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ABSTRACT

This investigation focuses on the major erosional forces affecting the shoreline which cause it to wear away and build up. The types of devices that protect the shoreline are also discussed. The investigation is presented in the form of a teachers' guide and a students' guide, both of which are included. In the teachers' guide, an overview of the material is followed by the objectives and procedures to use during the investigation. Materials and objectives are listed and suggestions are given on the approach to use. Transparency masters accompany the teachers' guide and instructions are included. Review questions are suggested. (SA)

OEAGLS- Oceanic Education Activities for Great Lakes Schools

COASTAL PROCESSES AND EROSION

by

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Ohio Sea Grant Program
Charles E. Herdendorf, Program Director
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OEAGLS INVESTIGATION 7

Completed February, 1979

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COASTAL PROCESSES AND EROSION

INTRODUCTION

The major natural forces affecting the shoreline are wind, waves, and currents. These forces wear away and build up a shoreline. Man can modify these forces and redirect them, but he will never totally control them.

Wind and Waves

The wind is the principal generator of waves. The longer and stronger the wind blows and the greater the distance over which it blows, the larger and more powerful the waves will be.

Waves have significant effects on shorelines. During storms, their energy can carry beach sands lakeward, erode cliffs and banks, and damage or carry away man-made structures. During calm periods, waves move offshore and onto the beaches, building them up.

Currents

Currents--streams of moving water within a body of water-- are another major force affecting the shoreline. Perhaps the most important current causing the shoreline to change is the longshore current, which is generated by waves as they strike the coast at an angle. A longshore current runs parallel to the shoreline and varies in speed and direction with the angle of waves and their energy. It often transports large quantities of sand along the beach. This transportation is known as littoral drift.

If there is an abundant supply of sediment, as from eroding cliffs or sediment-laden streams flowing into the lake, the littoral drift will deposit sediment wherever its speed is reduced. When sediment is scarce, the littoral drift will carry sand away from the beaches, causing erosion.

Because wind and waves determine the directions and amount of littoral drift, the overall or net sand movement in Lake Erie is from west to east.

OBJECTIVES

When you have completed this investigation you will be able to:

1. List the major natural forces of erosion along the lake shore.
2. Describe how the rate of erosion differs with different materials.
3. Explain the purposes of the three major categories of shoreline protection devices.

ACTIVITY A — WHAT CAUSES THE SHORELINE TO ERODE AWAY?

MATERIALS — Three rectangular plastic pans or plastic shoe boxes; one piece of board (2x4 or plank) as long as the width of the pans; sand; soil; several broken pieces of rock; ruler; 3x5 note card cut in three long strips; pencil for recording data.

PROCEDURE

1. In the end of one of the plastic pans place three handfuls of wet sand.

2. Using a piece of board, mash the sand up against the end of the pan and flatten the top. Make this "beach bluff" about as wide as it is high.

3. Repeat steps 1 and 2 with a second pan, building a beach bluff made of wet soil.

4. In one end of the third pan make a stack of rock pieces that will represent a rocky shoreline about the same size as the other bluffs.

You should now have three "beach bluffs" of various types and sizes of material. The three pans represent lakes.

5. Hold the piece of board up against the sand bluff to protect it while you slowly add water to the empty end of the pan. Create a lake about 1-1.5 cm deep. Remove the board gently when the lake water is still.

6. Repeat Step 5 to create lakes in front of the soil and rock bluffs

7. Gently place a strip of note card flat on top of each bluff.

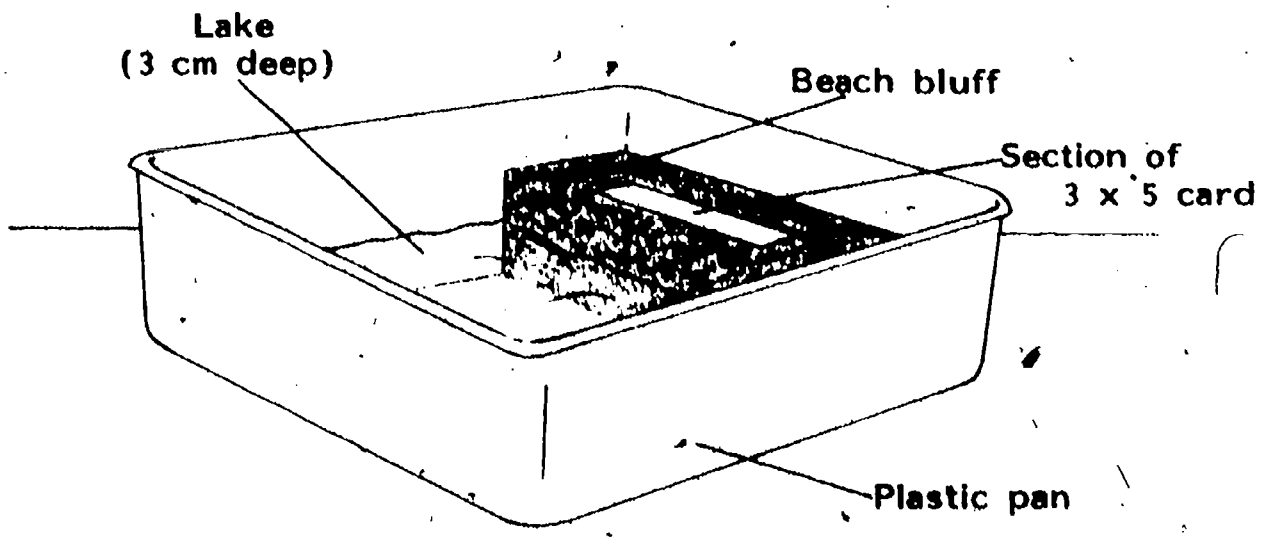

Figure 1: Shoreline Model

8. You are now ready to act as the wind, making waves and causing erosion on the shoreline. Using a ruler or the piece of board, make waves that move toward the beach bluff from the opposite end of the lake. Start gently, counting the number of waves you produce. Then gradually increase the strength of your waves as if the wind were becoming stronger. Record what happens to the beach bluffs as you repeat this process in each lake.

9. When the section of note card slips toward the water, your bluff has collapsed. If collapse has not occurred after 60 waves, stop and record your observations of the bluff's condition.

NOTE: To measure the height of waves, find the distance from the top (crest) of the wave to the lowest part (trough) of the wave. Do not measure from the bottom of the "lake" basin unless the bottom is actually exposed as the wave passes by.

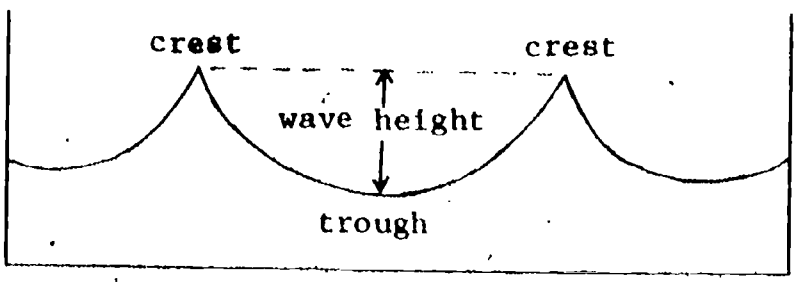

Figure 2: Determining Wave Height

DATA:

	Number of Waves	Height of Waves	Effects on Beach
SAND BEACH			
SOIL BEACH			
ROCK & MUD BEACH			

QUESTIONS

1. Which beach bluff is the least stable (collapsed first)?

_____

2. Which beach bluff is the most stable (withstood the msot waves)?

_____

3. Some beach bluffs on Lake Erie's shore are actually made of sand and some of clay similar to the soil bluff you constructed. The rocky bluffs of the lake shore may be of limestone or a soft shale.

   What type of beach bluff would you pick if you were building a cottage on the shoreline? Why?

_____

_____

_____

4. Below is a map of Lake Erie's shoreline. Based on what you have discovered about how different materials erode,

   a. Put X's on the sections of shoreline that are probably made of rock.

   b. Put O's on the sections of shoreline that are probably made of sandy material.

(You do not have to cover the shoreline with either X's or O's. The shape of the shore may not give you any clues about the type of material it has.)

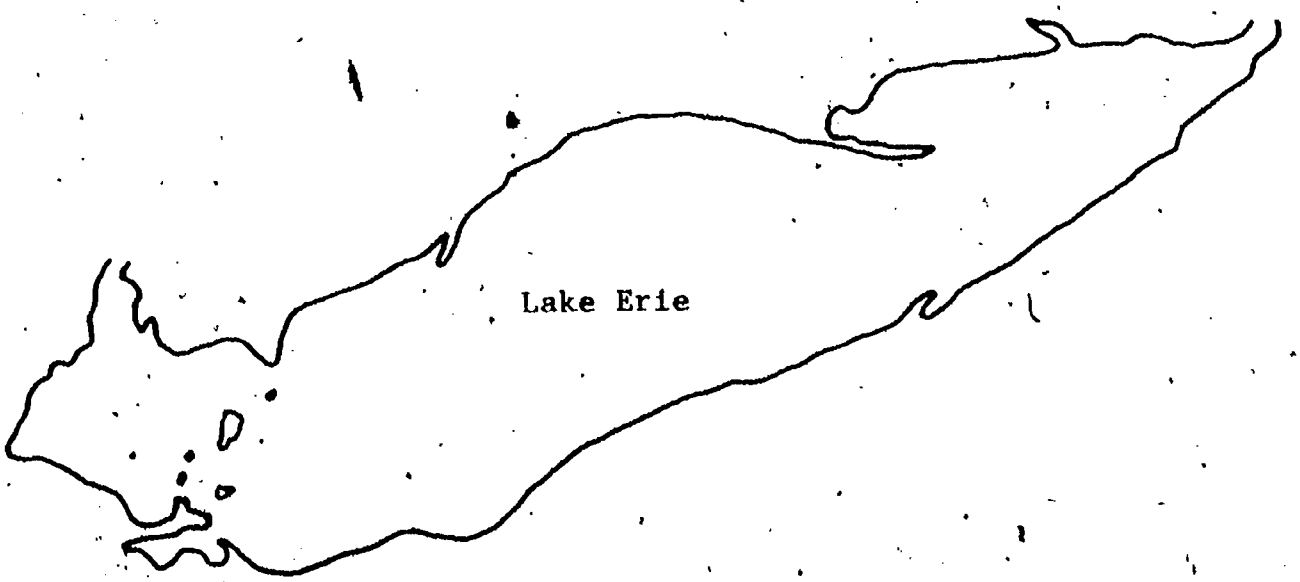

Figure 3: Lake Erie's Shoreline

5. Some points of land sticking out into the lake may be made of sand. What process is probably responsible for carrying the sand and depositing it there? (Re-read the introduction to Activity A.)

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6. How could you tell from their appearance which points of land might be sandy instead of rocky?

Erosion of coastal areas, as you have seen, occurs at different rates depending upon the material making up the shoreline. The same processes act upon the ocean as upon large lakes. Some of the coast of England, for example, has been worn back more than 3 km since the time of the Romans. The shore of Cape Cod retreats at the rate of 25 to 150 cm each year. These coasts are composed of relatively weak material, but the same process takes place more slowly in the hardest rock.

7. On the map below, draw your prediction of how the shoreline of Lake Erie will be shaped 100 years from now if the present rates of erosion and deposition continue.

