groundwater seepage in the surface mine? If so, how is the seepage removed? How are the wastes disposed? Do the tailings or seepage cause pollution problems? Why or why not? Is runoff water from the mining operation polluted? How? What are some solutions to these problems? How long have minerals been mined here? What will happen to the land after the mining operation is finished? What laws or regulations must the mining operator follow? Are these enforced? What happens if the regulations aren't followed? If mining is an important component of the local economy, have the students research how much it costs to mine and reclaim an area.

B. Abandoned mines pose perhaps an even greater threat to water quality than active mines. Runoff from abandoned or unreclaimed mines pollute water with acids, heavy metals, and sediment. At some abandoned mine sites, constructed wetlands are being used to trap erosion and acid mine drainage before it travels into a nearby waterway. For example, a constructed wetland has been built at Fabius Mine, an abandoned surface mine in Jackson, Alabama. Have students research what constructed wetlands are and how they cleanse pollutants from water. If a site is located near your school, arrange a visit with the class.

C. If a subsurface mining area is nearby, arrange to visit the operation with your students. Have the students research the water quality problems associated with deep shaft mining. Then examine what is being done at this operation to prevent water pollution.

RESOURCES

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R.I.P. RAIN

OBJECTIVES

The students will do the following:

1. Define pH and acidity.
2. Demonstrate the use of pH indicators.
3. Describe how acid rain forms and what types of environmental damage can result.
4. Describe how acid rain affects plant growth by performing a controlled experiment.
5. Demonstrate measures to prevent or reduce acid rain.

SUBJECTS:
General Science, Earth Science, Life Science, Physical Science, Ecology, Chemistry, Biology, Physics

TIME:
3 class periods

MATERIALS:
pH paper with color chart
common liquids, such as well water, stream water, pond water, puddle water, vinegar, carbonated beverage, coffee, tea, lemon juice, and ammonia
small beakers
concentrated nitric acid (HNO_3)
concentrated sulfuric acid (H_2SO_4)
potting soil or vermiculite
peat pots or paper cups (9 per lab team)
stick-on labels or masking tape
begonia, African violet, or other plants to take cuttings from
distilled water
tap water
10 ml and 100 ml graduated cylinders
data table (included)
graph paper
wide-mouthed jar with lids (optional)
local map (optional)
colored pencils (optional)
large beakers (optional)
funnels (optional)
crushed granite or sand (optional)
local soil (optional)
crushed limestone (optional)
grow light or sun lamp (optional)

BACKGROUND INFORMATION

Acid precipitation is a controversial national and international issue. Experts estimate that the cost for the U.S. to prevent acid rain will equal two percent of the Gross National Product (GNP) in the late 1990s. Many examples of the adverse effects of acid precipitation have been cited but there continues to be discrepancies as to exactly how the damage is caused (or if any damage has occurred), the extent of the damage, who is responsible for it, and how it should be dealt with. Since the pollutants that cause acid precipitation often originate several hundred miles or kilometers from where it falls to earth, the actual sources are especially difficult to detect and control. This is why acid rain is considered to be a nonpoint source pollutant of land and water.

The majority of acid rain is human-caused and results from the burning of fossil fuels by motor vehicles, homeowners for heat, coal-fired power plants, businesses, and other industries. Acid rain also occurs naturally due to volcanic emissions, decaying organic matter, and chlorine and sulfates from ocean spray. Most acid precipitation can be attributed to sulphur oxides (SO_x) and nitrogen oxides (NO_x) which enter the atmosphere in large quantities during burning. These gases are transported by the winds and weather. When these chemicals mix with water vapor, they form sulfuric and nitric acids. Eventually, they fall to the ground in the form of rain, snow, hail, frost, or dew. This precipitation is more acidic than normal. Usually, rain is mildly acid and has a pH of 5.6. This is primarily due to the carbon dioxide in the atmosphere combining with water vapor to produce a weak solution of carbonic acid ($H_2O + CO_2 \longrightarrow H_2CO_3$).

The pH scale ranges from 0 to 14 with 7 being neutral (i.e., distilled/deionized water), less than 7 being acidic, and greater than 7 being alkaline. The pH of natural waters is between 6.5-8.5. Acid precipitation can have a pH of 4 or sometimes even less. For example, in 1978, a lake in the Adirondack Mountains in New York measured a pH of 2.0! Since pH is a logarithmic scale, this means that the lake water was about 100,000 times more acidic than neutral.

While it has not been proven scientifically, acid rain is believed to have seriously disturbed aquatic ecosystems by (1) reducing or halting reproduction of many organisms, (2) increasing deformities in embryos and young fish, (3) reducing numbers of important food organisms for fish, and (4) releasing toxic heavy metals, such as aluminum, cadmium, iron, manganese, and lead, from soils into lakes and streams. Acid rain may also erode human-made structures, such as buildings and statues. However, a recent 10-year U.S. government study could not say conclusively that acid rain caused any detrimental effects.

Problems with the forests of the Adirondack Mountains in New York have been attributed to acid rain, however, the effects of acid precipitation on plant life are not as well understood as those on aquatic ecosystems. Some studies report that acid precipitation destroys the waxy surface on leaves, interferes with gas exchange and transpiration, poisons plants through their transport systems (thus, lowering their photosynthetic capacity), destroys root hairs, and decreases the percentage of seed germination.

Toxic metals, possibly released from the soil by acid precipitation, are more easily absorbed by plant roots. Acidic precipitation may also kill the nitrogen-fixing bacteria and microorganisms that decompose plant litter. Thus, acid rain may tamper with the nutrient cycles that maintain a viable ecosystem. The pH range for optimum growth varies for different plants. The examples in the following table are arranged by increasing pH measures.

Plant	Optimum pH
pine tree	5.0 - 6.0
carrot	5.5 - 6.5
alfalfa	6.0 - 7.0
beans	6.0 - 7.0
lettuce	6.0 - 7.0
oak tree	6.0 - 7.0
dandelion	6.0 - 8.0
radish	6.0 - 8.0

It should be noted, however, that dilute acid rain may improve some plants' growth rate. While it has not been proven scientifically, dilute nitric acid may fertlize some kinds of plants by adding nitrogen to the soil. Dilute sulfuric acid may aid plant growth for those growing in sulfur deficient soil, but too much nitrogen and/or sulfur can also be detrimental to plant growth.

ADVANCED PREPARATION

A. Obtain the plants to be used in this experiment. Make sure they are healthy.

B. Prepare the acid rain solution from the recipes provided. (CAUTION: Wear protective goggles when handling acids.)

C. Collect acid precipitation to be used in the experiment. If you collect your own sample of acid rain, cap it tightly and store it in the refrigerator until ready for use. (NOTE: Allow it to reach room temperature before use.)

D. Copy "Data Table" handout (included).

PROCEDURE

I. Setting the Stage

A. Discuss with the students the nature of the acid rain problem and list sources of pollutants that cause it.

1. Have students help demonstrate how to use pH indicator paper to determine the acidity of common substances and the prepared acid rain solutions.

2. Compile the data in a table and have students draw a pH scale and rank each substance tested on the scale.

B. Discuss with the students what pH means. They should realize that a pH scale is a logarithimic scale. A substance with a pH of 3 is ten times more acidic than one with a pH of 4. A substance with a pH of 2 is one thousand times more acidic than one with a pH of 5.

C. Discuss the possible effects acid precipitation may have on water bodies and aquatic organisms. Note information about the possible negative effects of acid rain on plant life. Point out that effects of acid precipitation on plant life are not as well understood as the effects of acid rain on aquatic ecosystems.

D. Tell the students they will be demonstrating the effects of acid rain on plant growth.

II. Activity

A. Practice using pH paper.

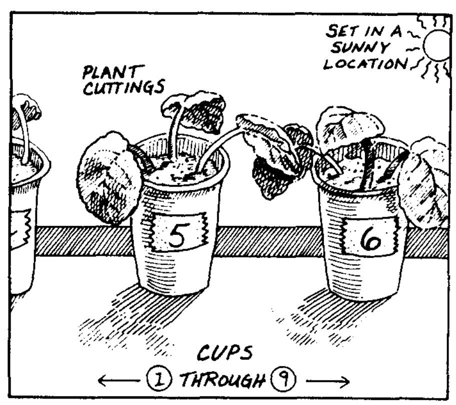
B. Pot plants for the experiment.

1. Have each lab team obtain nine pots/cups.

a. Label 1-3 as distilled water.

b. Label 4-6 as tap water.

c. Label 7-9 as acid precipitation. (NOTE: The potting procedure may require a whole class period.)



2. Fill each pot or cup with the same amount of soil. Then water with distilled water, tap water, or the acid rain solution depending upon the treatment.

3. Place 3 leaf cuttings from plants provided into each pot or cup. Make sure that each lab team uses the same type of leaves and the same amount of soil.

4. Record the potting date in the data table.

5. Place all the containers in a location where the leaves will be at the same temperature and receive the same amount of sunlight. (NOTE: If sunlight is unavailable, use grow lights or a sun lamp.)

6. CAUTION: Have the students wash their hands after the potting operation is completed.

C. Treat plants with solutions.

1. Determine the pH of the distilled water, tap water, and acid rain solution. Record these in the data table.

2. You might have students write down their hypotheses as to which leaf's roots will grow the fastest and which will grow slowest.

3. Water each cutting with the same amount of solution. Record the amount of solution added to each plant daily. (NOTE: Do not overwater the plants; the soil should be moist to the touch.)

4. Students should observe the leaves daily. Record observations in the data table.

5. Each week, remove one cutting and measure root lengths in inches (millimeters) and record the data in the data table. Also, draw a picture or write a description of the leaf and its roots. (CAUTION: Have the students wash their hands after handling soil.)

6. Observe the leaves for three weeks.

D. Discuss the results.

1. Have the students graph their results for each of the pots or cups as time (in weeks) vs. root length (in or mm).

   a. What do their results indicate?

   b. Which pots or cups were the experimental control?

   c. Why were replicates used in the experiment?

   d. In which pot or jar did the roots appear to grow longer?

   e. In which pot or jar did the roots appear not to grow?

   f. What were the corresponding pH readings of the solutions used to water the plants?

   g. Does the data you collected support your hypothesis?

   h. How did the acid precipitation affect the growth of the plants?

2. Discuss possible sources of acids.

   a. What are natural sources of acid precipitation? (volcanoes, plant decay, chlorine and sulfates from ocean spray)

b. What are the sources of human-made acid precipitation? (Coal-burning, power plants and industries, cars and other forms of transportation which burn fossil fuels, and homes which burn heating oil or natural gas.)

c. Where in the U.S., Canada, and the world are the problems of acid precipitation worse? Why? (Northeastern U.S., Central Ontario, Sweden, England; problems seem to be worse in areas where the bedrock is igneous such as granite or nonreactive such as sandstone as opposed to limestone which contains calcium carbonate, a pH buffer.)

3. Discuss solutions.

a. What might be done to reduce the acid rain problem? [Reduce dependence on fossil fuels, practice energy conservation measures such as drive less, and keep thermostats on 68°F (20°C) in winter and 72°F (22°C) in summer.]

b. What is currently being done to help correct the acid rain problem? (catalytic converters, scrubbers on power and industrial plants, research)

III. Follow-Up

A. Sample rain locally to determine the extent of the acid rain problem in your area.

1. Using a local map, select sites at which students (or lab teams) will collect samples of rain. Try to cover as large an area as possible within your watershed.

2. When it rains, students should go to their assigned sites with clean, dry, wide-mouthed jars with lids. The containers should have been previously rinsed with distilled water. They should place their open containers in spots where rain can fall directly into them and collect about an inch (2.2 centimeter) of water. They should label and cap their jars tightly and store them in a cool place until ready to use in class.

3. Students should also record the direction of the wind before and during the rainstorm, the date, and time of collection. Since some experts claim that the rainfall earlier in a storm is more acidic than that later in a storm, you might also incorporate this variable in the study design.

4. In class, have the students determine the pH of their rain samples using pH indicator paper.

5. Compile the class data and color code the local map to show the value of the pH of the rain at each sample site. Is there a pattern? Did the direction of the wind play a factor? Why or why not? Was the rain earlier in the storm more acidic? What might be the sources of the acids?

B. Investigate the geology of an area.

1. What affect might limestone bedrock have on acid rain?

a. Pour an acid rain solution through separate funnels of crushed granite or sand, local soil, and crushed limestone. Collect the runoff in a separate beakers.

b. Compare the pH of the runoff from each of these to the original pH of the acid precipitation.

c. How did each of the substrates affect the pH of the acid precipitation?

2. Define buffering capacity to the students.

   a. Which substrates had buffering capacity? Why?

   b. Why is limestone or lime being used as a measure to lessen the effects of acid precipitation?

3. Have the students research the use of lime in the Adirondack Mountains. Why do they need to use lime? Does it work? Why or why not?

IV. Extension

A. Have the students write the Forest Service, the U.S. Department of Agriculture, and the Environmental Protection Agency, or Environment Canada or provincal environmental ministries in Canada for more information about the effects of acid rain and what is being done to control this problem.

B. You might also arrange a visit to a power plant where scrubbers are being used to control sulfur oxide emissions or have someone from the automobile industry explain how auto emission controls on cars work.

RESOURCES

Global Science: Energy, Resources, Environment, Laboratory Manual, Second Edition, and Teacher's Guide, "(Acidic) Raindrops Keep Falling," "What's My Plant," and "More Raindrops Part II: Effect of Acid Rain on Plants," Kendall Hunt Publishers, Dubuque, Iowa, 1981, pp. 217-223 and 250-251.

The Class Project, "The Gentle Rain," National Wildlife Federation, Washington, D.C., 1982, pp. 29-32.

"Acid Rain," The Energy Sourcebook - High School Unit, Tennessee Valley Authority, 1986, pp. C-26-C-30.

ACID RAIN SOLUTION RECIPES

1. Solutions using nitric acid. (NOTE: Be sure that these solutions are thoroughly mixed and the pH of each is stable before they are used.)

   A. pH 1 = 6.5 ml concentrated HNO_3 per liter of solution. This solution of nitric acid and distilled water may be used as a stock solution. It is a 0.1 M solution.

   B. pH 2 = 20 ml of 0.1 M solution (pH 1) + 180 ml distilled water, creating a 0.01 M solution.

   C. pH 3 = 20 ml of 0.01 M solution (pH 2) + 180 ml distilled water, creaing a 0.001 M solution.

   D. pH 4 = 20 ml of 0.001 M solution (pH 3) + 180 ml distilled water, creating a 0.0001 M solution.

   E. pH 5 = 20 ml of 0.0001 M solution (pH 4) + 180 ml distilled water, creating a 0.00001 M solution.

   F. pH 6 = 20 ml of 0.00001 M solution (pH 5) + 180 ml distilled water, creating a 0.000001 M solution.

2. Solutions using sulfuric acid. The following solutions of H_2SO_4 may be used in place of the HNO_3 solutions. (NOTE: The pH of the stock solutions must be stable before they are used. As you add drops of H_2SO_4 be sure the solution is thoroughly stirred and that you measure the pH carefully. The number of drops recommended for each solution is approximate, so it is important that you take several pH measurements for each solution.)

   A. 500 ml of distilled water ≈ pH 7

   B. 500 ml of distilled water + approximately 5 drops of 10% H_2SO_4 ≈ pH 6

   C. 500 ml of distilled water + approximately 15 drops of 10% H_2SO_4 ≈ pH 5

   D. 500 ml of distilled water + approximately 25 drops of 10% H_2SO_4 ≈ pH 4

   E. 500 ml of distilled water + approximately 30 drops of 10% H_2SO_4 ≈ pH 3

   F. 500 ml of distilled water + approximately 35 drops of 10% H_2SO_4 ≈ pH 2

   G. 500 ml of distilled water + approximately 40 drops of 10% H_2SO_4 ≈ pH 1

Name ______________ Type of Plant ______________ Date of Potting ______________

DATA TABLE

Day#	Amount of solution added (in ml)	Distilled Water pH =			Tap Water pH =			Acid Precipitation pH =		
		Jar#	Root Length (Once a Week)	Daily Observations	Jar#	Root Length (Once a Week)	Daily Observations	Jar#	Root Length (Once a Week)	Daily Observations

LETHAL LOTS

OBJECTIVES

The students will do the following:

1. Explain how bioassay methods are used to determine toxicity.
2. Use Daphnia to determine the toxicity of an urban runoff water sample.
3. Explain how routine human activities and urbanization contribute to nonpoint source pollution of our water supplies.

SUBJECTS:
General Science, Earth Science, Life Science, Ecology, Biology, Chemistry

TIME:
3 class periods

MATERIALS:
3 liters runoff water from school parking lot (collect during or after a storm)
clean sponge, turkey basters, window cleaning squeegee, or rulers and clean dust pans to collect a sample
plastic containers with lids to store sample
50 live Daphnia (available from a biological supply company)
5 gallon (20 l) or larger aquarium or container
Daphnia food (recipe included)
aquarium
aerator
compound microscopes
microscope slides and coverslips
blender
1 floating aquarium thermometer
grease pencil or permanent ink pen
stick-on labels or masking tape (to label beakers)
30 eyedroppers
one 50 ml graduated cylinder
five 500 ml beakers
thirty 50 ml beakers
2 cycle semi-log graph paper
Saturation Concentration of Dissolved Oxygen handout (included)
data sheet (included)
water quality test kit (optional)
Daphnia anatomy review sheets (optional; available from Carolina Biological Supply Company; address included)

BACKGROUND INFORMATION

Daphnia (water fleas) are small freshwater crustaceans that are food sources for many other animals. They are very sensitive to changes in temperature and water chemistry. For this reason, they are sometimes used for detecting the presence of toxic substances in a water supply. However, because Fathead Minnows are more reliable, they are commonly used by commercial laboratories. The examination of such organisms to detect the presence and relative amounts of toxic substances in a water supply is called biomonitoring. The technique used in this activity is called a bioassay. A bioassay is a method used to test the concentration of a substance by observing its effects on the growth of an organism under controlled conditions.

Toxic chemicals in a water supply can harm the plants, animals, and humans that depend on it. Toxic chemicals and other pollutants can enter a water supply from many sources, such as urban and rural polluted runoff, leaking landfills, and mining areas. Toxic chemicals from a parking lot, for example, might include road salt, oil, antifreeze, brake fluid, lead, chromium, cadmium, iron, and manganese.

Runoff from large areas of pavement is likely to contain pollutants. Since none of the water or pollutants can be absorbed through the pavement, the water is unfiltered. In this activity, the toxicity of the runoff from the school parking lot will be determined.

ADVANCED PREPARATION

A. Order Daphnia from a biological supply company and obtain the necessary ingredients to produce the Daphnia culture medium and food (see recipes provided).

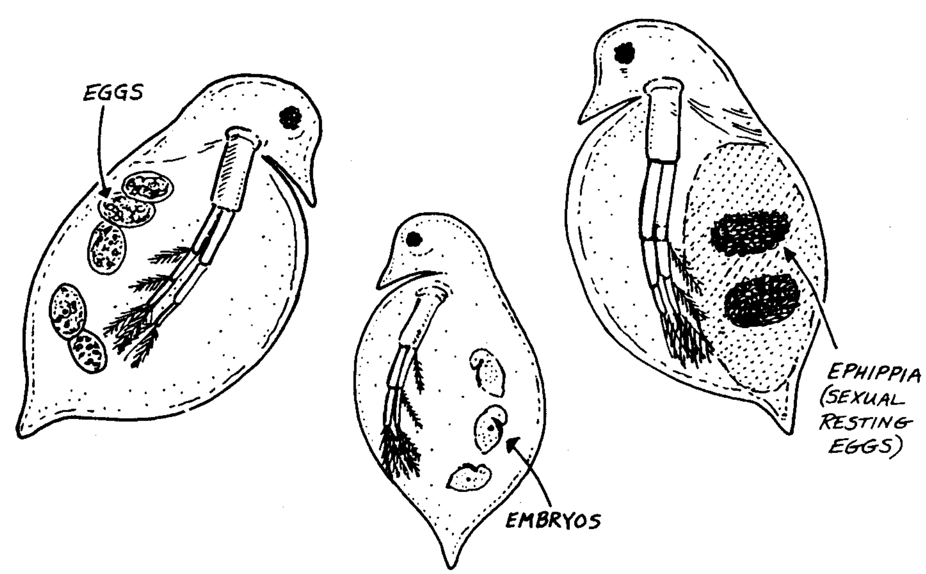
1. When the Daphnia arrive, acclimatize them to the laboratory or test room temperature in the container they came in before adding them to a 5 gallon (20 liter) or larger aquarium in the culture medium.

2. Have food mixture ready. Daphnia should be fed once a day with five ml of food when they are in a 5 gallon (20 liter) container. (NOTE: Adjust the amount of food to the volume of the container. CAUTION: Do NOT overfeed!) Use an aeration system to maintain good dissolved oxygen.

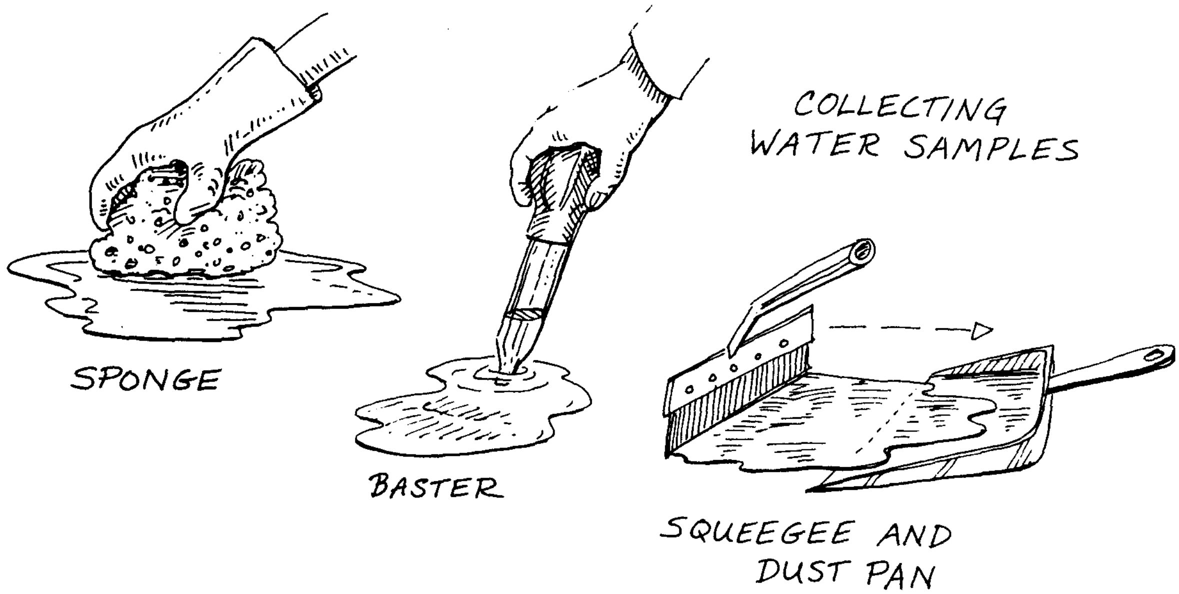
3. Two or more days before the experiment, prepare new culture media to be used in the experiment according to the recipe provided.

4. Check the Daphnia one day prior to running the experiment to ensure that the culture is healthy. If 10 percent or more of the Daphnia die between their arrival and this time, you should reorder. [CAUTION: Since Daphnia are very sensitive to changes in the water chemistry and temperature, they must be protected from perfume, hairspray, smoke, bug spray, etc., and the room temperature should be kept at a fairly constant 68°F (20°C).]

Daphnia - with sexual eggs vs. embryos



B. Collect approximately 3 liters of runoff water from the school parking lot during a rainstorm in a clean container with a lid and store in the refrigerator (up to 2 weeks) until two days before the experiment. Check local weather forecasts to determine when it will rain. Rainwater can be collected from parking lot surfaces in three ways, using: (1) a clean sponge to absorb the water and wringing it out into a container, (2) a turkey baster to siphon water and squeeze it out into a container, or (3) a window cleaning squeegee or ruler to push water into a dust pan and pour into a container. Water may also be collected directly into containers at points where it runs out of drain pipes or into sewer grates. (NOTE: It is best to conduct the experiment as soon as possible after collecting the runoff. Choose a day to begin and make the following preparations.)



1. The day before the experiment, place an aquarium thermometer in a separate beaker of runoff water to ensure that it is at room temperature before adding Daphnia.

2. When the water is at room temperature, place 10 Daphnia containing embryos in each of five 500-ml beakers with 300-ml of culture medium and 0.5 ml food. (See diagram to determine what Daphnia with embryos look like.) Follow the directions supplied with the test kit. (NOTE: Do not pour Daphnia directly into culture medium as air bubbles may become trapped underneath the Daphnia causing them to float to the surface and die.)

   a. Use an eyedropper and release them slowly into the medium.

   b. Do not use Daphnia with Ephippia or dark sexual eggs (see diagram included). Ephippia are a resting stage in reproduction. New Daphnia will not hatch from them in time for the experiment.

   c. Use the newborn Daphnia found in the beakers the next day for the experiment. Newborns will be smaller than the parent. Newborns are used to eliminate some sampling error from the experiment because this assures all organisms used in the experiment are the same age. (NOTE: If time does not allow for this step or there are too few newborn Daphnia in this culture, be sure none of the Daphnia used in the experiment contain embyros or Ephippia.)

3. If a water quality test kit is available, check the dissolved oxygen (DO) of this sample. Follow the directions supplied with the kit to determine DO. [NOTE: For the experiment to be valid, the DO must be 40 percent saturation or greater (see Saturation of Dissolved Oxygen handout, included), otherwise, the Daphnia will be stressed and die from low DO.]

PROCEDURE

I. Setting the Stage

A. Discuss with the students the role of urban runoff as a nonpoint source of pollution.

1. Note that urban runoff can be a source of toxic chemicals.

2. Point out that pavement runoff is likely to contain toxic chemicals since it is "unfiltered." What types of toxic chemicals could be in the runoff? What are the sources of these toxic chemicals?

B. Discuss biomonitoring.

1. Note that some organisms are more sensitive to pollutants than are others. Why are these sensitive organisms good indicators of water quality? (It is easier to detect low concentrations of pollutants with sensitive organisms.)

2. You may want to point out that Lake Erie still had fish in it even when it was seriously polluted. The fish that tolerated the pollution, such as smelt, replaced commercially valuable sportfish such as lake trout and white fish. These latter species were more sensitive to pollution and, hence, were among the first species to disappear.

3. Point out that the disappearance of certain plants or wildlife in a water body is an indicator of changing water quality.

4. Toxic chemicals can enter a water supply from many sources such as agriculture, mining, urban areas, construction sites, landfills, farms, and forestry operations.

5. Runoff from large areas of pavement is likely to contain pollutants since it cannot penetrate the pavement and travels unfiltered to the nearest water body.

