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ABSTRACT

This activity book is part of a series designed to take a concept or idea from the existing school curriculum and develop it in the context of the Great Lakes using teaching approaches and materials appropriate for students in middle and high school. The theme of this book is Great Lakes climate and water movement. Students learn about land-sea breezes, storm surges, ice coverage, and the effect of stratification on water quality. Activities are divided into several subjects: (1) Water Movement; (2) Temperature and Climate; (3) Lake Levels and Storms; and (4) Seasons on the Great Lakes. The activities are characterized by subject matter compatibility with existing curriculum topics. Several kinds of connections have been designed to assist teachers in finding the place where the new materials fit and also the justification for fitting them. The connections include a Framework of Seven Understandings developed by science teachers, science educators, and scientists to represent fundamental desired results of science education. Each activity in this book addresses a number of these Understandings and two or more Earth subsystems. Connections are also made to the National Science Education Standards and the Benchmarks for Science Literacy. (PVD)

Great Lakes
Climate & Water Movement

Earth Systems — Education Activities for Great Lakes Schools

The Ohio Sea Grant College Program is one of 29 state programs that works to increase understanding and wise use of the nation's ocean and Great Lakes resources. Projects are conducted in partnership with government, academia, industry, and the general public. Sea Grant fulfills its mission by promoting education excellence, responsive research and training, and broad, prompt dissemination of knowledge and technical information.

Earth Systems - Education Activities for Great Lakes Schools (ES-EAGLS)

This series of publications was produced as a result of Ohio Sea Grant Education Program's project "Cooperative Curriculum Enhancement and Teacher Education for the Great Lakes" funded by Ohio Sea Grant under grant NA46RG0482, project E/CMD-3, with support from The Ohio State University and cooperating schools.

ES-EAGLS are designed to take a concept or idea from the existing school curriculum and develop it in a Great Lakes context appropriate for students in middle and high school.

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ES - EAGLS

Earth Systems - Education Activities for Great Lakes Schools

Results of studies of student knowledge about the oceans and Great Lakes environments indicate a need for greater awareness and a greater understanding of the impact they have upon our lives. Earth Systems - Education Activities for Great Lakes Schools (ES-EAGLS) are designed to take a concept or idea from the existing school curriculum and develop it in a Great Lakes context, using teaching approaches and materials appropriate for students in middle and high school.

The activities are characterized by subject matter compatibility with existing curriculum topics; short activity time lasting one to three classes; minimal preparation time; minimal equipment needs; standard page size for easy duplication; suggested extension activities for further information or creative expression; teachability demonstrated by use in middle school classrooms; and content accuracy assured by critical reviewers.

Included with the activities are some suggestions about possible ways to use the activities in cooperative learning situations and how lessons can be structured according to the learning cycle.

This is one of a series of subject area activity books being published. The subject of this book is Great Lakes climate and water movement. Other subject areas available are land and water interactions, shipping, the Great Lakes ecosystem, and Great Lakes environmental issues. For a more detailed listing of the climate and water movement activities, see the matrix on page 8. Most of the activities in this book were modified from Oceanic Education Activities for Great Lakes Schools (OEAGLS), developed by the Ohio Sea Grant Education Program and revised from 1985 to 1991. All ES-EAGLS are listed inside the back cover.

Great Lakes Climate and Water Movement

Using *ES-EAGLS Great Lakes Climate and Water Movement*

An accompanying matrix (page 8) matches activities to the Earth Systems Understandings (ESU) and the Earth subsystems directly addressed (hydrosphere, lithosphere, cryosphere, biosphere, atmosphere). It demonstrates the range of instructional opportunities available for the classroom.

The principles that guided development of the activities should also direct their classroom use:

- Potential for collaborative learning and group decision making.
- Use of historical and descriptive as well as experimental data.
- Integration of science disciplines in a social context.

It is recommended that the format for the activities be retained when they are used in the classroom. Some short activities are designed for introduction to topics or for awareness. Longer activities focus attention for extended work and are designed to build understanding, synthesis, application, and evaluation skills. The extent and focus of the activities will help teachers decide which are useful in cooperative groups and which are best for use by the class as a whole.

1. Each activity is a question to be explored. Far too many classroom activities are done for the sake of activity alone. If an important and relevant question is the guide for learning, there is greater focus and a readily apparent reason for doing the activity. Be sure to call students' attention to the question driving the exploration and encourage creative approaches to problem solving.

2. Most activities are addressed to the student for direct use. Additional notes and answers for teacher use are found in narrow columns on each page so they can be concealed if the page is to be given to students.

3. Activities do not stand alone. They should be linked, before and after, to other curriculum topics and information resources such as the Internet. The best questions are those that lead to more questions!

COOPERATIVE LEARNING POSSIBILITIES

There are many ways to organize the activities with cooperative learning strategies, and all of them are the "right way." You are encouraged to modify strategies to make the activities work in your setting. Some possible strategies follow.

GROUPS

Divide the class into three or four groups, with each responsible for certain tasks that will contribute to class learning. Assign each group member a job or task appropriate to the lesson. They are then responsible to the group for doing this job. Jobs can be combined, and they should be rotated between group members periodically. Some possible job descriptions are:

Facilitator	Develops a plan with the group so that the group will finish within the time limit.
Recorder	Records plan, answers, and conclusions as appropriate.
Reader	Reads instructions and background material to group.
Artist	Sketches diagrams, posters, and charts as appropriate.
Checker	Checks to make sure the group is following instructions and the plan.
Speaker	Shares group progress report with class.
Materials Expert	Gets lab materials and makes sure things are cleaned up and returned.

JIGSAW

Divide the class into groups of four students each. These are the base groups. Then divide the class differently into four expert groups. One person from each base group will be in each of the four expert groups. (You will need to adjust the numbers of groups depending on your class size.) Each student should be in two groups. Instead of having every student doing all activities, you can assign each expert group a different activity or task that they become experts at. Then have students meet in their base group and share what was done in the expert group and what was learned. Or you could have the expert groups do their activities and then have the base groups rotate through the activities with the "expert" members leading their base groups through the activity.

STUDENT TEAMS ACHIEVEMENT DIVISIONS

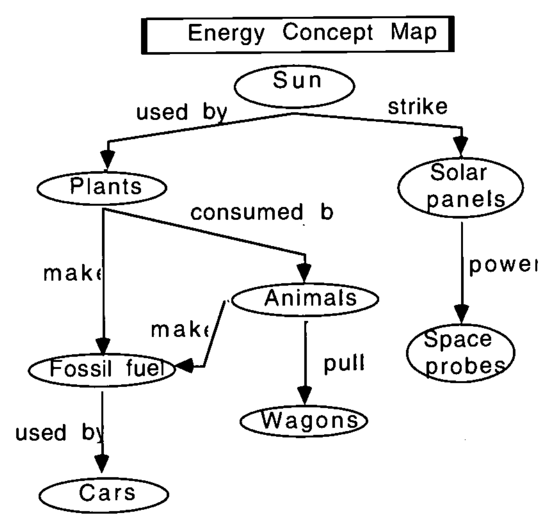
After some type of class presentation such as a lecture, video, or textbook reading, students are divided into teams. Students on the teams work together to make sure that all members of the team understand the material of the presentation. The students then take a quiz individually. Students have a minimum desired score, and the team works to get a high team improvement score (points above the minimum desired score). For more information about this strategy, read *Using Team Learning* by Robert Slavin (Baltimore: The Johns Hopkins Team Learning Project, 1986).

CO-OP CO-OP

This strategy is very student-directed. Students are in teams based on shared interest. The teams subdivide their topics and all students are responsible for researching their own subtopics. They then share what they have learned about the subtopic with their whole team. The teams then prepare a presentation for the entire class, and they are encouraged to include the class in the presentation in some way. *Cooperative Learning: Resources for Teachers* by Spencer Kagan (Riverside, CA: University of California, 1985) will provide you with more information about this strategy.

ASSESSMENT STRATEGY: CONCEPT MAPPING

Concept mapping is one way of having students show visually their understandings of concepts and the concepts' relationships to each other. This can be done as a pre-assessment or a post-assessment or both to see the change in a student's understanding. A brief strategy for use of concept mapping would be to brainstorm a list of terms that students know about a topic. Add terms that you want to make sure are included. Have students start with the topic at the top or center of a sheet of paper, and then, using arrows and labels, students place the brainstormed terms on the map, showing how they are related. See the example of a student's preliminary energy concept map.



There are many other ways of assessing student achievement, including performance assessment, portfolios, and grading rubrics. To learn more about these strategies you might read:

Aronson, J. 1978. *The Jigsaw Classroom.* Beverly Hills: Sage.

Hassard, Jack. 1990. Cooperating Classroom. *Science Scope.* March, p. 36-45.

Johnson, D.W., R.T. Johnson and E.J. Holubec. 1986. *Circles of Learning: Cooperation in the Classroom.* Edina, MN: Interaction Book Company.

Mayer, V.J. and R.W. Fortner, Eds. 1995. *Science is a Study of Earth - A Resource Guide for Science Curriculum Restructure.* Columbus, OH: Earth Systems Education Program, The Ohio State University.

Special Supplement on Assessment. March, 1992. *Science Scope.* This issue contains articles on performance assessment, portfolios, group assessment, concept mapping, and rubrics.

EXAMPLE COOPERATIVE LESSONS

Note: Complete information on materials and methods can be found in the activities listed.

<u>Example I</u>: Students will demonstrate examples of the amount and the flow of water in the Great Lakes system.

Engagement

1. Show a videotape such as *The Lake at Our Door* (Cleveland State University) or *The Great Lakes: Fragile Seas* (National Geographic).

2. Review the hydrologic cycle.

3. Topic Preparation: Assign the reading of Chapter 11 of *The Great Lake Erie* (Fortner and Mayer,1993) as homework for the next day. Discuss reading as a class or in groups.

Exploration

Jigsaw: Divide the class into four expert groups. A leader selected within each group will have the complete pages of the activities, including teacher notes. Other expert group members will have the student worksheets and other instructions from the activities. Assign each expert group different tasks as follows:

Task 1. Do steps 1-5 of the activity "How does water move in the Great Lakes Basin?" Students are responsible for making individual small maps to share with their base groups. The groups are responsible for examining, modifying, and producing a large poster version of the map for the classroom. Each student might be responsible for a different lake basin.

Task 2. Complete number 6 and 7 of "How does water move in the Great Lakes Basin?" Each student is responsible for working with and developing a different part of the data. Each member should be able to explain the charts of the other group members to their own base group.

Task 3. Complete the activity "Out one lake and in another: How long does it take water to flow through the Great Lakes?" Each student is responsible for building a model as described. The group then should work through (practice) the demonstration together, including the answers to the questions. Each student will then do the demonstration for the base group to which they belong.

Task 4. Complete the activity "Does the level of the Great Lakes change?" Questions 1-5: Answer as a group. Questions 6-10: Each student should use the data from a different lake to answer the questions. Are all of the lakes the same? Complete questions 11-17 together. Decide as a group what you should share with the base group and how to share what you have learned. The leader leads a discussion of the Review Questions that follow each activity **(Evaluation)**. The group decides how to present its information to base groups.

Base groups meet and share what the experts have learned and how the questions might be answered. Be certain that the objectives of each activity can be met by students in the base groups.

Elaboration and Evaluation
Assign a portfolio element in which students demostrate their knowledge from the jigsaw. An example might be:

Students produce their own concept maps using the following terms. Base groups should help each other understand the concepts and relationships, but students are responsible for developing their own concept maps.

Concept Map Title: Water Movements of the Great Lakes

Concept terms: rivers, basins, flow, Great Lakes, evaporation, precipitation, drought, wind, sun, time, retention, storms, pollution, damage, and erosion. Students should feel free to use other terms that help explain their concepts and show the depth of their understanding.

Example II: Students will investigate how convection currents and heat storage in and around the Great Lakes affect the weather and climate.

Engagement

1. Listen to regional folk songs about severe storms on the Great Lakes and how they affect people's lives (e.g. Pat Dailey - *Legend of the Lake, White Squall*).

2. Conduct the activity "What causes the land-sea breeze?" as a teacher demonstration for the whole class.

3. Topic Preparation: Assign the reading of Chapter 4 of *The Great Lake Erie* (Fortner and Mayer, 1993) as homework for the next day. Discuss reading as a class or in groups.

Exploration

Jigsaw: Divide the class into three expert groups. A leader selected within each group will have the complete pages of the activities, including teacher notes. Other expert group members will have the student worksheets and other instructions from the activities. Assign each expert group different tasks as follows:

Task 1. Complete the activity "What is the effect of the Great Lakes on temperature?" Decide how you will teach the concepts of heat sink and heat source to your base groups.

Task 2. Complete the activity "How do the Great Lakes influence weather of nearby land areas?" Decide how you will share what you have learned with your base group.

Task 3. Complete the activity "How do the Great Lakes affect climate?" Decide how you will share what you have learned with your base group.

Base groups meet and share what the experts have learned, and how the questions might be answered. Be certain that the objectives of each activity can be met by students in the base groups.

Elaboration and Evaluation

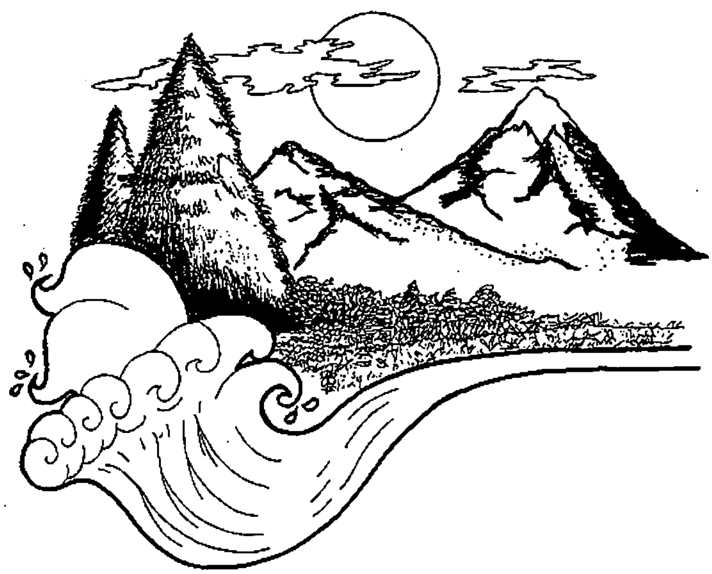
Base groups are to develop a product to demonstrate that they understand how the activities relate to the teacher demonstration and reading. The product might be an oral report, written report, bulletin board/display, video, series of diagrams/posters, or some combination of the above.

Making connections

There is always a danger in producing curriculum materials designed for infusion. How can we facilitate getting new material into the existing flow of classroom subject matter? In this project, we have designed several kinds of connections to assist teachers in finding not only the place where the new materials fit, but also the justification for fitting them and the ancillary resources that can contribute to their effectiveness. The connections we see are demonstrated here and in the charts on the following pages.

EARTH SYSTEMS EDUCATION

http://www.ag.ohio-state.edu/~earthsys

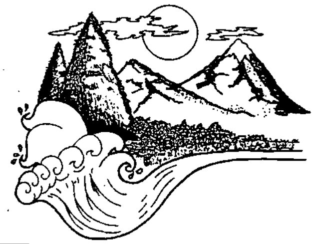


Earth Systems Education is a program of curriculum restructure in which teachers take responsibility for critical evaluation of their science curriculum, including content, classroom processes, learner outcomes, and assessment, and strive to make changes that create a curriculum more responsive to human needs and future quality of life. Earth systems education is based on integration of traditional science disciplines for a more comprehensive understanding of the interactions of Earth subsystems: the hydrosphere, lithosphere, atmosphere, biosphere, and cryosphere.

Efforts are guided by a Framework of Seven Understandings (p. 8 and 95) developed by science teachers, science educators, and scientists to represent fundamental desired results of all of science education. Each activity in this set addresses a number of the Understandings and two or more Earth subsystems, and includes suggestions for extending learning.

The process of curriculum change is assisted by scientists and science educators through development of materials such as these. Additional materials available for Earth Systems Education include a resource guide for science curriculum restructure using Earth as a focus. The guide, entitled *Science is a Study of Earth,* includes research background, teacher experiences, and samples of activities useful at elementary, middle, and high school levels. Another volume of activities is designed to help secondary science teachers address the complex issues of global change. *Activities for the Changing Earth System (ACES)* includes 20 interdisciplinary activities. These publications are available from the Earth Systems Education Program, c/o OSU School of Natural Resources, 2021 Coffey Road, Columbus, OH 43210.

Ohio Sea Grant has also produced regional information and activities about global change. *Great Lakes Instructional Materials for the Changing Earth System (GLIMCES)* includes classroom activities for secondary science, based on *Global Change in the Great Lakes Scenarios.* These can be ordered from Ohio Sea Grant, 1314 Kinnear Road, Columbus, OH 43212-1194.



pg. #	GREAT LAKES CLIMATE AND WATER MOVEMENT — Activities:	Earth Systems Understandings: Beauty & Value (1)	Stewardship (2)	Scientific Process (3)	Interactions (4)	Change Through Time (5)	Earth as Subsystem (6)	Careers & Hobbies (7)	Earth Subsystems: Hydrosphere (1)	Lithosphere (2)	Cryosphere (3)	Atmosphere (4)	Biosphere (5)
15	How does water move in the Great Lakes Basin?	X		X	X				X			X	
19	How long does it take water to flow through the Great Lakes?		X		X				X				
23	What happens to heat energy reaching the Great Lakes?			X	X		X		X	X		X	
29	What causes the land-sea breeze?			X	X		X		X	X		X	
33	How do the Great Lakes affect temperature?				X		X		X	X		X	
39	How is weather influenced by the Great Lakes?	X			X		X		X	X	X	X	X
47	What causes storm surges?				X		X		X	X		X	
53	How do storm surges affect water levels on Lake Erie?			X	X			X	X	X		X	X
57	How do the levels of the Great Lakes change?			X	X	X	X		X			X	
65	What should be the result of regulating the level of the Great Lakes?		X	X	X			X	X	X			
71	How do the Great Lakes change through the seasons?			X	X		X		X		X		
79	How does stratification affect water quality?		X	X	X	X			X				X
89	What factors impact ice coverage on the Great Lakes?			X	X	X			X		X	X	

Framework for Earth Systems Education*

Understanding #1. Earth is unique, a planet of rare beauty and great value.