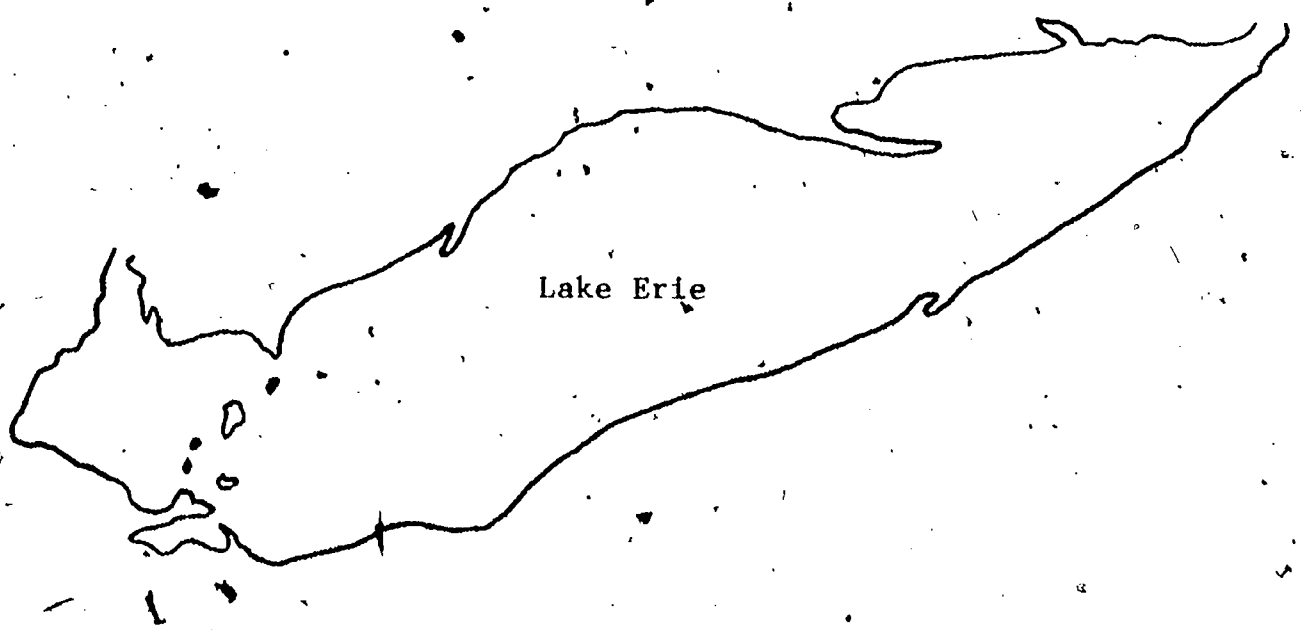


Figure 4: Predicted Shoreline of Lake Erie 100 Years From Now

ACTIVITY B

CAN EROSION BE STOPPED?

The shores of the Great Lakes are subject to the attack of winds, waves, longshore currents, ice, and floating debris. Winds having an average velocity of more than 40 km per hour and lasting from 6 to 10 hours are capable of creating waves from 2 to 3 m high on many portions of the Great Lakes. Some shoreline areas suffer damage from smaller waves as well as from the larger ones.

The possibilities for erosion along ocean shorelines are even greater. For instance, at Minot's Ledge in Massachusetts, waves from severe storms destroyed a lighthouse several times during its construction. In 1851, when the light was finally completed, waves brought the entire structure crumpling into the sea, killing its two keepers and leaving little evidence that the light had ever been there.

About 83 percent of Lake Erie's erodible shoreline is privately owned. Therefore, land owners must protect their shorelines. Methods of erosion prevention involve attempts to keep the force of the waves away from the bluffs. By chance, nature protects shorelines by building sand beaches where the waves can break and use up their energy before reaching the bluffs. Man can construct devices which duplicate the effectiveness of natural sand beaches.

Erosion cannot be permanently stopped, but construction of the proper devices can slow erosion down. What are the devices available to the homeowner and to coastal communities in general?

MATERIALS

Same as Activity A, plus a section of 2 x 4 equal to half the width of the lake pan.

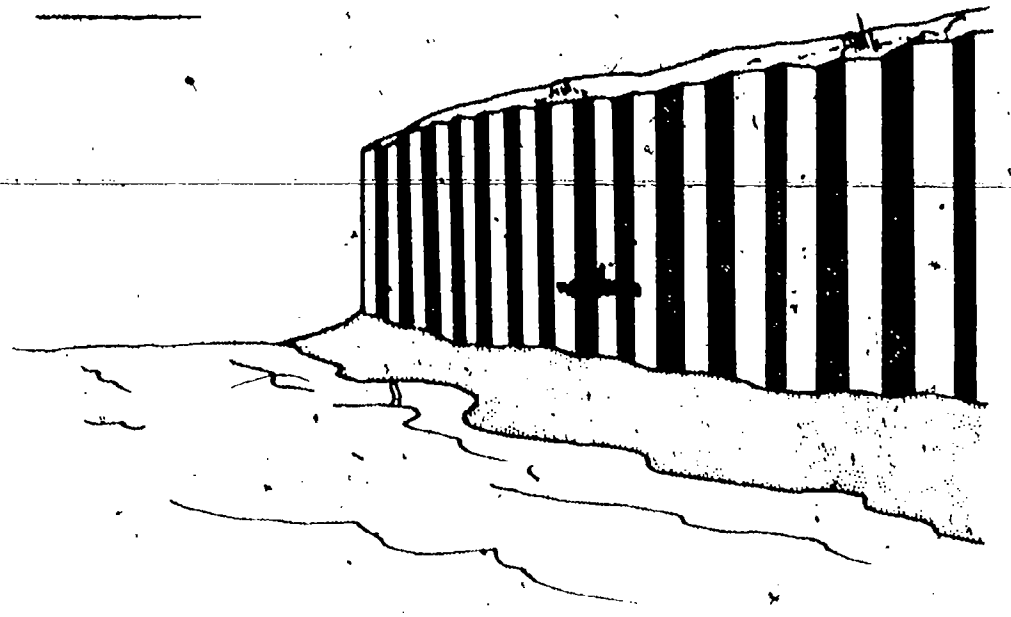
PROCEDURES

1. A description of each of the three major methods of shore protection follows. After reading each description, carefully examine the diagrams on pages 7 and 8. Label each diagram by letter (A,B,C) according to the method of shore protection which each one shows.

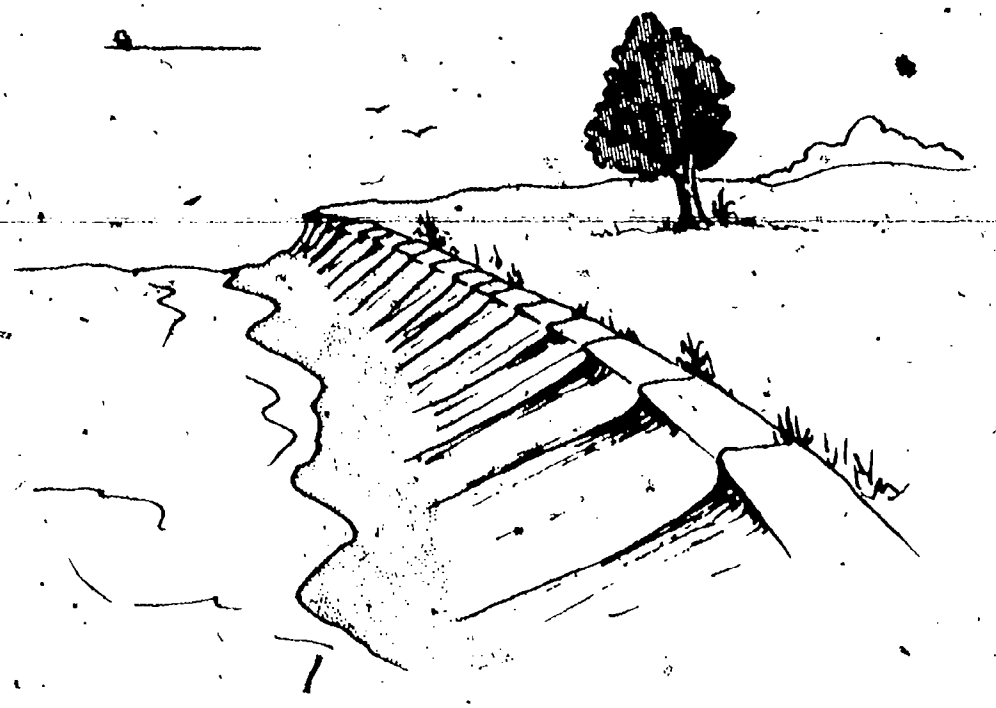
   (A) One method of shore protection involves the use of concrete, wood or steel structures built directly against and parallel to the shore. These structures are designed to help keep currents and waves from reaching the erodible shoreline. Some of these structures also serve as docking facilities.

   (B) A second method of beach protection is the construction of a device perpendicular to the shore and connected to it. This device traps the sand moving with the littoral drift. A beach is formed, which is excellent protection against shore erosion.

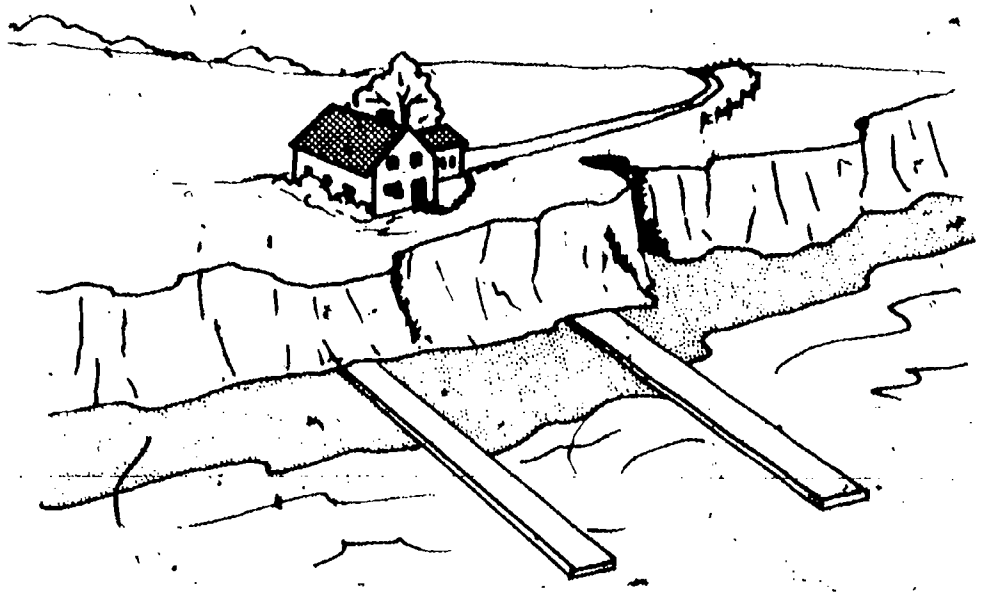
   (C) The third method of shore protection is an offshore structure. It usually consists of fairly large stones which are piled away from but parallel to the coastline. The wall of stone reduces wave attack on the shoreline much as a natural sand bar would.