6. Urban stormwater runoff may contain sediment, debris, and toxic chemicals such as herbicides, pesticides, oil, antifreeze, road salt, and heavy metals.

C. Explain what a bioassay is and why organisms such as Daphnia (water fleas) and Fathead Minnows are often used in water quality laboratory tests.

D. Briefly explain what kind of organism Daphnia is. Tell the students that in this experiment, they will be using Daphnia to determine the toxicity of the runoff from the school parking lot.

II. Activity

A. Introduce the students to the organism, Daphnia.

1. Divide the students into teams of two.

2. Give each team a compound microscope and Daphnia anatomy review sheet. (See Resources section to order.)

3. Allow the students to take turns observing Daphnia on slides.

4. Review Daphnia anatomy and go over how to distinguish between Daphnia with embryos or Ephippia. (See diagram included.)

B. Prepare the experiment.

1. In the laboratory or test room, have the students prepare and label four 50-ml beakers of each of the following concentrations of runoff water. Each student or pair of students will be responsible for setting up and recording results of one of the beakers.

Concentrations	Runoff Water	Culture Medium
100%	40 ml	0 ml
50%	20 ml	20 ml
25%	10 ml	30 ml
10%	4 ml	36 ml
5%	2 ml	38 ml
2.5%	1 ml	39 ml

2. Have the students label each beaker using a grease pencil. The labels should contain information including the date, temperature, and a space should be left to record the time when the experiment begins.

3. If a dissolved oxygen test kit is available, select students to prepare and label two beakers of undiluted runoff water to determine the DO of the undiluted samples at the beginning and end of the experiment to rule out DO stress. (NOTE: The DO should be at 40 percent saturation or greater. Other optional tests you may want students to perform include pH, alkalinity, and hardness.)

4. When the beakers are ready, select other students to introduce five Daphnia (newborns) into each of the beakers.

   a. Use an eyedropper to capture the Daphnia and transfer them to the test beakers.

   b. Record the time and date of introduction on each beaker.

   c. Do not collect Daphnia from the top or bottom of the container. Use only those that are swimming freely in the middle of the culture medium.

   d. CAUTION: Do not feed the Daphnia during the experiment.

C. Observe and record results.

1. Have the students count the number of dead Daphnia in each beaker at the end of 24 hours and 48 hours and record the results in a data table you have drawn on the chalkboard. (NOTE: Dead Daphnia will be lying on the bottom of the beaker and will not respond to gentle prodding.)

2. Each student or a pair of students could be responsible for setting up and recording the results of one of the beakers. However, all students should copy the data from the board onto their data tables.

3. Distribute 2-cycle semi-log graph paper to each student (or lab team).

a. Briefly discuss with students what logarithms are and what semi-log graph paper is.

   1) A logarithm is a kind of exponent. For example, if $n^x = a$, the log of "a" with "n" as the base is "x." If $10^2 = 100$, this means the log of 100, with 10 as the base is 2.

   2) Semi-log paper is a type of graph paper with a logarithmic y-axis. Data that forms a curve when plotted on regular graph paper will form a straight line on semi-log paper making it easier to extrapolate points.

   3) On 2-cycle semi-log paper, the lower half of the paper goes between 1-10 in logrithmic steps on the y-axis and the upper half goes from 10-100 in the same fashion.

b. Have them plot percent mortality (on the linear, x-axis) versus percent concentration (on the y-axis) and visually fit a line to the data. Be sure they have clearly labelled the axes. (See Sample Graph included.)

D. Have the students determine the LC50 or lethal concentration for the experiment.

1. Explain that an LC50 is the concentration where 50 percent of the Daphnia died.

2. On the percent concentration scale (x-axis), have students locate the point at which 50 percent mortality occurred. This point is the LC50 (or lethal concentration where 50% mortality occurred) for the experiment expressed as percent parking lot runoff volume. For example, if 25 percent concentration treatment results in 50 percent mortality, then report the LC50 as 25 percent. (NOTE: If the 2.5% concentration treatment results in greater than 50% mortality, report LC50 as less than 2.5% or repeat the procedure using a diluted sample.)

E. Discuss the results.

1. Why were four beakers of each concentration used? (Replicating experiments gives more accurate results.)

2. What is the purpose of the control? (To make sure other factors besides the runoff didn't kill the Dapnia.)

3. Why do some Daphnia die before others? (Some are more sensitive than others.)

4. Why is an LC50 used instead of an LC100? [LC50 is more exact. It is difficulut to extrapolate that because 100 percent of the organisms are dead (LC100), the concentration used in the experiment killed them.]

5. On the basis of your results, would you consider the runoff from the school parking lot to be toxic? (Answers will vary depending on results.)

6. Daphnia are not widely used by commercial laboratories because they can be unreliable. Ask the students how can they be sure the Daphnia were killed by toxic substances? Ask them what other factors could kill Daphnia? (If it weren't for the toxic substances, the control organisms would have died also. Low dissolved oxygen content, temperature range.)

7. How can they make sure these factors are controlled? What else could they do? (Close monitoring, testing before and during experiments, and addition controls.)

8. Note that bioassay tests are often replicated several times even in commercial laboratories to make sure it was toxic substances in the water and not other factors which killed the organisms. Repeat the test with the same water, if possible. Were the results the same?

III. Follow-Up

A. Survey the parking lot and identify sources and types of pollutants which are likely to be in the runoff.

1. Discuss ways to decrease the chance of these pollutants getting into our water supplies.

2. Invite someone from the State Department of Water Quality or a civil engineer to visit your parking lot with the class and discuss what best management practices (BMPs) could be used on your site to prevent pollution from being funnelled directly into water bodies. Options might include diversion ditches or grass filter strips. Ask them what kind of regulations would be useful?

3. Develop a written Best Management Plan for your school parking lot and work with school officials to get it implemented.

C. Determine the amount of runoff from the parking lot. (See the activity "All Messed Up and No Place to Go.")

D. Determine the toxicity of local stream water or agricultural runoff using this bioassay method.

RESOURCES

Adapted from "Using Daphnia to Detect Environmental Toxicity," TVA Teacher/Student Water Quality Monitoring Network, Tennessee Valley Authority, Norris, Tennessee, 1991.

Adopt-A-Stream Teacher's Handbook, Delta Laboratories, Rochester, New York 14607, 1987.

"Bioreference Sheet on Daphnia," and Daphnia cultures, Carolina Biological Supply Company, Burlington, North Carolina 27215.

Cole, Gerald A., Textbook of Limnology, 3rd Edition, CV Mosby Company, St. Louis, Missouri, 1983, pp. 84-86.

Pennak, R. W., Freshwater Invertebrates of the United States, 2nd ed., Wiley and Sons, New York, New York, 1978.

Daphnia FOOD

- Ingredients:

  6.3 g tropical fish food
  2.6 g yeast
  0.5 g alfalfa
  500 ml distilled water

- Blend all ingredients for five minutes on low speed. Cover and let stand in refrigerator one hour. Pour off top liquid and save in refrigerator. Dispose of the rest.
- Feed once a day.
- Make a new batch of fresh food weekly if possible. (A batch may be used for up to two weeks.)

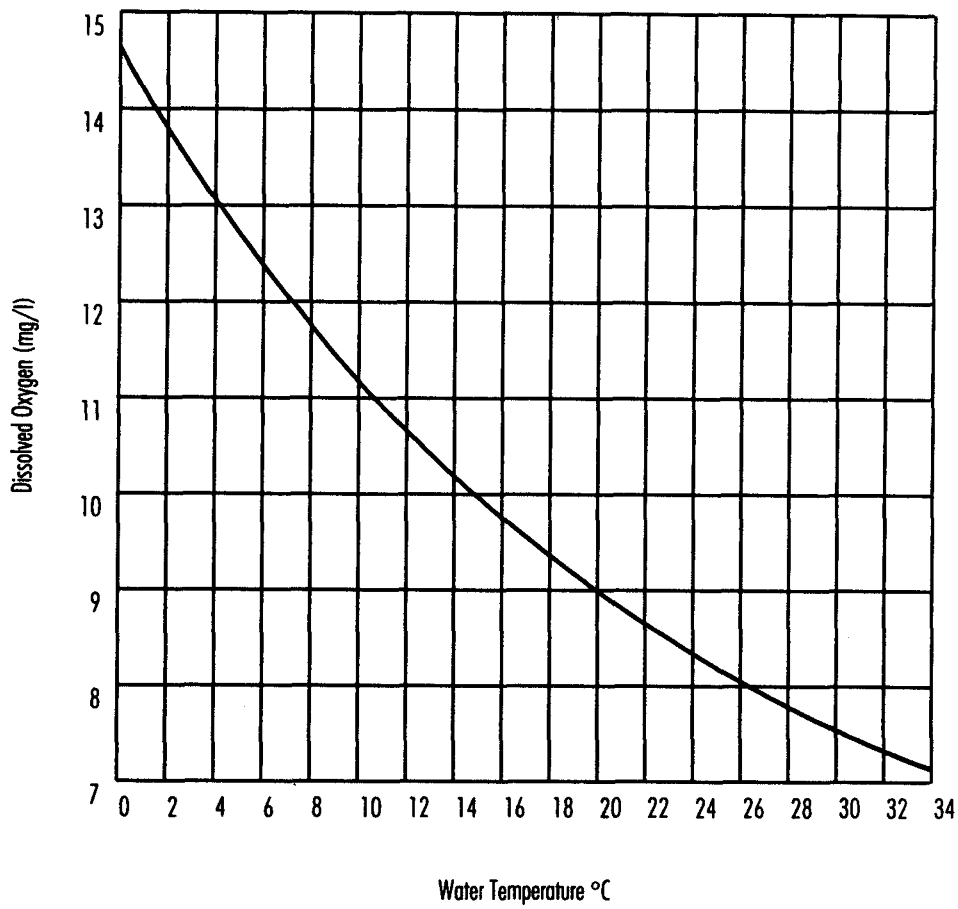
Daphnia CULTURE MEDIUM

- Fill a clean 20 liter container to the 19 liter mark with distilled water.
- Pour out approximately 500 ml into a separate clean beaker and completely dissolve the following chemicals in it before adding back to the 20 liter container:

  2.88 g $NaHCO_3$
  1.80 g $MgSO_4 \times 7H_2O$ (Epsom salt)
  0.12 g KCl

- Remove another liter from the 20 liter container into another clean container, add 1.80 g $CaSO_4$. Add this mixture back to the 20 liter container.
- Aerate the mixture for two hours using an aquarium aerator.
- Allow the mixture to reach room temperature before adding any *Daphnia*.

SATURATION CONCENTRATION OF DISSOLVED OXYGEN (IN FRESHWATERS AS A FUNCTION OF WATER TEMPERATURE)



The line on the graph above indicates 100% saturation concentration of dissolved oxygen at certain temperatures. To determine the percent saturation concentration of a sample, measure the DO and temperature of the sample and find the DO concentration for 100% saturation concentration at the sample temperature. Divide the DO concentration of the sample by the DO concentration from the graph and multiply by 100. For example, if your sample had a DO of 8 mg/l (ppm) and the temperature was 20°C, you would look at the graph and see that 9 mg/l DO is 100%. Divide 8 by 9 and multiply by 100. The percent saturation concentration of dissolved oxygen of your sample is 88.8%.

Name(s) ______________________ Date ______________

LETHAL LOTS

Site Name ______________________

Test Organism ______________________

Beginning Date/Time ______________________

Ending Date/Time ______________________

Your Sample:

Beaker # ______________

Concentration ______________

Dillution ______________

CHEMISTRY:

Test	Beginning	24-Hour	48-Hour
Temp.			
*DO			
*pH			
*Alkalinity			
*Hardness			

24-HOUR TEST/GROUP RESULTS:

Beaker #	# of Daphnia alive at concentrations					
	100%	50%	25%	10%	5%	2.5%
1						
2						
3						
4						
Control						

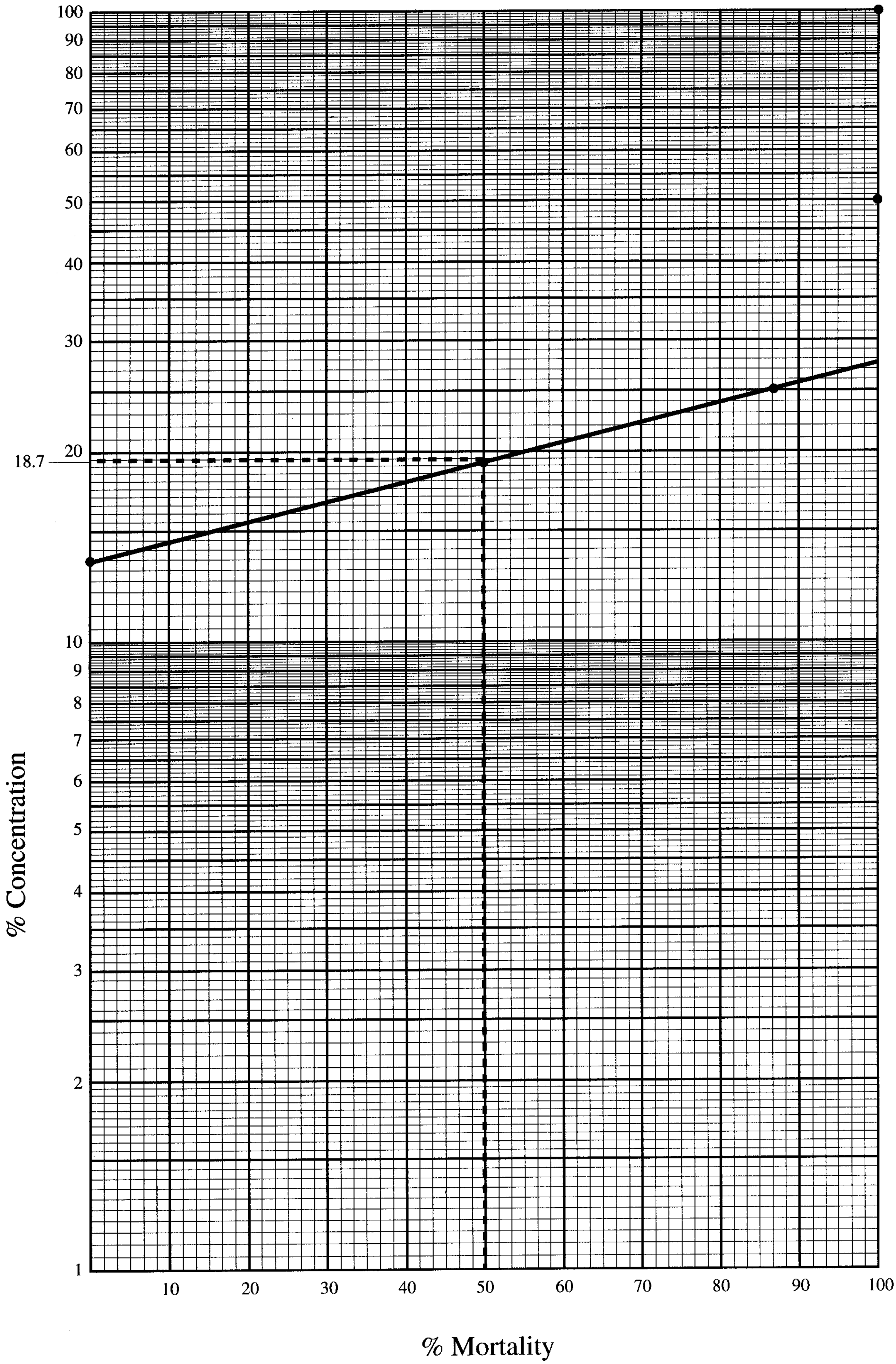
48-HOUR TEST/GROUP RESULTS:

Beaker #	# of Daphnia alive at concentrations					
	100%	50%	25%	10%	5%	2.5%
1						
2						
3						
4						
Control						

*Suggested tests using water test kit (optional).

Teacher Sheet

SAMPLE GRAPH



HOME IS WHERE THE HAZARD IS

OBJECTIVES

The students will do the following:

1. Explain how a homeowner can contribute to the problem of urban nonpoint source pollution.
2. Describe the household waste stream and how harmful household products reach water bodies.
3. Explain which products found in their homes can become potential pollutants, determine which environmentally safer products could be substituted for the potentially hazardous products, and determine how to safely dispose of household products.

SUBJECTS:
General Science, Earth Science, Ecology, Biology, Chemistry

TIME:
2 class periods

MATERIALS:
handout of figures and tables (included)
Home Survey (optional, included)
local map (optional)

BACKGROUND INFORMATION

Americans throw away more trash every day than any other nation in the world. On the average, Americans discard four pounds of trash per day per person or 1,460 pounds (660 kg) a year. Most of this waste is disposed of in landfills, almost 160 million tons (320,000,000,000 pounds; 144,800,000,000 kg) of municipal garbage every year.

Not only are Americans disposing of more waste, we are disposing of different kinds of wastes. We are using many materials that did not exist 50-100 years ago. There are new chemicals, medicines, insecticides, home permanents, detergents, plastics, paints, synthetic rubbers, glues, and so on. These products contain materials that do not exist in nature and are not broken down naturally in the soil or water by bacteria or fungi. Some of these new kinds of wastes can injure living things and are called hazardous wastes. A hazardous waste is any discarded substance whose chemical or biological nature makes it potentially dangerous to people and other organisms in nature. People have always produced hazardous wastes. But in the twentieth century, the amount produced has increased substantially!

In this "age of convenience," people use more potentially hazardous products in our homes than ever before. Common home hazardous wastes include transmission fluid, antifreeze, paint, paint thinner, batteries, fluorescent lamps, insecticides, flea powder, epoxy, oven cleaner, drain openers, metal polish, chlorine bleach, lighter fluid, shoe polish, expired prescription medicines, home permanents, nail polish, disinfectants, and toilet bowl cleaners. The list can go on and on. Used motor oil, while not considered hazardous by U.S. law, can also pose serious health risks to humans and the environment if it is deposited into storm sewers.

Most home hazardous wastes are being disposed of in sanitary landfills not designed to prevent them from polluting groundwater supplies. A sanitary landfill is a large outdoor place for waste disposal where waste is layered and covered with soil each day. Current EPA standards require double liners and leak detection systems to prevent contaminated leachate in landfills from percolating into the ground and polluting water supplies.

However, some harmful home wastes are disposed of improperly. For example, homeowners sometimes dispose used motor oil or leftover fertilizers and pesticides by pouring them on the ground or into storm sewers. Sinkholes, ravines, and abandoned water wells are sometimes used to dump garbage. Dumping garbage uncovered onto the ground, or depositing wastes directly on the land where wastes are exposed to the atmosphere, is called open dumping. Many people do not realize there is a connection between what is deposited on land and water pollution. People need to be made aware that improper waste disposal practices can cause water pollution. However, the best solution to this problem is to reduce the amount of waste generated, substitute safer products, reuse and recycle products, and use other disposal alternatives such as composting.

ADVANCED PREPARATION

A. Make one copy per student of figures and tables.

B. Make one copy per student of the home survey (optional).

PROCEDURE

I. Setting the Stage

A. Explain that homes are filled with products to make life easier, but they can become pollutants when "thrown out with the trash."

B. Have the students guess how much waste each person throws out in a day (average number of pounds or kilograms).

C. Point out that the average household contains 3-10 gallons (or 10-40 liters) of materials that are potentially harmful to human health or the environment. Then discuss what kinds of waste can be hazardous. Have each student list these materials and estimate the volume of combined hazardous chemicals in his/her home. These may include pesticides, herbicides, fertilizers, oil-based paints, solvents, car batteries, and expired medicines.

D. Discuss what happens to the chemicals in "empty" containers (flea powders, bleach, drain openers, etc.) that, in the course of their use, enter water bodies either directly or indirectly (flushing the toilet).

E. Explain what leachate is. As rainwater percolates through the landfill, rotting garbage decomposes and forms a syrupy liquid called leachate. Leachate can seep into the ground and pollute groundwater. It can contain sediment, bacteria, nutrients, and toxic chemicals.

F. Note that people can reduce nonpoint source pollution from household activities by (1) reducing the use of potentially harmful household, garden, and automotive products; (2) substituting safer products where they can; and (3) reducing the volume of waste they generate.

G. Explain that they are going to closely examine household product use, polution potential, and alternatives to potentially harmful products.

II. Activity

A. Conduct investigation.

1. Divide the students into teams of 2-3.

2. Distribute a copy of Figure 1, Table 1, and Table 2 to each team.

3. Using Tables 1 and 2 and the key on Figure 1, have the students decipher the code for the symbols used to represent the types of pollutants associated with the numbered household sites. (NOTE: The types of pollutants refers to the four major categories—sediment, nutrients, bacteria, and toxics.)

4. Record the symbols in Table 1 in the appropriate rows.

5. In Table 1, have the students list specific solutions to reduce the potential nonpoint source pollution from each household site.

   a. What current practices contribute to nonpoint source pollution?

   b. How could they reduce this nonpoint pollution?

B. Review how household toxic substances can enter waterways as nonpoint sources of pollution. (NOTE: If their home has a septic tank, wastes dumped down the drain or toilet are nonpoint pollutants. If their home is hooked to the municipal sewer system, dumping wastes down a drain or toilet is a potential point source pollutant instead.)

III. Follow-Up

A. Conduct home survey.

1. Have the students make a list of all the cleaning products and other substances they use. Then have them write down all of the ingredients in these products. (NOTE: You may want to concentrate on different areas in the home such as under the sink, in the garage, or in the medicine cabinet. Or you might want to have them monitor their garbage cans or drains such as the sink, tub, toilet, or washing machine, and make a list of what is going where.)

2. Have the students examine the ingredients in household products they listed from their homes and, using Table 3, determine the proper disposal practices of these substances.

   a. What toxic substances may reach a water supply through surface runoff?

   b. What toxic substances may reach a water supply from a leaking landfill?

   c. If hooked to municipal sewer system, what products end up at the wastewater treatment plant?

   d. If they live in a home with a septic tank, what toxic substances go down the drain and into the backyard?

   e. How many students use groundwater as their primary source of drinking water? What toxic substances could reach their water supply?

B. Investigate one product.

1. Ask the students to select a potential nonpoint source pollutant, preferably a household product they can bring from home.

2. Have them determine the following:

   a. Why is this product a potential nonpoint source pollutant?

b. What toxic substances does this product contain?

c. What is the typical disposal method? What is the proper procedure for disposal?

d. What alternative products could be substituted? Are they safer for the environment? Why?

e. Have students bring the alternative products to class.

f. You may also have them conduct research to find safer alternative products to substitute for the hazardous ones and produce advertisements for these products.

3. When the students have completed their research, have each student present information on his/her product, the safer alternative, and their advertisements to the class.

4. After the presentations, ask the class to develop a plan to reduce the use of all potentially harmful substances in their homes. Have this plan typed up and give a copy to each student to take home.

5. You might also give students a copy of Table 3 for a home reference.

IV. Extension

A. Have your class visit a local open garbage dump. (CAUTION: To avoid potentially risky situations, visit the site yourself before bringing the students. Check to see if there is safe access to the site, ample parking, and that students can view the site without coming in contact with the garbage. If the site is on private property, get landowner permission in advance. NOTE: Parental permission should be obtained in advance.)

1. Discuss the difference between an open dump and sanitary landfill. Which is more likely to be a nonpoint source of pollution?

2. Have the students identify the site's location on a map and estimate the size of the dump.

a. Why do people living in surrounding areas use this area as a solid waste disposal site?

b. What type of garbage do they dump?

c. What kinds of nonpoint problems could result from this site?

d. Is there any evidence that animals inhabit the dump? What kinds of animals? Do they present health and safety problems? Be sure to include animals such as flies and mosquitoes, rats, raccoons, dogs, and cats.

3. Briefly describe the uses of the land areas immediately adjacent to the dump property.

a. Are they residential, farmland, or public land?

b. What are property values in this area?

c. What kinds of problems does the dump present to adjacent landowners?

d. Are there any waterways within or near the dump site? Do they receive runoff water from the refuse area?

e. What problems might the dump cause for native communities of living things? What other evidences of pollution can you find in the dump area?

4. Consider alternatives.

a. What waste disposal alternatives are there for the people using this dump?

b. Is there a sanitary landfill or some "greenbox" system nearby?

5. Discuss how the people dumping here could reduce the amount of waste they generate. Recycling of certain wastes might be a good example. Can the disposal site be reclaimed? How? What could you or your class do to remedy this problem?

6. If this is a case of illegal dumping, decide if you or the class should get involved in this type of controversy? Why or why not? If possible, you may want to involve the class in getting the site cleaned up. The first step is to contact the local waste authority.

B. Have your students drive around the area and map open dumping or garbage problems using a city map or a topographic map. Have them write down the address and a description of the problem and bring it back to class. You may want to have them take pictures. Invite a local government official to the class and share the results. Investigate how the class can work to correct the problem.

RESOURCES

Hazardous Wastes from Homes, Enterprise for Education, Inc., Santa Monica, California, 1986.

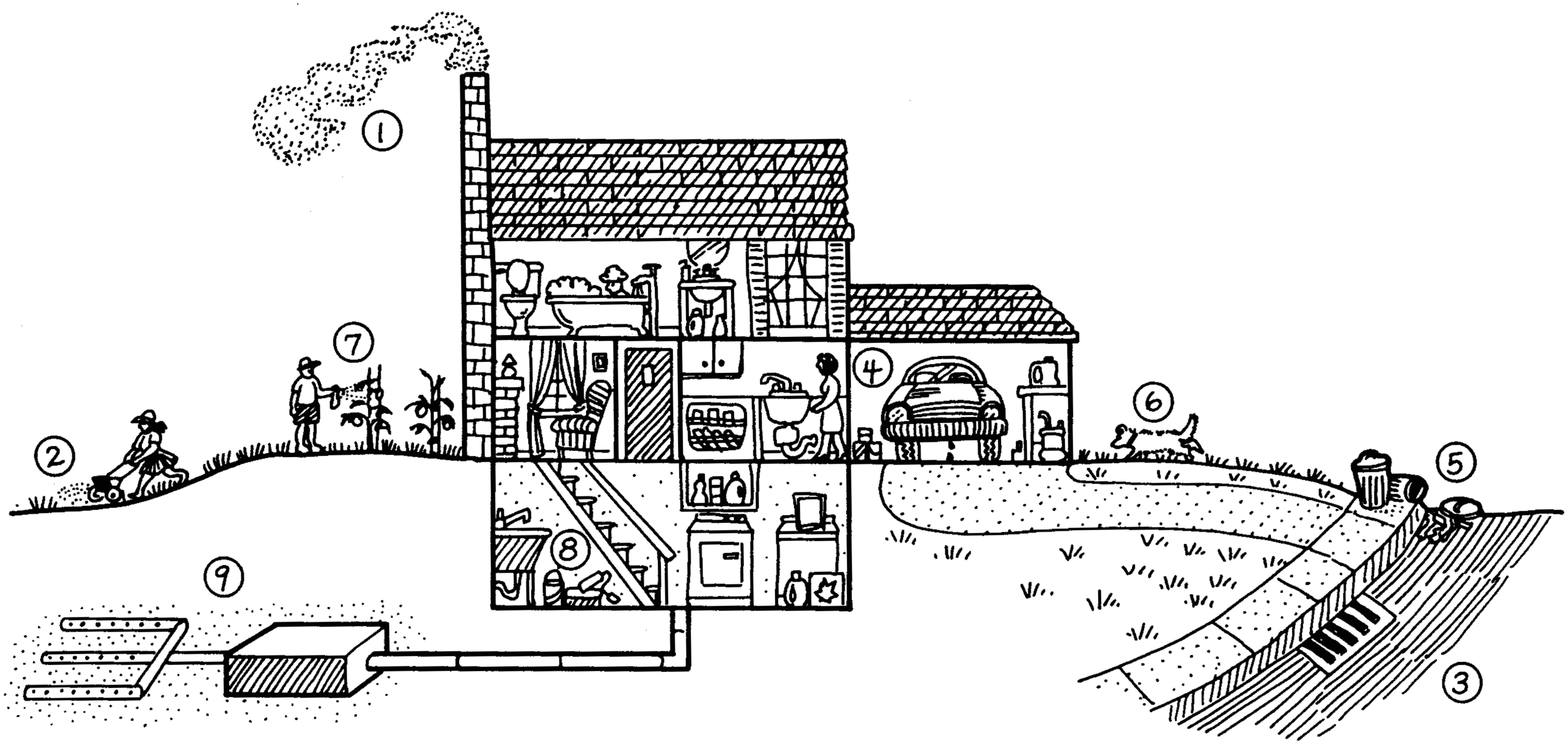
"Household Chemical Alternatives and Precautions," (SP 365-C) Agricultural Extension Service, University of Tennessee, Knoxville, Tennessee, 1989.