Understanding #2. Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

Understanding #3. The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

Understanding #4. The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

Understanding #5. Earth is more than 4 billion years old, and its subsystems are continually evolving.

Understanding #6. Earth is a small subsystem of a Solar system within the vast and ancient universe.

Understanding #7. There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

* complete Framework on page 95

NATIONAL SCIENCE EDUCATION STANDARDS

The activities in *Earth Systems - Education Activities for Great Lakes Schools* have connections to other national developments in science education. Numerous efforts have been underway in the 1990s to restructure science education in response to growing concerns that the historic "layer cake" (discipline-ordered) approach to science lacks relevance to students, prepares them poorly in life skills that demand science literacy, leaves U.S. students lagging on standardized international tests of science knowledge, and ignores or perhaps even perpetuates naive conceptions in science. The primary efforts to change these patterns have emerged from and been supported by national organizations in science and education.

The National Science Education Standards represent the National Academy of Science's attempt to develop guidelines for science curriculum restructure and systemic change in K-12 education. The National Standards include science content standards that express need for integration of disciplines, fewer topics in greater depth, and articulation across grade levels. They do more by providing guidelines for restructuring the teaching of science, the environment for science in schools, and assessment of science learning. The Standards emerged in 1995 as the most comprehensive and perhaps most esteemed of the restructure guidelines.

The following list demonstrates the connections of *Earth Systems - Education Activities for Great Lakes Schools* to many of the National Science Education Standards. Standards preceeded by an asterisk (*) are specifically addressed in this activity set.

Content standards, Grades 5-8

Science as inquiry
- * Abilities related to scientific inquiry
- * Understanding about scientific inquiry

Physical science
- * Properties and changes of properties in matter
- * Motions and forces
- * Transfer of energy

Life science
- Populations and ecosystems
- Diversity and adaptations of organisms

Earth and space science
- Structure of the Earth system
- Earth's history

Science and technology
- * Understanding about science and technology

Science in personal and social perspectives
- Populations, resources, and environments
- * Natural hazards
- Risks and benefits
- * Science and technology in society

History and nature of science
- * Science as a human endeavor
- * Nature of science

Unifying concepts and processes
- * Order and organization
- * Evidence, models, and explanation
- * Change, constancy, and measurement
- Evolution and equilibrium
- Form and function

Content standards, Grades 9-12

Science as inquiry
* Abilities related to scientific inquiry
* Understanding about scientific inquiry

Physical science
Chemical reactions
* Forces and motions
Conservation of energy
* Interactions of energy and matter

Life science
Biological evolution
The interdependence of organisms

Earth and space science
* Energy in the Earth system
Origin and evolution of the Earth system

Science and technology
* Understanding about science and technology

Science in personal and social perspectives
* Natural resources
* Environmental quality
* Natural and human-induced hazards
* Science and technology in local, national, and global challenges

History and nature of science
Science as a human endeavor
* Nature of scientific knowledge
Historical perspectives

Unifying concepts and processes
* Order and organization
* Evidence, models, and explanation
* Change, constancy, and measurement
Evolution and equilibrium
Form and function

Benchmarks for Science Literacy

Project 2061 is supported by the American Association for the Advancement of Science (AAAS). Through its book *Science for All Americans*, this project identified science concepts that every high school graduate in the United States should know. Major contributions of this effort include the idea that "less is more," or that a curriculum dealing with fewer concepts in greater detail is preferred over the traditional vocabulary-laden mini-college courses common in U.S. secondary schools. Follow-up work through selected school districts produced several models for implementing the curriculum changes implied by 2061, and has resulted in a set of Benchmarks for designing the course sequences and gauging the progress of students in science through their school careers.

Many of the Benchmarks are addressed through activities in this volume. They are too numerous to list here in their entirety, but the following Benchmarks are among those applicable to the activities.

Examples for grades 6-8 include:

- The cycling of water in and out of the atmosphere plays an important role in determing climatic patterns.
- Heat can be transferred through materials by the collision of atoms or across space by radiation. If the material is fluid, currents will be set up in it that aid the transfer of heat.
- Any system is usually connected to other systems, both internally and externally.
- Models are often used to think about processes that hapen too slowly, too quickly, or on too small a scale to observe directly.

For grades 9-12, these materials address:

- Benefits and costs of proposed choices include consequences that are long-term as well as short-term, and indirect as well as direct.
- The usefulness of a model can be tested by comparing its predictions to actual observations in the real world.
- Different cycles range from many thousands of years down to less than a billionth of a second.

Other Connections

NOAA Global Change Education Program, U.S. Department of Commerce,
1100 Wayne Ave., Rm. 1210, Silver Spring, MD 20910-5603
(301)427-2089. http://www.noaa.gov/

Great Lakes Environmental Research Laboratory (GLERC) conducts environmental research with an emphasis on the Great Lakes, including toxins in the Great Lakes, natural hazards, ecosystem interactions, hydrology, and effects related to global climate change.
2205 Commonwealth Blvd., Ann Arbor, MI 48105
(313)741-2244. http://www.glerl.noaa.gov/

Canadian Atmospheric Environment Service
Environment Canada, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4

International Joint Commission (IJC) is an appointed commission of representatives from U.S. and Canada who act as advisors of management activities of the Great Lakes and rivers along the border between countries. The IJC incorporates public input and efforts of research, environmental, government and business interests in their ongoing efforts. Main office: 100 Ouellette Avenue, Windsor, ON N9A 6T3.
(519)256-7821; Detroit Office: P.O. Box 32869, Detroit, MI 48232.
(313)226-2170. http://www.great-lakes.net:2200/partners/IJC/ijchome.html

Great Lakes Commission is an interstate commission of the eight Great Lakes states established in 1955 to "promote the orderly, integrated and comprehensive development, use and conservation of the water resources of the Great Lakes Basin."
The Argus II Building, 400 Fourth St., Ann Arbor, MI 48103
(313)665-9135. http://www.glc.org/

Great Lakes Information Management Resource (GLIMR) is an index of Environment Canada's Great Lakes programs, publications, and databases.
http://www.cciw.ca/glimr/intro.html

Great Lakes Information Network (GLIN) is a great place to start exploring the Great Lakes on the Internet.
http://www.great-lakes.net/

National Sea Grant College Program – Great Lakes Network
http://h2o.seagrant.wisc.edu/greatlakes/glnetwork/glnetwork.html (One Web site links all programs below.)
Illinois-Indiana Sea Grant, 1206 S. Fourth St., 104 Huff Hall, Champaign, IL 61820; (217)333-1824
Michigan Sea Grant, 2200 Bonisteel Blvd., Ann Arbor, MI 48109; (313)763-1437
Minnesota Sea Grant, 1518 Cleveland Ave., N., Rm 302, St. Paul, MN 55108; (612)625-2765
New York Sea Grant, SUNY, Nassau Hall, Stony Brook, NY 11794-5000; (516)632-6905
Ohio Sea Grant, 1314 Kinnear Rd., Columbus, OH 43212-1194; (614)292-8949
Wisconsin Sea Grant, 1800 University Ave., Madison, WI 53705-4094; (608)262-0644

Cooperative Institute for Limnology and Ecosystems Research (CILER).
Its research focuses on climate and large-lake dynamics, coastal and near shore processes, and large lake ecosystem structure and function. The institute is comprised of the University of Michigan, Michigan State University, and GLERL

CILER, University of Michigan, Ann Arbor, MI 48109
http://www.glerl.noaa.gov/ciler/ciler.html

Internet Sites of General Interest

Try a search using the name, if the address has changed.
National Climatic Data Center, http://www.ncdc.noaa.gov
U.S. Army Corps of Engineers, Detroit District, http://sparky.nce.usace.army.mil
Sea Grant Network, http://h2o.seagrant.wisc.edu/greatlakes/glnetwork/glnetwork.html
Canadian Great Lakes Information Management Resource, http://www.cciw.ca/glimr/intro.html
Lake Carriers Association, http://ne1.bright.net/lcaships/
NOAA Home Page, http://www.noaa.gov/
The Ohio State University Atmospheric Science Program, http://asp1.sbs.ohio-state.edu/
Great Lakes Forecasting System, http://superior.eng.ohio-state.edu/, Lake Erie maps updated every 6 hours.

Publications and Other Materials

The Great Lake Erie. A Reference Text for Educators and Communicators. Fortner, R.W. and V.J. Mayer. 1993. Columbus: Ohio Sea Grant. This is the source of information used in most of the activities. Chapters are written by experts in Great Lakes topics, and readings from the book can serve as the content base for additional instruction.

The Great Lakes: An environmental atlas and resource book. 1995. Jointly produced by the Government of Canada and U.S. EPA, 3rd edition. Copies available from Great Lakes National Program Office, U.S. EPA, 77 W. Jackson Blvd., Chicago, 1995. IL 60604.

Great Lakes Instructional Materials for the Changing Earth System. Fortner, Rosanne W., Heidi Miller, and Amy Sheaffer. 1995. Columbus: Ohio Sea Grant. A book of 31 activities for students in grades 7-12 that investigate the potential of global change on the Great Lakes region.

Great Lakes Solution Seeker CD-ROM. Fortner, Rosanne W., Rick Meyer, and Al Lewandowski. 1996. Columbus: Ohio Sea Grant. Databases and Hypercard program with vital data on Great Lake processes and characteristics.

International Station Meteorological Climate Summary Ver 2.0 (CD-Rom, DOS). Federal Climate Complex, Asheville, NC.

Science Is a Study of Earth: A resource guide for science curriculum restructure. Mayer, V.J. and R.W. Fortner, 1995. Columbus, OH: Earth Systems Education Program, The Ohio State University. Ideas on effective ways to improve science teaching and learning, assess progress, do cooperative learning, conduct workshops, etc. Sample activities for grades K-HS.

Weather and Climate of the Great Lakes Region. Eichenlaub, Val. 1979. The University of Notre Dame Press. Notre Dame, Indiana.

Arts and Literature of the Great Lakes

Many scientists report that their interest in science was at least in part related to their feelings of wonder at the Earth's beauty. As it is stated in Earth Systems Understanding #1, "The beauty and value of Earth are expressed by and for people of all cultures through literature and the arts." The developers of ES-EAGLS encourage teachers to use art, music, and literature in teaching. Not only does this address diverse learning styles and stimulate creativity, it also helps students find meaning behind what may otherwise appear to be topics irrelevant to their lives.

Much support is available for teachers to include the arts in teaching science. Listed below are some of the resources the authors have found most valuable. Your school's librarian and music teacher may know of other resouces that relate to your specific region or Great Lake. Consult local units of the Great Lakes Historical Society and merchants in resort areas of the lakes as well.

SELECTED MUSIC RESOURCES

Lee Murdock's Great Lakes folk songs are popular in auditorium programs, private performances, and on cassettes. *Cold Winds* and *Freshwater Highway* are our favorite albums. Depot Recordings, P.O. Box 11, Kaneville, IL 60144, (708)557-2742.

Pat Dailey is a country rock singer from Bay Village, Ohio. His albums are a mix of bar-room humor and serious songs of the Great Lakes. We use his "Great Lakes Song" and others on the *Freshwater* album most often. Albums are available from Olympia Records, P.O. Box 40063, Bay Village, OH 44140.

"Privateer," a Celtic folk duo from the Chicago area that sings traditional Great Lakes songs and original material related to the lakes. Sextant Music, 6342 W. Belmont, Chicago, Il 60634, (312)775-1257.

Banana Slug String Band's, *Dancing with the Earth* album, has an excellent "Water Cycle Boogie" for younger students. Contact them at BSSB, P.O. Box 2262, Santa Cruz, CA 95063.

SELECTED ART RESOURCES

The Canadian McMichael Collection (Government of Ontario, 1983) from the McMichael Galleries in Toronto includes the best collection of the Canadian Group of Seven landscape artists.

Herold, J.M. 1992. *Lasting impressions in meteorology.* Science Scope, February. p. 14-16. Impressionist paintings used in science class.

Gedzelman, S.D. 1991-92. *The sky in Art.* Weatherwise, Dec.- Jan., p. 8-13.

POETRY

Hangdog Reef. Poems Sailing the Great Lakes. This is the only volume we have found specific to Great Lakes topics. Please let us know if you find others!

How does water move in the Great Lakes basin?

You are familiar with the water cycle. The sun heats the surface of the earth, water evaporates, water vapor rises in the atmosphere and cools and condenses, precipitation falls, and then water flows in the streams, rivers, lakes, and oceans. Vegetation and ground water are important links in the movement of water as well. In this activity you will find out how water moves in the Great Lakes system.

OBJECTIVES

When you complete this activity you will be able to:

- Locate and identify the Great Lakes on a map.
- Identify the connecting waters.
- Define water basin.
- Begin an analysis of the flow of surface water.

PROCEDURE

1. A basin is the area that a lake or river drains. Look at the direction that the rivers flow on your map and draw the basin lines around the Great Lakes so that all rivers that drain into the lakes are enclosed, and any river that does not drain into the Great Lakes is outside of the basin. Each lake basin should be outlined in a different color.

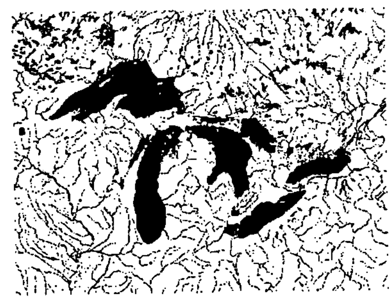
2. Compare your map with that of other students and resolve any differences you detect. Discuss the great differences in watershed sizes. Does the biggest watershed determine the biggest lake? What other factors may be involved in lake size?

3. Locate the following and label them on your map.

   Lakes: Erie, Georgian Bay, Huron, Michigan, Nipigon, Ontario, St. Clair, Superior.

   Rivers and Connections: Mackinac, Niagara, St. Lawrence, St. Marys, Detroit.

4. If you did not know which way the water flowed through the lakes, what information would you need to find your answer?



Authors

Richard Meyer and Rosanne W. Fortner

Earth Systems Understandings

This activity focuses on ESU 3 and 4 (scientific process and interacting subsystems).

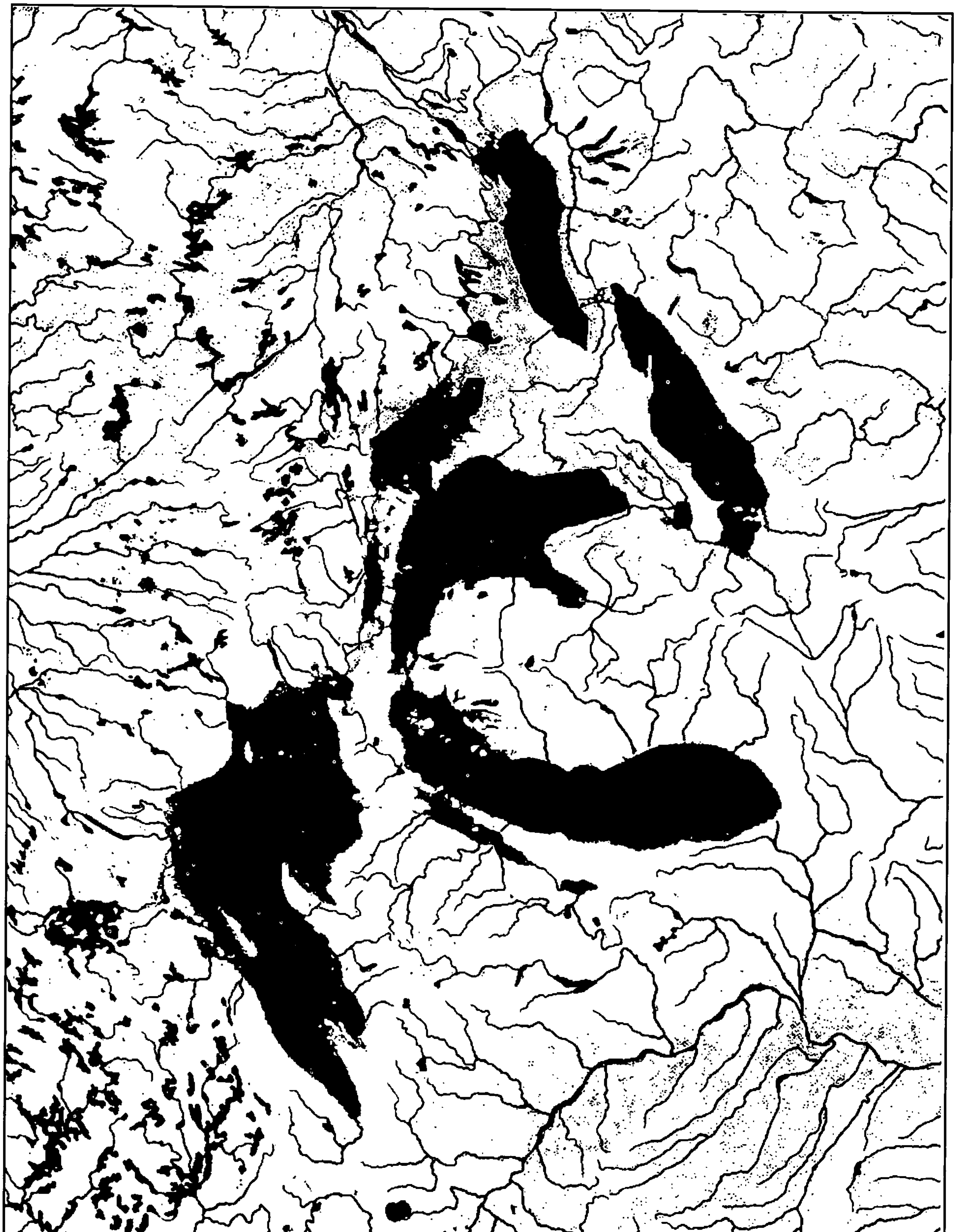
Materials

- Copies of the map of the Great Lakes area. (One per student.)
- Colored pencils or markers.
- Copies of activity data charts.
- Paper, rulers, and other supplies for student chart / diagram making.
- Atlas or maps of Great Lakes area.