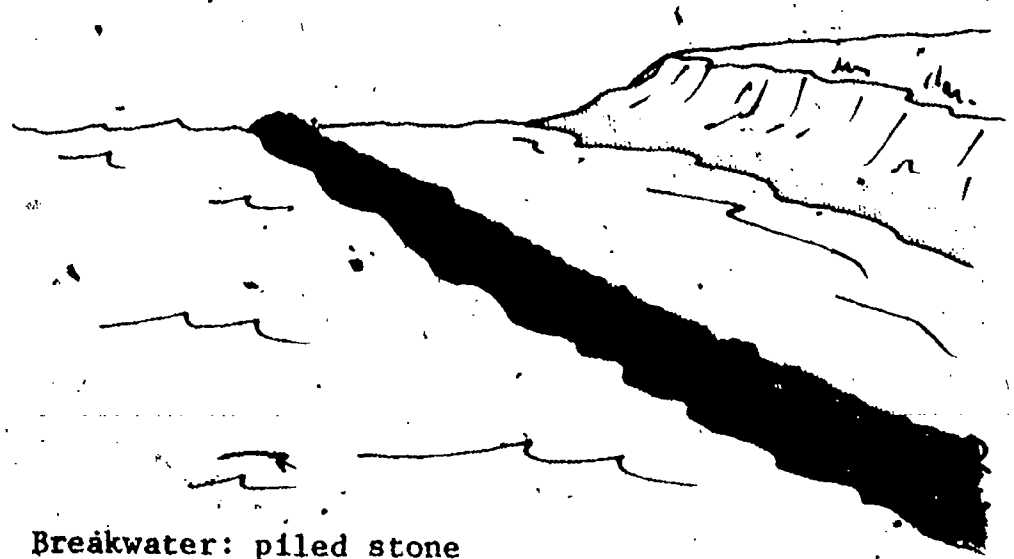
Sea Wall: sheet pile



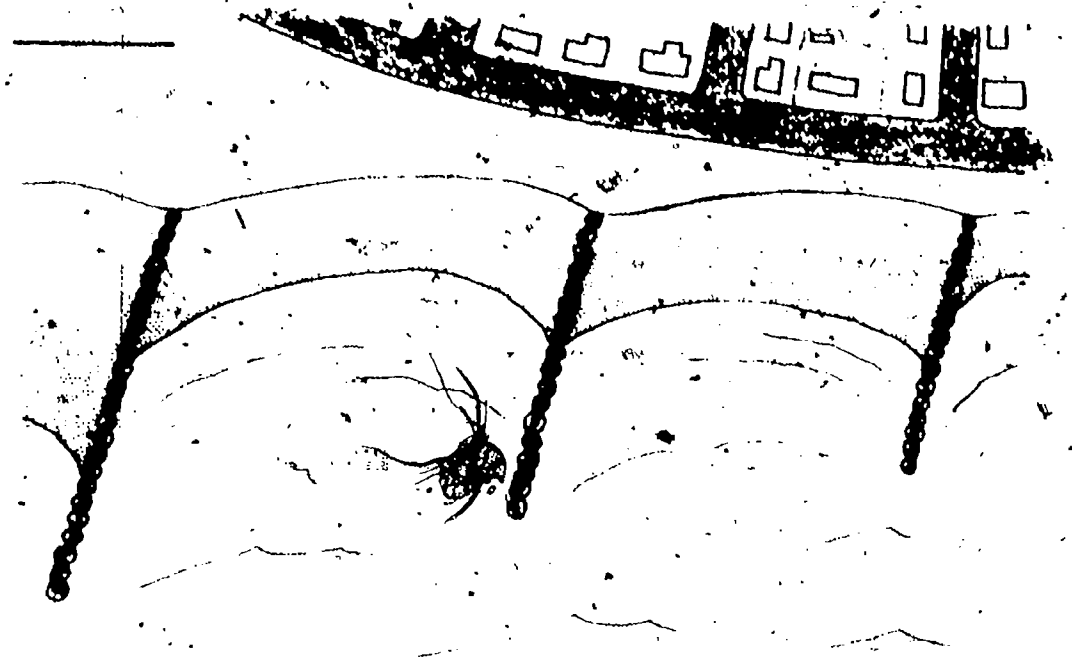
Sea Wall: cement



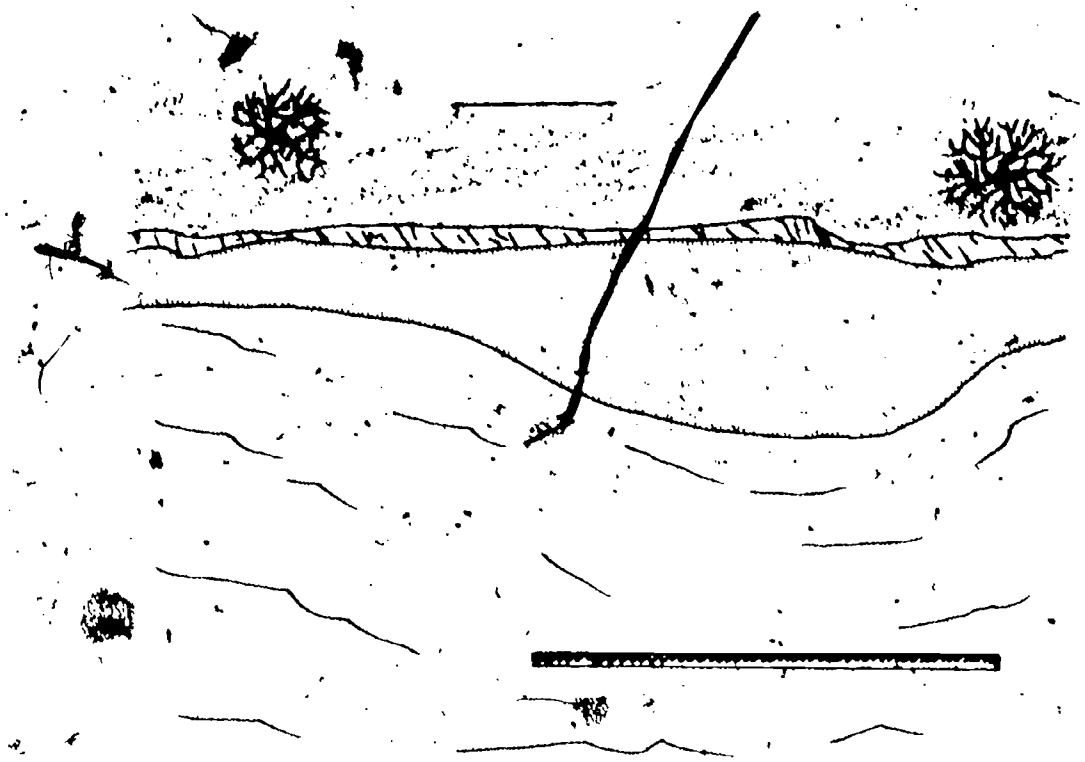
Groin: cement



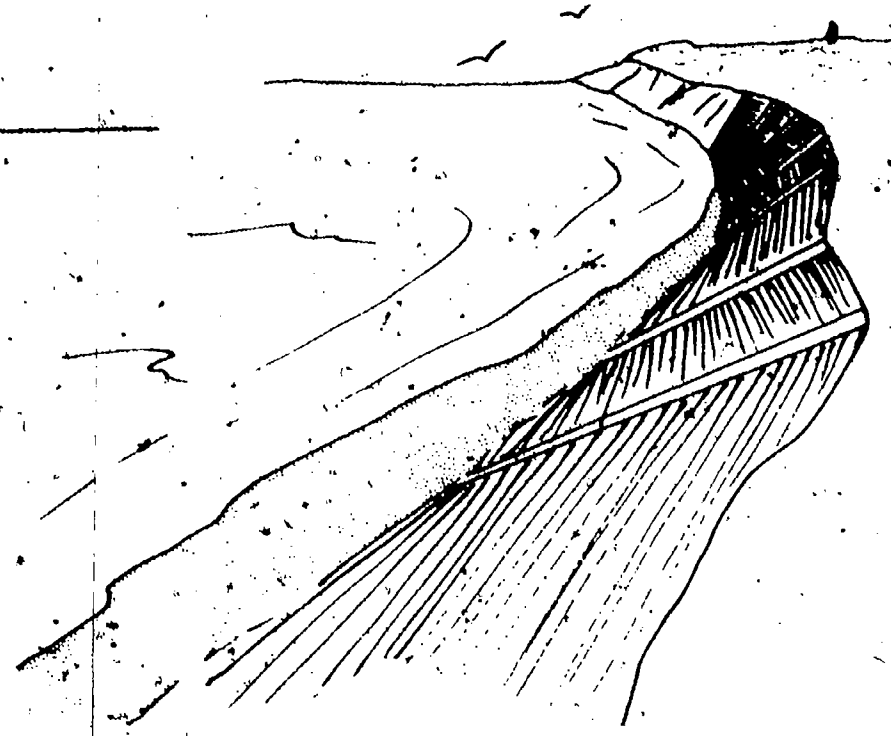
Breakwater: piled stone



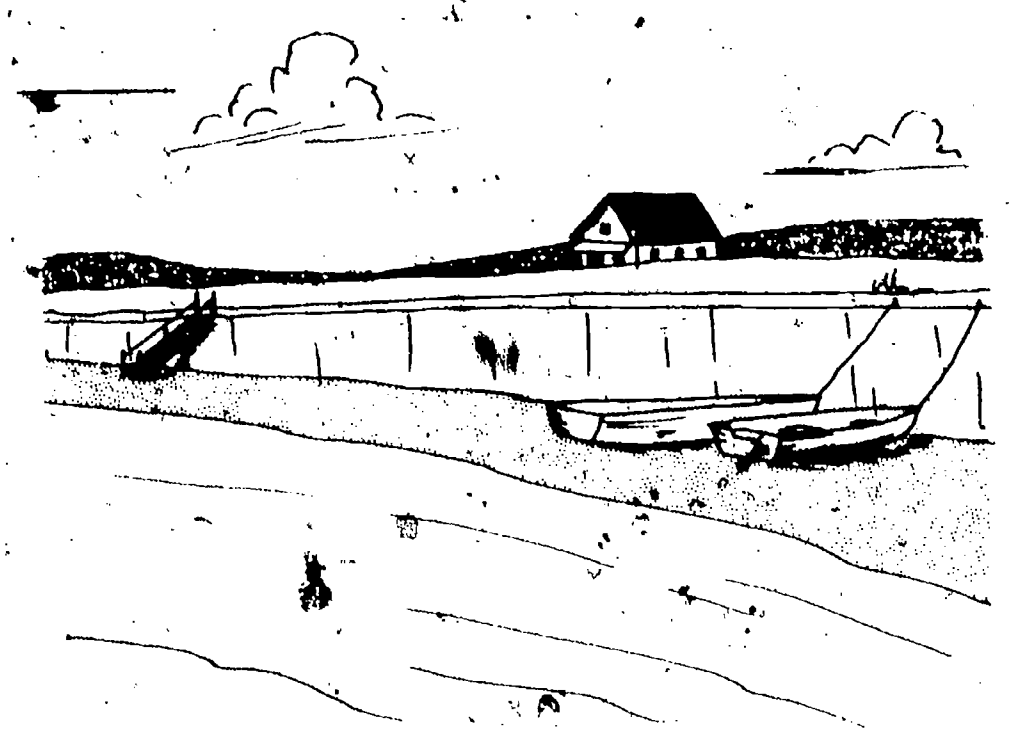
Groins: sheet pile



Breakwater: steel pile



Stepped Revetment



Sea Wall: concrete

2. Now you can test the effectiveness of some of these shoreline protection devices:

   A. Rebuild the sand bluff at one end of the lake.

   B. Put a short section of 2 x 4 firmly up against the bluff to act as a seawall.

   C. Repeat the wave-making activity as before. Record the condition of the bluff after 5 waves and again after 10 waves.

SEAWALL EFFECTS

Number of waves	Effects on Bluff: Behind seawall	Unprotected
5		
10		

   E. Repeat step A above. This time place the short 2 x 4 in the center of the basin to form a breakwater about 5 cm from the sandy bluff.