"Household Hazardous Waste: What You Should and Should Not Do," Water Pollution Control Foundation, Alexandria, Virginia.

Local Watershed Problem Studies, Elementary School Curricula, Bureau of Information and Education, DNR, Madison, Wisconsin, 1981.

"Septic Tanks and Soil Absorption Systems," Tennessee Valley Authority, Office of Natural Resources, Regional Quality Management Program, June 1979.

FIGURE 1: HOME IS WHERE THE HAZARD IS



SITES:

1 - Chimney smoke
2 - Leaves and grass clippings; lawn fertilizer
3 - Deicing compounds and sand
4 - Vehicle exhaust; wear of tires, brakes, and other moving parts; oil, and other fluid leaks
5 - Human litter; household waste
6 - Pet wastes
7 - Excessive application of chemical and organic fertilizers and pesticides; bare soil between rows
8 - Careless hazardous material storage, use, and disposal
9 - Improperly maintained septic system in inadequate soils

TABLE 1: TYPES OF POLLUTANTS FROM HOUSEHOLD SITES AND RECOMMENDED SOLUTIONS

Using Figure 1, determine nonpoint source pollutant type and decipher key.

Site	Type of Pollutants	Specific Solution
1	Δ	
2	© Δ	
3	Δ ◊	
4	Δ	
5	© ◊ Δ Ø	
6	© Ø ◊	
7	Δ © ◊	
8	Δ	
9	Δ Ø © ◊	

KEY

◊	
©	
Δ	
Ø	

TABLE 1: TYPES OF POLLUTANTS FROM HOUSEHOLD SITES AND RECOMMENDED SOLUTIONS
ANSWER KEY

Using Figure 1, determine nonpoint source pollutant type and decipher key.

Site	Type of Pollutants	Specific Solution
1	Δ	Make sure that hazardous products are not burned in the fireplace.
2	© Δ	Use fertilizers and pesticides sparingly according to manufacturers recommendations. Use self mulching mowers and mulches around landscaping to fertilizer and condition the soil and prevent weeds. Start a compost pile and put leaves, grass clippings, and yardbrush in it instead of sending them to the landfill.
3	Δ ◊	Shovel the walks and streets instead of using deicing materials. Use sand or cat litter sparingly when necessary to melt ice.
4	Δ	Keep your car tuned and in good working condition. Attend to leaks immediately. Dispose of used fluids appropriately at your local gas station or a home hazardous waste collection station.
5	© ◊ Δ Ø	Dispose of all trash properly. Reduce, recycle, and reuse when you can. Before you dispose of anything, consider whether it can be recycled or reused. Source separate your trash at home.
6	© Ø ◊	Use commercially available pooper-scoopers to collect waste and compost it.
7	Δ © ◊	Buy resistant plants. Use fertilizers and pesticides sparingly; better yet, try organic gardening. Many non-toxic pesticides can be purchased or prepared. Maintain your garden by weeding and mulching to prevent insect and diseases.
8	Δ	Buy only products you need in the amounts you require. Give leftover products to others in need. Read cautions on products and store appropriately. Make sure lids are tight and containers are not damaged to prevent leaks. Disposed of hazardous products appropriately at a home hazardous waste station. collection station.
9	Δ Ø © ◊	Maintain the system properly. Have it inspected every 2-3 years and pumped if needed. Never flush hazardous products down household drains. Make sure the drainfield is marked so you won't puncture it accidentally during a home improvement or gardening operation. Inspect the system routinely and repair the system immediately if it damaged.

KEY

◊	Sediment
©	Nutrients
Δ	Toxics
Ø	Bacteria

TABLE 2:
TYPES OF NONPOINT SOURCE POLLUTANTS AND GENERAL SOLUTIONS

Household Pollutant Type	Symbol	Sources	General Solution
Acid Precipitation			Decrease use of fossil fuels; properly maintain vehicles and chimneys.
Organic			Clean up and compost organic waste; properly maintain septic tank.
Toxic			Minimize use and production of toxins; clean up and dispose of toxins properly.
Nutrient			Compost organic wastes; use fertilizers only when necessary.
Pathogenic			Clean up and compost domestic animal waste; properly maintain septic tank.
Sediment			Minimize the amount of bare soil by using ground cover (e.g., such as mulch, grass, or gravel); minimize access to water supply by diverting runoff.

KEY

◊	
©	
Δ	
Ø	

TABLE 2:
TYPES OF NONPOINT SOURCE POLLUTANTS AND GENERAL SOLUTIONS
ANSWER KEY

Household Pollutant Type	Symbol	Sources	General Solution
Acid Precipitation	Δ	1, 4	Decrease use of fossil fuels; properly maintain vehicles and chimneys.
Organic	© ◊	2, 5, 6, 9	Clean up and compost organic waste; properly maintain septic tank.
Toxic	Δ	2, 3, 4, 5, 7, 8, 9	Minimize use and production of toxins; clean up and dispose of toxics properly.
Nutrient	©	2, 5, 7	Compost organic wastes; use fertilizers only when necessary.
Pathogenic	Ø	5, 6, 9	Clean up and compost domestic animal waste; properly maintain septic tank.
Sediment	◊	2, 7	Minimize the amount of bare soil by using ground cover (e.g., such as mulch, grass, or gravel); minimize access to water supply by diverting runoff.

KEY

◊	Sediment
©	Nutrients
Δ	Toxics
Ø	Bacteria

TABLE 3: SOURCE REDUCTION AND PROPER DISPOSAL OF TOXIC HOUSEHOLD PRODUCTS

KEY:

1. Pour down household drain with water, unless you have a septic tank. If so, first read the product label to determine if the product could damage the septic tank. If so, then 2.

2. Do not pour down drain. Be sure the material is properly contained before it is put out for collection or carried to a sanitary landfill.

3. Hazardous wastes should be given to a licensed hazardous waste contractor or saved for a community-wide collection day, even if the containers are empty.

4. Recyclable material which should be taken to an appropriate recycling center. If one is not available, then 3.

Household Products	Proper Disposal	Source Reduction - Solutions, Alternatives, and Precautions
Personal Grooming Products	1	Use pump spray or other nonaerosol versions of personal grooming products. For example, use cream, stick, or roll-on deodrants, pump spray hair spray, etc.
Air Fresheners	1	To freshen and deodorize the air, open a window, or use an exhaust fan, or do both. Sprinkle baking soda in odor-producing areas or set vinegar out in an open dish. Place an open box of baking soda in the refrigerator to absorb food odors.
Carpet Deoderizers	1	To deodorize carpets, sprinkle baking soda over the entire carpet. Use approximately 1 cup (0.24 l) per medium-sized room. Vacuum after 30 minutes.
Carpet and Rug Cleaners	1	To clean carpets and rugs, mix 1/2 cup (0.12 l) mild liquid dishwashing detergent with 1 pint (0.47 l) boiling water; let cool. Whip the paste into a stiff foam using an electric mixer. Apply it to the carpet with a damp sponge. Rub gently. Work in 4x4-foot (1.2 x 1.2 m) sections. Wipe off the suds with a clean cloth. To rinse, add 1 cup (0.24 l) of white vinegar to 1 gallon (3.79 l) of lukewarm water. Rinse each section and wipe the carpet dry as you go. Or sprinkle cornstarch or a mixture of 2 parts cornmeal with 1 part borax on the rug, let set 1 1 hour, then vacuum. For tougher stains, repeatedly rinse with vinegar in soapy water.

TABLE 3: SOURCE REDUCTION AND PROPER DISPOSAL OF TOXIC HOUSEHOLD PRODUCTS (continued)

Household Products	Proper Disposal	Source Reduction - Solutions, Alternatives, and Precautions
Ceramic Tile Cleaner	2	Measure 1/4 cup (.06 l) baking soda, 1/2 cup (0.12 l) white vinegar, and 1 cup (0.24 l) of ammonia into a bucket. Add 1 gallon (3.79 l) of warm water and stir until the baking soda dissolves. Or, mix borax and lemon juice to make a paste. Rub on paste and let set 2 hours before scrubbing.
Disinfectants and Germicides	2	Wash items with soap and water, or with borax or sodium carbonate (washing soda) in water. For mildew stains, chlorine bleach may be used although it should be used carefully and disposed of properly.
Drain Cleaners	1	Prevent clogging by covering drains with a screen to keep out grease, food scraps, and hair. To loosen blockage, mix 1 cup (0.24 l) each of baking soda and salt, add 1 cup (0.24 l) of white vinegar and pour down drain. Wait 15 minutes. Flush drain thoroughly with boiling water. Use a rubber plunger or plumber's snake if drain is seriously clogged.
Floor Wax and Strippers	3	To polish linoleum and vinyl floors without commercial wax, mix 1 part thick boiled starch with 1 part soap suds. Rub the mixture on the floor, and polish dry with a clean, soft cloth. To remove old wax, pour a small amount of club soda on a section of floor. Scrub well, let soak for a few minutes, then wipe clean.
Furniture Polish	3	Use olive oil, lemon oil, beeswax, or beeswax and olive oil. Or mix 2 teaspoons (30 ml) lemon oil and 1 pint (0.47 l) olive oil in a spray bottle.
Mothballs	3	Place cedar chips or sprigs of dried Tanzy around clothes, or store clothes in cedar chest.
Oven Cleaner (lye base)	2	Use pump spray or nonaersol versions. For example, liquid paste or powder oven cleaners. Better yet, prevent the need by wiping away grease and spills after preparing each meal. Wipe away charred spills with a nonmetallic bristle brush. To remove baked-on grease and spills, scrub with a baking soda, salt, and water paste. Or sprinkle with dry baking soda; scrub with a damp cloth after 5 minutes. Don't let baking soda touch wires or heating elements. Scour racks and burner inserts with steel wool.

TABLE 3: SOURCE REDUCTION AND PROPER DISPOSAL OF TOXIC HOUSEHOLD PRODUCTS (continued)

Household Products	Proper Disposal	Source Reduction - Solutions, Alternatives, and Precautions
Silver Cleaners	3	Pour water into an aluminum or enameled pan with aluminum foil covering the bottom. Fill to depth of 2-3 inches (50-75mm); enough to cover silver with water. Add 1 teaspoon (5 ml) baking soda, 1 teaspoon (5 ml) salt, and heat until water boils. Add tarnished silver and boil 3 minutes. Remove silver, wash in soapy water, and polish dry. (Not for use on silver jewelry or flatware with hollow handles.)
Toilet Bowl Cleaners	1	Pour 1/2 cup (0.12 l) liquid chlorine bleach into toilet bowl. Let stand for at least 30 minutes, then scrub with a long-handled brush and flush. (Do not use with septic systems; use cleaner with label stating "safe for use in septic tank.")
Window Cleaners	1	Measure 3 tablespoons (45 ml) ammonia, 1 tablespoon (15 ml) white vinegar and 3/4 cup (0.18 l) water into a clean spray bottle. Or use a solution of 2 tablespoons (30 ml) vinegar in 1 quart (0.95 l) water.
Home Workshop and Hobby Products: Paint (Oil-Based)	3	Use water-based paint whenever possible. Seal all paint cans with tight-fitting lids.
Paint Strippers, Glues, & Adhesives, Turpentine, Varnish, Lacquers, Auto-Body Repair Compounds	3, 4 (except paint brush: clean with solvent, paint thinner, or turpentine)	Use outdoors or in a very large room with steady flow of dry (not humid) air. Ventilate well. Open all windows and doors, and use a large large exhaust fan to blow fumes out. Wear a paper dust mask when grinding or sanding. Use a dust attachment on power tools. Clean up dust and filings with a vacuum cleaner, not a broom. Don't soak brushes in solvents. Clean them immediately, and soak them in plain water or soap and water. Always wear protective goggles, gloves, and a work apron. Separate the work area from the living space as much as possible.
Garden and Lawn Fertilizers	2	Use only when necessary. Use mulch to retain moisture and reduce leaching of nutrients and soil erosion from runoff. Use well-aged compost instead of inorganic fertilizers.

TABLE 3: SOURCE REDUCTION AND PROPER DISPOSAL OF TOXIC HOUSEHOLD PRODUCTS (continued)

Household Products	Proper Disposal	Source Reduction - Solutions, Alternatives, and Precautions
Pest and Weed Control	3	Spray plants with nonchemical compounds. Examples: Spray with a soap and water solution (3 tablespoons of soap per gallon of water) for aphids, mealybugs, mites, and whiteflies. Spray with pyrethrum, a product of a type of chrysanthemum, to control catepillars, beetles, aphids, mites, leaf-hoppers, thrips, moths, and dozens of other fruit and vegetable pests. Introduce other predatory bugs, such as soldier bugs, ladybugs, pirate bugs, spiders, lacewings, and gall midges to control unwanted pests. Use bacterial pesticides, such as *Bacillus popilliac* for Japanese Beetles and *B. thuringiensis* for many types of insect larvae. Interplant with pest-repellent plants: marigolds, coriander, thyme, yarrow, rue, and Tanzy. Indoors, dispose of garbage to avoid attracting ants and roaches. Store food in pest-proof containers or in refrigerator or freezer. Clean up crumbs and food residue promptly. Use flypaper and fly swatters. To control fleas on dogs and cats, bathe animals every two to four weeks with pet shampoos containing insect-repellent herbs such as rosemary, rue, eucalyptus, and citronella. For termites, ask exterminator to use organophosphates, such as chlorpyrifos Dursban T.C., by Dow.

CAUTION: Never mix products containing ammonia with chlorine bleach, vinegar, toilet bowl cleaners, or rust removers.

Name ______________________ Date ______________________

HOME SURVEY

Room/Product	Ingredients	Disposal	Alternative
Kitchen			
Bathroom			
Garage			
Workshop			

Name ______________________ Date ______________________

HOME SURVEY
(continued)

Room/Product	Ingredients	Disposal	Alternative
Workshop			
Garden			
Miscellaneous			

THE GRASS IS ALWAYS CLEANER

OBJECTIVES

The students will do the following:

1. Explain the relationship between land use practices and erosion.
2. Explain how sediments enter surface water runoff from different land use practices.
3. Explain the importance and need for agricultural, construction, mining, and forestry BMPs.
4. Simulate erosion and erosion control methods (BMPs) in classroom demonstrations.

SUBJECTS:
General Science, Earth Science, Life Science, Physical Science, Ecology, Biology, Chemistry, Physics

TIME:
2 class periods

MATERIALS:
sod or grass seed (annual rye grass sprouts quickly)
soil (30-40 pounds or 13.5-18 kg)
8 boxes about 16" (40 cm) long, 12" (30 cm) wide, and 4" (10 cm) deep
8 plastic garbage bags
old garden hose or similar size tubing
mist bottle
8 half-gallon (2 l) sprinkling cans
8 half-gallon (2 l) mason jars, wide-mouth jars or plastic containers
8 blocks of wood 14" x 1" x 1" (35 x 2.5 x 2.5 cm)
2 pieces of wood 16" x 1/2" x 1/4" (40 x 1.25 x .63 cm)
measuring cup or graduated cylinder
gravel
tar paper
gauze
toothpicks
large knife or shovel to cut grass
meter or yardstick
box preparation diagram (included)
"The Grass is Always Cleaner" Quiz (optional, included)

BACKGROUND INFORMATION

Erosion is the gradual weathering of the earth's sufrace. It is a natural process which results in soil being washed into water bodies. Human activities, however, can greatly increase the rate of erosion by removing vegetative cover and exposing bare soil to winds and rain. Heavy rains can wash a variety of suspended materials into water bodies. Soil stripped of its protective vegetation can easily be washed into nearby surface waters. Many other pollutants such as bacteria, nutrients, and harmful chemicals can be transported on sediment. Sediment can interfere with aquatic life, commerical and recreational activities, and hydroelectric power generation. When sediment settles out of the water, it can gradually fill in lakes and streams. This can reduce flood storage capacity and hydroelectric generating potential. It can also create navigation problems.

The best way to solve nonpoint source pollution problems caused by sediment is to prevent sediment from reaching waterways. Using best management practices (BMPs) for agriculture, construction, mining, and forestry can prevent or reduce soil erosion. One agricultural BMP for sloped land is to plant crops on a contour instead of planting vertical row crops. Mining and forestry BMPs include designing haul roads in a zig-zag pattern, gravelling them, and bordering the edge of the roads with timber. Construction BMPs include using silt screens around disturbed areas and planting some sort of ground cover such as grass, as soon as possible to stabilize soil and trap sediment. Diversion ditches and grass filter strips are two other BMPs used in agriculture, forestry, and construction to trap sediment and prevent soil erosion

ADVANCED PREPARATION

A. Grow eight boxes of grass for activity or prepare boxes of soil for the sod. (CAUTION: If you use sod, keep it moist. Don't let it dry out!)

1. Either make the boxes yourself or divide the class into eight equal teams and have each team make one.

2. Give each team a box, garbage bag, and soil.

a. Have the teams line the box with a garbage bag.

b. Fill the box halfway with soil.

c. Cut a hole in the middle of one end of the box level with the soil.

d. Cut a six inch (15 cm) length of hose or similar tubing and insert it in the hole. This is your spout.

e. If planting your own grass, sprinkle the soil evenly with grass seed. (See recommendations on package for seeds per inch.) If preparing the box of soil for sod, set the boxes aside for the activity. (NOTE: Purchase sod a day or two before activity.)

f. If growing grass, water the seed using a mist bottle, cover the box with clear plastic, and place in a sunny location. It will take 5-10 days to grow grass. Use the mist bottle to keep the soil moist until the seeds sprout. If purchasing sod, use a spray bottle to keep sod moist.

B. Obtain the wood, gravel, tar paper, gauze, and toothpicks.

PROCEDURE

I. Setting the Stage

A. Explain that soil stripped of its vegetative cover can easily be washed into nearby water bodies in surface water runoff. This is called erosion. The material transported is called sediment.

B. Note that sediment is the largest single contributor to nonpoint source pollution and results mainly from improper agricultural, construction, logging, and mining practices.

C. Point out that other pollutants, such as nutrients, bacteria, and toxics, can attach to sediment particles and be carried into water bodies.

D. Best Management Practices (BMPs) are management practices which prevent or reduce water pollution.

II. Activity

A. Prepare the demonstration. (See illustration provided.)

1. Pass out instructions on how to prepare each box and go over the directions.

2. Have the students get a box and prepare it according to the directions. (NOTE: If sod is used, have them press firmly down on the sod to merge it with the soil. Gravel, plastic, and tar paper should also be pressed firmly to the soil or they will wash off during the demonstration.)

   Box A — Either cut a piece of sod that will completely fill the entire box and place on top of the soil or do nothing if planted with grass.

   Box B — Either cut the sod into strips two inches (5 cm) wide by the length of the box and place the strips on the top of the soil two inches (5 cm) apart running lengthwise in the box or remove grass according to the diagram. This box will represent traditional row cropping.

   Box C — Either cut the sod into strips two inches wide (5 cm) and the width of the box and place the strips on the top of the soil two inches (5 cm) apart running crosswise in the box or remove grass according to the diagram. This will represent contour planting.

   Box D — Either cut a piece of sod that will fill the entire box and place it on top of the soil and cut a lengthwise strip of sod that is four inches (10 cm) wide from the middle of this piece of sod and remove it or remove grass according to diagram. The bare soil will represent a dirt road.

   Box E — Repeat the same procedure for Box D and place two 1/4 inch (0.63 cm) thick strips of plywood parallel to each other across the road at a 45 degree angle downward. This is called a diversion ditch.

   Box F — Repeat same procedure for Box D and line the road with gravel.

   Box G — Either cut a piece of sod to fit half the box lengthwise or remove grass according to the diagram. Measure a four inch (10 cm) wide road and cut plastic or tar paper strip this size and place it down to represent a road.

   Box H — Either cut a piece of sod to fit half the box lengthwise or remove grass according to the diagram. Measure a four inch (10 cm) road and cut a piece of plastic or tar paper strip this size and place down to represent an asphalt road. Then cut a strip of gauze the length of the road. Weave toothpicks through the gauze at two inch (5 cm) intervals and stretch the gauze along the edge of either side of the side of the road and push toothpicks into the soil to secure. This is a silt screen.

3. Then place the boxes on a table so that the spouts will extend over the edge of the table.

4. Put one inch (2.5 cm) blocks under the opposite end of the boxes to create a slope.

5. Place a stool or chair under each spout and a mason jar, plastic container, or measuring container (3-4 cups) under it to catch the runoff.

6. Put one pint (500 ml) of water in each sprinkling can. Pour the water on all eight boxes at the same time. Pour at as steady a rate as possible with the sprinkling cans at the same height from the boxes at approximately one foot (0.3 m). (NOTE: More water maybe required, up to 1/2 gallon (2 l) depending upon whether sod or grass was used.)

B. Observe the results.

1. The students should record their observations and measurements (if appropriate) made for each of the boxes in a data chart they make. (NOTE: You may want to measure the volume of runoff produced in each jar for comparison.)

   a. Which box had the most soil erosion?

   b. Which box produced the muddiest runoff water?

2. Allow the sediment in the collection jars to settle out.

   a. Rank the jars with respect to the amount of sediment in each jar.

   b. Compare the erosion produced from all eight boxes.

   c. Also, compare the amount of erosion produced from vertical planting (Box B) to that from contour planting (Box C).

   d. Compare the erosion of the bare road (Box D) to the road with diversion (Box E) and the road with riprap (Box F).

   e. Compare the erosion of the bare construction site (Box G) to the one using a silt screen (Box H).

C. Discuss the results. As you go through each box, discuss how the demonstration simulated a real land use practice and explain how sediment would enter a water body if a BMP was not used.

1. The water that flows from the Box A should be relatively clear. [NOTE: The water may be absorbed completely (not flow into the jar) or it may take a long time to get any runoff.]

2. In Box B, the students should note a more rapid flow of water with more soil in the water.

3. Box C should show some soil in the water, but there should be less soil and a slower flow of water than Box B.

4. For boxes D, E, F, G, and H, the students should observe the difference between water flow (speed) and soil content in the water.

5. What was the relationship between land use and erosion in each box?

6. Note that ground cover reduces erosion the most and the contour planting (illustrated in box C) reduces erosion more than traditional row cropping (illustrated in Box B).

7. Boxes E and F illustrate procedures to be used with logging or mining roads to lessen the problem of soil in runoff waters.

8. Box H illustrates construction practices to reduce erosion.

9. Ask the students to think of examples of erosion control practices being used in their community. How do they work?

10. Discuss why BMPs are needed.

III. Follow-Up

A. Give the students the quiz (included) and go over the results.

B. Label and display the boxes in an exhibit to share with other students and parents.

C. You may want to perform more quantitative measures on the results of this activity. For example, if the amount of water that was poured into each box is known, your students could calculate and compare the percent of water that became surface runoff. Also, the amount of sediment and percent sediment load of the runoff from each box could be determined. (See the activity "It's Sedimentary, My Dear Watson.") Have students analyze the results using the same set of comparisons as previously discussed.

IV. Extension

A. Get land owner/contractor permission to have a group of students survey a construction site for evidence of erosion and other potential sources of nonpoint source pollution. What preventive measures used for nonpoint source pollution are they employing? They might take photographs of the site and share their findings with the class. Have them research state and federal laws regarding proper practices at construction sites. Is this land owner/contractor complying with the law? What other things could the land owner/contractor be doing to control nonpoint source pollution?

B. Invite a local contractor or an agent from the U.S. Soil Conservation Service or Canadian equivalent to speak to your class.

RESOURCES

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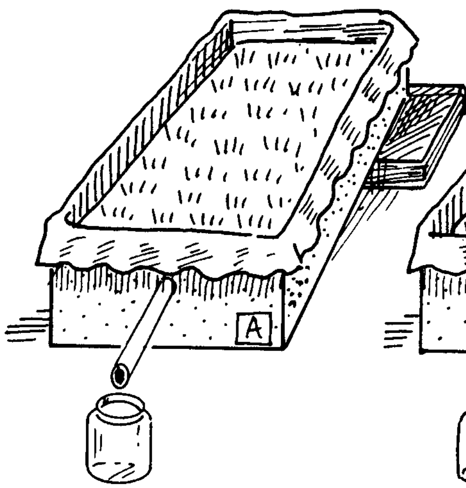
Forests Protect Water Quality, U.S. Environmental Protection Agency, Region IV, and U.S. Department of Agriculture-Forest Service, Southeastern Area, Atlanta, Georgia, 1979.

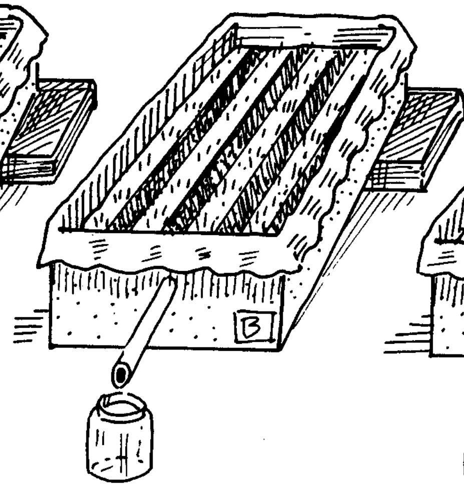
Turk, Jonathan and Amos Turk, Environmental Science, Saunders Publishers Company, Philadelphia, Pennsylvannia, 1988.