Teacher's Notes

You might want to follow this activity with the activity *Out One Lake and In Another: How long does it take water to flow through the Great Lakes?*

Jigsaw: Students could work in expert groups, each group assigned a different lake to focus on, and then return to base groups to put together an overall map and to share what they found significant about their lake.



Rivers of the Great Lakes Region Modified from "Water," a map produced by the National Geographic Society, 1993

5. Examine Table 1 about the Great Lakes water system and choose some part of the data set that you find significant. Develop a chart, diagram or some other meaningful way to display the chosen data. (Table 2 provides you with some background information about the Great Lakes. You may want to use it to help analyze Table 1.)

6. Share your chart, diagram or display with the class, demonstrating how/why the data were significant to you.

Teacher's Note

4. Elevation of lakes is the most logical.

5. Students may find that some of the numbers do not add up. (Input does not always equal output.) Have them hypothesize possible explanations (groundwater inflow and outflow, numbers rounded off, human use, etc.). The hypotheses could be used for further exploration.

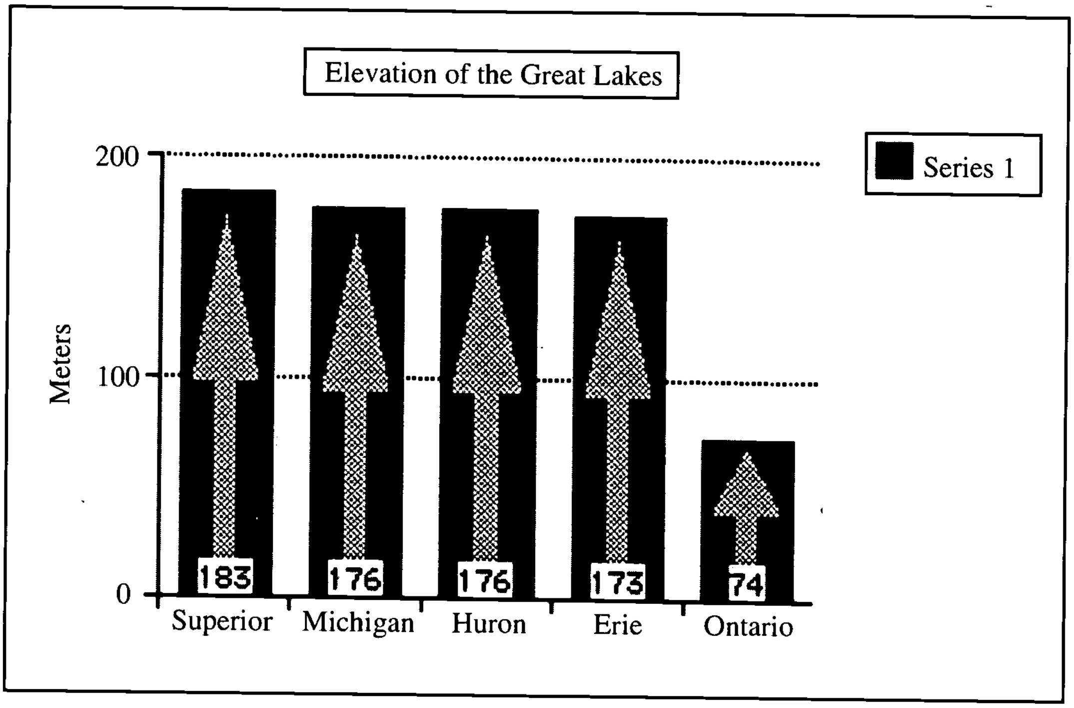
Table 1. The Great Lakes Water System.

The Great Lakes Water System (figures are in thousands of cubic meters per second)	Runoff into lake	Precipitation into lake	Inflow from upstream lake	Evaporation from lake	Outflow
Lake Superior	1.4	2.1	0.2	1.4	2.2
Lake Michigan	1.0	1.5	----	1.2	1.6
Lake Huron	1.4	1.5	3.7	1.2	5.3
Lake Erie	0.7	0.7	5.3	0.7	6.0
Lake Ontario	0.9	0.5	5.8	0.4	7.1

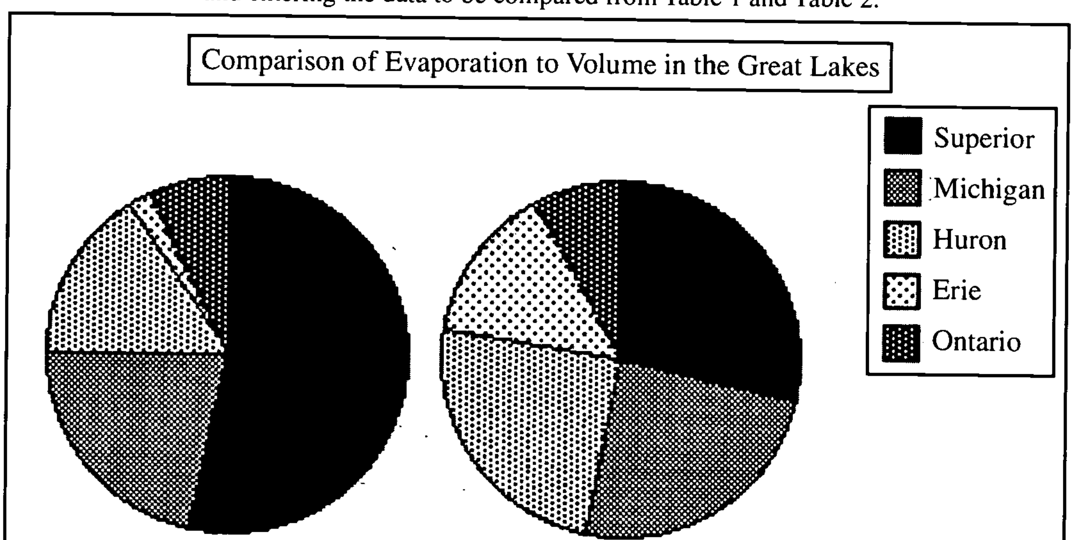
Table 2. Physical Data of the Great Lakes. (Data for Table 1 and 2 from *The Great Lakes: An Environmental Atlas and Resource Book*, 1987 and 1995, U.S. EPA & Environment Canada)

Physical Data	Superior	Michigan	Huron	Erie	Ontario
Elevation (meters)	183	176	176	173	74
Length (kilometers)	563	494	332	388	311
Breadth (kilometers)	257	190	245	92	85
Avg. Depth (meters)	147	85	59	19	86
Max. Depth (meters)	406	282	229	64	244
Volume (km^3)	12,100	4,920	3,540	484	1,640
Surface Area (km^2)	82,100	57,800	59,600	25,700	18,960
Drainage Area (km^2)	127,700	118,000	134,100	78,000	64,030
Total (km^2)	209,800	175,800	193,700	103,700	82,990
Shoreline (km)	4,385	2,633	6,157	1,402	1,146
Retention (years)	191	99	22	2.6	6
Population 1980/81	738,540	13,970,900	2,372,119	12,968,606	6,642,175
1990/91	607,121	10,057,026	2,694,154	11,682,169	8,150,895

Example 1 of student data comparison for #5. Completed using ClarisWorks spreadsheet and entering the data from Table 2.



Example 2 of student data comparison for #5. Completed using ClarisWorks spreadsheet and entering the data to be compared from Table 1 and Table 2.



The volume of Lake Superior is over 50% of the total Great Lakes volume. Its evaporation is much less in comparison to the other lakes. lake Erie on the other hand has a very small volume compared to the other lakes but a high evaporation rate. Why?

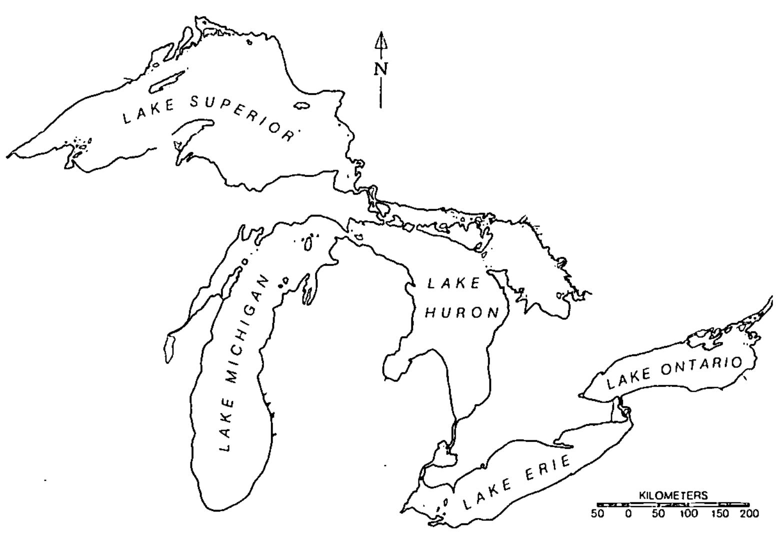
Out One Lake and *In* Another: How long does it take water to flow through the Great Lakes?

Water that is in a lake does not stay in that lake. Where does the water go? If you think about the water cycle, you will be able to figure out several places that it might go. The length of time that it takes for the amount of water in a lake to be completly replaced (enter the lake) is called *retention time*. Each of the Great Lakes has a different retention time. Lake Superior's retention time is much longer than the others: 194 years, compared to just 75 years for Lake Huron, for example. Since the water mixes as it pours in and out, over the course of 194 years, only half of the water in Lake Superior actually leaves.

OBJECTIVES

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

- Construct an appropriate model of the water flow of the Great Lakes.
- Define the concepts of retention time and flushing rate and describe how they are different.
- Discuss how Lake Superior affects the dynamics of water flow, retention time, and flushing rates for the Great Lakes system and why this is important.



Earth Systems Understandings

This activity deals with ESU 2 (stewardship) and 4 (interactions).

Source

Lake Effects, Early Fall, 1995 - A quarterly publication for and about Lake Superior education. Published by Lake Superior Center, 353 Harbor Drive, Duluth, MN 55802

Materials

Teacher has:
- Roll of duct tape.
- Measuring cups.
- Food coloring.
- Eye dropper.
- Scissors for each group.
- Sinks or dish pans for each group.

Students bring in:
- Paper milk cartons
  - half-gallon/2 liters (two per work group),
  - pint/500 ml (one per work group), and
  - half-pint/250 ml (two per work group).

Teacher's Notes

Length: Two class periods or 90 minutes.

If you plan on using the activity *What would be the result of regulating the level of one of the Great Lakes?*, you may want to modify the equipment setup of this activity so that you can use the same setup for both activities.

Procedure

A. Construct models (Day One)

Work in groups of three, as assigned by your teacher. You are going to build a model that demonstrates the water flow through the Great Lakes. Construct your Great Lakes model by following instructions given by your teacher. Use the diagram below and/or a model set up by your teacher as a guide to creating your model. Label the cartons from largest to smallest: "Superior," "Huron," "Erie." Use your model and review the concepts of evaporation, precipitation, and runoff with your group and/or class.

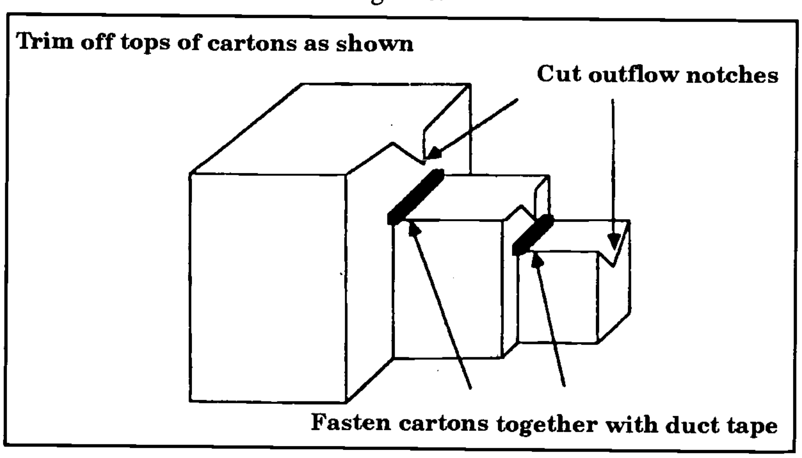
B. Demonstrate flow (Day Two)

Place your entire model inside a sink or dishpan to catch water that might overflow. Fill an extra half-gallon carton with water and pour it into Lake Superior. This represents 194 years of rain pouring into Lake Superior. Now pour another half-gallon in, very slowly. You should observe two things: the water pouring into the lower lakes, and the water in Lake Superior replacing itself.

C. The problem with pollution: Lake Erie

With the cartons full of water, add five drops of food coloring to your group's "Lake Erie" half-pint container (or enough to significantly darken the water). Use another half-pint container to model Lake Erie's retention time of 2.5 years by pouring the half-pint directly into the Lake Erie carton.

Figure 1.



1. Is the water in the Lake Erie carton clear? Why or why not?

   Count how many 2.5 year flushing cycles it takes to make the Lake Erie water really look clear. Multiply the number of cycles by 2.5 years.

2. How many years does that represent?

   In reality, it took Lake Erie about 15 years to significantly clean itself out after pollution controls were installed in the early 1970s.

D. The problem with pollution: Lake Superior
Imagine that Lake Superior is polluted to the same extent (water as darkened) as Lake Erie.

3. Assuming it would take equally as many flushing cycles to clean Lake Superior out, how long would it take in real time given Lake Superior's 194 year retention time?

E. The problem with pollution: The Great Lakes system

4. Where does pollution go when it leaves one lake?

   Toxins are being cleaned out from the Great Lakes. Locate the Gulf of St. Lawrence on a map or in an atlas.

5. Where is the Gulf of St. Lawrence?

   One of the animals found living in the Gulf of St. Lawrence is the beluga whale.

6. Predict what you think might be happening to the beluga whales as a result of the interaction of humans and retention time / flushing rates of the Great Lakes.

7. Why is it important to the Great Lakes system to keep Lake Superior clean?

Answers

1. It will not be clear, because only half of the food coloring will be gone.
2. Answers will vary from one group to another.
3. Answers will vary.
4. One place that pollution goes is downstream to another lake or river and eventually to the ocean. Other answers not examined by this activity are that pollution can get trapped in the sediment or it can be taken into the food chain.
5. East coast of Canada. Great Lakes water reaches the Atlantic Ocean.
6. Toxic chemicals have been found contaminating the beluga whales.
7. The "clean" water from Lake Superior helps to flush out the lower Great Lakes.

EXTENSIONS

1. Take your model to lower grade classrooms and demonstrate the flow of the Great Lakes to younger students.
2. Investigate the beluga whales of the Gulf of St. Lawrence and present your findings to the class. Use the Internet as one of your sources.

What happens to heat energy reaching the Great Lakes?

Even as far back as the "log cabin days," people knew that water absorbs a great deal of heat energy and can in turn release this heat. Pioneers would prevent foods from freezing on cold nights by placing a large container of water in the room. Can you think of why this might work? In this investigation we will explore how bodies of water can affect the surrounding areas.

OBJECTIVES

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

- Describe how soil and water differ in their ability to absorb and release heat energy.
- Describe how this difference in heat absorbed or released affects the atmosphere immediately above the land and immediately above the water.

Materials

Each lab group should have
- Four thermometers.
- A container of dark soil and one of water.
- Two 30 cm rulers.
- Masking tape.
- Ring stand.
- Graph paper.
- A light with reflector; the light should be at least 150 watts.

Source

Modified from OEAGLS EP -1
"The effect of the Great Lakes on temperature" by James D. Meinke, Lakewood Public Schools; Beth A. Kennedy, Newark Public Schools, and Rosanne W. Fortner, The Ohio State University.