   F. Make some waves again, and record what happens to the bluff after 5 waves and after 10 waves.

BREAKWATER EFFECTS

Number of waves	Effects on Bluff: Behind breakwater	Unprotected
5		
10		

3. As you may have observed, the water within your reconstructed sand bluff may have weakened it before wave erosion began. Groundwater and surface streams do the same thing on real lake shores. For this reason, trees, grasses, and shrubs are sometimes planted to go along with some other shore protection device. The life processes of plants remove ground water, the roots hold soil in place, and beach grasses trap sediment to actually help build the beach. (See Figure 5 below).

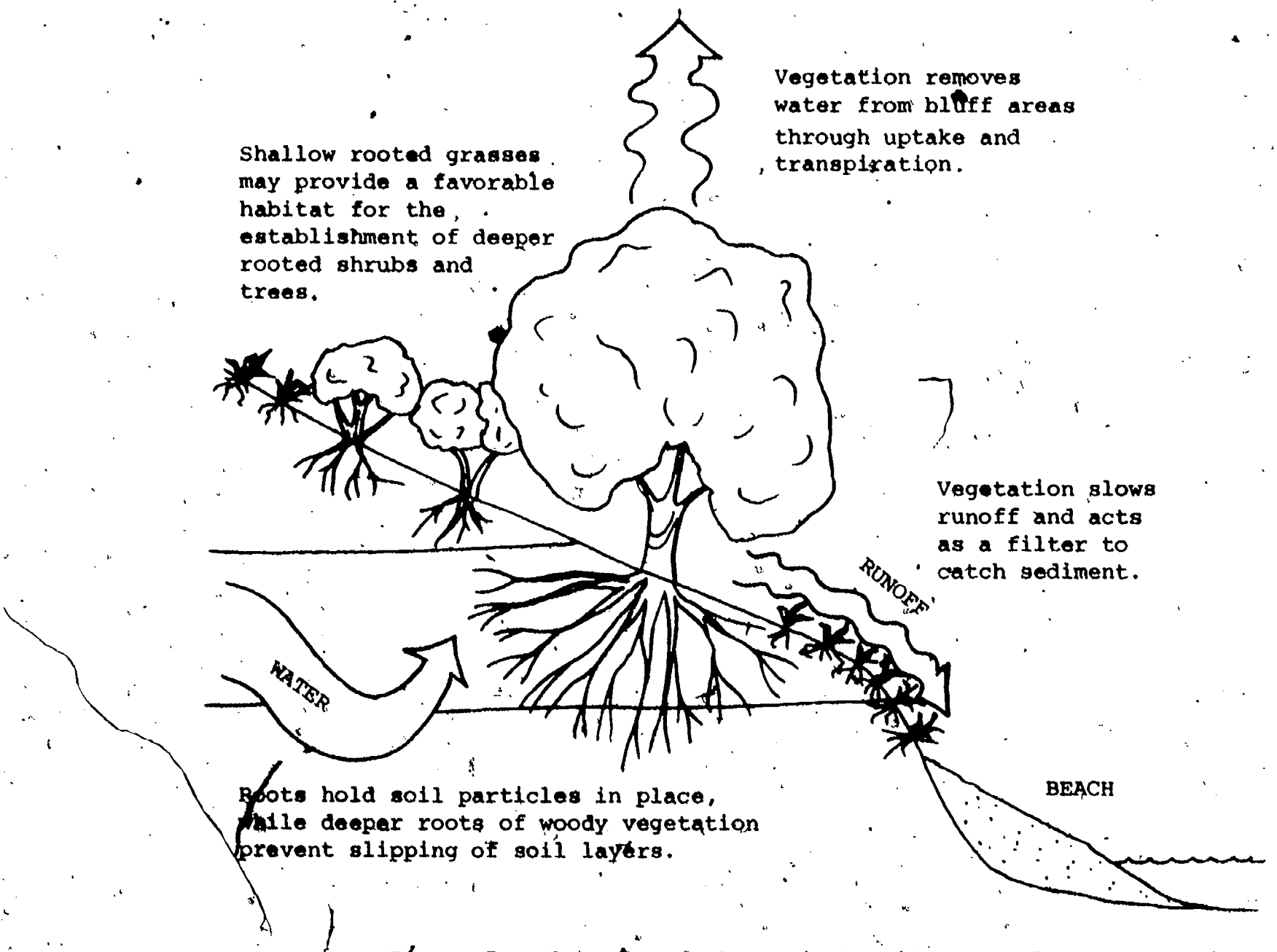


Figure 5: The Role of Plants in Erosion Control

4. In recent years there has been growing concern about the uncontrolled construction of shore protection devices such as groins, seawalls, revetments, and bulkheads. Many people interested in maintaining and improving the environment are concerned about the placement of multiple bulkheads along stretches of shoreline. Evidence strongly indicates that groins speed up erosion in nearby areas and that bulkheads cause shore loss and water turbidity. Some argue, "What harm does a single 50-foot or 100-foot bulkhead do to the environment?" There are many miles of bulkheads, seawalls, and other protective devices added to our shoreline every year. What is the long-term and the cumulative effect of these structures?

REVIEW QUESTIONS

1. List the natural forces which cause erosion along the Lake Erie coastline.

2. What types of shore materials erode faster? Slower?

3. Briefly describe the three major methods or categories of shoreline protection devices.

4. If you had a beach cottage, which type of device would you build to protect your section of shoreline? Explain your choice.

5. Would it be advisable to construct shore protection devices along all sections of Lake Erie's shoreline? Explain.

OEAGLS--Oceanic Education Activities for Great Lakes Schools

TEACHER GUIDE

COASTAL PROCESSES AND EROSION

by
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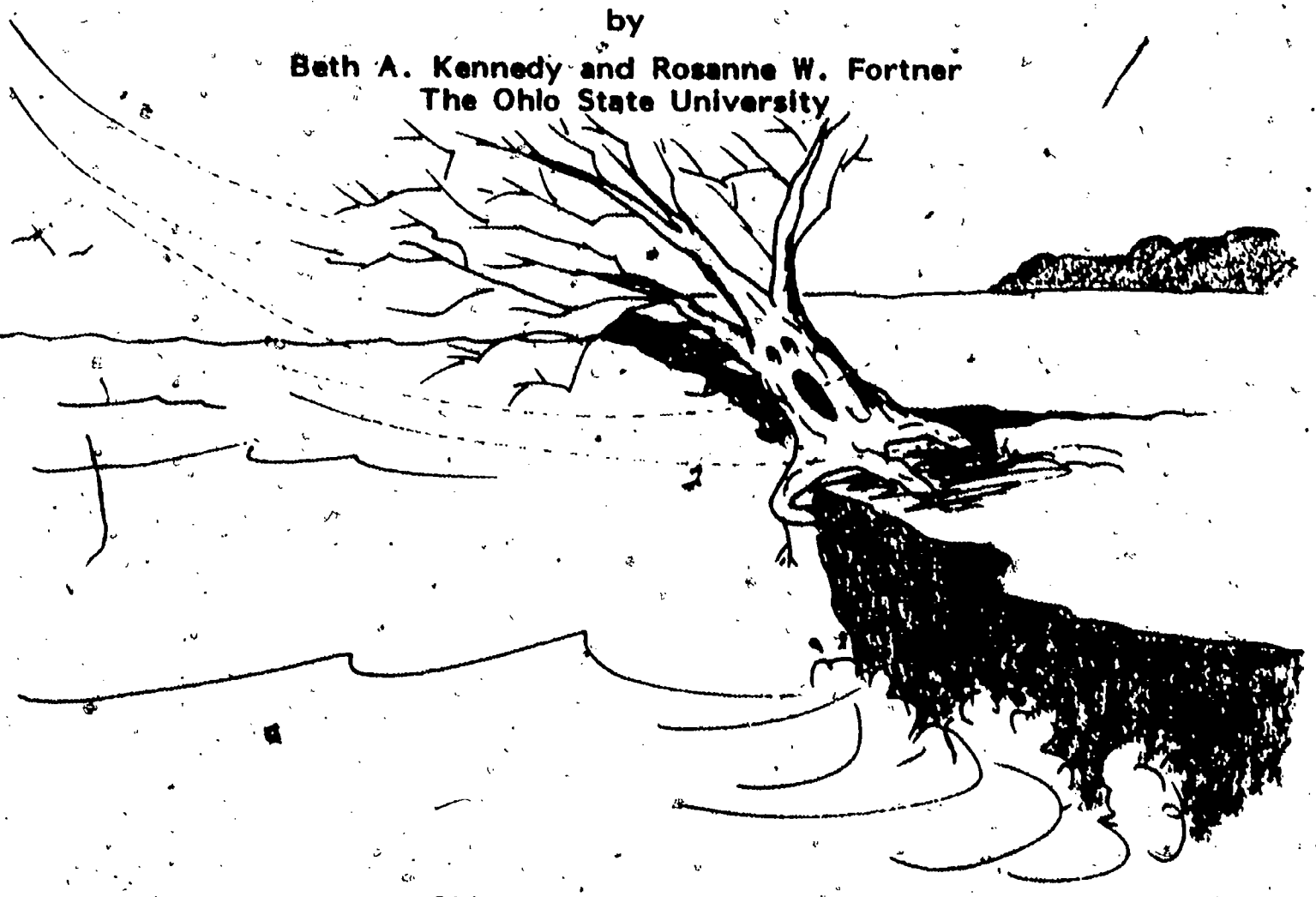
The Ohio State University



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OEAGLS INVESTIGATION 7

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TEACHER GUIDE

COASTAL PROCESSES AND EROSION

OVERVIEW

In Activity A, students study the idea that shoreline geology affects the rate and amount of erosion that occurs along the edges of the ocean or a lake. They conduct an experiment comparing the stability of three geolbgically different beach bluffs as they are attacked by waves.

Activity B deals with methods of slowing the rate of shoreline erosion. Three types of shoreline protection structures and their purposes are discussed. The students examine illustrations of several structures and label them for the type of protection device they represent. Two of the devices are tested in a laboratory experiment similar to Activity A.

PREREQUISITE STUDENT BACKGROUND

None.

MATERIALS

Each lab team should be supplied with three rectangular plastic dishpans or plastic shoe boxes; one piece of board (2x4 or plank) as long as the dishpan is wide; one piece of 2x4 half as long as the width of the pan; about 1 liter of sand and 1 liter of potting soil per team; several pieces of rock 5-10 cm long; a 3x5 note card; a ruler to measure wave heights; and access to a supply of water. Each student will need a pencil or pen for recording data and answering questions.