Weigle, Weldon K., Designing Coal Haul Roads for Good Drainage, Central States Forest Experiment Station, U.S. Department of Agriculture, Forest Service, Columbus, Ohio, 1965.

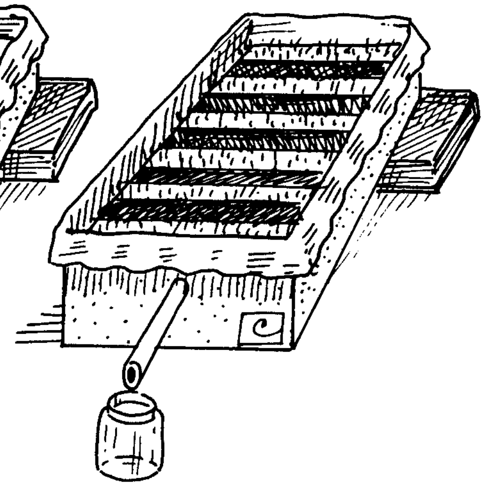
A. HOME LAWN



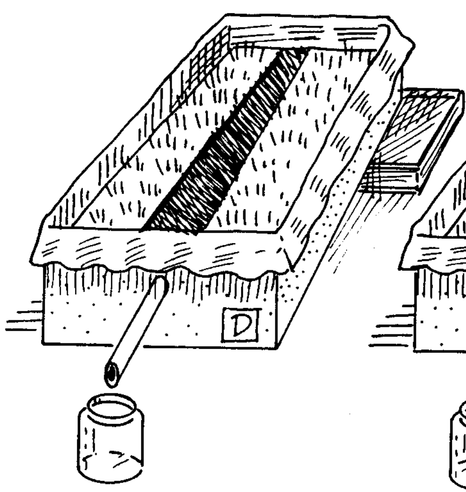
B. ROW CROPPING



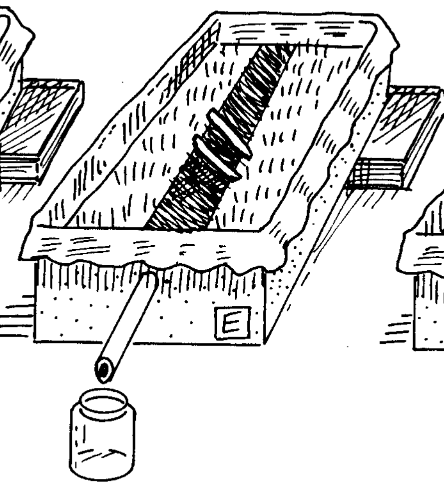
C. CONTOUR PLANTING



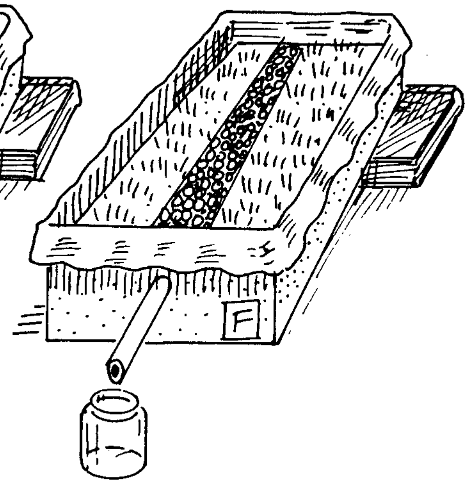
D. DIRT ROAD



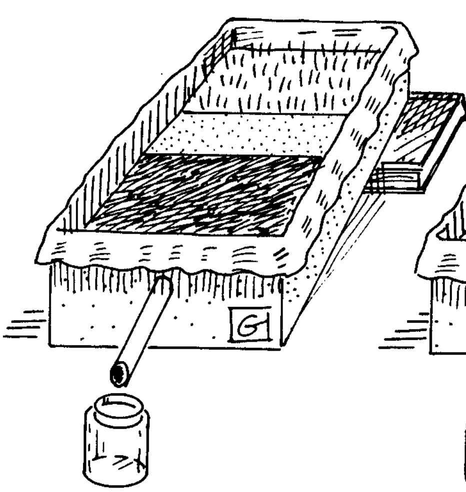
E. DIVERSION DITCH



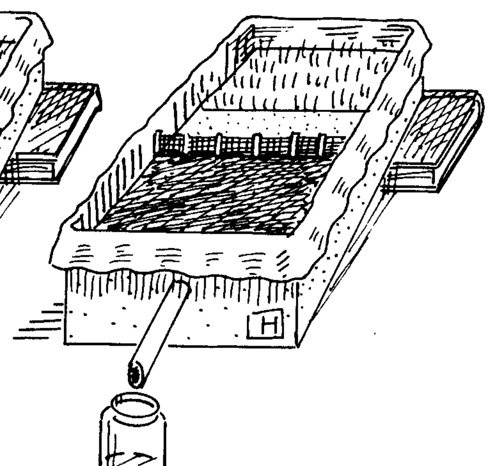
F. GRAVEL ROAD

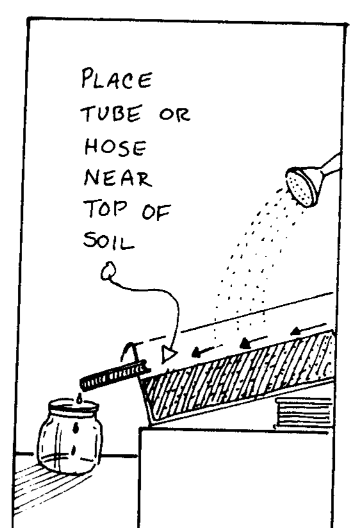


G. CONSTRUCTION BY ASPHALT ROAD



H. CONSTRUCTION BMP BY ASPHALT ROAD





Name ______________________ Date ______________________

THE GRASS IS ALWAYS CLEANER QUIZ

1. Soil stripped of its vegetation can easily be washed into nearby bodies of water. (True/False)

2. What is the single largest contributor to nonpoint source pollution? ______________

3. What does BMP stand for? ______________

4-6. List 3 types of land use which can cause erosion.

(1) ______________

(2) ______________

(3) ______________

7-9. List 3 problems caused by sediment in bodies of water.

(1) ______________

(2) ______________

(3) ______________

Use the data below to answer the following questions:

Box	Runoff	% Runoff
A - Home lawn	402 gal (1524 l)	13.4
B - Row cropping, highly erodable soils	939 gal (3559 l)	31.3
C - Contour planting	138 gal (523 l)	4.6
D - Dirt Road	471 gal (1785 l)	15.7
E - Diversion Ditch	318 gal (1205 l)	10.6
F - Gravel Road	441 gal (1671 l)	14.7
G - Construction by gravel road	981 gal (3718 l)	32.7
H - Construction by gravel road with silt screen	26 gal (98 l)	0.86

THE GRASS IS ALWAYS CLEANER QUIZ
(continued)

10. Based upon the data table, is contour planting or row cropping a better management plan?

____

11. Does the silt screen reduce erosion when used on a construction site near an asphalt road?

____

12. Which is a better management plan, a gravel road or a dirt road? ____________________

13.- 15. Construct a bar graph with boxes A-H represented on the horizontal axis and % runoff on the vertical axis.

THE GRASS IS ALWAYS CLEANER QUIZ
(continued)

16-18. Construct a bar graph with boxes A-H represented on the horizontal axis and gallons (liters) runoff on the vertical axis.

19-20. Calculate % runoff if 2500 gal (9475 l) of rainfall produces 600 gal (2274 l) of runoff.

THE GRASS IS ALWAYS CLEANER
TEACHER KEY

1. Soil stripped of its vegetation can easily be washed into nearby bodies of water. (True/False)

2. What is the single largest contributor to nonpoint source pollution? sediment

3. What does BMP stand for? Best Management Practice

4-6. List 3 types of land use which can cause erosion.

(1) agriculture (4) construction

(2) logging

(3) mining

7-9. List 3 problems caused by sediment in bodies of water.

(1) excess nutrients

(2) toxic substances

(3) bacteria

Use the data below to answer the following questions:

Box	Runoff	% Runoff
A - Home lawn	402 gal (1524 l)	13.4
B - Row cropping, highly erodable soils	939 gal (3559 l)	31.3
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H - Construction by gravel road with silt screen	26 gal (98 l)	0.86

THE GRASS IS ALWAYS CLEANER
TEACHER KEY
(continued)

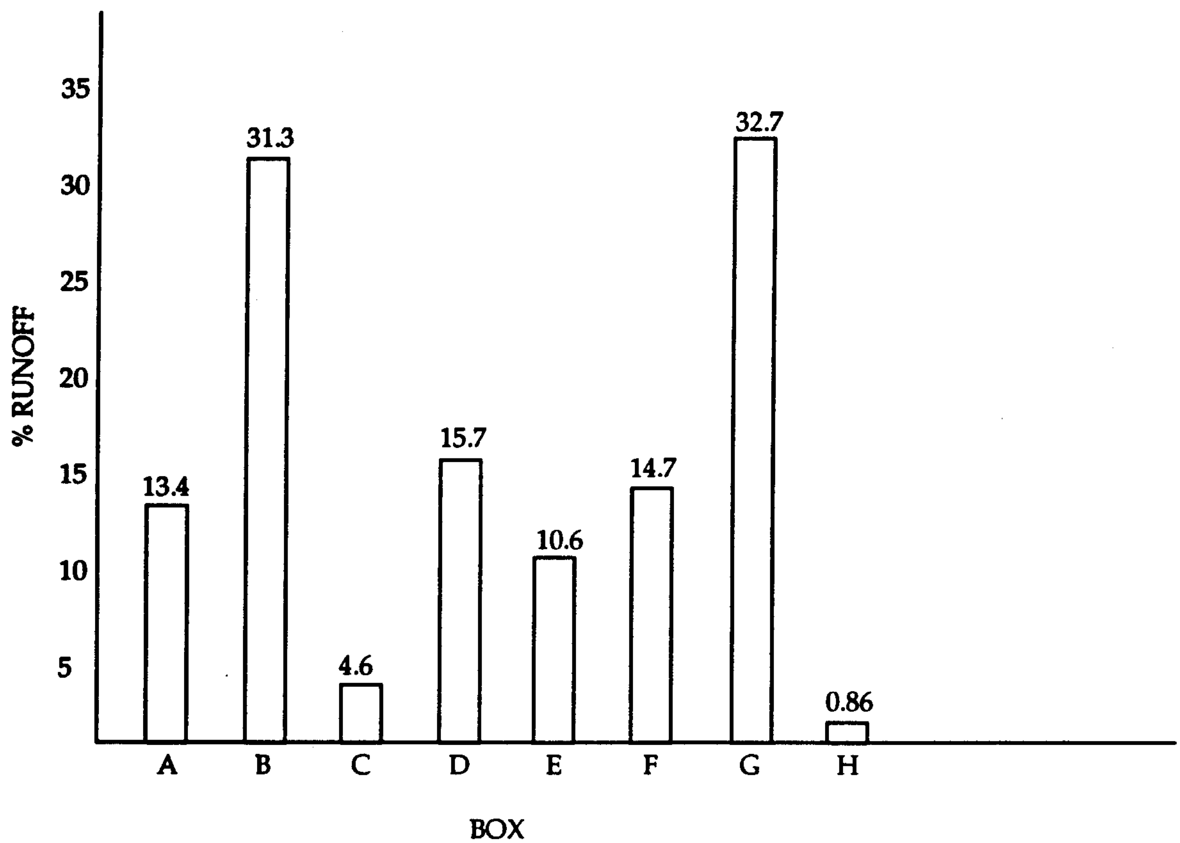
10. Based upon the data table, is contour planting or row cropping a better management plan?

    contour planting

11. Does the silt screen reduce erosion when used on a construction site near an asphalt road? yes

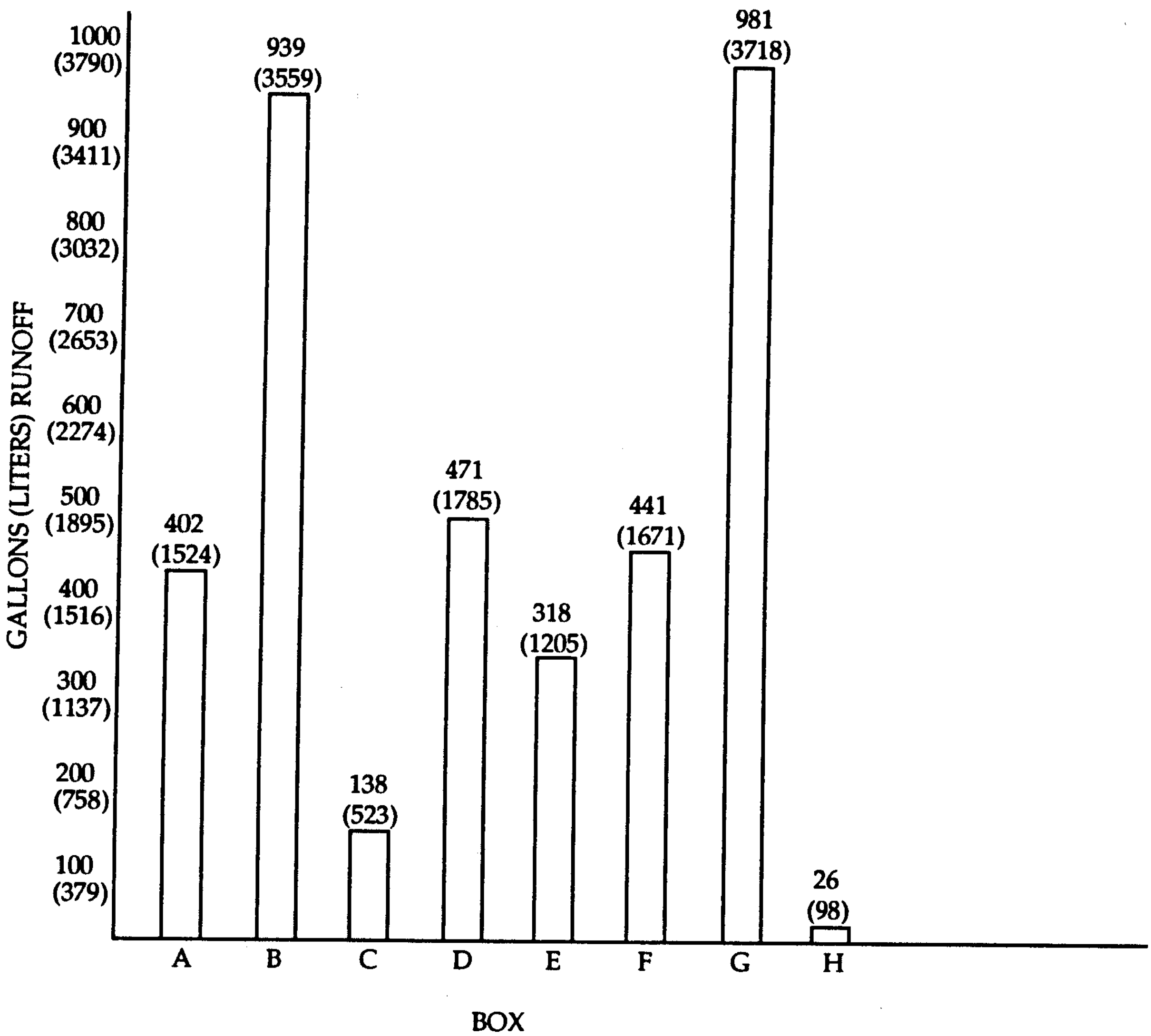
12. Which is a better management plan, a gravel road or a dirt road? gravel road

13.- 15. Construct a bar graph with boxes A-H represented on the horizontal axis and % runoff on the vertical axis.



THE GRASS IS ALWAYS CLEANER
TEACHER KEY
(continued)

16-18. Construct a bar graph with boxes A-H represented on the horizontal axis and gallons (liters) runoff on the vertical axis.



19-20. Calculate % runoff if 2500 gal (9475 l) of rainfall produces 600 gal (2274 l) of runoff.

$$\frac{600 \text{ gal } (2274 \text{ l})}{2500 \text{ gal } (9475 \text{ l})} \times 100\ \% = 24.0\%$$

Eee-Aye-E.I.S.

OBJECTIVES

The students will do the following:

1. Describe environmental and economic trade-offs involved in making decisions about agricultural practices.
2. Explain how certain agricultural and livestock management practices contribute to nonpoint source pollution.
3. Describe BMPs used in agricultural and livestock management that prevent or reduce nonpoint source pollution.

SUBJECTS:
General Science, Earth Science, Life Science, Physical Science, Ecology, Biology, Chemistry, Agriculture

TIME:
2-3 class periods

MATERIALS:
(for each team)
map of Farmer Freddy's farm (included)
set of role play cards and handouts (included)
student worksheet (included)
acetate sheets
newsprint paper
set of colored pencils or markers
calculators (optional)
materials to construct model (optional)
camcorder (optional)
VHS tape (optional)
TV and VCR (optional)
camera and film (optional)

BACKGROUND INFORMATION

The successful conservation farmer follows a plan that was designed for his/her particular farm much the same way a tailor cuts and fits a suit to a particular person. The first step in preparing this conservation plan is to find a good use for each acre (hectare) on the farm. The physical characteristics of the land, in combination with the climate, limit how the land can be used effectively. Essentially, a conservation farmer will assess the impacts various land uses will have upon the land and water resources on his/her farm. When other agencies, like state departments of transporation or city planners, want to significantly alter public land, they are required by U.S. law to prepare an Environmental Impact Statement (E.I.S.) An E.I.S. is a comprehensive document prepared when federal or state funds are used for a project that may have negative environmental effects. The document contains sections describing the present environmental conditions and sections evaluating the impacts the proposed plan will have if implemented. The plan evaluates costs versus benefits and considers several alternatives. Farmers are not required to prepare an E.I.S. because they are are altering privately owned land, but they follow a similar format when they prepare conservation plans for their lands. Many U.S. farmers receive assistance preparing their plans from the Soil Conservation Service (SCS).

No two acres (hectares) of land are alike. The differences include variations in slope, soil depth, productivity, moisture, soil texture, amount of erosion, and many other features. Some soils may be so shallow that cultivated crops will not yield enough for profit. This kind of soil is best suited for grass or pastureland. The amount of soil that has been lost by erosion has a lot to do with how land can be used effectively. Some land slopes so much that cultivation of the soil will result in serious erosion in spite of what the farmer does to protect it. Too much grazing or heavy cutting of timber may have negative effects. Steep slopes will be more profitable to the farmer and the environment in the long run if used for grass or trees. Gentle slopes, provided the soil is satisfactory in other ways, can be safely cultivated and used for crops like corn, cotton, and vegetables. Level lands are also good for livestock operations. Level land that is well drained, has deep soil, and has no physical impediments like outcropping rock, makes the best land for growing cultivated crops. Such land can be worked frequently without serious erosion. Even this land needs good management to keep it productive. SCS can assist landowners in determining the capability of their land. To do so, they designate into which land capability class different areas of the land fall.

After a careful study of the land and soil characteristics, the farmer makes a plan to use each part of his/her farm within its capability as imposed by nature. This plan becomes the farmer's blueprint for his/her farming and livestock operations. It includes a plan that puts each acre (hectare) of land to work effectively. A farmer's plan also takes into consideration what crops the farmer wants to grow and what livestock he/she wants to raise.

After the farmer plans for the effective use of each acre of cropland, he/she then plans the necessary supporting conservation practices like crop rotations, terraces, grassed waterways, strip-cropping, contour farming, pasture rotation, and woodland protection. If the farmer chooses to raise livestock, the plan will also include safe animal waste management practices such as dry stacks, holding ponds, grass filter strips, fences, and a plan to apply manure to croplands as fertilizer and soil conditioner.

Livestock farming may contribute animal wastes to water bodies. High concentrations of ammonia, bacteria, and organic matter in manure can contaminate surface waters directly when animals are allowed access to streams. Livestock farming produces a large amount of wet manure which contains nitrogen and phosphorus. The livestock pollution problem is extremely difficult to define and deal with because it is highly dispersed and involves operations ranging from large feedlots to small dairy operations. One major concern is the potential for shock loading of lakes and streams with toxic ammonia when barnyard waste directly enters a water source. Shock loading is when any pollutant enters a water body in large quantities. Shock loading can cause acute effects like fish kills and algal blooms.

The farmer must also consider if and how he/she will use pesticides on the crops. Pesticides are beneficial because they can improve crop yields significantly by controlling weeds, insects, and plant diseases. Each year, about three billion pounds (1.35 billion kg) of pesticides are used in the United States. Farmers are by far the largest users of pesticides. Because pesticides are designed to kill living organisms, they may cause serious health and environmental problems if not used properly. Some pesticides can stay in the environment for long periods of time and may travel from the soil into surface and groundwater. Some pesticides continue to move up the food chain from single-celled organisms and insects to animals and humans (bioaccumulation). Exposure to certain pesticides may cause illnesses in humans such as cancer or birth defects. Under the U.S. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA is responsible for controlling the risk of pesticides through a registration process. This registration only ensures that when a pesticide is properly used, it poses no unreasonable health or environmental risks. It is up to the person applying the pesticide to make sure it is used properly. However, the best way to limit nonpoint source pollution from pesticides is to reduce their use and consider safer alternatives such as biological controls and resistant plant species.

The improper use of chemical fertilizers by farmers also pollutes water. Improper uses include using too much fertilizer or applying it at the wrong time. For instance, it is not good to apply fertilizer to saturated ground or during the rainy season. After heavy rains, fertilizer can wash into rivers and lakes and supply aquatic plants with too many nutrients. As a result, algae can grow faster and cause algal blooms. This algae can reduce the supply of oxygen in the water and make it unavailable for fish and other aquatic organisms. This may cause fish kills.

When a farmer plans and manages his/her farm according to the physical nature of the land in a manner that protects land and water resources, it is called conservation farming.

ADVANCED PREPARATION

A. Make copies of the "Role Play Cards," "Farmer Freddy's Farm," and tables; one set per team (included).

B. Make acetate overlays of "Farmer Freddy's Farm," "Farmer Freddy's Farm Teacher Key," and "Farmer Freddy's Farm Suggested Plan" (included).

PROCEDURE

I. Setting the Stage

A. Discuss with the students the role agricultural and livestock operations play in nonpoint source pollution.

B. Discuss with the students what conservation farming entails and the role of BMPs to prevent or reduce nonpoint source pollution (see "Water Quality Expert Information," included). (NOTE: You may want each student to read the background section provided.)

C. Explain to the students that they are going to participate in a simulation to develop a managment plan for Farmer Freddy's farm.

II. Activity

A. Conduct simulation.

1. Divide the class into teams of six and give each team a map of Farmer Freddy's farm, a set of role play handouts, a worksheet, and a set of colored pencils or markers.

2. Familiarize the students with the major topographic features of Farmer Freddy's farm.

a. A road and a stream go across the land.

b. The stream, called Crystal Creek, flows from northeast to southwest.

c. A major tributary with two branches flows into Crystal Creek from a hillside.

d. The number of acres (hectares) represented on this map.

e. Where the steep and flat areas are located.

3. Pass out all of the handouts of Tables 1-4 and go over each one. Encourage the students to read the information and make notes before beginning the discussion.

4. Have each team designate which expert each member will be. Each member should study his/her appropriate role play materials. The background section and role play handouts provide the information needed for the teams to develop their management plans.

5. Allow the teams to develop their methods and establish their management plans.

6. Farmer Freddy should develop goals for the farm while others read their materials.

7. Each team should complete the student worksheet.

8. Have each team use colored pencils and a sheet of newsprint to draw their completed plan.

9. When the plans are completed, allow each team to give a brief presentation which describes their land use plan.

B. Discuss the results by having the students answer the following questions about their plan and the problems the group experienced in developing a comprehensive management plan.

1. What factors were considered in the development of your management plan?

2. What problems were encountered?

3. What compromises were made?

4. What plans were made for the maintenance and assessment of the effectiveness of your plan?

C. Display each team's management plans in the classroom.

III. Follow-Up

A. Give students the quiz included and go over the results.

B. Videotape their role plays and presentations and share them with another class. Discuss the results. Do they agree or disagree with members of the team? Which plan do they like best? Why?

C. Have each team construct a model of Farmer Freddy's farm as described by their management plan, using modeling clay, papier-mache, and/or fiber board. They should interpret and represent the contours of the topographic maps as accurately as possible. They should also include as many of Farmer Freddy's land use practices and physical representations of the features of the land as possible.

Models may be built of fiber insulation board, papier-mache, or a salt/flour mixture on a sturdy base. One good method is to use pieces of thick fiberboard cut to match the outlines of the different contours of the land. The pieces are stacked in the order of succeeding elevations and glued together. The edges of the layers are then shaved off with a wood rasp to make the slopes smooth and even. Make a base for the model from 1-inch (2.5 cm) lumber the size and shape of the farm. The first layer of the insulation board should be the same size as the base. Cut the succeeding layers according to the contour lines and glue them together. You may be able to save material and reduce the weight of the model by having the layers overlap only a little so the inside is hollow. Plastic crack filler or papier-mache may be useful during the final shaping. You may want to make some minor cuts and fill for roads, gullies, and other physical features.

As the first step in decorating the model, paint it with glue. While the glue is still tacky, sprinkle screened sand over it. This surface has a texture that will make it look like fields and pastures when painted. In deciding on the scale for the other items on the model, it is a good idea to start with the buildings. They need not be the same scale as the land; usually they can be somewhat larger. But other items such as fences, machinery, and livestock should be in scale with the buildings.

Buildings and Dry Stacks—Cut buildings and dry stacks from balsa or other softwood. You can do some carving but windows and doors can be painted on on the buildings. Dry stacks are built like picnic shelters—a roof with open walls. You may want to use toy farm buildings instead of making your own.

Fences—Drive dark nails or pins for fence posts and cut them off at a suitable height. For barbed wire, use fine wire fastened by a loop around each post. For woven wire cut strips of screen and push them into the modeling material; fasten with model cement. Some toy farms contain fences which might be used.

Storage Pond—You can use papier-mache or modeling clay to shape your storage pond. Manure can be represented with brown sawdust.

Clover, alfalfa, and grass—The best way to simulate these crops is to paint the areas and sprinkle sawdust of appropriate colors over them. Sawdust coming from different kinds of machines, such as sanders, saws, chippers, and jointers, has different textures. The texture can be altered by screening. Coarse-textured sawdust is best for crops like alfalfa and clover; fine sawdust would be best for grass. Color the sawdust and then spread it out to dry. You might also choose to glue small seeds on the model and paint them.

Bare Soil—Fine sawdust or sand, or the modeling material itself will give about the right texture then paint the appropriate color.

Terraces—Loosely twisted heavy cord or small rope can be glued to the model. The areas above and below the cord or rope can be filled with the crack filler, then shaped to give the form desired.