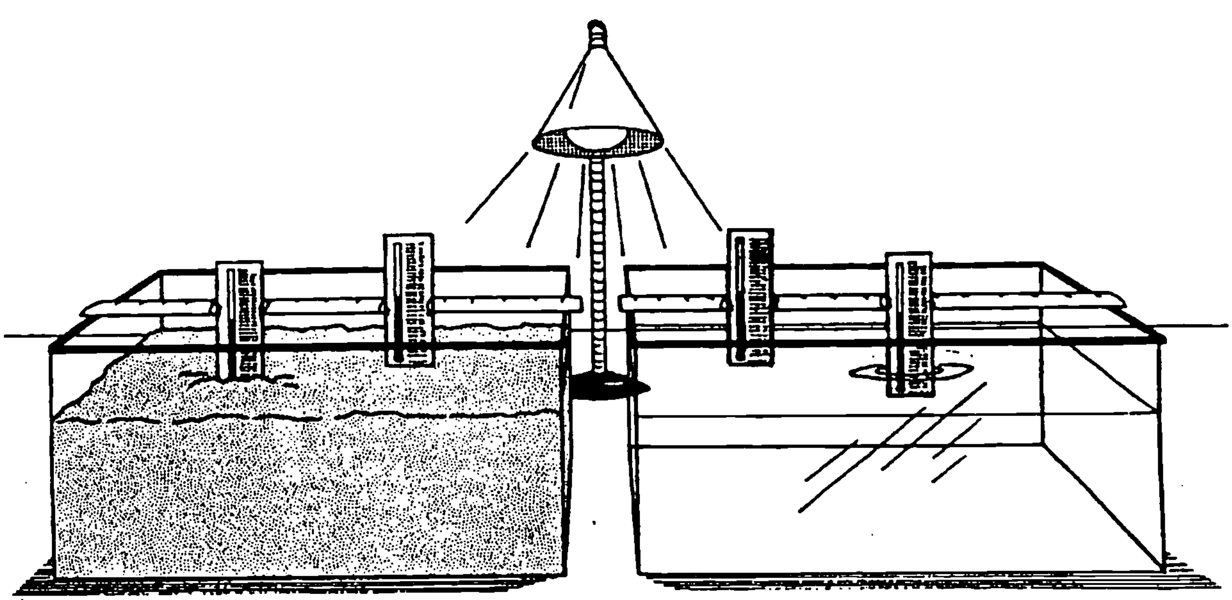
Earth Systems Understandings

This activity focuses on ESU 3 and 4 (scientific process and interacting subsystems).

Teacher's Notes

Set out the soil and water a day ahead to allow them to come to room temperature. Steps A-G of the procedure describe the experiment setup shown in Figure 1. It is also possible to demonstrate this in one aquarium with containers of soil (8x8 baking pan) and water.

Figure 1.



Teacher's Notes

Answer to the question in the introduction. When a large container of water is placed in a room with foods, the water will prevent the foods from freezing since the water acts as a heat source if it is at a higher temperature than its surroundings. Water adds heat to the atmosphere, keeping the room warm.

1. Headings on their tables should be:
   Time Elapsed
   Thermometer 1 - above earth
   Thermometer 2 - in earth
   Thermometer 3 - above water
   Thermometer 4 - in water
   Below Time Elapsed have students number 1 - 24 minutes.

2-4. To help make the graphs easier to interpret, it is best if all the initial temperature readings for the setup are the same. If the students' thermometers do not read the same at the beginning, then the temperature readings should be adjusted so that the initial temperatures are equal. This is done by finding the difference between the thermometer with the lowest reading and each of the others. The difference for each of the thermometers is then subtracted from each reading given by the thermometer.

Procedure

Set up your materials according to the following directions. (See Figure 1.)

A. Place the containers of soil and water about 3 cm apart.

B. Lay one ruler across each container, resting it on the container's rim.

C. Place one thermometer in the soil with the thermometer bulb just barely covered. Attach with masking tape to the ruler.

D. Place another thermometer close to the first one, but about 1 cm above the soil. Attach with masking tape to the ruler.

E. Repeat steps C and D for the container of water.

F. Place the lamp on a ring stand with the reflector pointing down.

G. Position the lamp 30 cm above and centered between the containers.

H. Be certain that the bulb of each thermometer is shielded from the direct rays of the lamp.

After your teacher has examined your setup, do the following:

1. Construct a data table to show the temperatures of the four thermometers each minute for at least 24 minutes.

2. Turn the lamp on. At one-minute intervals record the temperatures indicated on each of the four thermometers. Continue for 12 minutes.

3. Turn the lamp off after 12 minutes. Continue recording temperatures at one-minute intervals for 12 minutes.

4. Plot your data on the time-temperature graph that you construct. Use a different color for the data from each thermometer.

Answer questions 5-7 using data from the first 12-minute intervals on the data table and time-temperature graph. Put your answers on your work sheet.

5. With the light on, does air heat up faster over the soil or over the water?

6. Which changes more the temperature of soil or the temperature of the water?

7. Which absorbs more energy, soil or water?

Use the data for the last 12-minute intervals to answer questions 8-11.

8. With the light off, which changes more the temperature of soil or the temperature of the water?

9. Which changes most after the light is turned off, the temperature above the soil or the temperature above the water?

10. Which loses heat faster, soil or water?

11. Which keeps heat energy longest, soil or water?

Anything that adds heat energy to the atmosphere is called a *heat source*. A *heat sink* takes and stores energy from the atmosphere.

12. Could soil or water be considered a heat sink while the light was on? Discuss.

13. After the light was turned off, was the soil a heat source? Was the water a heat source? Discuss.

Answers

5. The air heats up faster over the soil.

6 and 8. While the lamp is on, the soil should be heating up more rapidly than the water since soil has a lower specific heat, and it absorbs all radiation close to the surface. Specific heat is the amount of heat (in calories) required to raise the temperature of 1 gram of substance by 1 degree Celsius. The specific heat of water is 1. For all other common liquids and solids, the specific heat is less than 1.

After the light is turned off, the soil should cool more rapidly than the water because of its lower specific heat. (See Figure 2.) Note that the curves for soil and water now show a drop at different rates in Section B of the graph. Most students should be able to notice the difference in this part of their data curves.

7 and 9. The water will absorb more energy. It will be very difficult for students to understand this. The clue is in the "air" curves. The air over the soil heats up much more rapidly than that over the water. This is because soil cannot hold onto the heat energy and gives it right back to the atmosphere. The difference in the two curves therefore implies that the water has a greater capacity for storing heat energy. This idea is further supported by the ends of the two curves. Note that they cross at about 19 minutes and continue to diverge after that. Water is acting as a source of heat energy for the atmosphere.

10. Soil loses heat faster than water.

11. Water keeps its energy the longest. If students place their thermometers too deeply in the soil, their temperatures will show a continuing rise in temperature after the light is turned off. This happens because some of the energy from the surface is conducted downward into the soil.

Answers

12. Normally soil will function very briefly as a heat sink after the light is turned on. Shortly, however, it will begin radiating energy back to the atmosphere (become a heat source) as indicated by the heating of the air above the soil. Water should remain a heat sink, however, and produce only a minimum rise in temperature of the air above. Figure 2 does not show this relationship.

13. After the light is turned off, soil functions only briefly as a heat source. Water, however, continues as a source to the end of the recording period. Since the air temperature above the water remains higher than that of the water itself, it will continue to act as a heat source until the surface water is the same temperature as the air over it.
14. C.
15. D.
16. B.
17. A heat sink is a substance or object that is absorbing more heat than it is radiating.

18. A heat source is a substance or object that is radiating more heat than it is absorbing.

Technology Extension

Use the Internet to collect temperature data from around the Great Lakes area. There are a couple of Macintosh programs that you may find useful. They are Blue Skies and Net Weather. These two programs make accessing weather information simple. They both require a slip or direct connection to the Internet. Using Netscape or another similar programs, you can check out these two addresses.

http://groundhog.sprl.umich.edu/blueskies.html

gopher://gan.ncc.go.jp:70/40/INFO/info-mac/app/mac-weather-10.hqx

Since addresses commonly change, try a keyword search on the names of the programs, shareware software, or weather software to locate new addresses.

14. A heat sink
    a. has a higher temperature than its surroundings.
    b. "gives off" excess heat.
    c. absorbs and stores excess heat.
    d. is the Great Lakes in the wintertime.

15. If you place a bucket of water and a bucket of soil out in the sun in the morning, what would happen to their temperature?
    a. Their temperature would not change.
    b. Both would warm up at the same rate.
    c. Water would warm up faster than the soil.
    d. Soil would warm up faster than the water.

16. If you kept the same two buckets outside until after the sun set, that would happen to the temperatures?
    a. Both would cool at the same rate.
    b. Soil would cool faster.
    c. Water would cool faster.
    d. Their temperature would not change.

17. Define in your own words the term "Heat Sink."

18. Define in your own words the term "Heat Source."

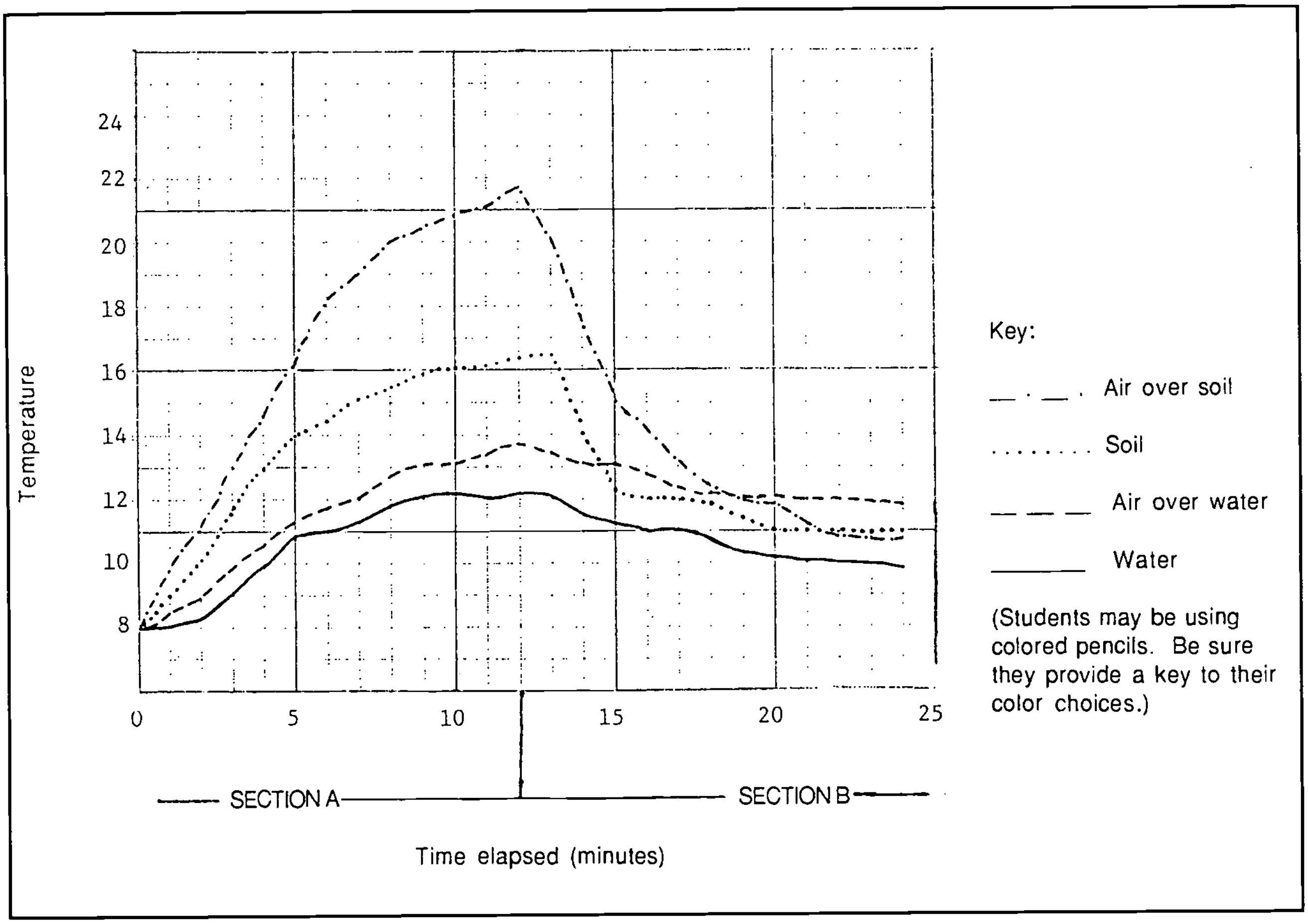
19. Predict how you think the Great Lakes affect temperature.

References

American Geological Institute, 1987. *Investigating the Earth*, Boston: Houghton Mifflin Company. This activity is adapted from an investigation in this volume.

Eichenlaub, Val L., The Effect of Lake Erie on Climate, in Fortner, R.W. and V.J. Mayer, eds. *The Great Lake Erie*, Chapter 4, Columbus: The Ohio State University, Ohio Sea Grant College Program.

Figure 2. Sample of student graph results.



What causes the land-sea breeze? A teacher demonstration.

Air movement is caused by different air masses having different temperatures and densities. The lower atmosphere absorbs heat from the surface of the earth. Different types of surfaces radiate heat differently so the atmosphere is not heated equally at all locations. This means that the atmosphere is warmer in some places and cooler in others and air movement (wind) results.

OBJECTIVES

Upon completing this activity, you will be able to:

- Explain how air temperature affects air density and movement.
- Describe how and why local winds near the shore change direction from day to night, and from winter to summer.
- Synthesize information about how the circulation of air is affected by the land-water interface.

> **CAUTION:** Follow directions carefully! If chemicals contact skin, wash the affected areas thoroughly at once. Clean up spills immediately. Both chemicals have a noxious odor, so keep containers sealed except when the chemicals are being used.

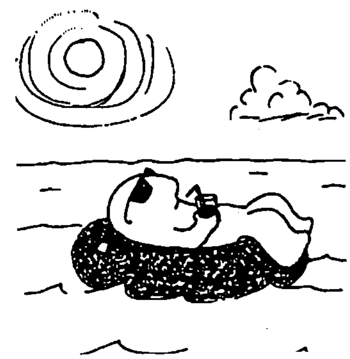
TEACHER PROCEDURE

A. Set up your apparatus as shown in Figure 1. Be certain that the lamp is centered over both water and soil.

Note: You should check to be sure that no thermometers are in a shadow when the lamp is turned on and also that the light does not shine directly on any thermometer bulb.

B. Use one dropper to put 3-5 ml of hydrochloric acid (HCl) into one of the pill caps.

C. Cover the aquarium and turn on the heat lamp for 10-15 minutes before doing the demonstration.



Source

Modified from OEAGLS EP - 2
"The effect of Lake Erie on climate," by James D. Meinke, Lakewood Public Schools; Beth A. Kennedy, Newark Public Schools; Victor J. Mayer, The Ohio State University

Earth Systems Understandings

This activity focuses on ESU 3, 4, and 6 (scientific process, interacting subsystems and Earth as a subsystem).

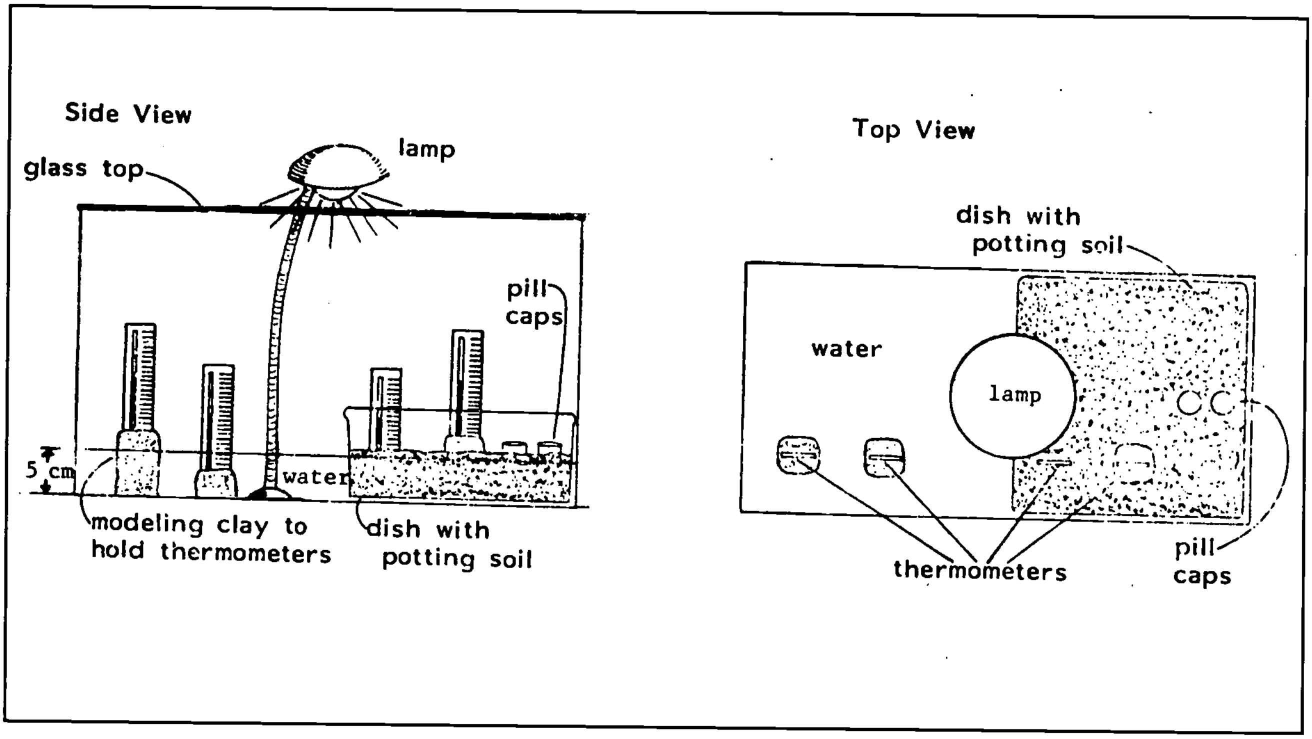
Materials

- 10-20 gallon aquarium tank.
- 8x8 baking dish or 8-inch pie pan.
- 3-5 ml of concentrated hydrochloric acid.
- Ammonium hydroxide.
- Heat lamp.
- Glass or plexiglass aquarium cover.
- Modeling clay.
- Two medicine droppers.
- Two plastic pill bottle caps.
- Four thermometers.
- Water.