If sand and soil are to be re-used for several classes have on hand a fine mesh screen or collander lined with gauze. When water is poured off at the end of class, these screens will serve as sediment filters.

NOTE: If potting soil is not available, a high grade of garden or forest soil can be substituted. Soil with a high clay content will not produce the desired comparison.

OBJECTIVES

When students have completed these activities, they should be able to:

1. List the major natural forces causing erosion on the shores of Lake Erie.
2. Describe how the rate of erosion differs with different materials.
3. Explain the purposes of the three major categories of shoreline protection devices.

SUGGESTED APPROACH

To help cut down on the amount of equipment needed, Activity A could be done in large groups or by a single group of students acting as demonstrators,

Procedure 1 of Activity B is best done individually or by teams of two to three students. More students may work together on Procedure 2 of this activity.

The film "Beach - A River of Sand" (20 minutes, Encyclopaedia Britannica Films) can serve as an excellent introduction or conclusion to this activity. It illustrates how beaches are built and destroyed by waves, how longshore transport functions, and how groins and breakwaters affect the shoreline.

A visual aid useful for Activity B is the wall chart, "Help Yourself: A discussion of the critical erosion problems on the Great Lakes and alternative methods of shore protection." This is available free from the U.S. Dept. of the Army, North Central Division, Corps of Engineers, 536 South Clark Street, Chicago, Illinois 60605.

ACTIVITY A

WHAT CAUSES THE SHORELINE TO ERODE AWAY?

Keywords: erodible, resistant, wave height.

PROCEDURE

The student guide contains all instructions necessary for setting up Activity A. Stress that the water used in Step 5 be poured in slowly; otherwise beach bluffs may begin to collapse before waves are generated.

In recording data, it is suggested that the number and height of waves be recorded only once for each shore type, when the bluff collapses. Under "Effects on Beach Bluff," the sequence of erosion events may be listed as in the example below:

Sand Beach

Number of Waves	Height of Waves	Effects on Beach Bluff
10	2 cm	1. Lower front edge was undercut 2. Top front edge slid down 3. Waves cut farther into slope 4. Bluff collapsed as waves washed over

Figure TG 1. Sample Data

Be sure to provide an appropriate place to dispose of the muddied water, preferably outdoors away from the school building.

QUESTIONS

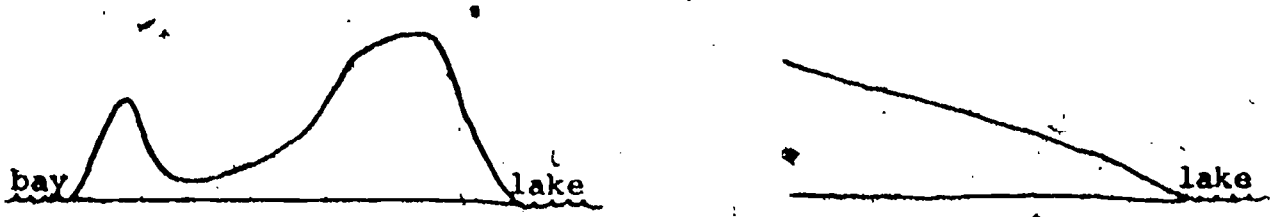
1. The sand bluff is the least stable. The small and fairly uniform grain size produces a porous surface that is quickly penetrated and disrupted by the water. On the board, record wave heights and number of waves from different lab teams. Note that higher waves erode the bluff more quickly (fewer waves are needed).

2. The rock beach is the most stable. This is because of the resistant nature of the rocks. Students may want to discuss which types of rocks would be more resistant to erosion. An interesting experiment could be designed by the class using small rock polishers (tumblers) loaded with different kinds of local rocks. Slate in one tumbler, flint in another and sandstone in a third could be processed simultaneously for the same number of days. Comparing the mass of rocks before and after the erosion would indicate which rock types were more resistant. ESCP's Investigating the Earth curriculum provides directions for a similar activity (Investigation 1.4) that does not require the use of tumblers.

3. If erodible characteristics are considered, students should choose the rocky bluff as a building site. At the end of this teacher's guide are transparency masters and instructions for their use in illustrating the types of shorelands and beaches around Lake Erie and the present use being made of these areas. Students who have completed Activity A should be able to identify areas of potential erosion problems using these maps.

4. See Transparency Master #1 for approximate locations of sandy and rocky shorelines. Student maps should be accepted if an attempt has been made to label shoreline sections. Points of land projecting into the lake are commonly labeled "X" by students, and cutaway sections of shore may be labeled "O." A discussion of students' responses and the transparency can lead to consideration of Question 5.

Figure TG 2 shows how the rocky and sandy bluffs look in cross-section. Rocky areas are generally steep and angular, while sandy bluffs have a gentle slope. The cross-sections shown were taken at areas marked A and B on Figure TG 3.



A. Rocky bluff profile (Eastern end of Marblehead)

B. Sandy bluff profile (West of Huron, Ohio)

Figure TG 2. Comparison of Lake Erie Coastline Features

5. The lake's longshore current, or littoral drift, is responsible for creating many of the points of land projecting into the lake. The "spits," as they are called, are made of sediments carried from other areas. The current direction produced by the prevailing winds determines which way a spit curves (Figure 2,)

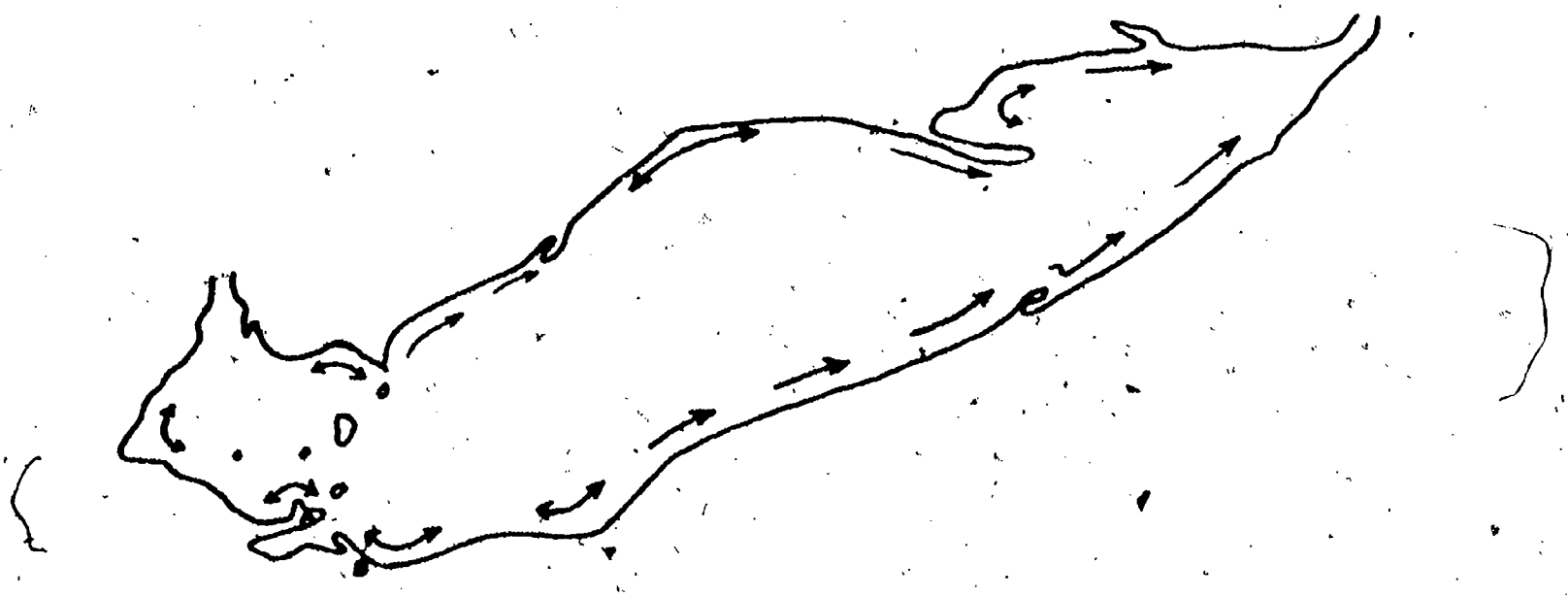


Figure TG 3. Net direction of littoral transport, and curvature of spits in Lake Erie

6. The points of land that form smooth curves out into the lake are generally sandy. Those with ragged or angular shapes usually have a rock base. The two lakeward projections surrounding the mouth of Sandusky Bay illustrate these differences. The Marblehead area to the west of the bay is limestone, and Cedar Point to the east is a sandy deposit..

7. In predicting future shoreline characteristics it is hoped that students will apply what they have learned about coastal processes. Answers will vary, and the differences between predictions can furnish material for class discussion of erosion and deposition rates, the future of lake shore property, and how the shore could be protected.

ACTIVITY B

CAN EROSION BE STOPPED?

The introduction to Activity B indicates to students that erosion is a personal problem to coastal landowners. There are ways to redirect the natural forces at work on the shoreline so that the rate of erosion can be slowed.

Keywords: breakwater, seawall, groin.

PROCEDURE

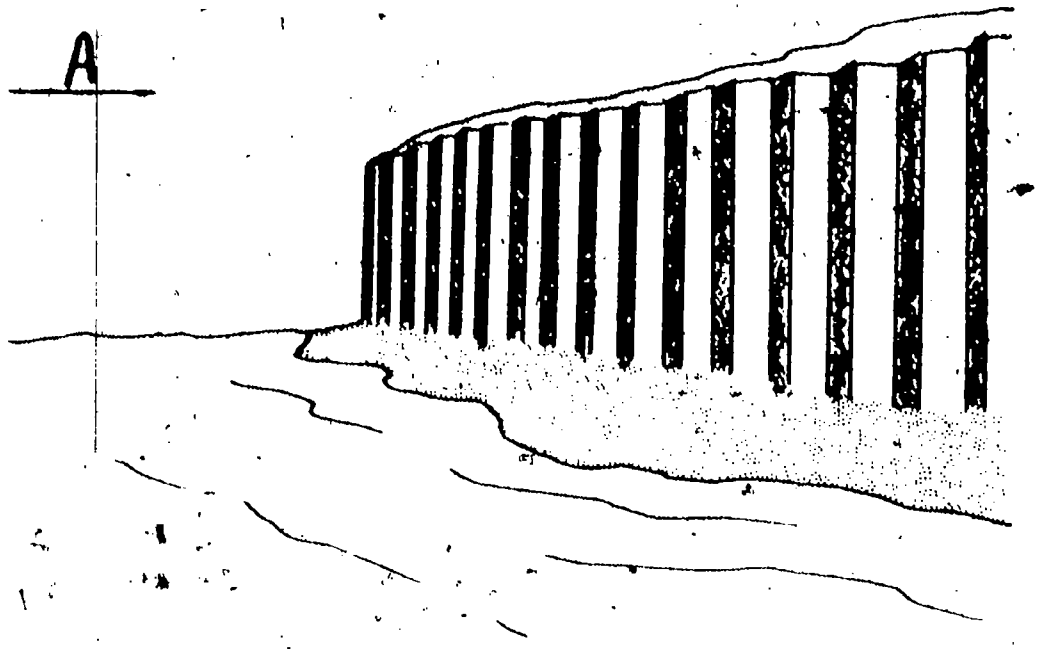
1. Using descriptions of the three major types of shoreline protection devices, students should be able to label diagrams of these devices as shown on the following pages. It may be necessary to review with students the meanings of the terms "parallel" and "perpendicular."