Corn—You can represent young corn by gluing strips of stiff burlap vertically in rows. After the glue has set, pull out the horizontal threads. Then split and curl the remaining vertical threads. Dried flowers might also work well.

Shrubs—Cut sections from colored sponge and glue them in place. You can make isolated trees in the same way, but to represent a woodlot, treat the whole area as a mass, using colored sponge. Dried flowers might also work well.

Trees—Twigs or dried flowers make great trees. You can spray paint the tops green.

Animals—Small plastic farm animals work great and can be glued directly to the model.

People—Small plastic figurines may also be glued to the model.

You may want to get pictures of actual farms and use them to plan your farm, especially animal waste management facilities. Models of farms can also be made with papier-mache. On a sturdy base, make the farm you want by bending and shaping chicken wire. Then cover it with layers of paper dipped in paste, until you have the right amount of strength and form. Add the buildings, fences, and crops as explained above. Display your models at a parent/teacher conference, local science fair, and at local gatherings.

IV. Extension

Have each team select a farm to study. They should perform a site visit and survey, and interview the owner about his/her management strategies. Have them prepare oral interview questions or a written questionnaire prior to their site visit. Their questions should include the date, information on the location, and types of activities. Types of activities described should include: (a) irrigation practices—type of irrigation and runoff problems; (b) tillage methods—plowing techniques used and evidence of runoff or soil erosion; (c) fertilizer and pesticide applications—amounts and types applied and timing of application relative to rainfall; (d) stream bank management—use of buffer zone (leaving space between fields and stream banks) and livestock access to streams (note bank damage from hooves or evidence of animal waste and silt in water); and (e) animal feedlots—storage of animal waste, runoff containment areas, and distance and slope of land from feedlot to stream.

Also, they should make a sketch of the site and of evidence of contributors to and preventers of nonpoint source pollution. Allow each group to share their findings with the class, using the visual materials they developed. Photographs would be useful here.

RESOURCES

Cattle Waste Management, Tennessee Valley Authority, 1985.

Hudson, N., Soil Conservation, Cornell University Press, Ithaca, New York, 1977, pp. 169-177 and 197-210.

Livestock Waste Facilities Handbook, MWPS-18, Midwest Planning Service, 1985, p. 21.

The Measure of Our Land, PA-128, United States Department of Agriculture, Soil Conservation Service, Washington, D.C., 1976.

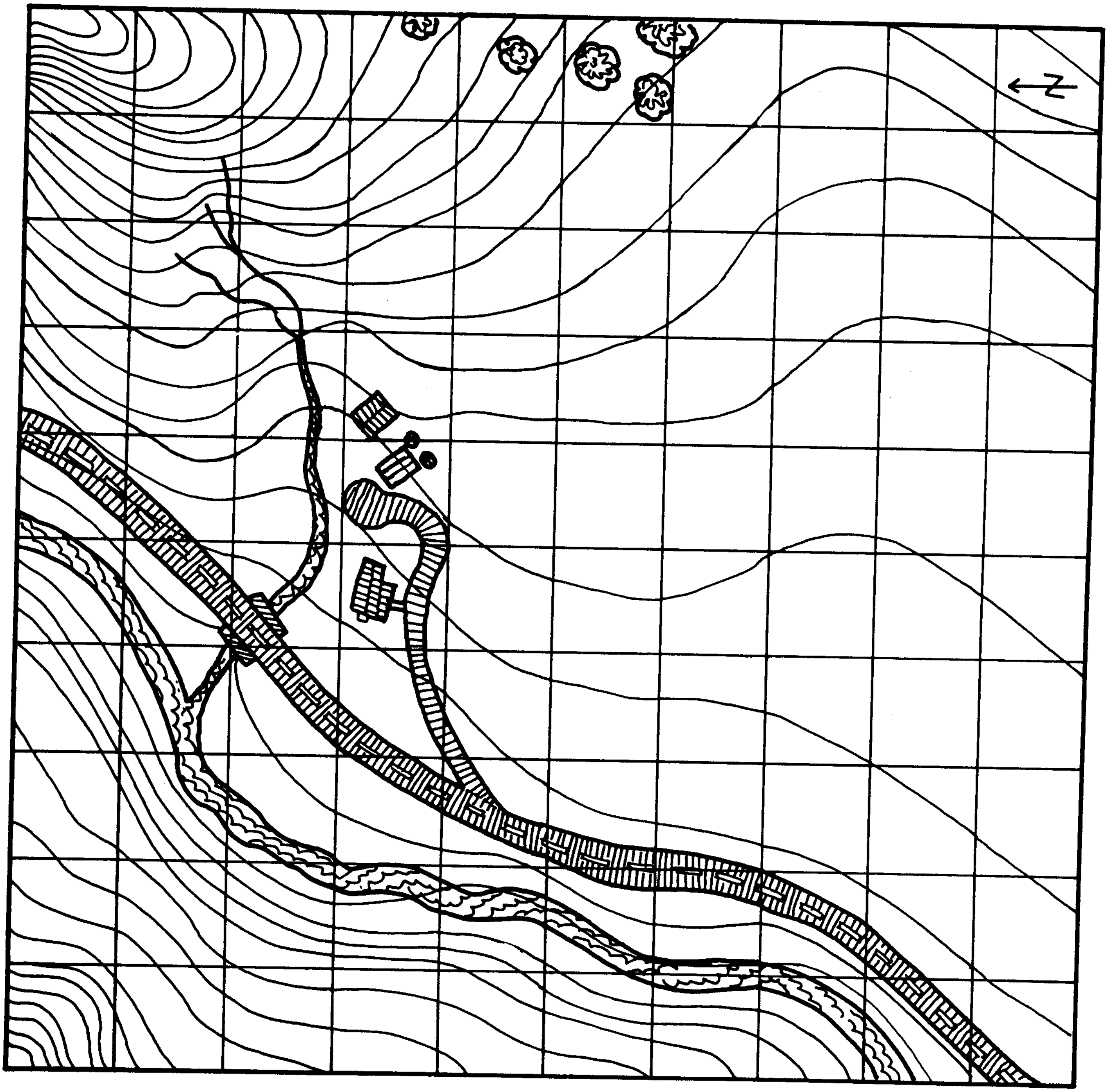
Miller, G.T., Jr., Environmental Science: An Introduction, Wadsworth Publishing Co., Belmont, California, 1990, p. 103.

"A Simulation Game: Water Quality Implications in Land Use Planning," Local Watershed Problem Studies, Elementary School Curricula, Bureau of Information and Education, Department of Natural Resources, Madison, Wisconsin, 1981, pp. 258-276.

Teaching Soil and Water Conservation: A Classroom and Field Guide, PA-341, United States Department of Agriculture, Soil Conservation Service, Washington, D.C., 1977, pp. 28-29.

"Understanding Pesticide Use and Contamination," Groundwater Resources and Educational Activities for Teaching, Iowa Department of Natural Resources, Des Moines, Iowa, 1989, pp. 11; 21-24.

FARMER FREDDY'S FARM



1 square = 1 acre (0.4 hectare) 1 contour = 1 yard (1 meter)

ROLE PLAY CARDS

Farmer Freddy You own the farm and want to make as much money as you can. You believe in the goals of protecting water quality but want low-cost alternatives.	**Cattle Operation Advisor** You are an expert in cattle operations and will advise Farmer Freddy on managing his/her cattle.
Waste Management System Advisor You are an expert in animal waste management and will advise Farmer Freddy about his/her options.	**Water Quality Expert** You are an expert in BMPs to prevent nonpoint source pollution from agricultural lands and will advise Farmer Freddy about his/her options.
Soil Conservation Service District Conservationist You are an expert at classifying and designating land use classifications. Based on your assessment, you will advise Farmer Freddy on the best use of his/her land.	**Agriculture Advisor** You are an expert in techniques for selecting, planting, and harvesting agricultural croplands. You will advise Farmer Freddy on crop management for his/her farm.

CATTLE OPERATION ADVISOR INFORMATION

To maintain healthy pastureland and support cattle grazing, the carrying capacity of a pasture must not be exceeded. The carrying capacity is the maximum population, in this case cattle, that a given ecosystem can support indefinitely. If the carrying capacity is exceeded, overgrazing and consequent environmental degradation will occur. Class I and II land should be able to maintain two cows/acre (0.4 hectare), while Class III, IV, and V land should be able to maintain one cow/acre (0.4 hectare).

A complete cattle operation includes proper animal waste management. Beef cattle production involves two phases: (1) pasturing or grazing on open lands, and (2) finishing in partial or total confinement. During finishing, the cattle are confined in a feedlot or farm area and fed grain prior to going to market. (Farmer Freddy should consult the Agriculture Advisor about storing grain grown on the farm to feed the cattle.) In either phase, the cattle producer must be concerned with the disposal of animal waste. If not disposed of properly, animal waste can pollute the environment. The polluting of groundwater and surface water is costly to correct and its effects are widespread.

Actually, animal waste should be considered a resource rather than a waste. It is a valuable source of fertilizer. The actual nutrient value depends on the production phase and feed ration of the cattle, but on the average, one ton (0.91 metric tons) of beef cattle manure is equal to about 100 pounds (45 kg) of fertilizer. Using waste as fertilizer is a logical way to recover the costs of handling a product that must be disposed of anyway. Note, however, that the cost of some waste management systems may be greater than the fertilizer value.

Because cattle maintained on open pastures disperse manure over a large area, waste build-up is not likely to be a major problem. However, when cattle are confined in an area such as a feedlot, manure builds up and must be disposed of properly. The greatest concentration of waste is found in feedlots or barn areas.

The annual production of waste for 50 head of cattle averages over 500 tons (455 metric tons). An efficient waste management system is essential in handling such large volumes. Several waste management systems exist. Recommend that Farmer Freddy contact the Waste Management System Advisor for more information about different systems.

WASTE MANAGEMENT SYSTEMS ADVISOR INFORMATION

A waste management system for livestock has three major components: collection, transportation, and storage for utilization or treatment and disposal.

The most important decision in choosing a waste handling system for the confinement phase of production is the choice between temporarily storing waste for later use or treating waste and disposing of it.

Collection—Collection methods vary, ranging from scraping to washing and flushing. They may also include installation of such structures as slotted floors where manure drops into pits and then is transported for storage or treatment.

Transportation—Transportation involves the movement of the manure. Depending upon the system selected to handle the waste, this can be accomplished with cross-conveyors, pumps, wagons, or manure spreaders.

Storage Facilities—The objective of storing waste for utilization (later use) is to conserve nutrients, so the waste can be effectively used as fertilizer for land application. Storage systems can be divided into two categories: wet and dry.

The main components of wet storage systems are storage ponds, concrete pits, and above-ground tanks. Wet storage facilities can be used alone or in conjunction with dry stacking. The purpose of these facilities is to store wastes for a short period of time (such as 60 days) before land application. This system requires a smaller land area for holding the wastes and the initial cost for construction is low. The sludge and liquid mixture can be spread on the land with a liquid manure spreader or irrigation equipment. These facilities and spreading equipment must have scheduled maintenance, which includes cleaning on a regular basis.

The main component of a dry storage system is a covered dry stack. The purposes of dry storage facilities are to conserve nutrients and provide storage to limit land application to two or three times per year. This system must be constructed as a pole barn with a sloping concrete floor and requires frequent scraping of wastes from the lot or barn into the dry stack. A separate facility, such as a storage pond, is needed to collect runoff from open feedlots. The use of curbs and gutters is important to prevent rainfall from entering the storage area.

Treatment Facilities—The objective of waste treatment and disposal is to lower the concentration of nutrients in waste. The liquid portion can be land-applied. The reduced nutrient levels prevent overfertilizing on limited acreage which reduces the chance of polluting streams through surface water runoff. These systems are intended to store wastes for long periods (6 months to 1 year or more) in order to provide time for decomposition. The most common method for treating livestock operation wastes is a lagoon. Lagoons collect not only the animal waste but the flush water, runoff from paved feedlots, and rainfall on the lagoon surface. There are two types of lagoons: anaerobic and aerobic.

Anaerobic lagoons break down waste material without oxygen or aeration and can handle all wastes from a livestock operation. These lagoons need to be constructed deep enough to promote waste breakdown and they require addition of waste on a regular basis for the system to function effectively.

Aerobic lagoons break down waste material with oxygen (mechanical or natural aeration). This type of lagoon creates less odor than anaerobic lagoons when aerated. Aerobic lagoons require a larger surface area, shallower depth, and regular additions of waste to function properly.

WASTE MANAGEMENT SYSTEMS ADVISOR INFORMATION (continued)

Anaerobic and aerobic lagoons both accumulate solids or sludge in the bottom that must be periodically removed (every 10 to 15 years for anaerobic lagoons, more frequently for aerobic); these solids can be land-applied. Each type of lagoon reduces the concentration of nutrients, and therefore, requires less acreage for spreading. Both allow disposal of waste by irrigation or possibly by controlled gravity flow to grass filter strips.

One of the more common methods of animal waste disposal is regular hauling of fresh waste. This method is popular because it is a nearly complete system from collection to disposal, although a storage pond or lagoon may be needed to collect polluted runoff from open feedlots. The advantages of scraping and hauling are that it is low cost and relatively simple to operate and maintain. It also reduces flies and odors, and the labor is distributed throughout the year. The disadvantages are that the schedule of disposal must be maintained because of lack of storage space and wastes cannot be disposed of during harvesting, planting, wet weather (damages the land), or on frozen ground. Also manure cannot be spread after the crops reach a certain height.

Note: Precautions must be exercised to prevent accidental entry into storage or treatment areas by livestock, pets, and humans. Fences and gates should be installed to restrict access to the system, and warning signs should be posted.

Ultimately, your client will need to decide which system is feasible and best for the farm. Discuss all the options with your client and list the pros and cons of each method.

WATER QUALITY EXPERT INFORMATION

The best way to prevent water quality problems is to improve infiltration and reduce the amount of exposed soil. In farming, land preparation techniques and application rates of fertilizers and pesticides are critically important. In livestock operations, preventing wastes from coming in contact with a water body is essential. Practices to reduce pollution are called Best Management Practices (BMPs).

Land Preparation

To prevent excessive amounts of sediment from entering a stream in rainfall runoff, a field must be terraced or strip-cropped if the land has more than a five percent slope. If it has between a two and five percent slope, it must at least be contour plowed and row crops should be contour planted. Fields should have grassed waterways and buffer strips should be maintained along all water bodies.

Fertilizer Application Rates

The use of fertilizers should be limited to the manufacturer's recommendation, or less, to prevent excess nutrients from entering the stream in runoff. The use of pesticides should be limited, especially broad spraying and spraying near water bodies, to prevent toxics from entering the water. The critical watershed areas must also be protected. These areas should not be plowed or sprayed.

Livestock Operations

Overgrazing of pastures results in increased deposit of sediment into streams. Livestock access to streams results in severe erosion along streambanks and fecal contamination and nutrient enrichment from the direct deposition of animal wastes.

BMPs to prevent nonpoint source water pollution from livestock include:

- Fencing to exclude livestock access to streams.
- Providing alternative watering systems for livestock with watering devices installed on concrete pads.
- Managing pastures properly so the carrying capacity is not exceeded, which includes maintaining proper stocking rates and rotational grazing.
- Construction of concrete walkways or guides if cattle must cross a critical area.
- Establishing cattle feedlots and watering stations 1,000 feet (305 m) away from a stream.
- Employing proper animal waste management procedures, such as building and maintaining collection and storage facilities.

Ultimately, your client will decide which methods he/she wants to implement. Discuss all the options and list the pros and cons of each method.

SOIL CONSERVATION SERVICE
DISTRICT CONSERVATIONIST INFORMATION

A land capability classification system has been established to show how farmland can be used profitably and safely with respect to soil erosion. The land capability classification system is based on the combined effects of soil features, climate, and difficulty in utilizing conservation methods when cultivating land.

When classifying land as being suitable for cultivated crops or not, a relatively good yield is assumed. However, the classifications are not guides to either profits or yields. In addition, topsoil type, the slope of the land, soil depth, wetness, and erodibility of the soil are also important factors in determining into which class a portion of land falls. The broad class designations, represented by Roman numerals, indicate the degree of limitations for the safe use of the land. The higher the number, the more restrictions apply to the use of the land and the less suitable it is for cultivation.

There are five land classes. Classes I and II represent soil suited for cultivated crops with, respectively, increasing levels of conservation practices. Class III requires extensive crop management and conservation practices if it is to be used for cultivated crops. Class IV is suited for limited strip cropping and may be used as pasture, orchards, or wildlife. Finally, the use of Class V land should be restricted to wildlife, recreation, or water supply. District conservationists base their assessments on climate, soil types, wetness, and erodibility factors.

Using Tables 3 and 4, assist Farmer Freddy in designating the class of each acre (hectare) on the map. Record these in Table 4. Next, establish a color key for indicating the class to which each acre (hectare) belongs. Enter the key in Table 4. Now, mark each acre (hectare) with the proper color to indicate into which class it falls. Record the total number of acres (hectares) in each class in Table 4. Determine how much land can be devoted to various management practices using the allowable slopes listed for clients in Table 4. Discuss with Farmer Freddy what the limitations are for the various acres (hectares).

AGRICULTURAL ADVISOR INFORMATION

Agricultural advisors counsel farmers on which crops to plant and what farming practices to use. Reducing erosion, managing crops, increasing rainwater penetration, improving fertility, and protecting soil are the main problem areas agricultural advisors address. They try to balance profitability, practicality, and resource protection.

Erosion Control

Contour plowing is a method of plowing sloped land by going around the hill instead of up and down. It follows the contour of the land and reduces erosion, controls waterflow, and increases rainfall penetration. Although some modern machinery is too large for contour farming, smaller, more appropriate machinery is available.

Terracing is very effective on steep slopes which could not otherwise be cultivated. Terracing uses a combination of embankments and channels constructed across a slope to control erosion by diverting or storing surface water runoff.

Crop Management

Clearly improved conservation practices like terracing are important, but good crop management can be up to ten times more effective in reducing the amount of erosion.

Crop rotation is one of the most effective methods of enriching and protecting soil. It also reduces the need for pesticides. Row crops such as corn and cotton can be rotated with crops which nourish soil, such as clover, and grasses which protect soil and provide humus when plowed under. Quick growing "green manure" crops such as rye, oats, and winter wheat may be grown to cover fields in winter and then plowed under in spring, adding organic matter to the soil. Crop rotation can reduce weeds and insects.

Livestock is generally an integral part of a farm system. Animals can feed on rotation crops such as hay or alfafa, which may be not be profitable otherwise, and in turn provide manure for fertilizer. However, a grain farm, that also has a livestock feeding program, should plan to grow enough grain and have enough storage capacity for the grain to feed the animals. A farm can become almost self-sufficient in this way.

Increased Rainwater Penetration

Increasing organic matter in the soil improves soil structure and allows rainwater to penetrate deep into the soil instead of becoming runoff. This prevents soil loss and improves plant vigor. Decaying stems, roots, and leaves from last years crop can be plowed under providing a rapid buildup of organic matter. For example, in the first year after corn is harvested and plowed under, water penetration is is improved eighty percent. Another fifteen percent is acquired in the second year. However, from the erosion control point of view, there is little advantage gained beyond two years. The breakdown of coarse vegetable matter is rapid and must be repeated year after year to achieve continuous benefits.

Improved Fertility

Maintaining fertility with continuous crops at yields like 80 bushels per acre (5 metric tons per hectare) requires a high level of management, and incurs high capital (equipment, etc.) and recurring expense (fertilizer, etc.) costs. It may be more profitable on a big commercial farm to apply nitrogen out of the bag than to grow a legume, but the farmer often has no choice. He/she can only afford to reduce out-of-pocket costs by applying manure from his/her animals and/or by choosing the best crops and rotations. Apart

AGRICULTURAL ADVISOR INFORMATION
(continued)

from fertility, there are other reasons why rotations may be desirable: (1) to break the buildup of a pest or disease, (2) to change rooting depth to vary the uptake of moisture or nutrients, or (3) to prepare the way for a subsequent crop by planting a nurse crop (i.e., legume). There are a variety of reasons. Often the primary purpose of a rotation is to interrupt the progressive development of unfavorable features, for example, the introduction of grass.

Soil Protection

However, annual crops cannot provide cover in the early season during the young stages of growth. Protection at this time must be provided in other ways. Grass and forage crops grown in rotation will reduce soil erosion and increase organic matter if the residues from the previous year's crop are turned under.

In conventional farming, the land is plowed in the fall, during the winter, and early spring making the soil quite susceptible to wind and water erosion. Among the newer and more successful techniques to control erosion control are various forms of conservation tillage. In conservation tillage, crop residues and litter from the previous crop are left in the field instead of turning them under by plowing. Conservation tillage lowers labor costs, uses less fuel than conventional tillage, and reduces erosion, but requires much more careful crop management. Special subsurface tillers are then used to break up the soil without turning over previous crop residue and cover vegetation. This techniue requires increased used of herbicides to control weeds. Also this approach can only be used for 3-7 years before extensive soil cultivation is required to prevent crop yield from declining. In one form of conservation farming, "no-till" farming, the land is not even tilled and special planters are used to inject the seeds into the soil without plowing.

Trash farming is a farming method where you harvest the standing crop, cut and spread the crop residues on the surface, and then plow and cultivate the soil in the normal manner in the spring. This means that some of the crop residue is incorporated into the plowed layer, leaving some buried and some showing at the surface. This gives the soil the "trash" appearance. The combination of some crop residue on the surface (giving top cover) and some close to the surface (giving an open texture) allow good moisture penetration; this is as effective as having the crop residue entirely on the surface. The problem of soil protection is solved by combining trash farming and high-yield cropping. At the beginning of the season, the crop residue effectively reduces erosion, but as the trash decays the growing crop progressively takes over the job of providing cover.

Pesticides

Pesticide spraying, with respect to both land and water quality, should be kept to a minimum. However, weeds such as foxtail and pigweed may greatly affect the corn and soybean yield, especially with minimum or no-tillage practice. Thus, herbicides may need to be used in order to obtain a profitable harvest.

Discuss what types of crops your client is interested in cultivating and go over farming methods for these crops. Discuss the pros and cons of the different methods.

TABLE 1

REDUCTION IN SOYBEAN YIELD FROM PIGWEED	
Pigweed Density	Yield In Bushels Per Acre (Metric Ton Per Hectare)
No Pigweed	50 (3.2)
1 Plant/Foot (3 Plants/Meter)	35 (2.2)
2 Plants/Foot (6 Plants/Meter)	25 (1.6)
4 Plants/Foot (12 Plants/Meter)	22 (1.4)
32 Plants/Foot (96 Plants/Meter)	14 (0.9)

TABLE 2

REDUCTION IN CORN YIELD FROM FOXTAIL	
Foxtail Density	Yield In Bushels Per Acre (Metric Tons Per Hectare)
No Foxtail	91 (5.7)
1 Plant/2 Feet (3 Plants/2 Meters)	86 (5.4)
1 Plant/Foot (3 Plants/Meter)	85 (5.36)
6 Plants/Foot (18 Plants/Meter)	81 (5.1)
12 Plants/Foot (36 Plants/Meter)	76 (4.8)

TABLE 3

MAP CONTOURS AND PERCENT SLOPES	
# Contours Per Acre (0.4 hectare)	Percent Slope
1	1.5%
2	3.1%
3	4.7%
4	6.3%
5	7.8%
6	9.4%
7	11.0%
8	12.6%
9	14.1%

Table 4 - Land Capability Classes

Land Class	Maximum Slope*	Characteristics	Primary Uses	Secondary Uses	Conservation Measures	Key	# Acres (# Hectares)
I	2%	Excellent, flat, well-drained land	Cultivation Wildlife Grazing	Recreation	None		
II	5%	Good land, has minor limitations such as slight slope, sandy soil, or poor drainage	Cultivation Grazing	Recreation Wildlife	Strip cropping Contour farming		
III	8%	Moderately good land with important limitations of soil, slope, or drainage	Cultivation Grazing	Recreation Wildlife Urban Industry Terraces	Contour farming Strip cropping Waterways		
IV	12%	Fair land, severe limitations of soil, slope, or drainage agriculture Urban Industry	Grazing Orchards Limited Strip cropping	Pasture Wildlife Contour farming	Farming on a limited basis		
V	15%	Use for grazing and forestry, slightly limited by rockiness, shallow soil, wetness, or slope prevents farming	Grazing Forestry	Recreation Wildlife Terraces	No special precautions if properly grazed or logged. Must not be plowed		

*Based on hypothetical soil types, wetness, and erodibility factors.

STUDENT WORKSHEET

1. Estimate the number of acres (hectares)of land occupied by buildings, roads, bridges, streams, and trees.
2. How many acres (hectares) are suitable for cultivation?
3. How many acres (hectares) are suitable for cultivation only if soil conservation practices are used?
4. How many acres (hectares) are suitable for only very limited or no cultivation?
5. What types of agricultural conservation practices could be used on Class II and III land to protect the soil and prevent erosion?
6. What are the advantages and disadvantages of conservation tillage or no-till farming?
7. How will crop rotation benefit the farmer? Will this benefit the water supply? How?
8. Pigweed is a big problem in soybean fields. How many bushels of soybeans per acre (metric tons/hectare) would be lost if a field was found to have four pigweed plants per foot (12 plants/meter) of row?
9. Foxtail is a problem in corn, so many farmers use herbicides which kill foxtail. If a 1/2 acre (0.2 hectare) area was not sprayed which has six foxtail plants per foot (18 plants/meter) of row, what was the yield in the unsprayed portion? Explain your answer.
10. If treating corn to kill foxtail cost $16 per acre ($40 per hectare) and corn sold at $2.40 per bushel ($96/metric ton), was the decision to spray economically feasible (if based on immediate costs)? Explain your answer.
11. If only one foxtail plant per foot of row (3 plants/meter) were found in the above example, would spraying herbicides be a good economic decision? Explain your answer.
12. If other factors (such as long-term costs for health care and water quality) were considered, the farmer may have chosen an alternative to spraying the foxtail. Describe at least one alternative to using herbicides.
13. What precautions need to be taken to prevent water pollution from farming operations?
14. How many acres (hectares) are suitable for grazing?
15. How many acres (hectares) will sustain only one cow per acre?
16. How are animal wastes managed on a farm? Describe the 3 major components of an animal waste management system.
17. What is the most common method for treating animal wastes in feedlots? Briefly describe the different types.
18. What precautions must be taken to avoid having livestock waste pollute a water body?

STUDENT WORKSHEET
(continued)

19. Will you locate a feedlot on Farmer Freddy's farm? Where? Why?

20. Will you locate corn and soybean fields on Farmer Freddy's farm? Where? Why?

21. Will you pasture cattle on Farmer Freddy's farm? Where? Why?

22. Briefly describe how you would manage Farmer Freddy's farm.

STUDENT WORKSHEET
TEACHER KEY

1. Approximately 20 acres (8 hectares).

2. Approximately 38 acres (15 hectares). (Add acres of land classified I-IV and subtract acreage in question 1.)

3. Approximately 39 acres (16 hectares). (Add acres of land classified II, III, and IV and subtract acreage in question 1 that is classified II, III, or IV.) 39 - 16 = 23

4. Approximately 6 acres (2.5 hectares). (Add acres of land classified IV or V and subtract acreage in question 1 that is classified IV or V.)