Teacher's Notes

CAUTION: Care should be taken to prevent students from tampering with chemicals!

Figure 1. Demonstration Setup.



Students:

Carefully observe the demonstration (Figure 1) that your teacher has set up. Answer the following questions on your work sheet.

D. While waiting for heat to build up inside the tank, hypothesize what you will observe. Share your hypothesis in groups of 2-3. Some of the groups will be asked to discuss their ideas with the class.

E. After 10 minutes, answer questions 1-4, and put your answers on your work sheets.

1. Observe the four thermometers in the container. Where is it hottest? Where is it coolest? Both land and water are serving as heat sinks, absorbing energy from the "sun" during warm days. Which appears to be absorbing more heat?

2. How do you think air inside the tank might be moving?

3. Can you see air around you move? List some ways you could observe the air's motion.

4. What could we do to actually see how the air is moving inside this tank?

Continue Demonstration (Teacher):

F. Draw 1 ml of ammonium hydroxide into a clean dropper.

G. Quickly slide the aquarium cover over a bit and carefully drop ammonium hydroxide into the empty pill cap. The vaporizing HCl and ammonium hydroxide react in the air to produce ammonium chloride, the white plume.

H. Remove dropper quickly and replace the aquarium cover. (A white "smoke" plume should trace out the circulation pattern within the tank.)

Answers

1. Hottest area is over "land," coolest is under water. The land absorbs more heat and increases in temperature faster than the water.

2. Accept any reasonable hypothesis about how air is moving in the tank. Heated air should rise over the land, and cooler air should flow in from the water to replace the rising air.

3. Moving air is not visible, but its effects are. We can see trees swaying and clouds and smoke being carried by the wind.

4. Here the answers may vary. Some suggestions might work on a large scale but be impossible for use in this small tank. Accept each of the suggestions of your students, discussing them with the class.

Students:

I. Answer the following questions based on your observations.

5. Where would the denser air be located in the tank? The less dense air? Why?

6. Why does the air move in the way that it does?

The process you observed in the tank is the land-sea breeze effect in miniature. The land quickly reacts to changes in the amount of heat from the sun (the lamp), whereas the water is slow to react to such changes. Water has a high specific heat. It stores heat more efficiently and longer than does the land.

7. During what part of the day will wind move from lake to shore? Why?

8. Sketch what you have observed in the demonstration.

9. At night, when the sun's energy is no longer being added to the system, air temperatures will be influenced by the amount of heat stored during the day. Which part of the land/water system in the model absorbed the most heat?

10. When no more solar energy is being added to the system and the surrounding air temperature cools (as at night), both the land and water can become heat sources, releasing heat energy to the atmosphere. Which will be the greater heat source? Why? Which surface do you expect to be slower to release its heat? Why?

11. Diagram or describe a set of conditions in which the water could be a greater heat source than the land. In which direction would the breezes blow at such a time?

Extension

Write a report on careers that might need to consider the effect of land-sea breezes.

Answers

5. The denser air would be located over the cooler water. The less-dense air would be rising over the hotter land.

6. The "smoke" particles are light enough to be carried by air. Therefore, they are carried by the movement of the air and outline the air currents. The less dense air over the land is rising, and the denser air over the water is moving in over the land to fill in the "empty space." The lighter air has then moved over the water, cooled, dropped, and moved in over the soil to complete the convection cell.

7. The wind will move from the lake toward the shore during the mid-day to afternoon. By this time, the sun has warmed up the land more than the lake.

8. Diagram.

9. Land.

10. Land, Water.

11. Autumn - when the water temperature is greater than the land temperature.

How do the Great Lakes affect temperature?

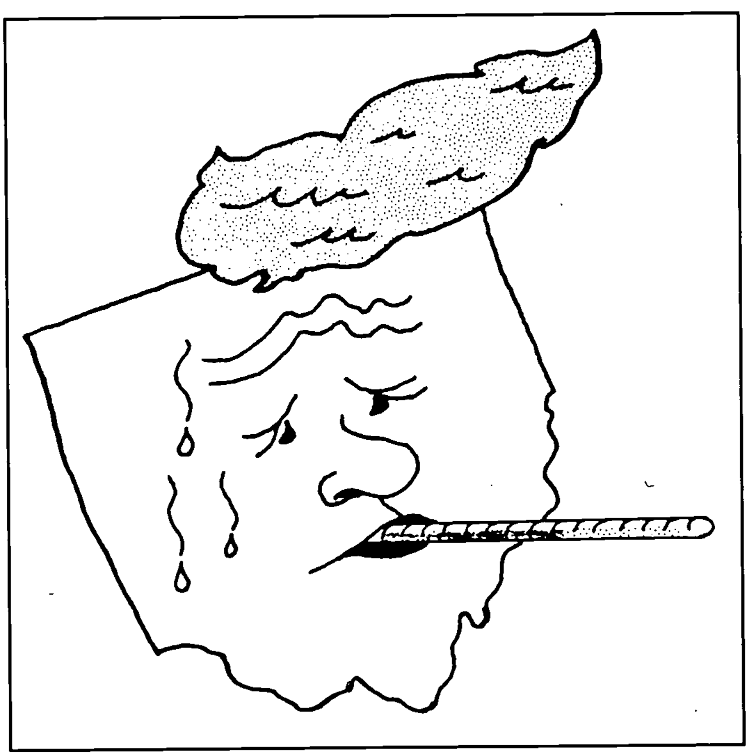
In the activity "What happens to heat energy reaching the Great Lakes?" you learned that the pan of water was a good heat sink while the lamp was on and a good heat source while the light was off. Soil also acts as a heat sink and source, but its capacity to hold energy is much lower than that of water. Therefore, soil will become a heat source soon after the light is turned on and will quit acting as a heat source not long after the light is turned off.

Lake water tends to increase in temperature all summer. This indicates that it is storing up extra energy from the atmosphere. It acts as a heat sink throughout the summer. In the winter, however, there is less radiation from the sun. Then lakes become heat sources, giving up their energy to the atmosphere.

OBJECTIVES

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

- Synthesize information about the effects of the Great Lakes upon the temperature of the surrounding land.



Source

Modified from OEAGLS EP - 1
"The effect of the Great Lakes on temperature" by James D. Meinke, Lakewood Public Schools; Beth A. Kennedy, Newark Public Schools; and Rosanne W. Fortner, The Ohio State University.

Earth Systems Understandings

This activity focuses on Earth System Understandings 3, 4 & 6 (scientific process, interacting subsystems, and Earth as a subsystem).

Materials

- Figures 1- 6.

Teacher's Note

This activity assumes students have completed those in "What happens to heat energy reaching the Great Lakes?" and "What causes the land-sea breeze?"

Procedure

Figures 1 and 2 are maps of Ohio with isotherms drawn on them. An isotherm is a line that connects points of equal temperature. Those on Figure 1 represent the average temperature in Fahrenheit for the month of July. The isotherms in Figure 2 represent average temperatures for the month of January.

1. What happens to the average temperature along line AB in Figure 1 as Lake Erie is approached from the west?
2. What happens to the average temperature along line CD in Figure 2 as Lake Erie is approached from the west?
3. Explain the differences in temperature patterns between July and January.
4. Is Lake Erie a heat source or sink? Discuss.
5. Describe the effects of Lake Erie on the temperature of northern Ohio.

Use Figures 3 and 4, July and January mean daily maximum temperatures for the Great Lakes basin, to answer the following questions.

6. Which of the Great Lakes has the greatest impact on temperatures in July? In January?
7. What is your reasoning for your answers in question 6?
8. What factor do you think controls what you observed in question 6?
9. Explain the differences in temperature patterns between July and January.

Answers

1. As you approach the lake, the temperature decreases.
2. As you approach the lake from the west, the temperature increases.
3. During the summer the lake absorbs energy, but the land reradiates energy to the atmosphere. Therefore, air over land is warmer than that over the water. In the winter the energy absorbed by the lake water is gradually released to the atmosphere, making the air over the water warmer than that over the land.
4. Lake Erie is both a heat source and a heat sink, depending on the season. In the late spring and summer, it is a heat sink; but in the fall and winter, it is a heat source.
5. Lake Erie acts as a moderator for northern Ohio's climate. It keeps the air cooler in the early summer and warmer in the rest of the fall and the winter than other parts of the state.
6. On July Lake Superior in January, Lake Superior.
7. Greatest number of isotherms are found on Lake Superior.
8. Lake Superior has the largest volume of the Great Lakes and is the largest heat sink.
9. Same as question 3. During the summer the lake absorbs energy, but the land reradiates energy to the atmosphere. Therefore, air over land is warmer than that over the water. In the winter the energy absorbed by the lake water is gradually released to the atmosphere, making the air over the water warmer than that over the land.

Figure 1. Mean Maximum Temperature of an Average July (°F).

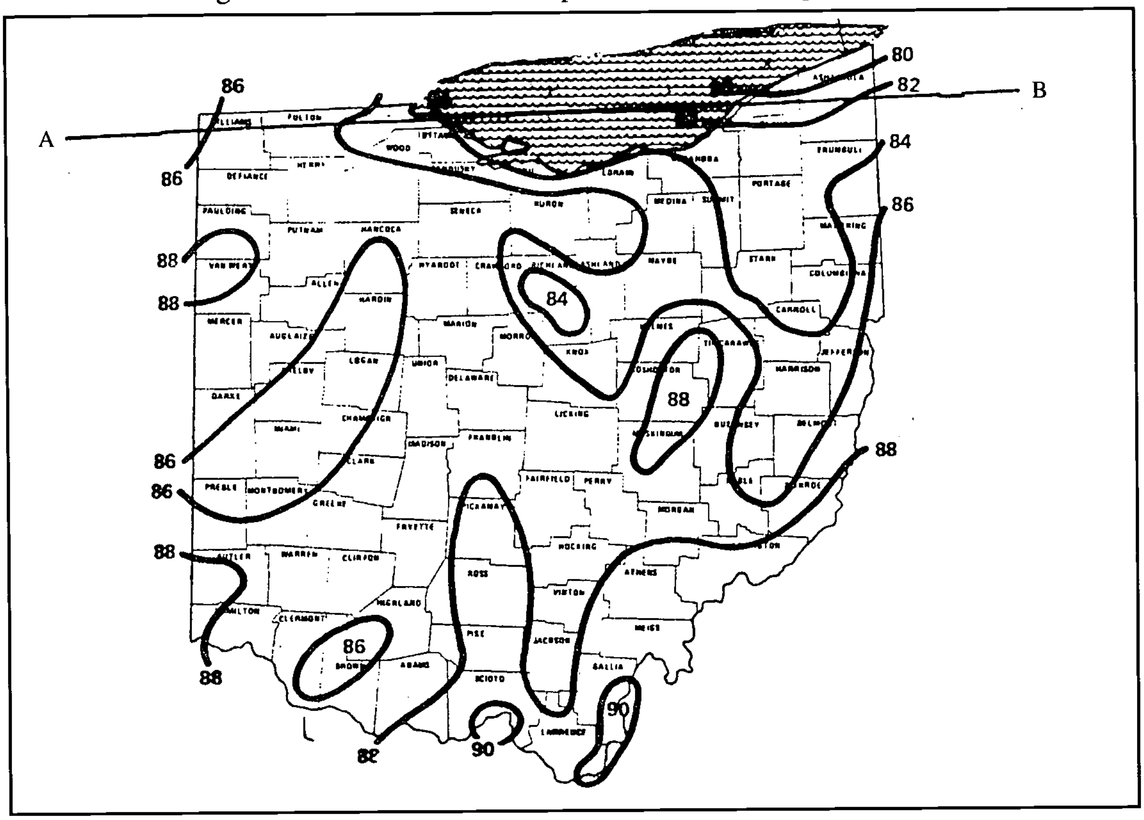


Figure 2. Mean Minimum Temperature of an Average January (°F).

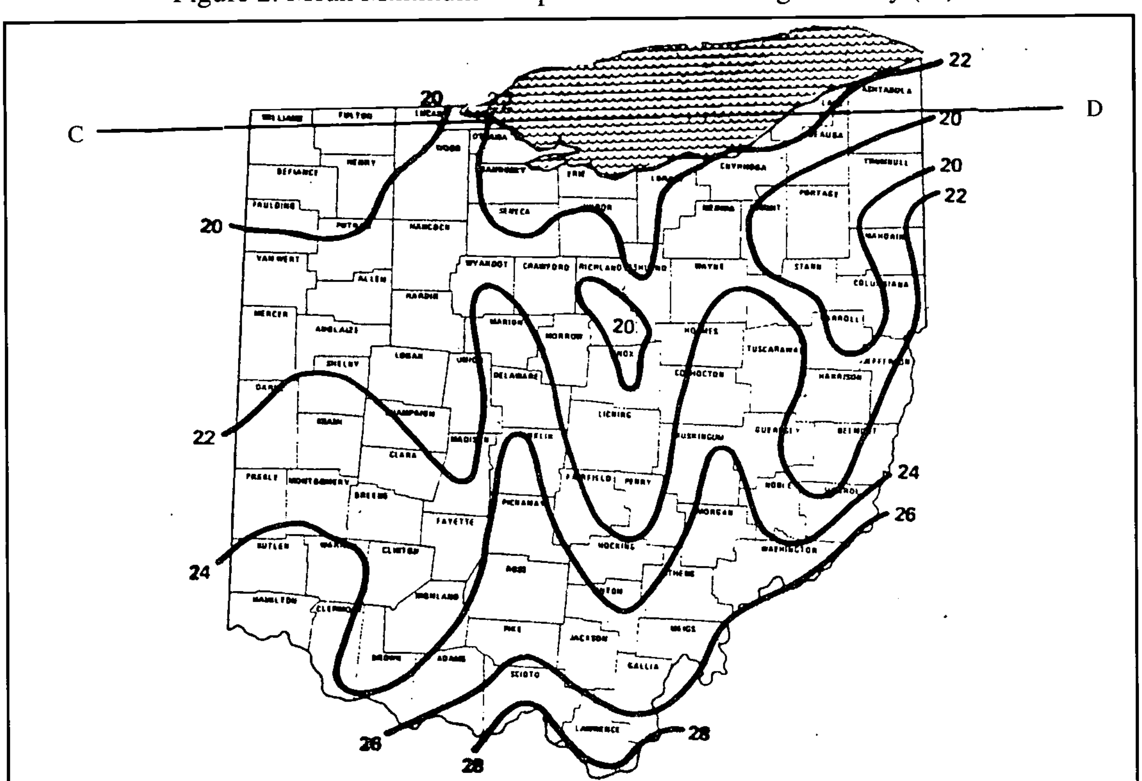


Figure 3. July Mean Daily Maximum Temperature.