2. Instructions for completion of this procedure are complete within the student activity guide. Students should find that the seawall type of device is more effective than the breakwater design in reducing bluff erosion.

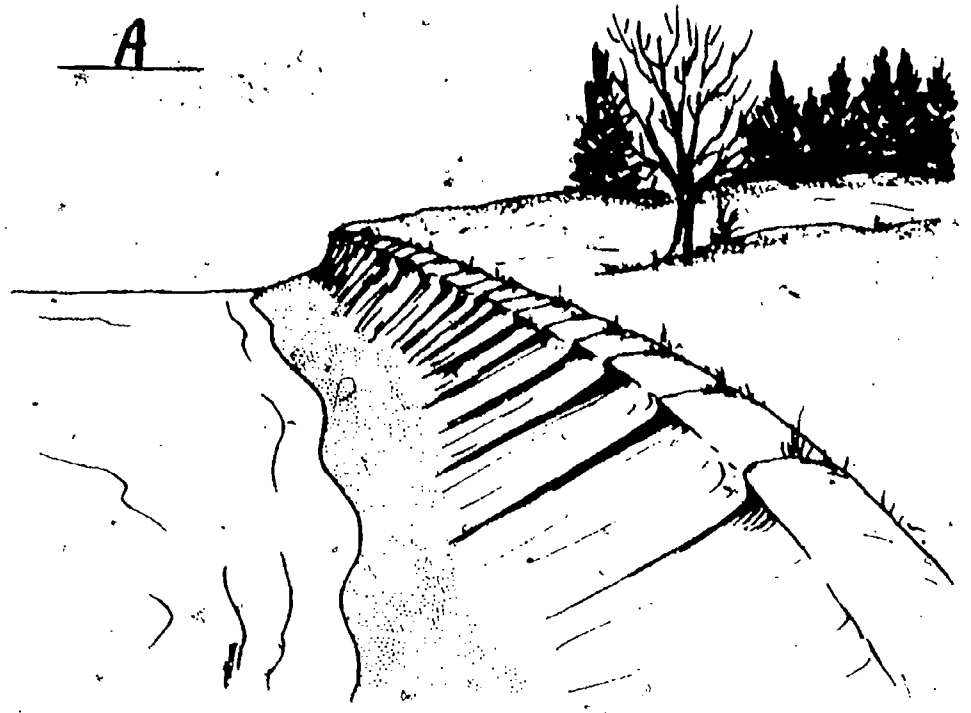
If further investigation about effects of shore protection devices is desired, you may wish to use a stream table. Studies of the effect of groins in trapping sediment, filling in of sediments behind breakwaters, and formation of spits can be made using the guidelines of a reference such as Fisher Scientific's Stream Table Laboratory Manual. This can be ordered from Fisher (1979 price $3.85), 5481 Creek Rd., Cincinnati, Ohio 45242.

3. As Figure 5 of the Student Activity Guide indicates, lake processes are not the only ones involved in erosion of shoreline features. Precipitation and groundwater contribute to the erodible nature of shore areas. The Corps of Engineers' free booklet, The role of vegetation in shoreline management, explains these effects in detail and provides some illustrations that could be effective transparency masters for discussion of the topic.

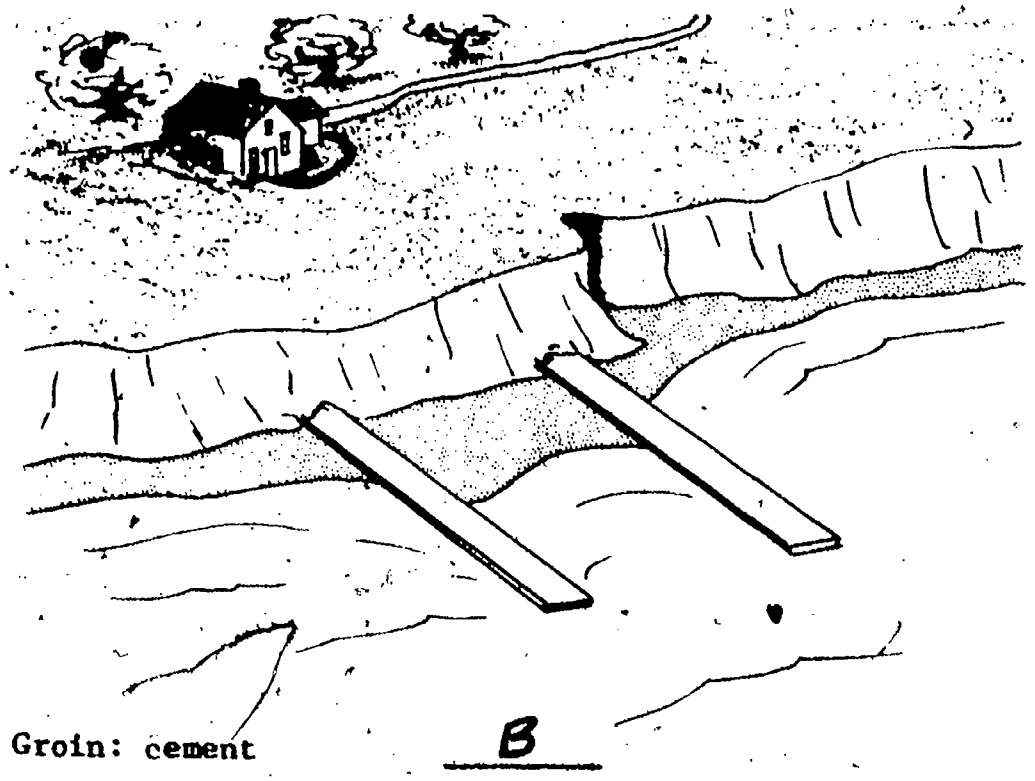
4. Pros and cons: There are advantages and disadvantages to each of the construction alternatives for shoreline protection. Construction costs, maintenance problems, and beach changes associated with some devices