5. Trash farming, conservation tillage, strip-cropping, contour farming, terracing, no-till farming

6. Advantages: lower labor and fuel costs, reduces erosion
Disadvantages: more careful crop management required, increased use of herbicides

7. Reduces need for pesticides by weed and insect infestation, adds organic material and nutrients to soil, increases moisture penetration, and improves drainage

8. 28 bushels/acre (1.8 metric tons/hectare). [Yield with no pigweed is 50 bushels/acre (3.2 metric tons/hectare), yield with 4 plants per foot is 22 bushels/acre (1.4 metric tons/hectare): 50 - 22 = 28 bushels/acre (3.2 - 1.4 = 1.8 metric tons/hectare) reduction in yield]

9. 40.5 bushels (2.55 metric tons/hectare). [Corn with 6 foxtail plants per foot of row (18 foxtail plants/meter) yields 81 bushels per acre (5.1 metric tons/hectare). 1/2 acre (0.2 hectare) would yield 40.5 bushels: divide 81 by 2 (divide 2.55 by 2.]

10. Yes. (By using the herbicide, there was an $8 greater profit per acre ($17.60 per hectare) than would have been gained not using it. 91 bushels/acre x $2.40/bushel = $218.40/acre - $16 herbicide cost/acre = $202.40/acre. 81 bushels/acre x $2.40/bushel = $194.40/acre. 5.7 metric tons/hectare x $96/metric ton = $547.20/hectare - $40/hectare herbicide cost = $507.20/hectare. 5.1 metric tons/hectare x $96/metric ton = $489.60/hectare.)

11. No. (By using the herbicide, profit was reduced by $4 per acre ($11.20 per hectare). 91 bushels/acre x $2.40/bushel = $218.40/acre - $16 herbicide cost/acre = $202.40/acre. 86 bushels/acre x $2.40/bushel = $206.40/acre. 5.7 metric tons/hectare x $96/metric ton = $547.20/hectare - $40/hectare. Herbicide cost = $507.20/hectare. 5.4 metric tons/hectare x $96/metric ton = $518.40/hectare.)

12. Mechanical removal or removal by hand, crop rotation

13. Terrace or strip-crop land if slope is more than 5%; contour plow if between 2-5% slope; use grassed waterways and maintain buffer strips along all water bodies; limit use of pesticides and fertilizers, and follow manufacturers directions; protect critical watershed acres by not broad spraying or spraying near water

14. Approximately 80 acres (32 hectares). [Take total area and subtract area in question 1: 100 acres - 20 acres = 80 acres (40 hectares - 8 hectares = 32 hectare).]

STUDENT WORKSHEET
TEACHER KEY
(continued)

15. Approximately 21 acres (8.4 hectares). [Add areas classified III-IV and subtract area in question 1 classified III-IV: 24 acres - 3 acres = 21 acres (9.6 hectares - 1.2 hectares = 8.4).]

16. There are two methods of animal waste management. One is where waste is temporarily stored for later use on farmland, and the other is treating the waste and disposing of it. Three major components: collection, transportation, and storage.
    Collection: Methods vary from scraping to washing and flushing. Also, slotted floors where manure drops into a pit.
    Transportation: cross conveyors, pumps, wagons, manure spreaders.
    Storage: Two types—wet and dry storage. Wet storage can be storage ponds, concrete pits, and above-ground tanks. Dry storage is done with a dry stack which is a pole barn designed with a sloping concrete floor.

17. Anaerobic and aerobic lagoons.
    Anaerobic: Deeper than aerobic, requiring addition of waste on a regular basis. Microbes break down wastes in the absence of oxygen.
    Aerobic: Larger surface area, shallower depth, require regular addition of waste to function properly. Microbes break down wastes in the presence of oxygen.

18. Keep livestock out of water bodies using fences; maintain grass filter strips around all water bodies; install concrete walkways where livestock must cross critical areas; install alternative watering systems with watering devices installed on concrete pads; employ proper animal waste management procedures.

19. There is no one correct answer for where to locate the feedlot or even if Farmer Freddy will have one. Some groups may decide not to raise livestock on Farmer Freddy's Farm. If they decide to have a feedlot, things to consider about the location would be keeping it at least 1,000 feet (about 300 meters) from a water body, and incorporating a waste handling system.

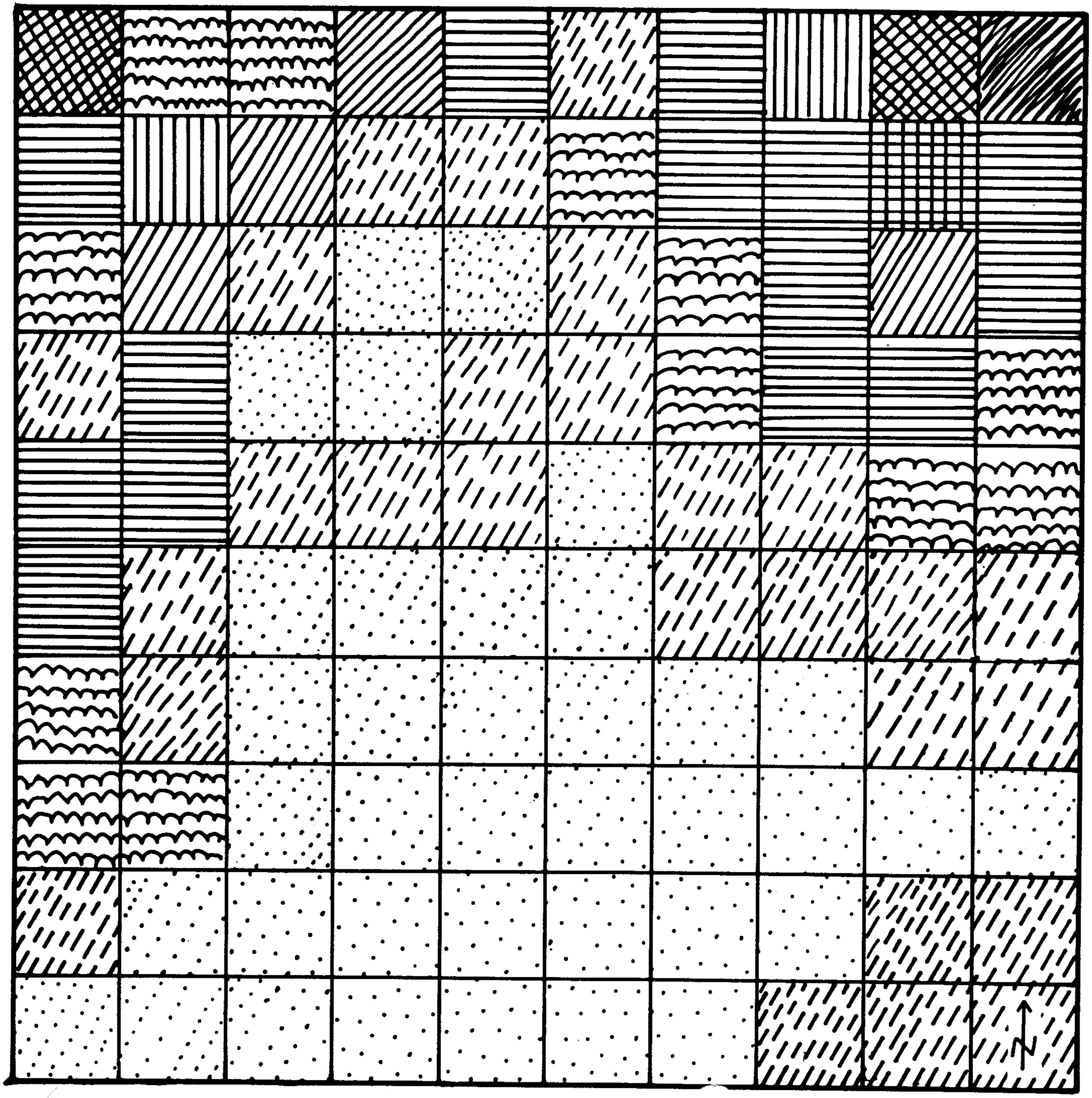
20. Yes. On the land that is class I and II with no buildings, roads, streams, or trees. That would be the best use of the land. Use part of the grain to feed cattle.

21. Yes. In areas other than farmland, feedlot, buildings, roads, or streams; less erosion than farming; protects the soil and makes profit.

22. This answer will vary depending on how the groups set up their farms (see "Farmer Freddy's Farm Suggested Plan," included). Things to consider:

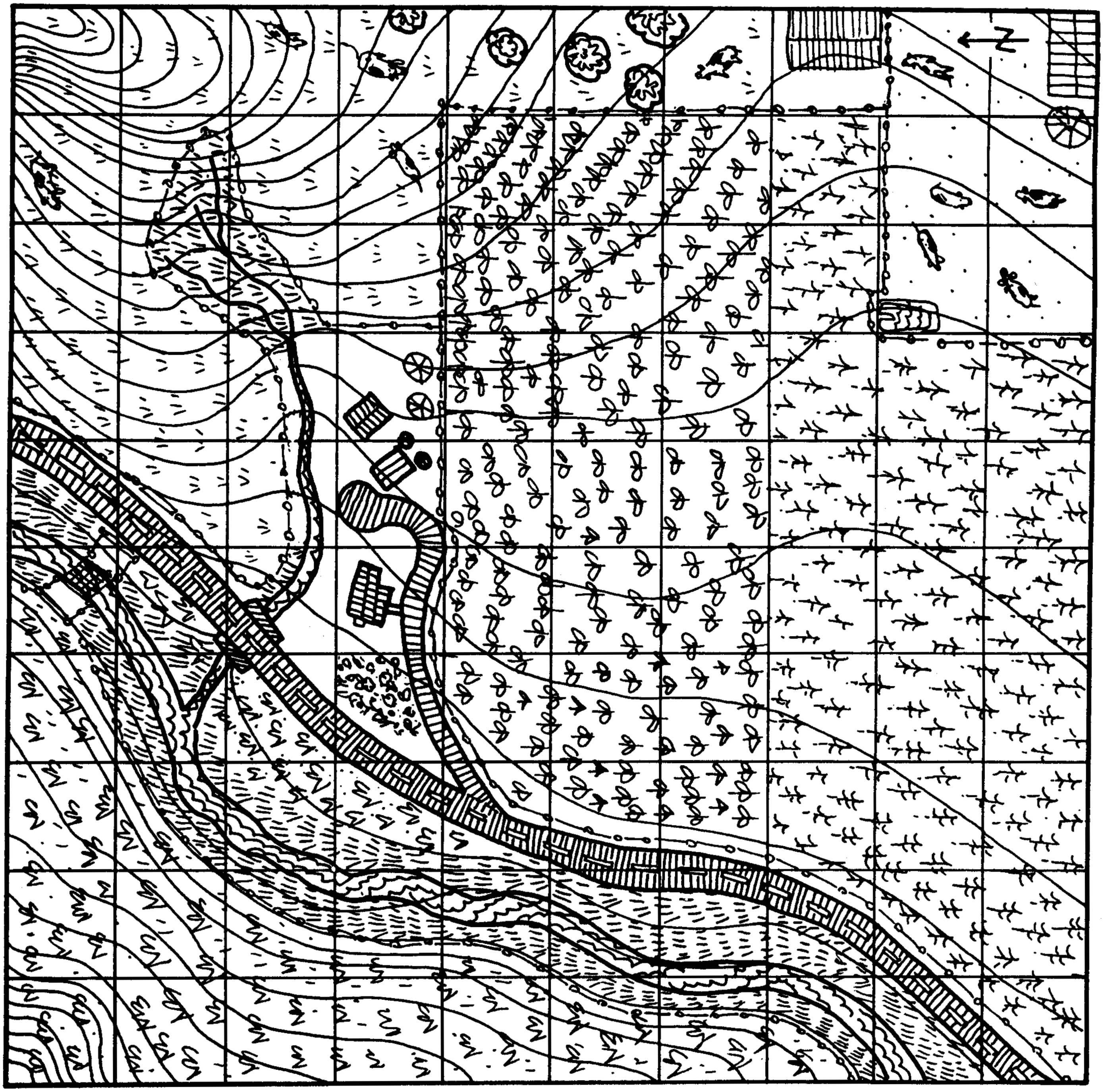
    - conservation tillage methods employed according to slope of land
    - closely monitored use of fertilizer and pesticides on farmland
    - appropriate number of cattle (and rotational grazing) on pastureland
    - water bodies fenced off from livestock
    - appropriate waste handling system and management for livestock
    - feedlots established 1000 feet (300 meters) from water bodies
    - grain storage facilities to satisfy livestock needs
    - silo to store forage crop for livestock (or barn to put hay in, or both)
    - appropriate water supply for livestock (a well may be used)
    - concrete pads for watering livestock or where they cross a critical area

FARMER FREDDY'S FARM TEACHER KEY



LAND CAPABILITY CLASS		# SQUARES
I	1	37
II	2	27
	3	12
III	4	14
	5	4
IV	6	2
	7	1
V	8	2
	9	1

FARMER FREDDY'S FARM
SUGGESTED PLAN



1 square = 1 acre (0.4 hectare)   1 contour = 1 yard (1 meter)

Name ____________________ Date ____________________

Eee-Aye-E.I.S. QUIZ

True/False

1. ________ No two acres (hectares) of land are alike.
2. ________ Steep slopes should be used for grass or trees.
3. ________ Some pesticides can stay in the environment for long periods of time.
4. ________ Homeowners are by far the largest users of pesticides.
5. ________ Algal blooms can cause fish kills.
6. ________ Even with the Federal Insecticide, Fungicide, and Rodenticide Act in place, it is the responsibility of the individual to apply pesticides properly.
7. ________ Level lands are good for raising livestock.
8. ________ Pesticides can move up the food chain.

9-10. List two potential sources of nonpoint source pollution from agricultural practices.

(1) ____________________

(2) ____________________

11. What does E.I.S. stand for? ____________________

12. What is shock loading? ____________________

13. In what way are pesticides beneficial? ____________________

14. List at least one alternative to pesticide use.

____

____

15. What causes algal blooms? ____________________

Eee-Aye-E.I.S. QUIZ
(continued)

16-17. Agriculture-related soil erosion occurs as a result of the following:

(1) ______________________________

(2) ______________________________

18-19. List two ways that farmers improperly use chemical fertilizers.

(1) ______________________________

(2) ______________________________

20. What is conservation farming? ______________________________

____

Eee-Aye-E.I.S. QUIZ
TEACHER KEY

True/False

1. True — No two acres (hectares) of land are alike.
2. True — Steep slopes should be used for grass or trees.
3. True — Some pesticides can stay in the environment for long periods of time.
4. False — Homeowners are by far the largest users of pesticides.
5. True — Algal blooms can cause fish kills.
6. True — Even with the Federal Insecticide, Fungicide, and Rodenticide Act in place, it is the responsibility of the individual to apply pesticides properly.
7. True — Level lands are good for raising livestock.
8. True — Pesticides can move up the food chain.

9-10. List two potential sources of nonpoint source pollution from agricultural practices.

(1) sediment from soil erosion

(2) nutrient enrichment from fertilizers and livestock waste

(3) bacteria from fecal contamination

(4) toxic chemicals from agriculture

11. What does E.I.S. stand for? Environmental Impact Statement

12. What is shock loading? Any pollutant entering a body of water in large quantities.

13. In what way are pesticides beneficial? Improving crop yields

14. List at least one alternative to pesticide use.

biological controls

resistant plant species

15. What causes algal blooms? nutrient enrichment

Eee-Aye-E.I.S. QUIZ
TEACHER KEY
(continued)

16-17. Agriculture-related soil erosion occurs as a result of the following:

(1) improper tilling methods

(2) poor or no use of cover crops

(3) overgrazing

(4) trampling of stream banks

18-19. List two ways that farmers improperly use chemical fertilizers.

(1) too much fertilizer

(2) applying at the wrong time

20. What is conservation farming? Planning and managing a farm according to the physical nature of the land in a manner that protects the land and water resources.

GLOSSARY

acid: a substance with more hydrogen (H^+) ions than hydroxide (OH^-) ions.

acidity: the strength (concentration of hydrogen [H^+] ions) of an acidic substance.

acid mine drainage: acidic water which forms when water contacts exposed mine wastes and ores and is carried into adjacent streams as runoff.

acid rain (or acid precipitation): rain with a pH of less than 5.6; results from atmospheric moisture mixing with sulphur and nitrogen oxides emitted from burning fossil fuels; may cause damage to buildings, car finishes, crops, forests, and aquatic life.

aerobic: living or occuring in the presence of oxygen.

algae: a group of microscopic photosynthetic plants.

algal bloom: a heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from farm fertilizers and detergents; phosphates are also naturally occurring in rock formations.

anaerobic: living or occuring in the absence of oxygen.

aquatic life: all the life forms in water; ranges from invertebrates and fish to algae, and larger aquatic plants.

aquifer: any geological formation capable of storing water, especially one that supplies water for wells and springs.

atmospheric deposition: particles from the atmosphere deposited on the earth's surface in either wet or dry form.

bacteria: single-cell microscopic organisms which break down organic materials.

best management practices (BMPs): an engineered structure or management activity, or combination of these, that eliminates or reduces adverse environmental effects of pollutants.

bioaccumulation: the process by which the concentration of a substance is increased through successive links in a food chain resulting in toxic concentrations at the topc of the chain. For example, DDT entered a water body, was absorbed by plankton, which was eaten by small fish, who were eaten by eagles. Eagle populations declined as a result. Also called biological magnification or biomagnification.

bioassay: a method to test for the concentration of a substance by observing its effects on the growth of an organism under controlled conditions.

biodegradable: capable of being decomposed by natural biological processes.

biological oxygen demand (BOD): the amount of dissolved oxygen required for anaerobic organisms to break down the organic matter in a volume of water.

biomonitoring: monitoring the health of an ecosystem by observing the resident life forms.

buffering capacity: the ability of a solution to resist a change in pH when an acidic solution is added.

buffer strip or zone: grass or other erosion-preventive vegetation planted between a waterway and an area of intensive land use (e.g., cultivated farmland).

catalytic converter: a reaction chamber typically containing a finely divided platinum-iridium catalyst into which exhaust gases from an automotive engine are passed together with excess air so the carbon monoxide and hydrocarbon pollutants are oxidized to carbon dioxide and water.

clarity: the state or quality of being clear.

clearcutting: felling and removing all trees in a forest area.

Clean Water Act of 1972: the federal law which sets national water quality goals and directs states to upgrade surface waters through the control of point and nonpoint sources of pollution. It was amended in 1977 and 1987.

coliform bacteria: bacteria found in the intestines of warm-blooded animals that aid in the digestion process; used as indicators of fecal contamination in water quality analyses.

combined sewer: a sewer system that carries both sanitary sewage and stormwater runoff.

composting: mixing together leaves, grass clippings, table scraps, and soil and allowing the mixture to decompose into mulch that is high in nutrients and useful to fertilize gardens and flower beds.

conservation farming: the management of farm activities and structures to eliminate or reduce adverse environmental effects of pollutants and conserve soil, water, plant, and animal resources.

contamination: the introduction of a substance to a water supply that reduces the usefulness of the water to humans and other organisms in nature.

contour farming: field operations such as plowing, planting, cultivating, and harvesting conducted following the contours of a slope.

contour plowing: plowing sloped land by going around the hill (instead of up and down) to reduce erosion, control water flow, and increase moisture penetration.

contour strip-cropping: farming operations performed on the contour with the crops planted in narrow strips, alternating between row crops and close-growing forage crops.

conventional tillage: standard method of preparing a seedbed by completely inverting the soil and incorporating the residue with a plow.

critical area: an area of land where, due to the topography, any disturbance of the cover will result in a serious erosion problem.

crop-dust: the application of pesticides to crops from the air using an airplane or helicopter.

crop rotation: a planned sequence of a variety of crops planted in a regular succession on the same area of land to reduce the depletion of soil nutrients as opposed to the growing of one crop, year after year.

Daphnia or water fleas: a small crustacean between 0.25 and 2.5 mm long which is found in virtually all freshwater habitats; organism used in bioassays to test for the presence of toxic substances.

disinfectant: a cleaning agent that destroys, neutralizes, or inhibits the growth of harmful microorganisms.

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water.

diversion: a best management practice (BMP) used to divert water across or away from a hillside, exposed soil, or other potential sources of contamination.

diversion ditch: a channel constructed across a slope to divert runoff water and help control soil erosion.

drainfield: the part of a septic tank system where the wastewater is carried to the soil for absorption.

dredging: removing solid matter from the bottom of a water body to make a deeper channel.

drinking water treatment: the filtration, treatment, and chlorination of water to make it suitable for human consumption.

dry stacks: livestock manure stored in a pole barn with a sloping concrete floor.

ecosystem: the biotic community (living organisms) and its abiotic environment (non-living factors) functioning as one system.

effluent: waste material (i.e., smoke, sewage, etc.) discharged into the environment.

endangered species: a plant or animal in serious danger of becoming extinct.

environmental impact statement (EIS): a report of the potential effect of plans for land use in terms of the environmental, engineering, aesthetic, and economic aspects of the proposed objective.

erosion: the wearing away of the earth's surface by running water, wind, ice, or other geological agents; processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is removed from the earth's surface.

Escherichia coli: a specific coliform used as an indicator organism of pathogenic bacteria in fecal coliform testing (see coliform).

eutrophic: pertaining to a lake with high concentrations of nutrients; often shallow, with periods of oxygen deficiency.

eutrophication: naturally occurring changes that take place after a water body receives inputs of nutrients, mostly nitrates and phosphates, from erosion and runoff of surrounding lands; this process can be accelerated by human activities.

fish kill: the sudden death of fish due to the introduction of pollutants or the reduction of the dissolved oxygen concentration in a water body.

fungicide: an agent that kills fungi.

germicide: an agent that kills germs (microorganisms; esp. pathogenic).

grassed waterway: a natural or constructed waterway covered with grasses used to trap sediment and prevent erosion.

grass filter strip: a strip or section of land in permanent vegetation (e.g. grass), established downslope of agricultural operations to control erosion and slow, reduce, or prevent pollutants from entering an adjacent water body.

greenbox system: a rural garbage/recycling collection system where large (often green) refuse containers are placed in a centralized location. This garbage is then recycled or transported to a landfill. The purpose of these systems is to reduce open dumping on rural roadsides by providing convenient local access.

groundwater: water that infiltrates into the earth and is stored in the soil and rock below the earth's surface.

gully: a channel caused by the concentrated flow of water over unprotected erodible land.

hazardous waste: discarded solid, liquid, or gaseous material that can harm humans or other animals.

heat retention: the retaining of heat.

heavy metals: a metal whose specific gravity is approximately 5.0 or higher; present in industrial, municipal, and urban runoff including copper, cadmium, zinc, nickel, mercury, and chromium.

hydrologic cycle (water cycle): the movement of water from the atmosphere to the earth and back to the atmosphere through precipitation, runoff, infiltration, percolation, storage, evaporation, and transpiration.

hydroseeding: the process of sowing seed by using a machine to disperse seed, water, and fertilizer together in a high pressure stream of water; used primarily to seed steep banks.

impervious: resistant to penetration by water or plant roots.

infiltration: the gradual downward flow of water from the surface of the earth into the subsoil.

landfill: a large, outdoor area for waste disposal; landfills where waste is exposed to the atmosphere are called open dumps; in sanitary landfills, waste is layered and covered with soil.

leachate: the syrupy liquid formed when water (from precipitation) infiltrates through the soil covering a landfill and percolates down through the waste, picking up a variety of suspended and dissolved materials from the decomposing waste.

lead: a soft, malleable element (atomic number 82) used in metals, solder, pipes, paints, and bullets; a toxic pollutant known to cause nervous system disorders.

LC 50: lethal concentration at 50%; the concentration of a substance where 50% mortality occurs in a bioassay.

limiting factor: a factor whose absence exerts influence upon a population and may be responsible for no growth, limited growth (decline), or rapid growth.

loam: a soil consisting of a pulverized mixture of clay, silt, and sand.

mercury: a metallic element (atomic number 80) that at room temperature is a silvery, heavy liquid; used in thermometers and certain industrial processes. Mercury has been known to increase in concentration as it moves up through the food chain (from discharges to plankton to fish and to humans; (bioaccumulation) resulting in toxic concentrations at the top of the chain.

midnight dumping: a term used for the illegal disposal of hazardous wastes in remote locations often at night, hence the term "midnight."

mine spoils: the discarded remains leftover from mining operations; a source of acidic and other toxic pollutants.

molarity: the concentration of a substance expressed in moles per liter of solution.

mollic soils/mollisols: an order of soils having a dark, thick topsoil layer that is high in organic matter and alkaline. In the United States, these soils are found in the grassland areas.

mulch: any material such as straw, sawdust, leaves, plastic film, or pine bark that is spread upon the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting, freezing, and evaporation.

municipal sewage: sewage from a community; may be composed of domestic sewage, industrial wastes, or both.

nitrate (NO_3 or compounds containing it): fertilizer consisting of sodium nitrate or potassium nitrate, an urban and agricultural nonpoint source pollutant.

nitric acid (HNO_3): a component of acid rain; corrosive; damages buildings, vehicle surfaces, crops, forests, and aquatic life.

nitrification: the oxidation of nitrogen in ammonia.

nitrogen (N): a nonmetallic element (atomic number 7); one of the major nutrients required for the growth of plants; present in water usually as organic nitrogen, ammonia, nitrate, and forms of nitrate; excess nitrogen causes accelerated eutrophication in water bodies.

nitrogen oxides (NO_x): toxic, colorless gases of nitrogen dioxide (NO_2) and nitric oxide (NO) that result from the burning of fossil fuels; mixes with atmospheric moisture forming nitric acid, a major component of acid rain.

nonpoint source pollution (NPS): pollution that cannot be traced to a specific point, because it comes from many individual places or a widespread area (e.g., urban and agricultural runoff).

no-till or zero tillage: a method of planting crops that involves no land disturbance other than opening the soil for the purpose of planting seeds at an intended depth.

nutrient: an element or compound, such as nitrogen, phosphorous, and potassium, that is necessary for plant growth.

nutrient pollution: human-caused addition of excess nutrients to a water body in runoff.

open dump: an unprotected, unauthorized, open area used to dispose of loose garbage on the land's surface.

organic materials: carbon-containing substances found in plants, animals, and their remains.

oxygen-demanding substances: biodegradable organic matter in water that is broken down by microorganisms utilizing dissolved oxygen in the process.

parts per million (ppm): the number of "parts" by weight of a substance per million parts per liquid (e.g., one gram of salt in one million grams of water equals 1 ppm of salt); milligrams per liter.

pathogen: disease-causing organism (e.g., bacteria, viruses, fungi, etc.).

pathogenic: capable of causing disease.

percolation: the downward movement through the subsurface soil layers to groundwater.

pesticide: any chemical or biological agent that kills plant or animal pests; herbicides, insecticides, fungicides, rodenticides, etc., are all types of pesticides.

pH: a measure of the concentration of hydrogen ions in a solution; the pH scale ranges from 0 to 14, where 7 is neutral and values less than 7 are acidic and values greater than 7 are basic or alkaline; pH is 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.

phosphorous (P): a nonmetallic element (atomic number 15); one of the major nutrients required for the growth of plants; one of the ingredients used in the production of detergents and phosphate-containing fertilizers; excess phosphates causes accelerated eutrophication in water bodies.

photosynthesis: the process that occurs in the cells of green plants where solar energy is utilized to combine water and carbon dioxide and produce simple nutrient molecules, such as glucose.