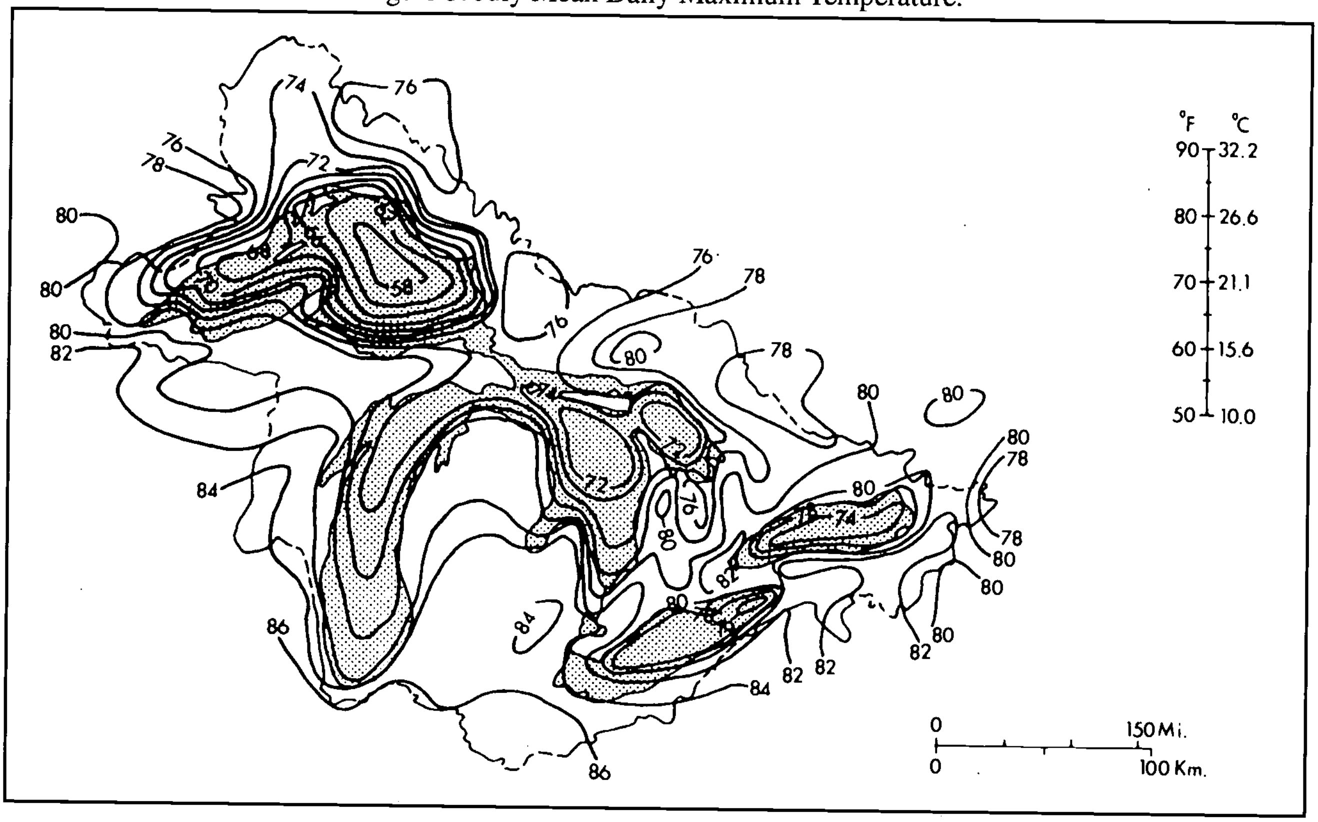
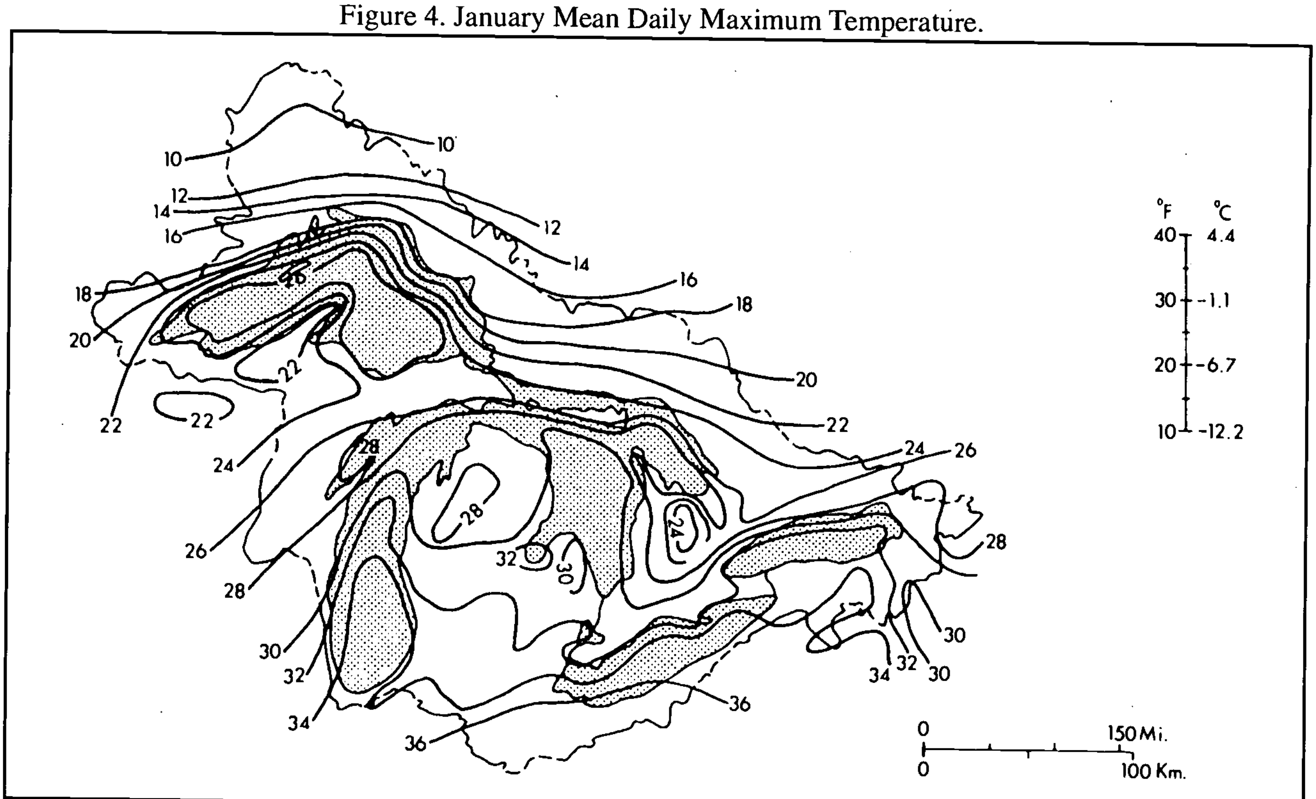


Figure 4. January Mean Daily Maximum Temperature.



Figures 3 and 4 are from *Weather and Climate of the Great Lakes*, Val L. Eichenlaub, 1979, University of Notre Dame Press.

Oceans are also large bodies of water. They affect temperature in much the same way as large lakes. Figure 5 is a map of the world on which are drawn isotherms representing the average temperatures in July. Notice that the average temperatures in Figures 5 and 6 are given in degrees Celsius. The Ohio temperature maps are in degrees Fahrenheit.

10. Follow parallel 60° N latitude across Figure 5. How is temperature affected by the continents? By the oceans?

11. Do the same for Figure 6. Describe the differences in average temperature.

The oceans affect the temperature of the Great Lakes region. When we have warm winter temperatures we are under the influence of air that starts over the oceans. The cold, frigid winter air comes from northern Canada, where the oceans do not have an effect.

12. Do oceans act as heat sources or sinks? How do you know?

13. Do continents ever act as heat sources? Explain.

14. Define a heat source and a heat sink.

Answers

10. As you follow 60° N parallel across the map for July, the temperature rises over the continents and falls over the oceans.
    If your students are familiar with how to make a topographic profile, they could make a temperature profile here to show this more graphically.
    You might also wish to look at other latitudes such as 30° S for examples of temperature differences.

11. As you follow 60° N parallel across the map for January, the temperature falls over the continents and rises over the oceans.

12. Oceans act as heat sources in winter and heat sinks in summer, just as Lake Erie does.

13. The continents act as heat sources in summer and heat sinks in winter, just like the land in Ohio does.

14. A heat source adds heat energy to the atmosphere. A heat sink takes energy from the atmosphere.

Figure 5. World Map of Average Temperatures in July (degrees C).

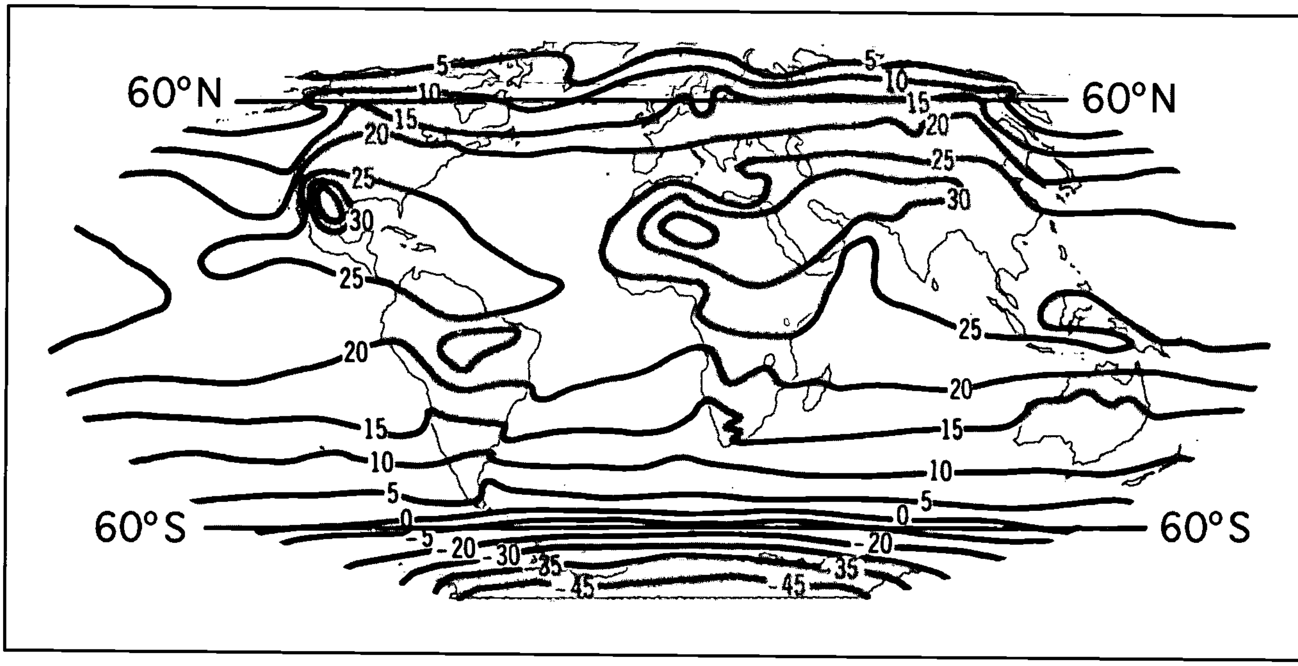
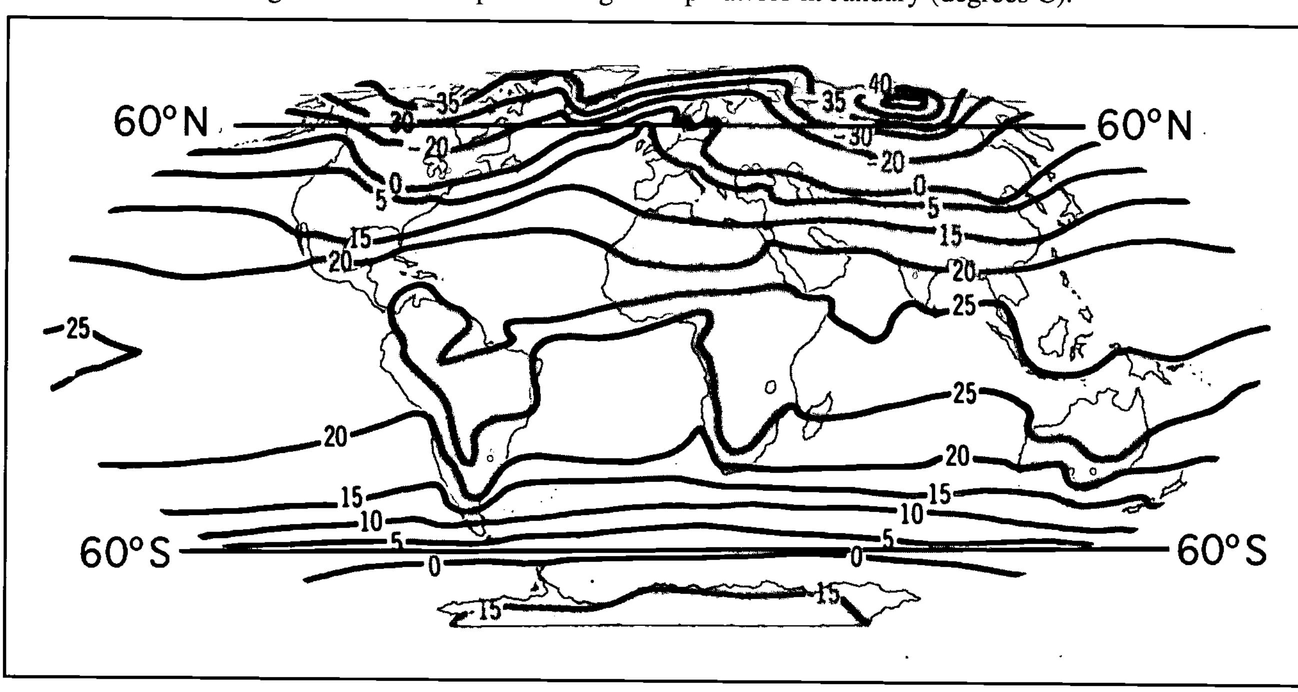


Figure 6. World Map of Average Temperatures in January (degrees C).



How is weather influenced by the Great Lakes?

A comedy group in Duluth, Minnesota, calls itself "Colder by the Lake." When you visit the Great Lakes in summer, do you expect temperatures there to be cooler than temperatures at inland areas? Most people do. The Great Lakes have a major impact on the climate of surrounding areas.

OBJECTIVES

When you have completed this activity you should be able to:

- Explain how air temperature affects air density and movement.
- Describe how and why local winds near the shore change direction from day to night, and from winter to summer.
- Give examples of how the circulation of air and the amount of precipitation are affected by the land-water interface.

PROCEDURE

In this part of the activity your team will be constructing a graph showing the relationship between precipitation, temperature, and distance from the shore of one of the Great Lakes. Figure 1 has three regions to study. Use the region assigned by your teacher.

Source

Modified from OEAGLS EP - 2 "The effect of the Great Lakes on climate" by James D. Meinke, Lakewood Public Schools; Beth A. Kennedy, Newark Public Schools; Victor J. Mayer, The Ohio State University.

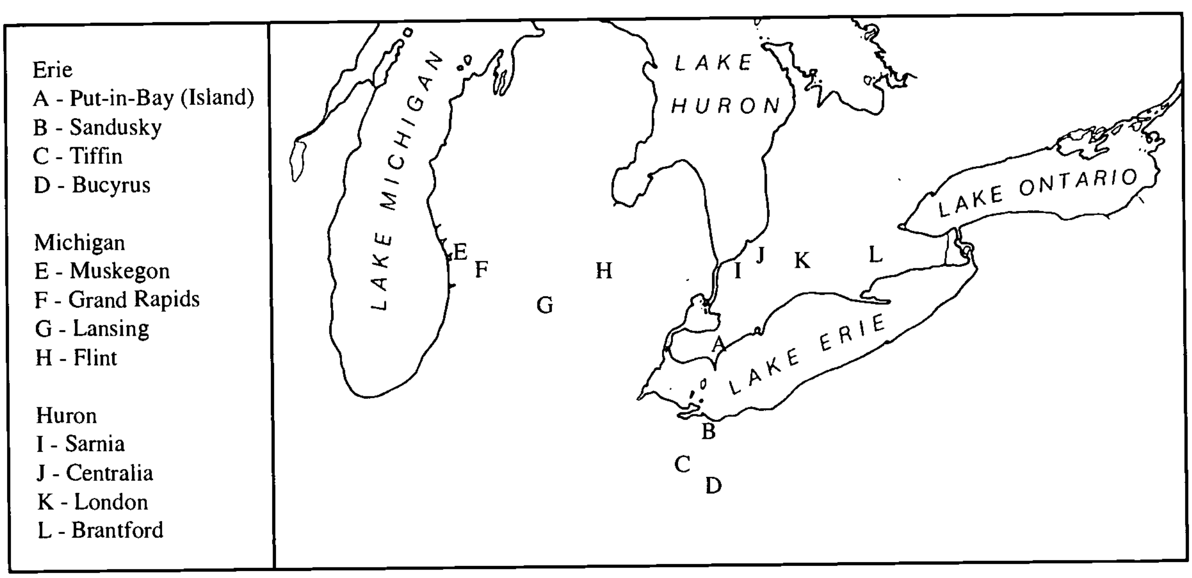
Earth Systems Understandings

This activity focuses on ESU 4 (interacting subsystems).

Materials

- Graph paper and pencil.

Figure 1. Location Map.



Answers

1. Graph - The average monthly range in temperature increases as you move farther from the lake. The range is caused by the lake acting as a moderator for the immediate surrounding temperature. The range is part of the "lake effect," because the lake slowly releases its stored up energy (specific heat) to the air and keeps it warmer in the fall and winter. Therefore, the temperature does not vary as much near the lake.

2. The average monthly range in temperature increases as you move farther from the lake. The range is caused by the lake's acting as a moderator for the immediate surrounding temperatures.

3. The range is part of the "lake effect," because the lake slowly releases its stored-up energy (specific heat) to the air and keeps it warmer in the fall and winter. Therefore, the temperature does not vary as much (have as great a range) near the lake.

1. Prepare a graph on your work sheet from the data in Table 1. Plot the distance from the lake (Column 2) on the horizontal axis and the average monthly range of temperature (Column 3) on the vertical axis.

2. What happens to the average monthly range in temperature as the distance from the lake increases on your graph? Compare your graph to the graphs of the other regions prepared by other students.

3. How is this related to what you observed in the activity "What causes the land-sea breeze?"

Table 1. Distance from Lake and Temperature.

Locations (Cities)	Distance from the Lake (miles)	(km)	Average Monthly Range of Temperature (°F)	Number of Frost-Free Days
Lake Erie				
Put-in-Bay	0	0	13.7	205
Sandusky	1	1.7	15.9	194
Tiffin	30	50	19.5	162
Bucyrus	50	83	21.5	154
Lake Michigan				
Muskegon	5	8.3	16.6	224
Grand Rapids	27	45	19.2	219
Lansing	80	133	19.9	216
Flint	125	208	18.8	210
Lake Huron				
Sarnia	1	1.7	17.2	234
Centralia	10	16.6	15.6	223
London	37	62	19.3	217
Brantford	75	125	19.7	217

4. Prepare a second graph from the data in Table 1. Plot the distance from the lake (Column 2) on the horizontal axis and the number of frost-free days (Column 4) on the vertical axis.

5. What happens to the number of frost-free days as the distance from the lake increases?

6. How does the lake cause this? (Refer to your answer to Question 1.)

The Lake islands, such as the one where Put-in-Bay is located, seem especially well adapted for growing grapes. This is primary because of the climate.

7. Based on what you know about Put-in-Bay from this activity, what temperature conditions are important for good viticulture (grape growing)?

A moderate climate is one which does not have extreme conditions, like extremely hot or extremely cold periods. We have now seen that the Great Lakes have a moderating effect on the temperature of regions in and around the lake.

8. How do the lakes affect precipitation? (What is your prediction before examining the data?)

9. **Use Table 2.** Prepare a graph of the precipitation per month for the area your team is studying. Use a different color to plot a line for each of the 4 locations. Plot the months on the horizontal axis and the precipitation in inches along the vertical axis.