Sea Wall: sheet pile



Sea Wall: cement

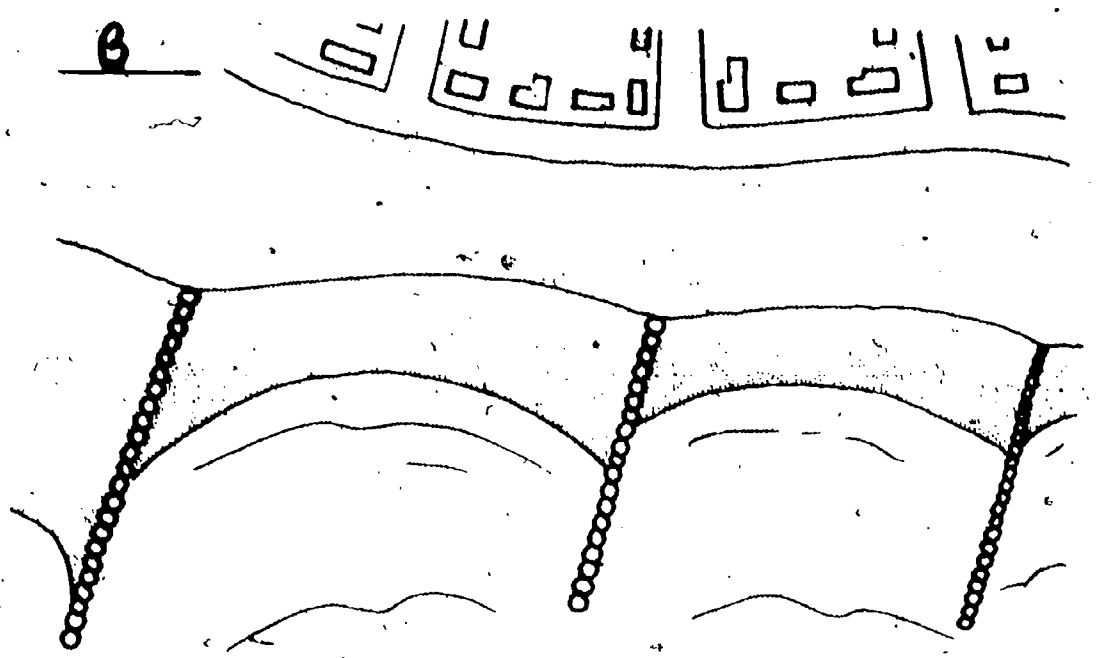


Groin: cement

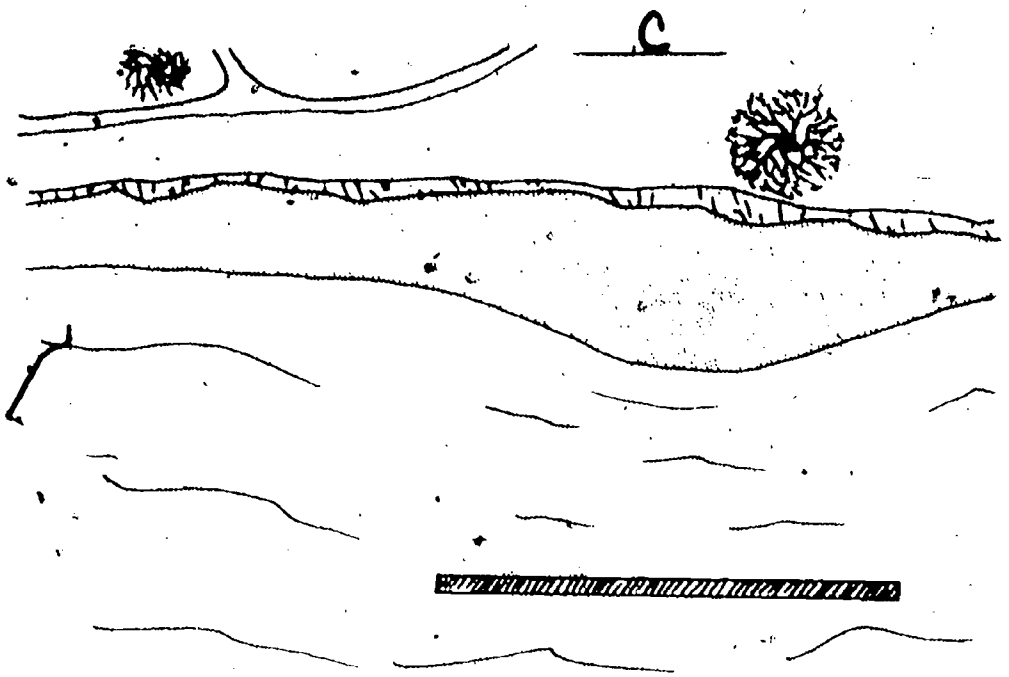
B

Breakwater:
piled stone

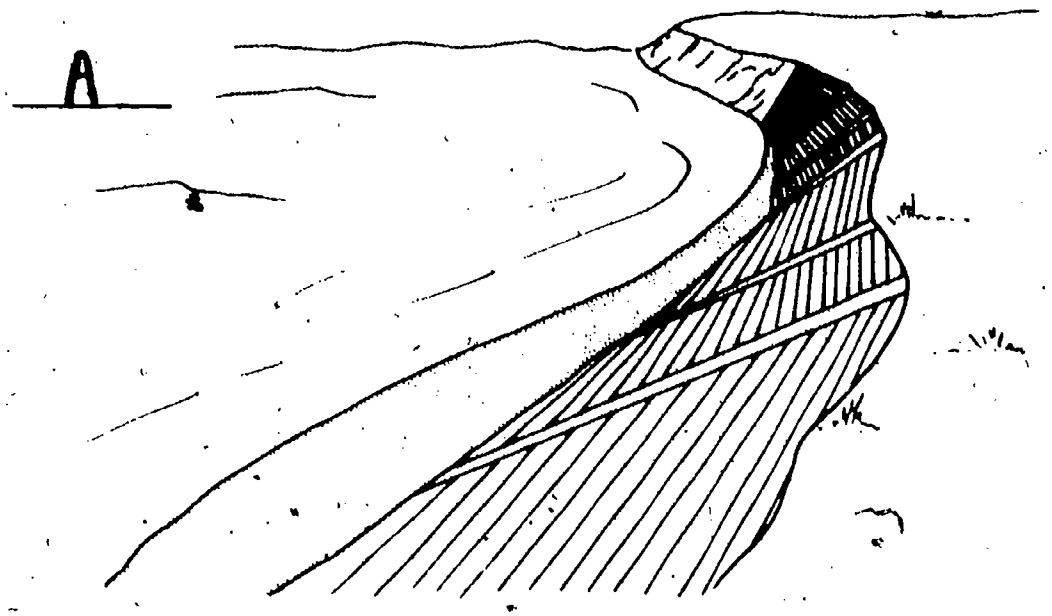
C



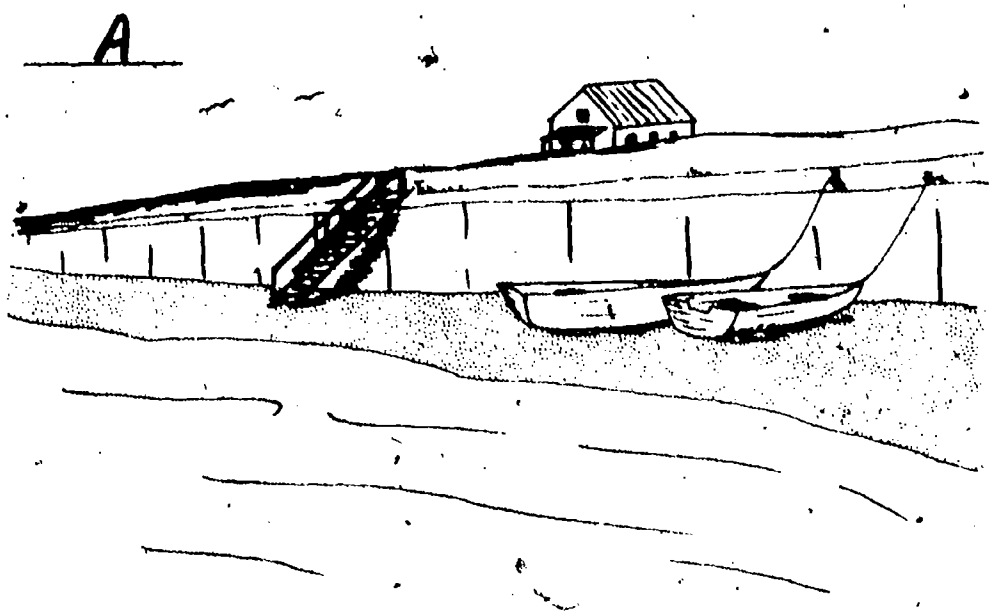
Groins: sheet pile



Breakwater: steel pile



Stepped Revetment



Sea Wall: Concrete

make them unsuitable or undesirable for use by private landowners. Legal responsibilities to owners of adjoining land may also be factors in determining which shoreline protection method is used. To examine the pros and cons of each type of structure, refer to the Corps' of Engineers' free "Help Yourself" wall chart listed in the "Suggested Approach" section on page 2.

REVIEW QUESTIONS

1. Wind waves, and currents are natural forces which cause erosion along Lake Erie's coastline.

2. Loosely packed material with fairly uniform particle size (sand, in this activity) erodes faster. Erosion proceeds more slowly with resistant or tightly packed material.

3. (a) A wall built up against the shoreline to keep waves from actually hitting the land.

   (b) A wall sticking out from the shoreline into the water to interrupt the longshore current and trap sand.

   (c) A wall of rocks or pilings built out in the water parallel to the shoreline to break the force of waves as they come in to shore.

4. Answers will vary. Many students tend to choose a breakwater because they think there can be no beach with a seawall. Refer them to pages 7 and 8 of the student manual to see that beaches can still exist when either structure is used.

5. There are several reasons for not putting shore protection devices all along the shore of Lake Erie:

   (a) Some areas are not erodible to any great extent.

   (b) Some areas are not developed, so erosion is not a critical problem.

   (c) Shore protection devices cause a build-up of sediments in new places. This could be harmful to existing land use along the shore (i.e., filling in of harbors, redistribution of pollutants, filling in of wetlands that are valuable as wildlife habitat.)

On the other hand, the Great Lakes Basin Commission makes the following comments:

"Lake Erie basin shore damage problems are complex. Most of the shorelands, 290 miles, are erodible and 162 miles of these are developed. Flooding is a problem on 44 miles of shorelands. Projections of future shoreland use show all of Lake Erie's shorelands committed to urban use by the year 2000. The percentage of developed shoreline and density of development suggest that structural shore protection would be the most effective method of reducing damages to existing development."

Future activities on undeveloped shorelands should be controlled to reduce future damages. Shoreland management measures including setbacks in zoning, acquisition, and relocation could reduce future damages on Lake Erie."

ADDITIONAL BACKGROUND INFORMATION

For a more complete discussion of wave dynamics and littoral drift effects, you may wish to read Willard Bascom's Waves and Beaches. Chapter X of this book, entitled "The Littoral Conveyor Belt," and Chapter XI, "Man Against the Sea," contain interesting supplements to the material presented in this investigation.

REFERENCES

Bascom, Willard. Waves and Beaches. Garden City, NY: Doubleday and Company, 1964.

Sanko, Peter. Shoreline Protection Guide for Property Owners. Albany, NY: New York Sea Grant Advisory Service.

Stream Table Laboratory Manual. Fisher Educational Materials, 5481 Creek Rd., Cincinnati, Ohio 45242.

U.S. Army Corps of Engineers, North Central Division. Great Lakes Basin Framework Study. Appendix 12: Shore Use and Erosion. Ann Arbor, Michigan: Great Lakes Basin Commission, 1975.

_____. "Help Yourself: A discussion of the critical erosion problems on the Great Lakes and alternative methods of shore protection." 536 S. Clark St., Chicago, IL 60605.

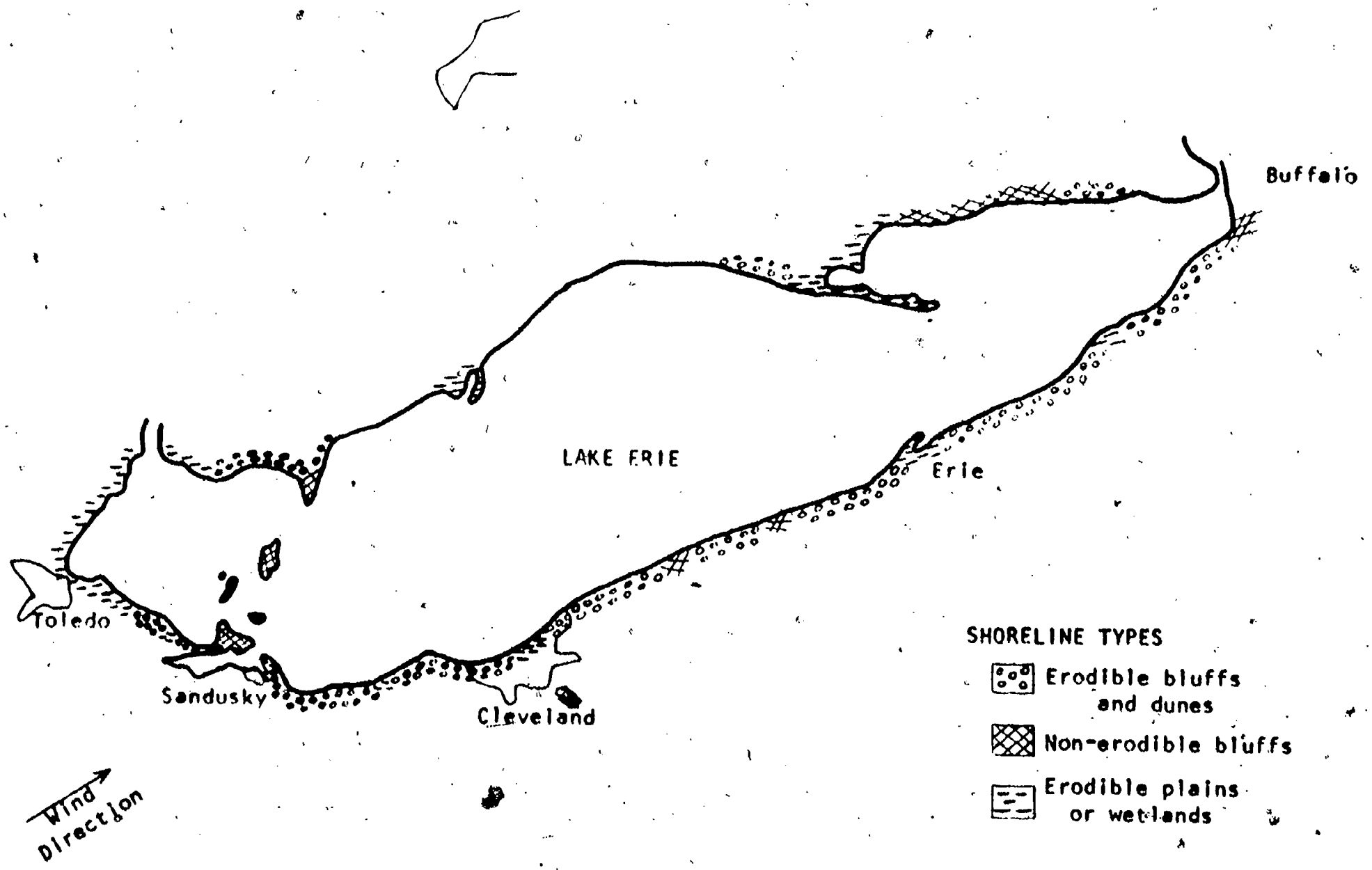
_____. The Role of Vegetation in Shoreline Management. Ann Arbor, Michigan: Great Lakes Basin Commission, 1977.

TRANSPARENCY MASTER #1

INSTRUCTIONS FOR USE

This diagram is adapted from the Great Lakes Basin Commision's Framework Study of 1975. The study dealt only with U.S. lands bordering the Great Lakes, so information concerning the Canadian side is incomplete. Note that most of the lakeward projections of land are erodible spits built in the direction in which the longshore current flows.