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

pollutant: any substance which causes pollution.

pollution prevention: the use of processes, practices, or products that reduce or eliminate the generation of pollutants and wastes including those which protect natural resources through conservation or more efficient utilization of resources.

polychlorinated biphenyls (PCBs): a group of stable human-made industrial chemicals used as insulation fluids in electrical transformers and capacitors; PCBs are harmful because they do not break down and can bioaccumulate in humans and animals.

recreation: any activity which restores or refreshes strength and emotional well-being; water-related recreation includes swimming, fishing, boating, water-skiing, picnicking, hiking, and camping.

reduced-tillage or conservation tillage: any tillage practice which involves less soil disturbance and retains more plant residues on the soil's surface than conventional methods.

riprap: large rocks placed along the bank of a waterway to prevent erosion.

rodenticide: any chemical or biological agent used to kill rodents (mice, rats, etc.).

row-cropping: a farming practice where crops are planted in rows usually between 24 and 42 inches (.62 - 1.15 m) wide; commonly used in growing corn, soybeans, and cotton.

runoff: the portion of rainfall, melted snow, or irrigation (e.g., lawn sprinkler) water that flows across the land's surface, does not soak into the ground, and eventually runs into water bodies; may pick up and carry a variety of pollutants.

sanitary sewer: a system of drains and underground pipes that collects and transports wastewater from homes and businesses to the local wastewater treatment plant.

scrubbers: pollution control equipment used to remove sulfur dioxide and particles from coal-burning power plant emissions.

sediment: insoluble material suspended in water that consists mainly of particles derived from rocks, soil, and organic materials; a major nonpoint source pollutant that other pollutants may attach to.

sedimentation: the transport and deposition of sediment particles by flowing water or wind.

sediment basin: a depression lined with grass or gravel where water is diverted for storage. Sediment is filtered out as the water percolates through the soil.

sediment load: the solid material that is transported by water.

selective cutting: the timber harvesting practice where only selected trees are cut and the rest are allowed to remain.

septic tank or septic system: a domestic wastewater treatment system into which wastes are piped directly from the home into the ground; consists of a septic tank and drainfield; wastewater is exposed to bacteria that decompose the organic waste; dead bacteria and sediment settle to the bottom of the tank, and treated effluent flows out into the ground through drainage pipes.

sewage: the waste liquids or solids carried off by sewers.

sewer system: an underground system of pipes used to carry off sewage and surface water runoff.

shock-loading: the sudden introduction of pollution to a water body that severely impacts the aquatic life.

silt: fine particles of rock, soil, or organic material suspended in water.

siltation: the deposition of silt carried by flowing water; the filling-in of water bodies with silt.

silt screen: a sheet of fabric placed like a fence around construction sites that traps sediment and prevents it from entering a water body.

slash: branches and other residue left on a forest floor after the cutting of timber

Soil Conservation Service(SCS): a branch of the U.S. Department of Agriculture with local offices that provide technical and educational assistance through conservation districts with watershed projects, flood protection, water supply/management, recreation, and wildlife habitat.

spoil piles: the piles of leftover materials from mining operations (see mine spoils).

storm sewer: a sewer or pipe that usually carries surface water runoff, street waste, and snow melt from the land, directly into a nearby water body.

strip cropping: a type of conservation farming where crops are planted in narrow strips alternating between row crops and close-growing forage crops.

strip mine: an open mineral mine (e.g., coal, copper, zinc, etc.) where the topsoil and overburden is removed to expose and extract the mineral.

sulfuric acid: the acid (H_2SO_4) formed when sulfur oxides combine with atmospheric moisture; a major component of acid rain.

sulfur oxides: toxic gases (SO_x) that are a result of burning fossil fuel; a major contributor to acid rain.

surface 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.

surface water: precipitation which does not soak into the ground or return to the atmosphere by evaportation or transpiration, and is stored in streams, lakes, wetlands, and reservoirs.

suspended solids: a mixture of fine particles dispersed in a liquid.

switchbacks: roads or trails with a zigzag pattern designed to minimize erosion.

tailings: rock and other waste materials removed when minerals are mined; usually dumped onto the ground or deposited into ponds.

Tanzy: a fragrant annual or perrenial herbaceous plant.

terrace: an embankment, or combination of an embankment and channel, constructed across a slope; used to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

topographical map: a map that shows the surface features of a region.

topography: the representation of surface features of a region on maps or charts.

toxic: being harmful, destructive, or deadly to humans, animals, or plants.

toxic chemicals: any chemical that causes death or harm to humans, animals, or plants.

toxic substances: poisonous wastes or substances in wastewaters that may end up in water bodies; may harm fish or other aquatic life.

trace metals: naturally occurring metals found in minute quantities in the environment.

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter.

Universal Soil Loss Equation (USLE): an equation used to predict erosion and design erosion control systems. [NOTE: A revised version of this equation (RUSLE) was released January 1993 by the USDA.]

wastewater treatment: physical and chemical processes used to remove pollutants from wastewater before discharging it into a water body.

water cycle: (see hydrologic cycle).

water pollution: any human-caused contamination of water that reduces its usefulness to humans and other organisms in nature.

Water Quality Act of 1987: amended the Clean Water Act; instituted the nonpoint source pollution program.

water quality management plan: a plan for managing water quality within a watershed that considers both point and nonpoint sources of pollution.

watershed: the total land area that contributes runoff to a particular water body.

water table: upper surface of the zone of saturation of groundwater.

zone of saturation: the underground area above an impermeable layer where all openings are filled with water.

WATER

More than three quarters of the earth's surface is made up of water. Approximately 80 percent of the human body is water. Water is essential to all plant and animal life. Many organisms can live without oxygen, but none without water. So water supply and quality are critical.

The Water Cycle

Water is the original renewable resource. We use the same water today as we did centuries ago. We just keep recycling and reusing it over and over.

Water has its own cycle in which it is naturally purified and replenished. In this cycle, water naturally circulates through seven principle places: oceans, lakes, and rivers; ice caps and glaciers; underground; and the atmosphere. This cycle consists of the processes of evaporation, sublimation, transpiration, condensation, and precipitation.

Evaporation is the changing of a liquid to a gas. Sublimation is the changing of a solid (ice) directly into a gas. It is a slower process than evaporation, but it is still part of the water cycle, particularly in colder areas. These processes are critical to the renewal and purification process because as water changes into a gas, it leaves behind any contaminants that it may have picked up in liquid or solid form.

Transpiration is the process by which plants use water from the ground and give off water vapor into the air. A single tree can release more than 10,000 gallons (37,850 liters) of water a day back into the atmosphere. This is also a purification process.

As the atmosphere absorbs water vapor from evaporation, sublimation, and transpiration, it reaches a saturation point. As the air is saturated, water vapor condenses into droplets that form clouds, fog, dew, and in cold weather, frost. When water droplets in a cloud become too heavy, they fall as precipitation in the form of rain, snow, sleet, or hail. Condensation and precipitation complete the cycle of water from the earth to the atmosphere and back again.

Surface Water and Groundwater

Much of our water supply is visible, in the form of surface water in oceans, lakes, streams, rivers, and glaciers. Surface water originates as either runoff from rain, melting snow, and/or groundwater.

But much of the water supply is unseen, in the form of groundwater. Groundwater originates either as rain or snow which gradually seeps into the ground until it reaches impermeable layers, such as shale, slate, or clay. When water completely fills the spaces between soil and rock particles, it forms a zone of saturation. The top of this zone is called the water table. The water table can rise or fall, depending on how much water is absorbed into the ground or how much water is removed from it. An area capable of supplying a significant amount of groundwater to a well or spring is known as an aquifer.

Groundwater may be trapped in rock formations, or it may flow through porous rock or even underground rivers. The ability to access groundwater supplies through wells or springs is vital to the development of some areas. Deserts have been transformed into viable agricultural areas using groundwater resources.

WATER POLLUTION

Water pollution is any human-caused contamination of water that reduces its usefulness to humans and other organisms in nature.

From the moment it begins to fall as rain, water begins to collect natural impurities. These can be dust particles in the air, minerals and organic matter in the soil, or material that enters lakes, streams, oceans, or groundwater. Some of these impurities, in small quantities, can be beneficial. Minerals are a good example. But in larger quantities, natural impurities become water contamination. For example, when a volcano erupts and dust from the volcano enters water bodies, the water is contaminated, not polluted.

According to the U.S. Clean Water Act of 1977, and its 1981 and 1987 amendments, water pollution is caused by humans and can be divided in two classes. Point source pollution is contamination that comes from a single, clearly identifiable source, such as a pipe which discharges material from a factory into a lake, stream, river, bay, or other body of water. Point source pollution is relatively easy to identify and control.

Nonpoint source pollution is more difficult to identify because it originates over a broad area from a variety of causes. Examples of nonpoint source pollution include 1) animal wastes from agriculture; 2) pesticides and fertilizers; 3) sediment from mines, construction, agriculture, and logging; 4) leachate from landfills; 5) effluent from failing septic tanks; 6) petroleum-based products from streets and parking lots; and 7) atmospheric deposition. Because of its dispersed sources, this type of pollution can be difficult to control.

Water pollution, whether point source or nonpoint source, can be broken down into four main categories:

LAND USE AND WATER QUALITY

Urbanization

The urbanization of land concentrates people, and the pollutants that result from their lifestyles, in areas that are largely covered with impervious surfaces—buildings, driveways, roads, sidewalks, and parking lots. This combination of people, pollutants, and pavement produces urban runoff that can carry a greater pollutant load than municipal sewage.

The amount of pollutants carried in urban runoff with stormwater or snowmelt is influenced by traffic density, littering, fertilizer and pesticide use, construction site practices, animal wastes, soil characteristics, topography of the area, percentage of impervious surfaces, atmospheric deposition, and amount of precipitation.

Pollutants transported in urban storm sewer systems to nearby waters include nutrients, bacteria, litter, soil, toxic chemicals, and organic (oxygen-consuming) materials.

Construction Sites

Construction activities can harm nearby waters in three ways. The first occurs when natural land cover is disturbed during excavation and grading operations. Soil stripped of its protective vegetation can be easily washed into nearby surface waters.

Second, stormwater runoff often carries materials used on the site, such as oil, grease, paints, glues, preservatives, acids, cleaning solutions, and solvents, into nearby lakes or streams.

And third, inadequate planning—failure to design and construct projects with water quality factors in mind, such as peak runoff and flow routing—can accelerate runoff.

Septic Systems

Many homes are not connected to municipal wastewater treatment systems and rely on septic tanks and field lines for sewage treatment.

If they are well designed, installed, and maintained, septic systems will safely treat wastewater for 20 to 50 years. Improper design, installation, or operation of septic systems or holding tanks can lead to pollution of surface or groundwater by bacteria, nutrients, and household toxic chemicals. A recent U.S. Environmental Protection Agency (EPA) report stated that most waterborne diseases are probably caused by old or poorly designed and operated septic systems.

Septic systems use natural decomposition to treat wastes. Holding tanks do not treat wastes, but simply contain them on site. Both septic systems and holding tanks must be periodically pumped out or cleaned. Care must be taken in disposing of the materials removed in this cleaning. Solids cleaned out of septic systems can be land-spread since they are partially treated, but continuous spreading on a single site of land should be avoided. Wastes removed from holding tanks need additional treatment since they generally have not undergone much decomposition.

Deicing Materials

Keeping roads safe in the winter requires the use of deicing materials, but the stockpiling and application of these materials (primarily sand and salt) can harm surface and groundwater.

Runoff from inadequately protected stockpiles of salt or sand and salt mixtures has contaminated both surface and groundwater. One study estimated that if all stockpiles were covered, most of the reported cost to the environment from the use of deicing materials would be eliminated.

Frequent or highly concentrated road salt application can cause surface water quality problems, particularly in small lakes or streams. Shallow groundwater contamination may be caused by the use of deicing materials, particularly in areas of sandy soils or karst topography (where there are direct connections, such as sinkholes, between surface and groundwater).

Croplands

Stormwater and snowmelt runoff from croplands can carry sediments, nutrients, bacteria, and organic contaminants into nearby lakes and streams. Nitrates and pesticides can seep from agricultural lands and contaminate underlying groundwater supplies.

By volume, sediment is the pollutant entering waters in the largest quantity. Cropland erosion is the most significant source of sediment.

Good water quality and soil erosion management practices by individual land managers is the key to stopping valuable soil loss. This also protects water quality by preventing the movement of sediment and other pollutants from croplands to water bodies.

Livestock Operations

Animal feedlots are defined as lots and buildings used to confine animals for feeding, breeding, raising, or holding purposes. This definition includes open ranges used for feeding and raising poultry, but does not include pastures.

Poor or inadequate feedlot management can allow stormwater runoff to carry pollutants from accumulating manure into surface and groundwaters.

The trend nationally has been toward the construction and operation of fewer, but larger and more specialized livestock and poultry farms.

Feedlots can create significant pollution problems. Pollutants coming from animal feedlots include nutrients, oxygen-demanding materials, and pathogens that may affect humans and animals. High nitrate levels in groundwater have been associated with improper storage of animal manure.

Fertilizers

Nitrogen, phosphorus, and potassium are the three primary nutrients applied to crops, gardens, and lawns as fertilizers.

Phosphorus and nitrogen entering water bodies in runoff from overfertilized areas can cause nuisance conditions, such as heavy algal blooms and excessive weed growth, making lakes unsuitable for swimming, water skiing, and other uses.

The presence of nitrates in rural well water presents a risk to infants under six months old whose formula is prepared with nitrate-contaminated water. Young infants lack the ability to handle high levels of nitrate and may develop methemoglobinemia (blue-baby syndrome), a disease impairing the ability of blood to carry oxygen throughout the body.

Studies have indicated that nitrogen in fertilizers and manures is a probable source of elevated nitrate concentrations in rural groundwater supplies.

Pesticides

Pesticides are used to control undesirable plants or animals. They include herbicides, insecticides, fungicides, and rodenticides. Pesticides are used on agricultural lands, on urban and suburban lawns and gardens, as aquatic nuisance controls in lakes, and in forest management.

Pesticide application can lead to groundwater contamination. Surface waters can be contaminated by drift from pesticide spraying and by runoff from pesticide-treated soil. Both surface and groundwaters are vulnerable to contamination by stormwater runoff flowing from storage, mixing, loading, and spray-tank cleaning areas.

Mining Activities

Mining activities can cause dramatic changes in surrounding watersheds. Lakes, streams, and ground-water can be polluted by sediment, tailings, dust, chemicals, and wastes from open pit, strip, and underground mines.

Regulations to control mining activities have been instituted at both U.S. Federal and state levels. The National Pollutant Discharge Elimination System (NPDES) permit program administered by state agencies regulates discharges from industries into state waters and is used as a tool to regulate pollution from mining.

Forest Practices

Waters in forested areas usually are of very high quality, so pollution, when it does occur, is likely to harm a valuable and relatively sensitive ecosystem.

Forestry activities that can transfer pollutants from land to water are road construction, clearing land for fire breaks, stacking and loading operations during harvest, mechanical site preparation, controlled burning for site preparation, and application of pesticides and herbicides.

Many large forested areas are managed by the U.S. Forest Service and state agencies. These agencies have authority to protect water quality by regulating forestry practices on public lands. Establishing effective forest management practices on private land is the primary concern for continued water quality protection from forestry activities.

SOURCE: Tennessee Valley Authority, Teacher/Student Water Quality Monitoring Network Fall Workshop Teacher Guide, TVA, Norris, Tennessee, 1992.

SEDIMENT WATER POLLUTION

Sediment is the most prevalent water pollutant. America's water is polluted by more than one billion tons of sediment annually. Every day, Americans lose millions of dollars because of sediment pollution.

Sediment is mineral or organic solid matter that is washed or blown from land into lakes, rivers, or streams. It can be point source or nonpoint source pollution. Typically, it comes from nonpoint source causes. Sources of sediment pollution include construction, row-cropping, livestock operations, logging, flooding, and runoff from urban areas. Sediment by itself can be a harmful pollutant and it can transport other contaminants.

The results of sediment pollution can be devastating. It can clog municipal water systems. Lakes and reservoirs can receive so much sediment that they actually fill in. Sediment can turn a deep lake into a shallow wetland area over time. Fine sediment can blanket the bottoms of lakes and rivers and smother aquatic life such as insects and mussels. Sediment can also interfere with spawning.

Sediment can be detrimental while it is still suspended in water. It can make water cloudy or turbid. High turbidity makes water aesthetically unpleasant and reduces recreational opportunities. Suspended sediment can clog fish gills which interferes with breathing. Some species of fish, such as smallmouth bass, will not live in a highly turbid aquatic environment, and studies indicate that high turbidity decreases fishing success.

Sediment in water can also create thermal pollution problems. Sediment darkens water which causes it to absorb more solar radiation. This raises water temperatures to the point where it may not support some forms of life. At the same time, sediment blocks light from reaching aquatic plant life, slowing or stopping plant growth. Also, warmer water cannot hold as much dissolved oxygen. In fact, oxygen levels can be reduced to the point that fish kills occur.

Solutions

Because many causes of sediment pollution are nonpoint source, finding solutions to the problem can be difficult. In some cases, solutions are ongoing activities like dredging and water filtration. In the U.S., over 2,000 billion gallons (7,570 billion liters) of water are filtered annually to remove sediment and silt.

However, many causes of sediment water pollution can be reduced or eliminated through proper land management, particularly for activities that create erosion, such as agriculture, construction, mining, and logging.

Croplands account for the largest amount of sediment pollution. Bare earth erodes quickly, since there is no plant cover to protect soil from rainfall or wind. Careful land management can reduce erosion dramatically. Better livestock management practices can also reduce sediment pollution from livestock trampling streambanks and reducing vegetative cover. Runoff can be channelled into lagoons where sediment settles before water is released into streams. The nutrient-rich sediment can then be used to fertilize croplands.

Construction sites and strip-mined areas can lose soil to erosion at a rate up to 70 tons (63.5 metric tons)per acre per year—fifteen times higher than the normal rate from croplands. Many U.S. Federal and local laws require construction and mining companies to reclaim land instead of leaving it bare to the ravages of erosion and subsequent sediment pollution. Proper management of logging areas can reduce runoff, improve forest stands, and make reforestation easier. Aerial photography is now being used to determine land use in specific areas, identify drainage patterns, and establish erosion rates. Information can be quickly gathered in this manner and steps taken sooner to alleviate nonpoint source water pollution problems.

NUTRIENT WATER POLLUTION

Many of the nutrients used to bring the earth to life can "overfeed" a waterway to death. Nutrients like phosphates and nitrates stimulate plant growth and are primary ingredients in fertilizers. These compounds occur naturally. In fact, certain levels of nutrients are necessary to maintain healthy aquatic ecosystems. But in excess quantities they can cause great damage. Approximately 80 percent of nitrates and 75 percent of phosphates introduced to lakes and streams in the U.S. are the result of human activities.

Naturally occurring nitrates and phosphates usually are limiting factors in the growth of plant life. In other words, they occur in limited amounts that help govern the growth of different organisms and keep ecosystems in balance. But when excess amounts of these nutrients are introduced into a waterway, some plant species can experience explosive growth, literally out-competing other life forms.

Sources of nutrient pollution are sewage and septic runoff, livestock waste, fertilizer runoff, detergents, and industrial wastes. Some of these are point sources, while others are nonpoint sources.

When soluble inorganic nitrogen concentrations in water reach just 0.3 parts per million and inorganic phosphorous concentrations reach 0.01 parts per million, algae "blooms" or multiplies rapidly. An algal bloom can become so severe that an entire lake can be covered with green, foul-smelling mats of algae. Clear water can become so cloudy that visibility is restricted to a depth of a foot (30 cm) or less.

Rapid and excessive growth of algae and aquatic plants can change the character of lakes, streams, and coastal waters and impair their recreational uses. Nutrients can cause aquatic weeds and other undesirable plants to flourish. Filamentous or branched algae can foul up boat propellers. Blue-green algae can stain boats and give swimmers a skin rash. Algal blooms can also impair water quality. If the waterway is a source for municipal water supplies, it can be expensive to remove impurities and odors caused by algae. Algal blooms can impart toxins into water that cause human and livestock digestive problems. Blue-green algae is toxic to most livestock. In fact, in some coastal areas it is dangerous to eat foods like oysters at certain times of the year because of algal toxins. Masses of algae can wash up on shore, decay, and produce hydrogen sulfide gas, which smells like rotten eggs.

Algal blooms can harm other aquatic life. Algae, like all plants, requires oxygen for respiration and growth. When algae multiply rapidly, the larger population requires more oxygen, which can deplete the supply for other aquatic life. This can cause other organisms to suffocate. For example, it is not uncommon for fish kills to occur at night when algae are using oxygen to respire and grow instead of producing it through photosynthesis.

When an algal bloom clouds water, it can block sunlight from reaching other plants, killing them or limiting their growth. And as the algae dies, the bacteria which feed on it can deplete oxygen levels in the water to the point where other life forms are weakened or killed.

Eutrophication is a process where lakes and other water bodies accumulate decaying plant materials and begin to shrink in size. The addition of nutrients to a lake or other waterway causes plant growth and subsequently causes eutrophication is a naturally occurring process. It happens slowly over millions of years. When the process is accelerated by the addition of excess nutrients, it can be very serious. Eutrophication caused Lake Erie to "age" nearly 15,000 years between 1950 and 1975.

Solutions

Since many sources of nutrient pollution are human-caused, they have the potential to be controlled. It has been estimated that the amount of fertilizers used has increased more than 15 times since 1945. There is a movement to curb the use of high phosphate and nitrate fertilizers in areas where nutrient pollution is a problem, even though crop yields would be reduced. Land management practices, such as crop rotation to reduce fertilizer requirements, is another option.

Homeowners can also adopt more environmentally sound lawn and garden practices. In many places, chemical tests indicate that individuals use 10 to 50 times more fertilizer than necessary for good plant health. Substituting compost as a mulch and fertilizer can eliminate this potential pollution source. (Composting also reduces waste going into landfills.)

Most sewage treatment plants only remove about 50 percent of the nitrogen and 30 percent of the phosphorous from domestic sewage. This still allows an estimated 200 to 500 million pounds (90 to 225 million kg) of phosphates into waterways every year. The use of lower phosphate detergents has been encouraged to reduce this, along with improving sewage treatment systems to remove more nutrients before water is released.

Proper management of livestock can also reduce nutrient pollution from animal wastes. Lagoons and holding ponds near feedlots can trap animal wastes and reduce nutrient pollution. U.S. Federal and local wastewater release laws govern industrial releases of materials that could contribute to nutrient pollution.

BACTERIAL WATER POLLUTION

Bacteria are necessary for the decomposition of organic material in water . But decomposition requires oxygen. There is plenty of oxygen in the air, but oxygen dissolved in water is limited. If there are too many bacteria in water, they must compete for oxygen with fish and other organisms.

The amount of bacteria present in water bodies depends upon the amount of organic material to decompose. The more organic material to decompose, the faster bacteria multiply to decompose the material. Large numbers of bacteria can deplete oxygen supplies in water from a normal level of about ten parts per million to under one or two parts per million. At this level, many aquatic insects and fish can suffocate. Even a short-term drop in oxygen levels can be enough to cause fish kills. Long-term reductions in dissolved oxygen levels can cause game fish like lake trout to die off and be replaced by trash fish like carp, which can survive on lower oxygen levels. The Federal government monitors waterways across the country for oxygen content, because this factor is considered critical to the health of a lake or stream.

Bacterial water pollution can be caused by a variety of point and nonpoint sources. These include 1) improperly treated sewage; 2) runoff from livestock wastes; 3) industrial sources such as slaughter-houses, food processing plants, or paper mills; and 4) poorly designed or mismanaged landfills.

In addition to oxygen depletion problems, bacterial water pollution can be the source for the spread of many diseases. This can be a danger for both surface and groundwater supplies. Among the diseases that can be spread in this manner are diarrheal diseases, infectious hepatitis, parasitic diseases, cholera, dysentery, salmonella, and typhoid fever. Testing for all these diseases would be complicated, so health officials analyze water for the presence of coliform bacteria. Most coliforms, by themselves, are not harmful but are used as indicators of fecal contamination where most waterborne disease-causing organisms originate. Water is considered unsafe for human consumption if tests indicate the presence of more than one coliform bacterium per 100 milliliters of water. During periods of heavy runoff, beaches may be closed because of high coliform counts. The principal source of this type of bacterial pollution is poorly treated municipal sewage, although urban runoff (which can contain high levels of pet wastes) can also be a problem after heavy rains.

In rural areas, runoff from livestock operations can create bacterial pollution, as can failing septic systems, which can contaminate groundwater supplies and make well water unsafe. Rural ponds and lakes used as watering sources for animals can rapidly spread disease among entire herds. In urban areas, runoff containing pet wastes contribute bacteria to urban waterways. Poorly designed or mismanaged landfills, open dumping, and litter also contribute harmful bacteria to water bodies.

Solutions

The fight against bacterial water pollution is almost as old as man himself. Epidemic diseases such as cholera killed hundreds of thousands of people before the link between them and polluted water supplies was established. In third world countries, the lack of clean water still allows disease to run rampant.

Proper sewage treatment is the key to stopping most bacterial pollution. Modern municipal sewage treatment plants are capable of controlling bacterial pollution, unless stormwater runoff overwhelms the treatment systems. Private septic systems, however, can be a significant problem.

Well-designed septic systems will safely treat wastewater for 20 to 50 years, but a failing system can lead to pollution of both surface and groundwater. The U.S. Environmental Protection Agency reports that most waterborne diseases are caused by old or poorly designed septic systems. Systems should be periodically pumped out and cleaned, with the removed material disposed of properly.

Today most landfills are designed with liners to prevent leachate from contaminating water supplies. Open dumps and litter problems can be controlled by always disposing of wastes properly. Wastes can be reduced by decreasing what we buy, reusing items, purchasing reusable products instead of disposables, purchasing products with less packaging, composting organic wastes, and recycling.