10. How does the amount of precipitation change as you get farther from the lakes? Is this what you expected?

Answers

4. Graph - In general, the precipitation increases as you move inland from the lake.

5. The number of frost-free days decreases as you move farther inland from the lake.

6. This decrease is also part of the "lake effect." The lake slowly gives off its heat energy to the atmosphere, thereby keeping nearby land warmer and keeping the frost away longer than areas farther inland.

7. Viticulture requires a long growing season (more frost-free days) and moderate temperatures (warm, with no severe changes.)

8. Students should answer this question before making their graphs.

9. Graph.

10. In general, the precipitation increases as you move inland from the lake.

Teacher's Notes

Weather and climate data for this activity came from the CD-ROM International Station Meteorological Climate Summary, Ver 2.0, June 1992, Federal Climate Complex, Ashville, NC.

You may want to check online sources of data such as current buoy data at:
http://thunder.met.fsu.edu/~nws/buoy/gtlakbuoy.html

The Great Lakes Environmental Research Laboratory has a data and information services Web page at:
http://www.glerl.noaa.gov/data/data.html

Table 2. Average Monthly Precipitation Data in Inches.

Locations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Lake Erie												
Put-in-Bay	2.0	1.5	2.4	3.0	3.1	3.0	2.4	2.8	2.7	2.2	2.0	2.0
Sandusky	2.5	1.8	2.8	2.7	2.9	3.4	3.3	3.1	3.1	2.4	2.0	2.1
Tiffin	3.0	2.3	3.4	3.4	3.6	3.7	3.7	3.0	3.3	2.7	2.3	2.6
Bucyrus	3.2	2.3	3.4	3.3	3.6	4.1	4.1	3.2	3.2	2.9	2.6	2.6
Lake Michigan												
Muskegon	2.3	1.7	2.5	3.0	2.7	2.5	2.4	3.2	3.3	2.8	3.1	2.8
Grand Rapids	1.9	1.6	2.6	3.5	3.0	3.5	3.2	3.2	3.7	2.7	3.1	2.7
Lansing	1.7	1.6	2.3	2.8	2.7	3.6	2.6	3.1	3.2	2.1	2.6	2.3
Flint	1.6	1.5	2.1	3.0	2.8	3.2	2.9	3.5	3.2	2.2	2.5	2.0
Lake Huron												
Sarnia	1.6	1.8	2.3	2.7	3.1	2.9	2.2	2.8	2.2	2.1	2.0	2.0
Centralia	4.0	3.4	2.5	2.7	3.5	3.0	3.0	3.1	2.9	2.8	3.8	4.5
London	4.0	3.5	2.8	2.9	2.8	3.1	3.2	2.8	3.0	2.9	3.7	3.5
Brantford	2.6	2.1	2.2	2.5	2.9	2.7	3.1	2.9	2.6	2.5	2.4	2.2

The prevailing winds over the Great Lakes are from the west.

11. Examine Figures 2 and 3. Where does the highest snowfall occur in relation to the Great Lakes?

12. Is this also the area of highest annual precipitation?

13. Where do you think most of the water comes from that falls in these areas of high precipitation, either in the form of rain or snow?

14. How does this water get into the air?

During the summer, air over the surface of the lake is cooler than that over land. Because of this, few thunderstorms form over the lake. There simply is not enough energy (heat) coming up from the lake surface to cause them to form. The moisture in the air, therefore, stays there until it gets over and beyond the eastern end of the lake.

15. Refer to the graph prepared in Step 9. Which city gets the most precipitation and when? Which city gets the least precipitation and when?

16. How do you think the Great Lakes affect the climate during the winter before and after the lakes freeze?

17. Examine Figure 4. What affects the length of the frost free period around the Great Lakes? Explain your reason.

EVALUATION

Using what you have learned about the Great Lakes' effect on weather and climate, make a general climate prediction for one city from each group.

Group A	Group B
Vermilion, Ohio	Sudbury, Ontario
Sault Ste. Marie, Michigan	Madison, Wisconsin
Kingston, Ontario	Duluth, Minnesota

Answers

11. The highest snowfall occurs on the east side of large open areas of water.
12. Yes, this is also the area of highest annual precipitation.
13. The water that falls in these areas comes from the lakes.
14. The water gets into the air by evaporation as the prevailing westerly winds blow over the lake's surface.
15. Answers will vary depending on the location.
16. Before the water freezes, the lakes are acting as heat sources and warm the air over them, thus moderating the climate. After the water freezes, they no longer are a heat source.
17. Latitude, distance to lake, elevation.

Extension

Do research on a career related to this topic, such as agriculture, viticulture, meteorologist, and horticulturist, and report on the career to the class.

Use the Great Lakes Solution Seeker CD-ROM from Ohio Sea Grant or the Earth Systems Education web page (activities section) to compare satellite images, water temperatures, and weather reports for the Great Lakes region.

Figure 2. Mean Annual Precipitation (in inches).

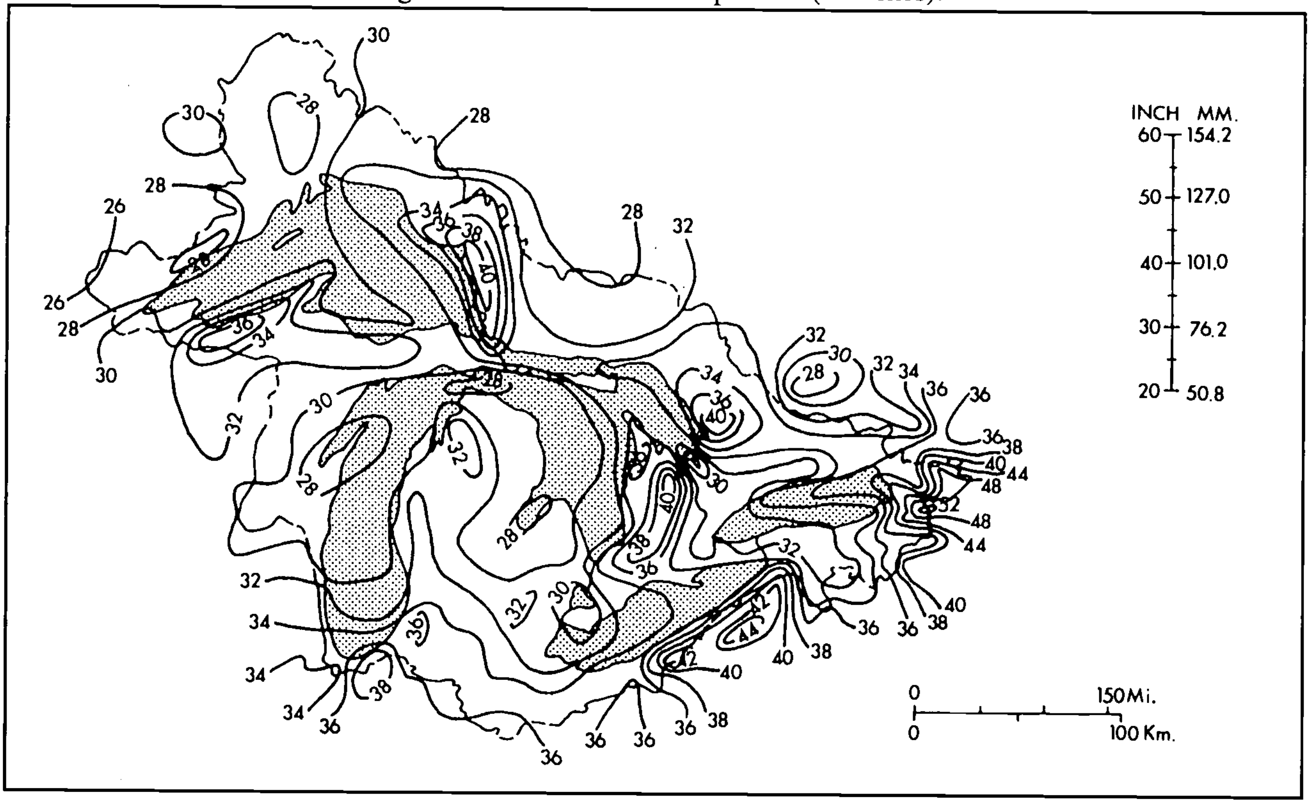


Figure 3. Mean Annual Snowfall (in inches).

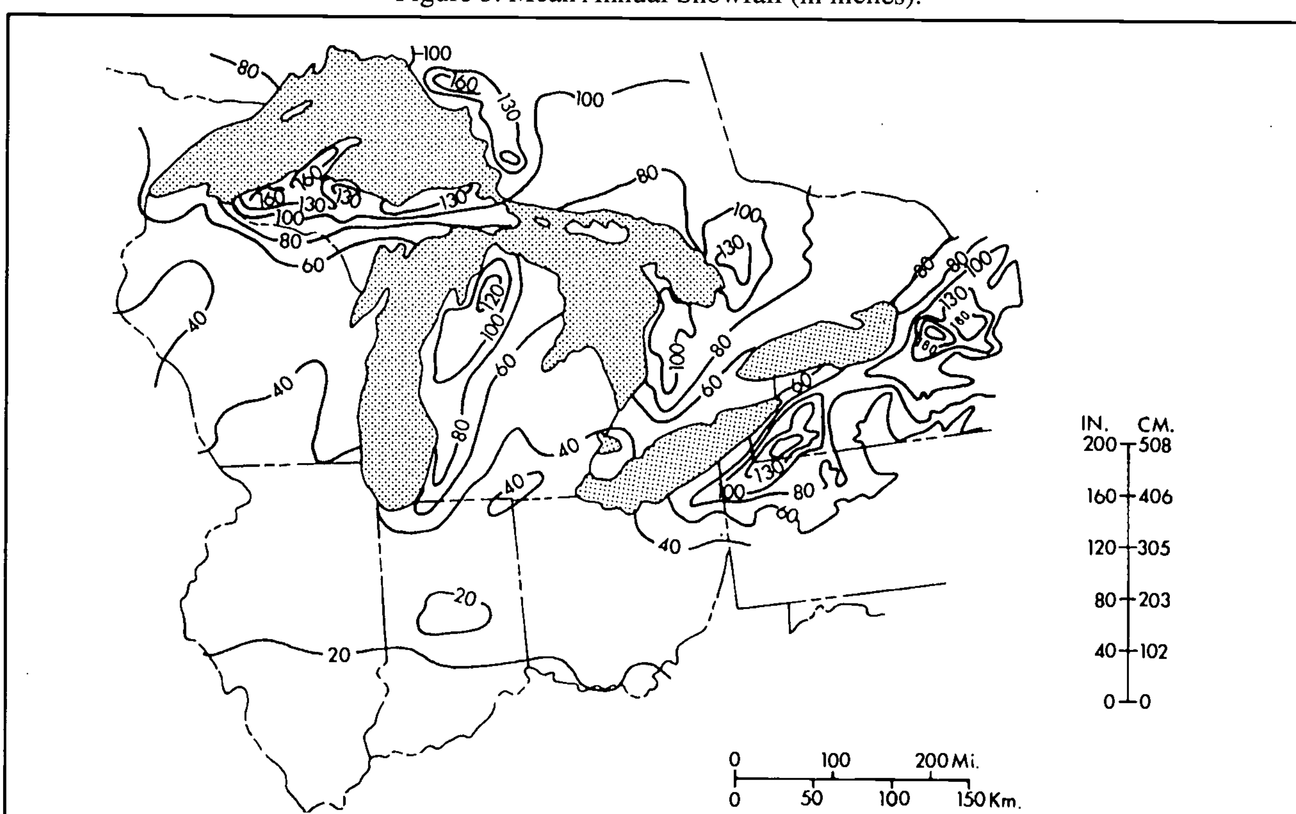
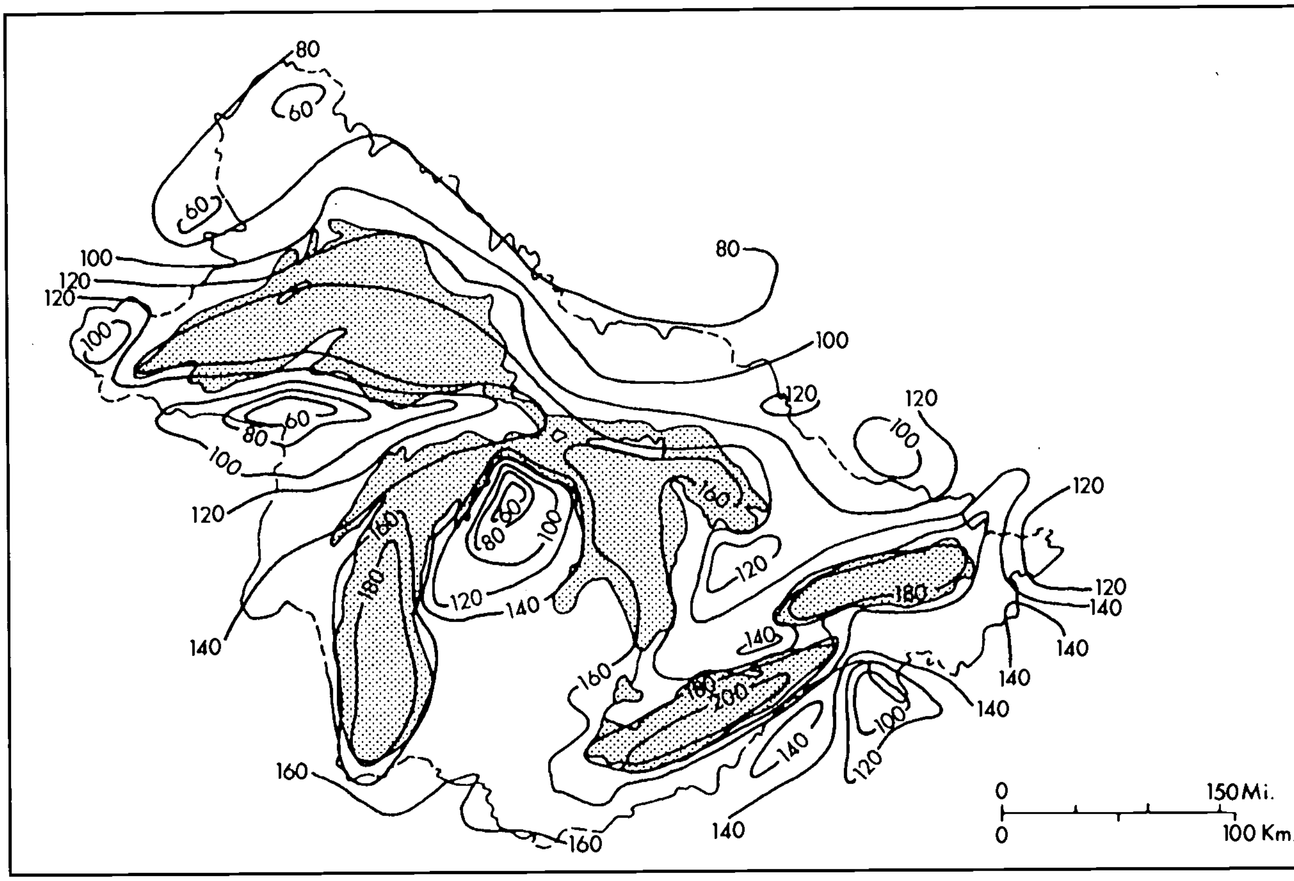


Figure 4. Mean Annual Frost Free Period (in days).



Figures 2, 3, and 4 are from *Weather and Climate of the Great Lakes Region* by Val L. Eichenlaub, 1979, University of Notre Dame Press.

What causes storm surges?

You are familiar with waves, but they are not the only type of water movement. On the Great Lakes there is a special type of water motion when a storm (low pressure center, or cyclone) moves across the lake. This motion is called a storm surge.

OBJECTIVES

Upon completion of this activity, you should be able to:

- Describe the causes of storm surges on Lake Erie.
- Discuss why Lake Erie is affected by more severe storm surges than any of the other Great Lakes.
- Compare the similarities and differences between wind set-ups and storm surges.
- Describe what is meant by resonance, as it applies to storm surges.

PROCEDURE

Figure 1 on the next page is a map of the major storms tracks that affect the Great Lakes region.

1. What is the direction taken by most storms in the Great Lakes region? (Your choices are: W to E, SW to NE, NW to SE, or S to N.)

2. A. What would be the direction of a line drawn the length of Lake Erie through its middle? What would be the directions for Lake Ontario, Huron, Michigan and Superior? (Your choices are: W to E, SW to NE, NW to SE, or S to N.)

   B. Which lakes are oriented in the same direction as that taken by most of the storms?

Source

Modified from OEAGLS EP - 25 "Storm Surges" by John Keir, Westerville, Ohio, Public Schools and Victor J. Mayer, The Ohio State University.

Earth Systems Understandings

This activity focuses on ESU 4 (interacting subsystems).

Materials

- Enough paint roller pans for each team of students. Some students may be able to bring one from home to share.
- One roll of masking tape.
- A water supply.
- Paper towels to clean up spills.

Answers

1. Most storms move west to east.
2. A. Erie - W to E, Ontario - W to E, Michigan - S to N, Huron - N to S, Superior - W to E.
   B. Lakes Erie, Ontario, and Superior.