The size of the map does not permit inclusion of an interesting feature of Pelee Island. Though the island itself is rocky, it has a sandy spit at its southern tip. Changes in the direction of the longshore current around the islands in that area cause the spit to curve eastward at some times and westward at others. Sailors on the lake therefore, speak of Pelee as "the island that wags its tail."


Buffalo
LAKE ERIE
Erie
Toledo
Sandusky
Cleveland
Wind Direction
SHORELINE TYPES
Erodible bluffs and dunes
Non-erodible bluffs
Erodible plains or wetlands

TRANSPARENCY MASTER #2

INSTRUCTIONS FOR USE

This diagram shows in general terms how the lake shore is being used. A transparency made from this master may be used as an overlay for Transparency #1. In order to make the sections of developed and undeveloped shoreline apparent, the transparent sheet itself (not the master) should be colored with marking pens according to the coloring guide. Green and orange are suggested, but you may use any light colors that will let the information from Transparency #1 show through.

When this overlay is added, it should be apparent that the shoreline is heavily developed in some erodible areas (such as between Erie and Cleveland). When a developed area (orange) overlies erodible bluffs (●●●) or plains (- - -) there is a potential problem in the form of destruction of coastal property by erosion. Erosion of undeveloped areas, while it may have an equally severe effect on the land, is generally not considered so great a problem since man-made structures are not threatened.

As an extension of the discussion generated by these transparencies, the following are recommended:

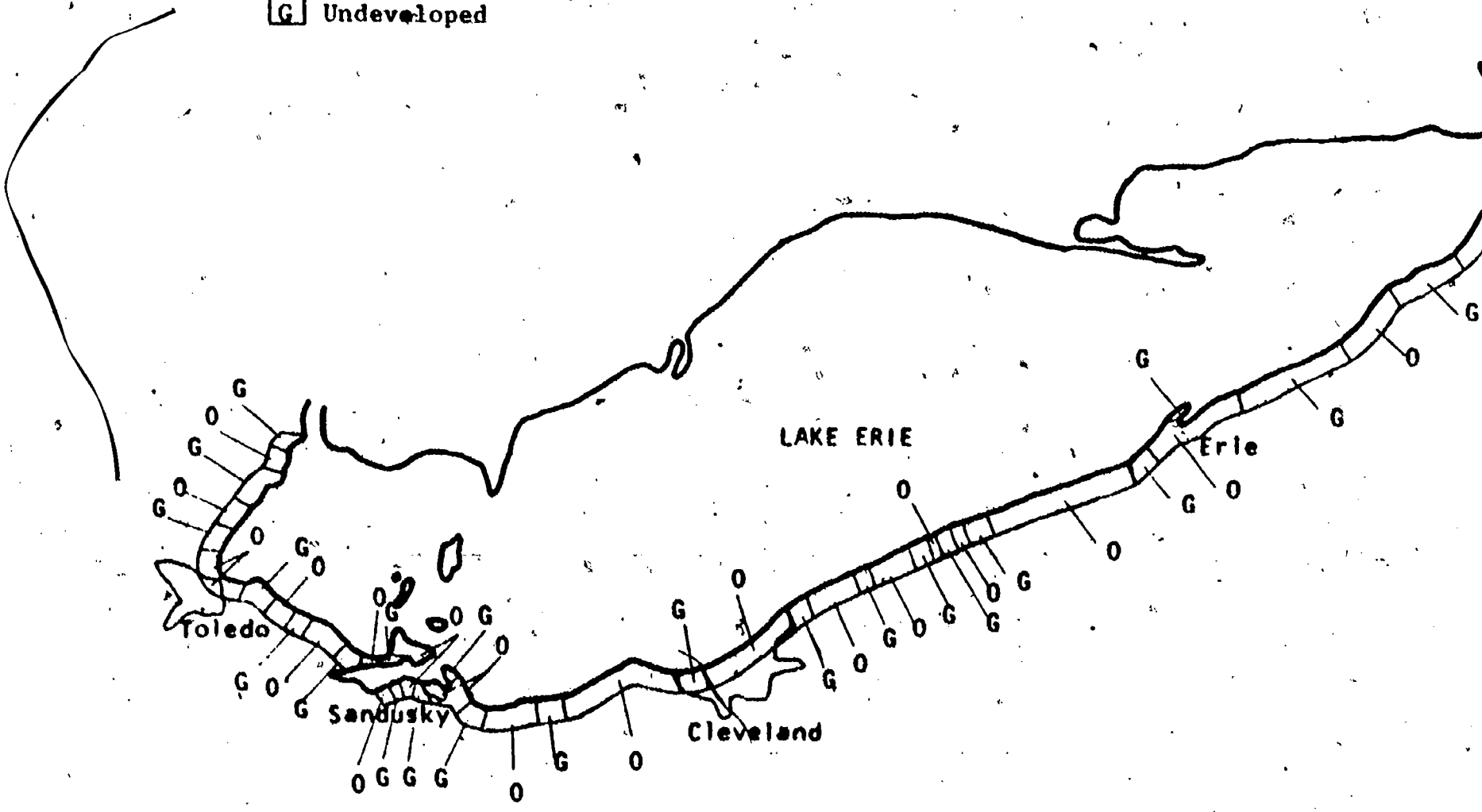
1. Have students investigate what erosion control methods are being used to protect the problem areas (use aerial photos or topographic maps).
2. Investigate what the undeveloped areas are actually being used for, and recommend land uses that are productive but do not require shoreline protection (e.g. wildlife preserves, tree farming). Sources of this information may be road maps, topographic maps, or the Soil Conservation Service's land capability classification for each county.

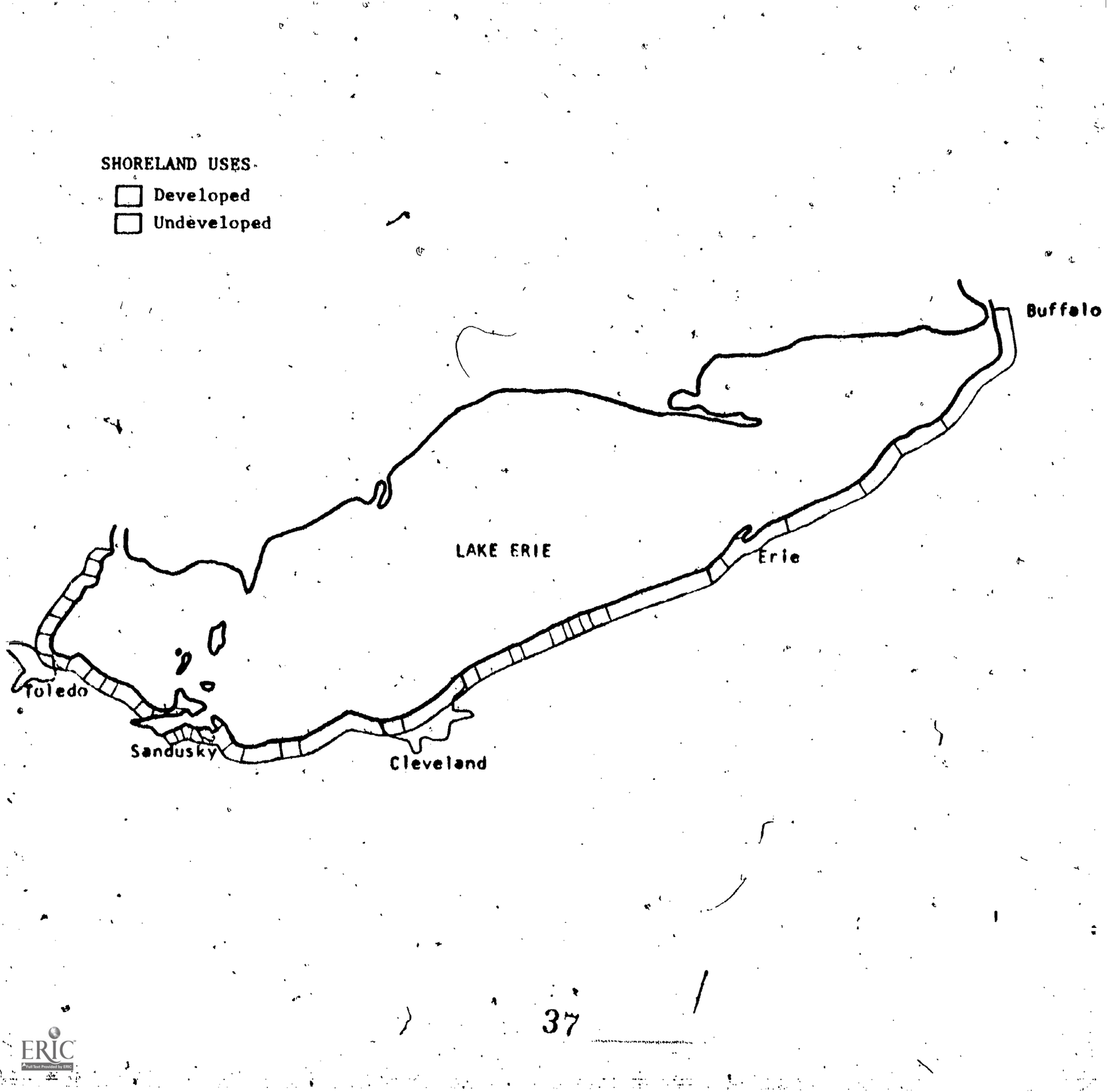
TRANSPARENCY #2
COLORING GUIDE

G = Green
O = Orange

SHORELAND USES

O Developed
G Undeveloped




SHORELAND USES
Developed
Undeveloped
Buffalo
LAKE ERIE
Erie
Toledo
Sandusky
Cleveland

EVALUATION ITEMS

1. Longshore currents are caused by

   *1. wind.
   2. river water moving into the lake.
   3. rotation of the earth.
   4. tides.

2. Trees and other plants are often placed on bluffs along a shore that is rapidly eroding. This is done to

   1. beautify the shoreline.
   2. reduce the wind.
   *3. hold soil in place.
   4. provide a source of firewood.

3. A breakwater is a device used to reduce erosion along a shore. It does this by

   1. slowing down the wind.
   2. changing the direction of the longshore currents.
   *3. blocking the waves.
   4. changing the shape of the bluffs.

4. A groin protects the shore by

   *1. trapping sand behind it.
   2. blocking the waves.
   3. stabilizing the bluffs.
   4. changing the direction of the wind.

5. What is the major cause of sand being transported along a shore?

   1. wind blowing along the shore.
   2. rivers that empty into the lake.
   *3. longshore currents.
   4. slumps occurring in lake bluffs.

6. Which of the following would increase shore erosion?

   *1. more waves
   2. fewer waves
   3. more pollution
   4. smaller waves
   5. less pollution

7. Which type of shoreline material resists erosion best?

   1. sand
   2. soil
   3. clay
   *4. rock

8. A structure built against and parallel to the shore to protect the shore from erosion is called a

   *1. sea wall.
   *2. breakwater.
    3. groin.
    4. littoral drift.

9. The islands in western Lake Erie are mainly composed of

   *1. rock.
    2. sand.
    3. gravel.
    4. soil.

10. The movement of sand along the shore is called

    1. stepped revetment.
    2. a beach.
    3. a wave front.
   *4. littoral drift.