Proper management of livestock wastes can also eliminate bacterial pollution problems affecting both humans and animals. In urban areas, particularly where domestic animals are abundant, pet owners should collect and dispose of pet waste either in compost piles or with their other garbage.

TOXIC WATER POLLUTION

Modern nations rely on thousands of organic and inorganic chemicals in industry, agriculture, and the home. These materials provide many benefits, and new chemical compounds are constantly being developed to improve existing processes. But with modern chemicals come pollution problems. Improperly used or disposed of, reasonably safe chemical compounds can become toxic. The effects of such toxics can be immediate illness or allergic reactions. Or they can be delayed for years before resulting in diseases or even death. For this reason, toxic water pollution is regarded as a major national and international health concern.

Toxic water pollution is most often linked to point source causes, such as industrial discharges or accidents in transportation (such as oil spills). But it can also come from nonpoint source causes. These include runoff from both urban and rural areas, and atmospheric transport.

Hard surfaced roads and parking lots in urban areas collect toxics such as lead, oil, cadmium (from tires) and other pollutants, which can be washed into streams through storm drains. These materials are not only immediate toxics, but remain and accumulate in sediment or in the tissue of living organisms. (In the 1970s many people suffered severe health problems from eating swordfish containing high levels of mercury, which accumulated in the fish over a long period of time.)

In agricultural areas, pesticides containing toxic compounds are applied to crops to improve crop quality and increase yields. Their proper use has helped eliminate hunger in many parts of the world. But improper application of pesticides can create serious water pollution problems, because runoff from fields can introduce large amounts of toxics into waterways. Pesticides can also cause groundwater contamination.

The cost of disposing of toxic chemicals created by industry is high. U.S. Federal and state laws or Canadian provincial laws require careful monitoring of industrial processes and specific storage and disposal procedures of these materials. This cost has caused some unscrupulous business people to illegally dispose of toxic chemicals, a process called "midnight dumping." Pollution from this source may go undetected for years, and when discovered, it can be very difficult to determine the source and very expensive to clean up. U.S. Legislation adopted since the late 1970s has imposed large fines and jail sentences for people caught illegally dumping toxic wastes.

Another, perhaps surprising, source of toxic water pollution comes from individuals. Household chemicals such as cleaners, dyes, paints, and solvents are a large source of toxic water pollution, particularly in urban areas. Many of these materials are simply poured down drains or flushed down toilets with no regard to the consequences. And while the toxic chemicals from one household may not seem like much, they can cause problems. In fact, a single quart (liter) of motor oil can pollute a quarter of a million gallons (1 million liters) of water. And homeowners may use ten times the amount of pesticides per acre as farmers. The amount of toxics released by an entire city, one person at a time, can be staggering.

An often overlooked form of toxic water pollution is from atmospheric transport. Pollutants can be deposited directly into water or wash off the land in runoff. Acid rain, for example, is caused when sulfur and nitrogen gases emitted from automobiles and coal-burning power plants combine with water in the atmosphere to form acids. Acid precipitation can damage buildings, car finishes, crops, forests, and aquatic life. Many other chemicals emitted from industrial stacks at plants can also end up in water bodies. For example, prior to lead-free gasoline, lead was being emitted from car exhaust, being deposited on land, and then washed into water bodies.

Another source of toxic substances are landfills. Leachate formed when precipation percolates through garbage may contain toxics that can contaminate surface and groundwater supplies.

Solutions

Increased concerns over industrial toxic pollution have created strict regulations for most companies, ranging from large plants to small businesses like dry cleaners, which use potentially toxic solvents. Since the effects of some toxics have not yet been determined, it is expected that even more regulations will be created in the future to limit the material that can be released into both the nation's atmosphere and waterways. This creates a major challenge for industry to keep up with changing regulations and develop ways to meet new requirements. Efforts are being made to install air cleaners on factories, power plants, cars, and wood stoves to trap pollutants before they get into air and are transported into water. The use of nonpolluting methods of power production such as hydroelectric, thermal, and solar also helps.

Individual actions can also have a big impact on the toxic pollution problems. Homeowners can substitute biocontrol agents, like praying mantises or ladybugs, for pesticides. Other natural insect repellents include plants like mint (which discourages ants), garlic, and marigolds. Acid rain can be reduced by using the car less and conserving electricity at home and work.

Properly tuned automobiles and adequate pollution control devices will also reduce acid rain. Since virtually every liquid in an automobile can be a serious pollutant, care should be taken to avoid spilling oil, antifreeze, or other fluids from automobiles. In some cases, it may be more ecologically sound to have repairs done by a reputable garage than to attempt messy do-it-yourself work. Reformulated gasolines designed to reduce harmful emissions can also reduce pollution.

Household cleaners can add toxic chemicals or nutrients to water. In most cases, harsh chemicals are not necessary to do an effective cleaning job, and less-damaging substances can be substituted. Baking soda can be used as a scouring powder or water softener to increase the cleaning power of soap. Soap biodegrades safely without adding phosphates or dyes to water like many detergents. Borax cleans, deodorizes, and disinfects. An all-purpose cleaner made of a teaspoon (5 ml) of liquid soap, two teaspoons (10 ml) of borax, and a teaspoon (5 ml) of vinegar in a quart (liter) of water is an effective grease cutter. A quarter cup (62 ml) of baking soda followed by a half cup (125 ml) of vinegar makes a good drain cleaner. Consumers should also take care in disposing of potentially dangerous household waste like batteries, nail polish, drain cleaner, and paint. Many communities offer regular hazardous waste pickups. The U.S. EPA Resource Conservation and Recovery Act hot-line (703) 486-3367 can supply more information.

OTHER WATER QUALITY FACTORS

Water in different areas will have different qualities, (caused by natural impurities and conditions) that can affect pollution levels. These considerations often affect the ways in which pollution problems can be addressed.

Dissolved Oxygen (DO)

The amount of dissolved oxygen (DO) or concentration in a water body is a very important indicator of the "health" of a lake or stream. For aerobic organisms, such as fish, zooplankton, and invertebrates, the concentration of DO in the water will determine the type of organisms which can live in a lake or stream. If dissolved oxygen levels fall below desirable levels, aerobic organisms can suffocate and die. Different organisms have different preferences. For example, brook trout require high levels of DO while carp can survive at lower levels. The production of oxygen by green plants, either algae or aquatic macrophytes, during the day, and respiration by aquatic animals and plants at night greatly affect DO concentrations.

DO is supplied to a water body through (1) the diffusion of atmospheric oxygen into the water and (2) the production of oxygen through photosynthesis by algae and aquatic macrophytes. Usually, a natural gradient exists favoring the diffusion of oxygen from the atmosphere into water. The agitation of water by wind, waves, or as occurs in the riffles or falls of a stream quickens the diffusion process. Internal mixing in a lake or stream helps distribute the oxygen throughout the water body. The solubility of oxygen in water is related to temperature. Oxygen is more soluble in cold water than in warm water. Thus, during the winter, the surface waters of a lake usually will have a higher concentration of DO than they will in the summer.

DO can be depleted by respiration or decomposition. At night, when photosynthesis ceases, the plants take up oxygen. Coupled with bacterial respiration associated with the decomposition of material, and the respiration of fish and invertebrates, this can lead to a serious depletion or even exhaustion of the DO content. This places a great stress on the organisms living in the water and leads to a condition where the water body becomes dominated by highly tolerant organisms.

Low DO can be caused by (1) increasing nutrients such as nitrogen and phosphorus that accelerate plant growth, (2) runoff of manure and other organic wastes directly into water bodies, and (3) discharge of poorly treated wastewaters with high concentrations of organic compounds.

Temperature

The temperature of a water body affects the solubility of oxygen. In addition, nearly all organisms have some temperature range they prefer or even require. For example, trout only live in cool mountain streams. Water temperatures often increase when tree cover is removed from stream banks or when sediment clouds the water. Sediments absorb heat. Also, some factories and power plants discharge heated water.

pH

By definition, pH is a measure of the concentration of free hydrogen ions (H^+) or acidity. The pH level of water is determined by its acidity or alkalinity. The pH scale ranges from 0 (very acidic) to 14 (very alkaline). Distilled water has a pH of 7. The introduction of impurities into water changes its pH and affects the numbers and types of aquatic plants and animals which can live in it. Pollution problems like acid rain can lower the pH of a body of water to the point that it can become essentially "dead" or devoid of aquatic organisms.

Alkalinity

Buffering capacity refers to the ability to resist pH change upon addition of an acid or base. In fresh waters, buffering is accomplished through the chemical interrelationship between carbon dioxide, bicarbonate, and carbonate. In essence, the alkalinity helps the water body resist changes in pH due to the addition of acids or bases. Alkalinity measures the total amount of carbonate, biocarbonate, and strong bases (like hydroxide) present in the water.

In soft water bodies which drain land overlying igneous rock, the alkalinity is fairly low. In hard water bodies which drain limestone formations or calcareous deposits, alkalinity is fairly high.

Highly productive lakes will tend to be more alkaline than lakes of low buffering capacity or resistance to change in pH. This is the result of photosynthetic activity which fixes carbon dioxide. As the carbon dioxide content of the water decreases, the pH of the water body will shift toward the basic side of neutral. The buffering capacity of water bodies determines the extent to which the pH will deviate from neutral. Low alkalinity water bodies will be more affected by acid rain, whereas high alkalinity water bodies are less affected because they buffer pH changes due to acid rain.

Hardness

This is a measure of calcium and magnesium ions in water. Hardness is a concern where water is being used for municipal or industrial supply. Hard water can have a "slimy" feel to it, and the hardness limits the ability of soaps to lather. Hard water can also cause deposits to form in pipes, eventually blocking them. This is of particular concern for industry. Hard water used in manufacturing may contain enough impurities to affect the quality of materials being produced. There is also some concern that hard water used for drinking may encourage health problems like kidney stones.

Chlorides

In water bodies where a septic or sewage problem is suspected, chloride analyses typically may be conducted. Natural chloride concentrations in water bodies are typically very low. Because humans eat so much salt as seasoning and most of this salt is not necessary, it passes through into urine and is a good indicator of human sewage. Road salts are another source of chloride. In most cases, the concentration of chloride in fresh waters is approximately 8-20 mg/l. The concentration of chlorides in waters subjected to pollution from wastewater or road runoff may be as much as 200 mg/l. At times, groundwater contributions to water bodies may be very high in chloride depending upon the geological nature of the watershed.

Oxygen-Demanding Pollutants

While land animals extract oxygen from the air, aquatic life depends on dissolved oxygen (DO) in water. The oxygen consumed by aquatic life is naturally replenished through photosynthesis by living aquatic plants, and through reaeration, which occurs when the layer of oxygen-depleted water contacts surface air. Reaeration takes place more quickly in fast-moving, shallow streams where the rate of air/water interchange is greater than in quiet lakes.

Pollutants, such as inadequately treated sewage, manure, crop residues, and natural loadings of leaves and algae require oxygen for decomposition, creating an oxygen demand on a water body. A discharge of organic nitrogen or ammonia can also create an oxygen demand through the process of nitrification.

When oxygen-demanding pollutants enter a water body as a result of poor land use practices and waste disposal activities, they upset the delicate balance between oxygen-consuming aquatic life and the oxygen-replenishing process. The pollutants can increase the rate of oxygen consumption to a level higher than the water body is adequately replenished. As a result, the oxygen content of the water will fall below what is needed to support aquatic life.

BEST MANAGEMENT PRACTICES

There are many approaches to stopping or preventing water pollution. These vary depending on the type of pollution and its source. Human activities on land have a direct impact not only on the types of pollution created, but also on the methods used to control pollution. The most effective ways of controlling water pollution are sometimes called best management practices (BMPs).

Urban And Suburban

Control of both point source and nonpoint source pollution in urban and suburban areas is increasing. Tremendous investment by cities and industry have helped curb pollution problems immensely. Municipal sewage treatment facilities have grown faster than the nation's population. However, more improvements are still needed to make sure that water treatment systems can keep up with our needs. U.S. Federal and state laws, beginning with the landmark 1972 Clean Water Act, are continually being developed that limit what types of contaminants can be released into water systems. These controls have stopped many of the fish kills and other problems associated with pollution in the 1970s. Many urban area lakes that were considered "dead" are now clean enough to support many fish species and other animals. Urban runoff is still controlled primarily by voluntary means, but cities have adopted new practices like leaf collection and street cleaning at critical times, that can reduce the flow of sediment and other contaminants into waterways. City planning places new emphasis on water conservation and control, particularly in areas where water supplies may be limited. Detention-retention ponds have been incorporated into some water control systems to allow contaminants to settle, and to feed rainwater into runoff channels at a controlled rate.

In some cases, building codes limit construction based on water demand. A single new household consumes more than a hundred thousand gallons (370,000 liters) of water each year, placing more demand on water supplies and on wastewater and sewage treatment systems.

Education programs designed to teach people the proper use of water and disposal of potential pollutants are also having a positive impact. These programs show people the staggering amounts of water they consume each day, and steps they can take to reduce consumption. Less consumption means less wastewater that has the ability to carry pollutants.

Construction

Construction must take into account both short-term and long-term water pollution management practices. Construction removes vegetation from the ground, inviting erosion and sediment pollution. Practices to reduce this include temporary measures such as diverting water flow through trenches or sediment ponds that allow silt and other materials to settle before water runs off into streams. Silt screens, hay bales, mulch, and other materials may also be used as temporary controls, as well as the planting of temporary grasses to control erosion before more permanent landscaping can be done.

One key to success in BMPs for construction is proper site planning. The type of soil, the location of streams, and the topography of the area must all be considered before the construction process begins. Permanent measures may have to be taken to ensure that slow erosion doesn't create problems several years in the future. These measures may include storm drains; "riprap," a permanent layer of stone that retards water flow and enhances infiltration; or even construction of grassed or lined waterways that convey excess storm water away from developing areas or critical slopes. The construction process itself may be modified to include a stone "pad" at the construction entrance to reduce the transportation of mud off the building site by vehicles or runoff.

Croplands

Croplands are the primary source of sediment pollution and they can be a source of nutrient or toxic pollution from fertilizer or pesticide runoff. New management methods are being used to reduce these problems.

One practice for reducing erosion and sediment pollution is conservation tillage. Instead of plowing under the residue from a previous crop and exposing bare soil, conservation tillage uses a disc or other device to cut through the residue so seeds can be planted. This process allows a protective layer of vegetation to remain on top of the soil to retard erosion and to retain more water in the soil. One negative impact is that this process may require increased use of herbicides. Another process, called ridge planting, puts seeds in ridges of plowed soil. This method allows warmer soil temperatures for planting and traps rainwater in the furrows between the ridges.

Agricultural extension services also provide soil testing to farmers so that fertilizers can be properly used. The tests indicate which nutrients may be needed for the type of soil and the crop being grown so that over-fertilization does not occur. Not only does this practice reduce pollution, it can reduce the cost of producing a crop.

Other BMPs include crop rotation, which may replace a row crop with a grain or other plant that covers more ground and reduces erosion. Planning field layouts can also reduce erosion and sediment pollution by contour farming, changing the direction of rows, or creating runoff channels that allow sediment to settle before the runoff water is released into streams.

Feedlots and Pasture Lands

Animal wastes can be sources of sediment, bacterial, and nutrient pollution. Waste management systems, however, can be used to convert animal wastes into reusable resources. A ton (908 kg) of animal manure is equal to about 100 pounds (45.4 kg) of high quality chemical fertilizer.

There is no one single system that is best for animal waste operations. Depending on the size of operation, type of livestock, and the potential for pollution, systems may need to be customized to a particular location. Considerations for system design include local environmental regulations, the number of animals, fertilizer needs, location of water sources, and the location of residences around the livestock operation.

A waste management system has three basic components: collection, transportation, and storage or disposal. For some farms, a system may provide collection and transportation functions, with the wastes delivered to another location for storage or disposal. Collection methods vary, ranging from scraping to washing and flushing. Transportation methods include conveyors, pumps, wagons or manure spreaders.

Collection and storage methods are based on the principles of either keeping wastes for later use or providing a safe method for their treatment and disposal. Proper storage facilities are important because wastes can lose nutrients and fertilizer value. A common treatment facility is a lagoon. Anaerobic lagoons break down waste materials without oxygen or aeration. Aerobic lagoons break down waste material with oxygen. This type of lagoon creates less odor than anaerobic lagoons. Aerobic lagoons require more surface area. Both types reduce the concentration of nutrients (by as much as 90 percent), making it safe to dispose of wastes by irrigation or even through controlled flow into streams.

Other alternatives include collecting wastes and drying them for use as household fertilizers or even additions to silage for animal feeds.

Mining

Mining is one activity that is specifically regulated as a potential source of pollution. Since 1965, more than three million acres (1,215,000 hectares) of land in the U.S. have been disturbed by strip-mining activities. Severe problems have been created by erosion and acidity. However, mined lands must now be "reclaimed," or restored to acceptable condition after operations are complete.

BMPs included in this process are preplanning to determine how the site will be used after operations are finished, stabilization of the site while work is in progress so that it does not create an immediate source of pollution, creation of storm water control and storage, and re-creation of natural beauty by replanting the site so it has minimum aesthetic impact on the area. Since mining can destroy topsoil, new soil or nutrients may need to be added before plants can thrive, or different vegetation requiring less nutrients may be used to start growth.

Underground mines can also be pollution sources, particularly for groundwater. These are also subject to reclamation and other laws requiring steps be taken to keep sediment or toxic substances from entering waterways.

Forests

Forestry practices have been modified voluntarily and by law to reduce their pollution potential. Instead of clearcutting sites and inviting erosion, many logging companies now use selective cutting practices that allow for better timber choices and minimal impact on the land. Many forest product companies have found that proper land management can actually increase their profits by increasing forest yields.

For softwoods like pine, which are used for paper production and lumber, forest products companies manage their own "plantations" of timber, replanting several trees for every one cut down. This has increased the amount of usable timber available in the U.S., and has reduced the potential of pollution. Site planning is now an important consideration. Logging roads may wind around hills to reduce erosion and allow natural growth to quickly "retake" the land after cutting is finished.

INDIVIDUAL ACTIONS

There are a number of things that individuals can do on their own to reduce water pollution. Many of these practices are simple ones that only require changing old habits or switching to more environmentally responsible products.

Lawn And Garden

Individuals can create more pollution on small plots of land than many farms create over hundreds of acres (hectares). One reason for this is that individuals tend to overuse fertilizers and pesticides. The excess that runs off during rains combined with similar overuse from the rest of a neighborhood can cause significant pollution problems. Homeowners may apply 50 times more fertilizer than necessary for plant health, for example.

One good alternative is to create a compost pile to produce natural fertilizer. Composting can be started by simply gathering leaves, branches, and other materials, and placing them in a location where there is enough aeration and moisture to allow bacteria to begin breaking the material down. This produces a rich mulch that can be applied to gardens or plant bases for fertilizer.

Chemical pesticides can be avoided by the use of natural insect controls, including predatory insects like ladybugs or praying mantises. These creatures feed on many garden pests and some people actually keep mantises as pets. Simply installing a bird feeder to attract birds can help control populations of Japanese Beetles and other pests. Pesticidal soaps that do less harm than chemicals are also available, as are some forms of insect diseases that wipe out pests but don't harm other organisms. Proper selection of plants for gardens and lawns can also reduce pests. Some, like mint, garlic, and marigolds, will drive insects away, while others may not affect the local insect populations at all.

Automobiles

Even sitting still with their engines off, automobiles are sources of pollution. Petroleum based fluids can wreak havoc in water supplies, contaminating thousands of gallons of water. Do-it-yourselfers spill or dump more oil in a month than is lost in major tanker disasters.

Do-it-yourself jobs like oil changes should also have oil disposal taken into consideration. Many service stations accept oil for recycling, and most auto parts stores offer oil collection boxes that soak oil into shredded paper or other material. These boxes can then be taken to waste oil collection stations for proper disposal. Low price quick oil change businesses can actually be more economical than doing it yourself, particularly if your car requires special tools to reach oil filters and drain plugs. And most of these businesses have waste oil handling procedures in place so that used oil is collected and recycled.

Fluids like antifreeze and battery acid are especially dangerous toxics. Even small amounts can cause personal health problems or great environmental damage. Special care should be taken when dealing with these materials so they are not spilled. If a job appears that it may be particularly messy, it may be best to take the vehicle to a responsible professional mechanic. Many garages now use safer environmental practices to make sure toxic chemicals are disposed of properly.

Household Cleaners and Solvents

Many household shelves would be considered toxic waste dumps in industrial situations. Even common cleaners and solvents contain acids, lye, volatile organic compounds, and other materials that can contaminate drinking water, even in small amounts. Detergents can add nutrients like phosphates to water and create problems like algal blooms. People tend to practice "overkill" with cleaners as they do with fertilizers and pesticides. And since these materials are usually much more toxic—and much more concentrated—they can create serious pollution problems.

Natural cleaners like baking soda, vinegar, and borax can be substituted for many harsh cleaners. These materials can make good all-purpose cleaners, grease cutters, and even drain cleaners. It is also possible to buy low-phosphate laundry detergents and detergents that are free of dyes and perfumes. These are more easily handled by sewer systems and cause less nutrient or toxic pollution.

Common household products like paint thinner may contain volatile organic compounds like methylene chloride, ketones, and other chemicals that have been proven to cause cancer. Yet many people ignore warning labels and dispose of these materials in water systems. The U.S. Environmental Protection Agency (EPA) tests on drinking water supplies found that nearly a fourth of the samples tested contained traces of one or more hazardous compounds like these. So proper disposal is critical. The U.S. EPA hot-line (703-486-3367) can give advice on the best waste disposal procedures.

Water Conservation

Each of us uses about 150 gallons (565 liters) of water every day. One half-gallon (2 liters) is used for drinking. The other 149 1/2 gallons (563 liters) go for cleaning, cooking, toilet flushing, and other uses. It is in itself, a form of runoff. One very effective way to reduce water pollution is to simply reduce water consumption.

This can be done by changing a few habits. Putting a bottle of water in the refrigerator for drinking rather than letting water run into the sink until it gets cold uses less water. Peeling fruits and vegetables and then rinsing them saves two gallons (7.5 liters) every minute. A dishwasher uses less water than washing by hand—about six gallons (23 liters) a load. And washing an entire load of dishes—or clothes—saves water over washing several partial loads. New washing machines can reduce water consumption by one third, or more than 400 gallons (1500 liters) monthly for a family of four. But the greatest water use occurs in the bathroom. Simply turning off the water while brushing your teeth will save as much as ten gallons (38 liters) per person per day. Taking a shower instead of a bath will save about 25 gallons (95 liters), and new low-flow shower heads can reduce consumption even more.

Forty-five percent of the water used every day is flushed down the toilet. New toilets use about half the water as old models, and older toilets can be modified to work effectively with less water. Devices like toilet dams block part of the water in the tank and reduce the amount used with each flush. If a toilet dam sounds too difficult to install, you can get the same effect simply by putting a water-filled plastic bottle in the toilet tank. This displaces water and means that less is used.

Washing the car with a running hose will use more than 100 gallons (380 liters) of water. Using a bucket and sponge cuts that by 90 percent. And it's best to water lawns and plants late in the evening or early in the morning so water will soak into the ground and not be lost to evaporation. Another personal choice that can be made to reduce water consumption is to eat less meat. Half the water consumed in the U.S. goes to meat production. Eliminating a single eight-ounce (225g) portion of meat a month will save more water than not turning on your kitchen sink for the same 30-day period.

ABOUT THE AIR & WASTE MANAGEMENT ASSOCIATION

The Air & Waste Management Association is a nonprofit, technical and educational organization with nearly 15,000 members in more than 50 countries. Founded in 1907, the Association provides a neutral forum where all viewpoints of an environmental management issue (technical, scientific, economic, social, political, and public health) receive equal consideration.

This worldwide network represents many disciplines—physical and social sciences, health, engineering, law, and management. The Association attracts decisionmakers from government agencies, industry, and the academic and research communities who exchange technical and managerial information about air pollution control and waste management. The Association serves these members and the public by promoting environmental responsibility and providing technical and managerial leadership in the field of air and waste management. Dedication to these objectives enables the Association to work towards its goal—a cleaner environment.

Through the Association, environmental management professionals develop technical expertise, management skills, and familiarity with all sides of an environmental issue. Members learn about technical advances in environmental control, trends in the profession, and the probable effect of each on their work.

Although the Association has nearly 15,000 members worldwide, the majority of the members reside in North America. As a result of regional and local issues, these members formed sections and chapters to offer additional programs and activities in their geographical areas.

Each year the Association conducts the largest environmental conference in North America—its Annual Meeting and Exhibition. This conference features a five-day exhibition and the many business and ancillary meetings that drive the Association. Thousands of environmental management professionals attend this annual event.

Throughout the year, the Association conducts hundreds of specialty conferences, workshops, seminars, section and chapter meetings, and continuing education courses. Since all of these meetings are produced and conducted by the members themselves, their topics vary among the many issues surrounding air and waste management.

The Association's support and administrative offices are located in Pittsburgh, Pennsylvania. Any questions about the Association, its members, programs, or outreach activities can be answered by the staff by contacting:

Air & Waste Management Association
One Gateway Center
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Pittsburgh, PA 15222 U.S.A.
(412) 232-3444

ABOUT THE ENVIRONMENTAL EDUCATION PROGRAM, TENNESSEE VALLEY AUTHORITY

The Tennessee Valley Authority (TVA) is a regional agency of the United States Government. TVA employs an integrated resource management approach to accomplish power production, natural resources management, management of the river system and associated lands, and economic development. The Environmental Education Program works to promote educational partnerships and develops educational programs and products addressing environmental issues.

TVA's Environmental Education Program administers a network of 16 centers for environmental education. Each center has four primary functions: teacher training, program development and distribution, regional service, and research. The network is being used by the Alliance for Environmental Education as a model for a national network. It also cooperates in international partnerships.

The Program employs a process using "expert teams" to develop quality educational materials. The expert teams consist of practicing specialists in the field, TVA education specialists, and technical experts. This process ensures that programs and materials are both educationally and technically sound.

The Environmental Education staff cooperates with a variety of groups both inside and outside TVA to develop and distribute educational programs and products. Current projects developed for other TVA program areas deal with water quality, energy, waste management, and stewardship in materials for classroom use. The program is also working with various groups within TVA to develop environmental training programs for TVA employees. To date these include a training program for employees in TVA's fossil, hydro, and nuclear operations, and a training program on environmental regulation and compliance.

The program has cooperated with a variety of groups outside of TVA, such as technical groups and government agencies, including Air & Waste Management Association, the U.S. Army Corps of Engineers, the Electric Power Research Institute, the U.S. Environmental Protection Agency (EPA), and state environmental agencies. Projects have included the development of posters, factsheets, brochures, interpretive signage, and curriculum materials.

Proper stewardship of environmental resources begins with environmental education, a lifelong process of gaining the awareness, the knowledge, and the skills to deal with complex environmental issues. TVA's Environmental Education Program is committed to preserving environmental quality by educating people to deal with these vital issues.

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