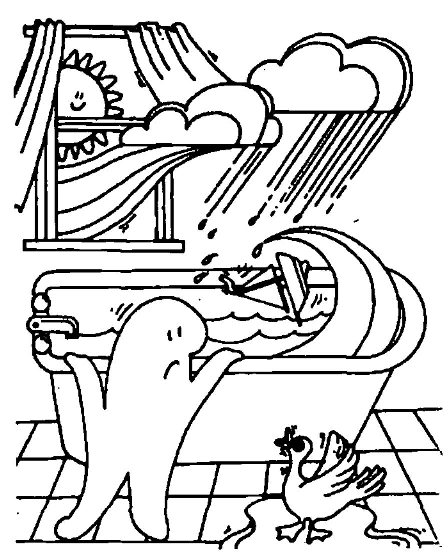
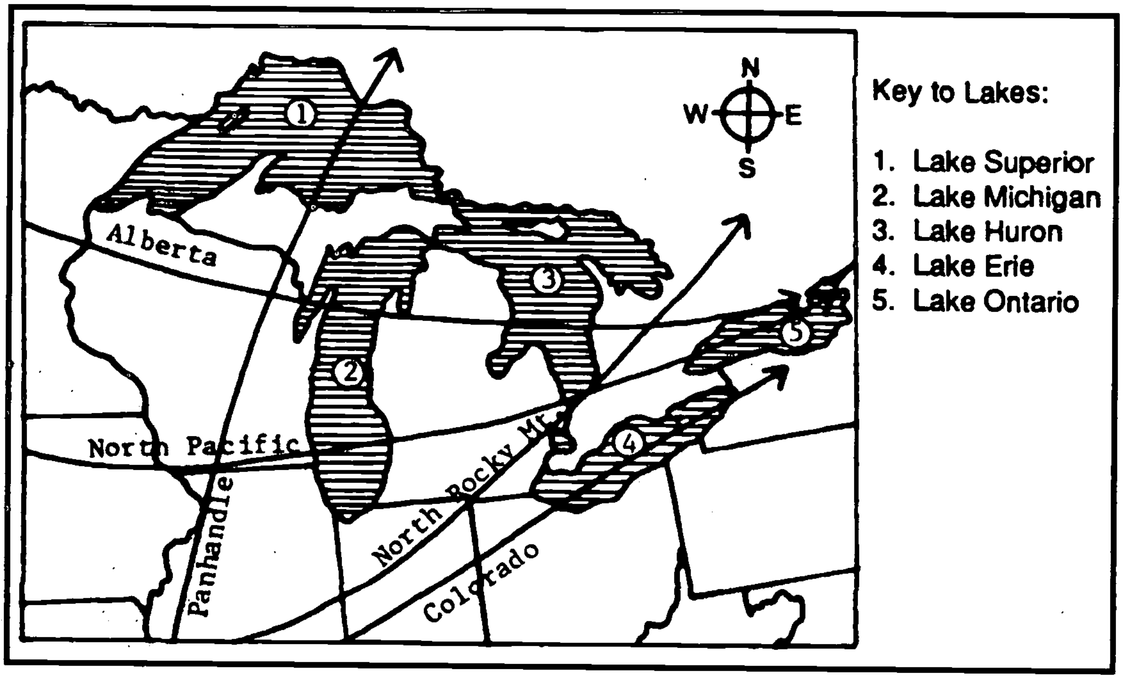


Figure 1. Storm Tracks in the Great Lakes Region.



If a lake is oriented in the same direction as the path of storms, it is more likely to be affected by storm surges. That is because the winds can blow across the water for a greater distance or *fetch*.

Answers

3. Lakes Erie, Ontario, and Superior.

3. Which of the Great Lakes are most likely to be affected by storm surges because of orientation?

Orientation of a lake is not the only factor that will affect the severity of storm surges. During a surge, the water is actually moved from one side of the lake to the other side. Therefore, the amount of water in a lake affects the severity of storm surges. The more water in a lake, the harder it is for a storm to move it, and the less water in a lake, the easier it is for a storm to move it. Table 1 lists the volumes of the Great Lakes.

Table 1. Volume of the Great Lakes.

Lake	mi^3	km^3
Superior	2935	12,100
Michigan	1180	4,920
Huron	849	3,540
Erie	116	484
Ontario	393	1,640

4. Which Great Lake would be the least likely to have a storm surge because of its volume of water? In other words, which lake would be hardest for a storm to move?

5. Which Great Lake would be the most likely to have a storm surge because of its volume of water? In other words, which lake would be easiest for a storm to move?

Answers

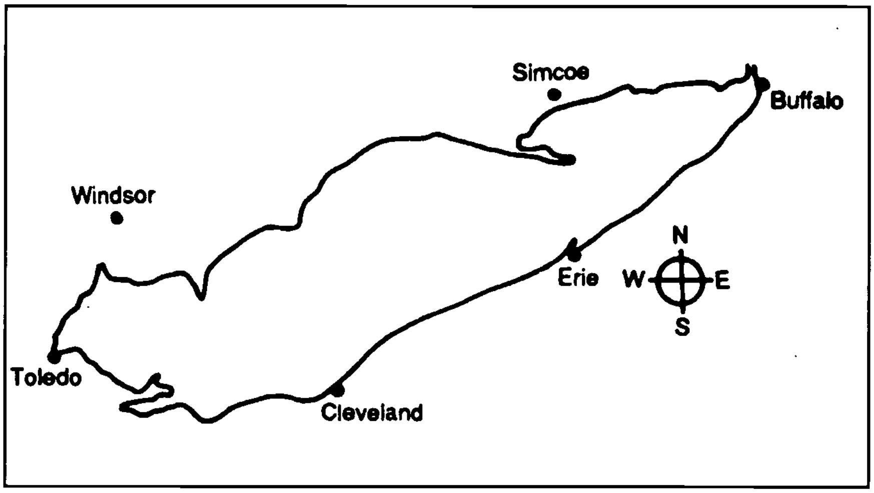
4. Lake Superior.

5. Lake Erie.

When a *cyclone* (storm) first moves over Lake Erie, the temperature drops, and the wind changes direction. This disturbs the water in the lake and causes it to move in the same direction as the storm is moving. Since most cyclones move from the west towards the east, water is moved by the cyclone into the eastern end of the lake, which narrows quickly (see Figure 2). The water level in the eastern end of the lake is raised. This is called a *surge*.

The shape of the lake concentrates the effects of a surge at both ends. When the water level is raised at Buffalo, it will be lowered at Toledo (see Figure 2 for the location of these cities). A surge can cause a difference in water level of several feet between both ends.

Figure 2. Lake Erie.



On rare occasions, the wind blows out of the northeast. When this happens, a surge occurs at Toledo, which raises the water level there. After the cyclone leaves the lake, the piled up water moves toward the other end. The water sloshes from one end of the lake to the other a few times until the water level is returned to normal. This sloshing back and forth is called a *seiche*.

6. How is a seiche different from a surge?

When two things work together they are said to be in *resonance*. The speed at which a surge or seiche moves across a lake depends on the depth of the lake (see Table 2). Surges and seiches move slower in deeper water. Surges and seiches move across Lake Erie at about 35 miles per hour.

7. Would surges and seiches move faster on any other Great Lake?

If a cyclone moves across Lake Erie at 35 miles per hour it will be in resonance with the surge. This makes the surge bigger than normal, which means that the water level will change even more than if the storm were traveling at another speed.

Look at Figures 3 and 4 on the next page. It is about 245 miles from Toledo to Buffalo. Find the speed of the storm by dividing the time it takes the storm to cross the lake into the distance from Toledo to Buffalo.

8. What is the speed of the storm in Figure 3?

9. What is the speed of the storm in Figure 4?

10. Which storm would be in resonance with the surge it produced?

Table 2. Average Depth of the Great Lakes.

Lake	Feet	Meters
Superior	487	147
Michigan	276	85
Huron	195	59
Erie	58	19
Ontario	283	86

Answers

6. A surge is the piling up of the water by a storm. A seiche is the sloshing back and forth motion of the water.

7. No, since the other lakes are a different depth than Lake Erie, a surge or seiche would move at a different speed than the 35 miles per hour.

Demonstration

If students are having trouble with the concept of resonance, You might try this short demonstration.

a. Bounce a golf ball on the floor several times. Try to bounce the ball smoothly with the least amount of effort. Make your hand and the ball work together.
b. Ask students to write down their observations. (Teacher's hand and ball are working together.)
c. Now bounce the ball with your hand and the ball moving at different speeds. This may take a lot of effort to do. Try to bounce the ball with your hand moving down while the ball is coming up.
d. Ask students to write down their observations. (Teacher's hand and ball did not work together.)
e. Ask students "When were the ball and my hand in resonance?" (First time.)

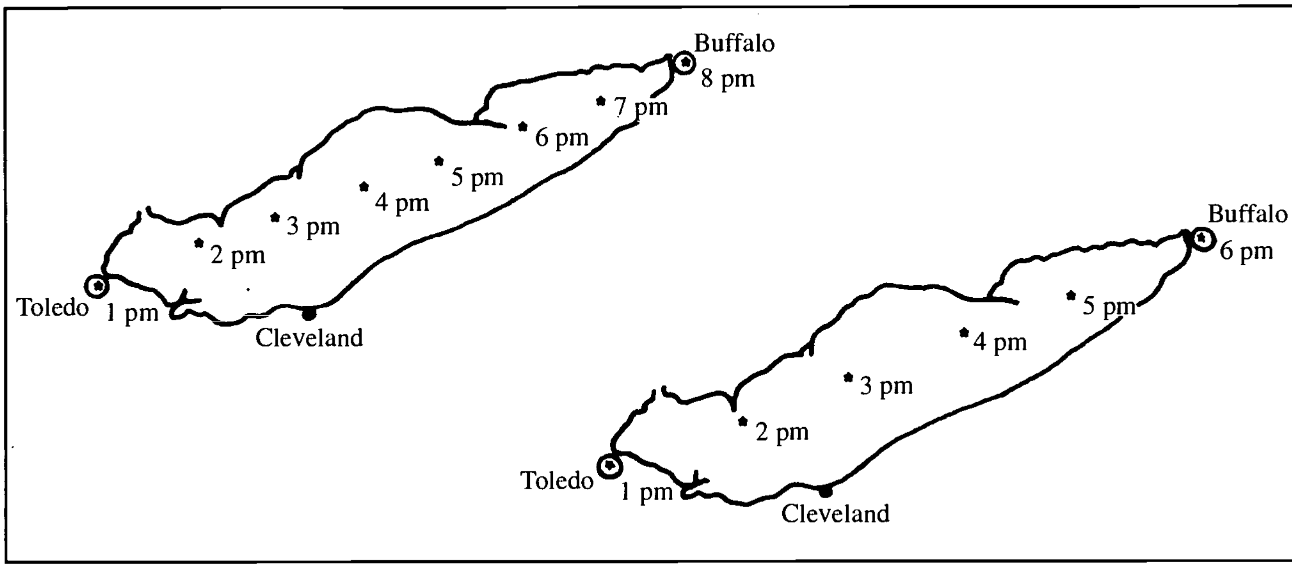
Answers

8. 35 miles per hour.

9. 49 miles per hour.

10. The storm in Figure 3 would be in resonance.

Figure 4. Cross-Lake Movement of Cyclone Center.
* Cyclone center and time.

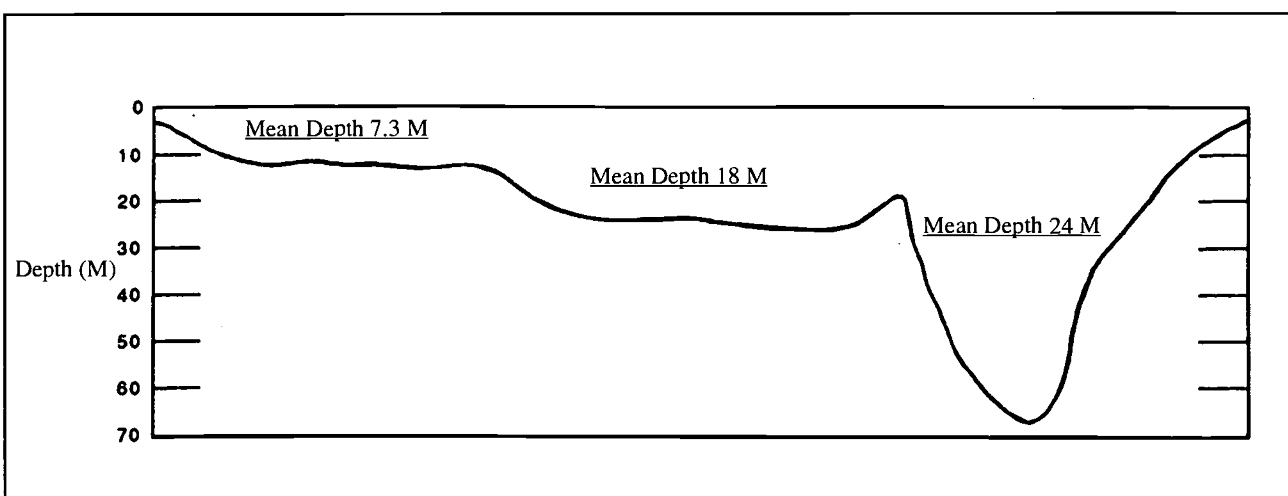


The average speed of cyclones that cross Lake Erie is about 35 miles per hour. Lake Erie contains three different basins that have different depths (see Figure 5). The water is shallow near Toledo at the western end and deep near Buffalo at the eastern end.

In the following activity, you will use a paint roller pan to simulate Lake Erie and its different water depths.

11. Fill the paint roller pan with water until the water level is about 8 inches from the edge of the shallow end. This represents Lake Erie. Write "Toledo" on a piece of masking tape and put it at the edge of the water in the shallow end. Write "Buffalo" on another piece of tape and put it an inch above the water level at the deep end of the pan.

Figure 5. Lake Erie Longitudinal Cross Section.



Answers

13. The water drained out of the shallow end.
14. The water level sloshed back and forth until the water returned to a normal level.
15. This motion is called a seiche.
17. Toledo is flooded.
18. Commercial boating is disrupted, water supplies can be cut off, flooding, damage to boats and docks.
19. Orientation same as storm tracks, low volume makes it easier for storms to move the water, shallow depth, resonance.

12. Hold the shallow end of the pan and gently tip it up an inch or so. This represents the water being moved toward the eastern end of the lake in a surge. Observe what happens to the lake near Toledo.
13. Describe what happened to the shallow (Toledo) end of the pan when the pan was tipped up.
14. Describe what happened to the shallow end of the pan when you set the end of the pan down.
15. What is this water motion called (in question 14)?
16. Hold the deep end of the pan and gently tip it up. Be careful not to spill any water. This represents a surge moving toward Toledo.
17. Describe what happened to Toledo (in question 16).

Buffalo, New York, is at the eastern end of Lake. The water is deep at Buffalo, and the shoreline rises quickly to high ground. This limits problems caused by storm surges at the eastern end of the lake. However, boats and the docks they are tied to are damaged when the water level rapidly rises and falls, causing the boats to move around and bang against the docks.

Toledo has more problems to deal with. The water is shallow, and the land surrounding the western end of the lake is flat and lies at about the same elevation as the lake surface. When the water in Lake Erie is moved toward Buffalo in a large surge, a big part of Maumee Bay near Toledo can actually dry up. Boats that are tied to docks there will be sitting on the lake bottom when this happens. Commercial boating is disrupted and the water supply for some towns is cut off as well. When the water comes rushing back into the bay, the boats can be shoved under the docks and then lifted up, which damages or destroys both the boats and docks. In addition, when a surge is pushed toward Toledo, the western end of the lake cannot hold all of the water that rushes into it. The water will spill out of the lake, flooding the land. Such floods have caused a lot of damage to property around Toledo.

Technology Resource

Lake level, wave height, wind speeds, and other information is available online from the Great Lakes Forecasting System. Check out their Web page at: http://superior.eng.ohio-state.edu/

18. List four problems caused by storm surges in the western part of Lake Erie.
19. List three reasons why Lake Erie is affected by storm surges more than any other Great Lake.

How do storm surges affect water levels on Lake Erie?

In April, 1979, a storm moving across Lake Erie caused the water level at Toledo to drop 7 feet below normal when the surge was at Buffalo. Water rose 5 feet above normal when the seiche returned water to Toledo. How much impact would occur as a result of such a storm?

OBJECTIVES

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

- Describe the frequency of problems caused by storm surges at the western end of Lake Erie.
- Describe the effects that a surge will have on the western end of Lake Erie.

PROCEDURE

With a map of the coastal area of Toledo we can investigate where the water levels would be during a storm surge. The numbers printed in the water area of the maps are depths.

1. In the storm described above, water level dropped 7 feet below normal. Draw a line in the water on the map at a depth of 7 feet. This will represent the new, temporary Toledo shoreline when the surge was at Buffalo.

2. Use the scale at the bottom of the map to find out how far from shore the water moved. Write this information on your worksheet.

By using records of storms and their effects on water level accumulated over many years, scientists have determined how often storms occur that cause a certain change in lake level. For example, every 3 three years, on average, a storm will occur that will cause the water level to drop 6 feet.

Source

Modified from OEAGLS EP - 25 "Storm Surges" by John Keir, Westerville, Ohio, Public Schools, and Victor J. Mayer, The Ohio State Universtiy

Earth Systems Understandings

This activity focuses on ESU 3 and 4 (scientific process and interacting sub-systems).

Materials

- Laminated maps of the Oregon Quadrangle, Ohio-Michigan 7.5 minute series (topographic), #N4137.5–W8322.5/7.5.
- Several colors of washable marker pens.

Answers

2. Over 2 miles.

Scale for Map of Lake Erie:
1 inch = approx. 60 miles
2 inches = approx. 120 miles
1 cm = approx. 37 km

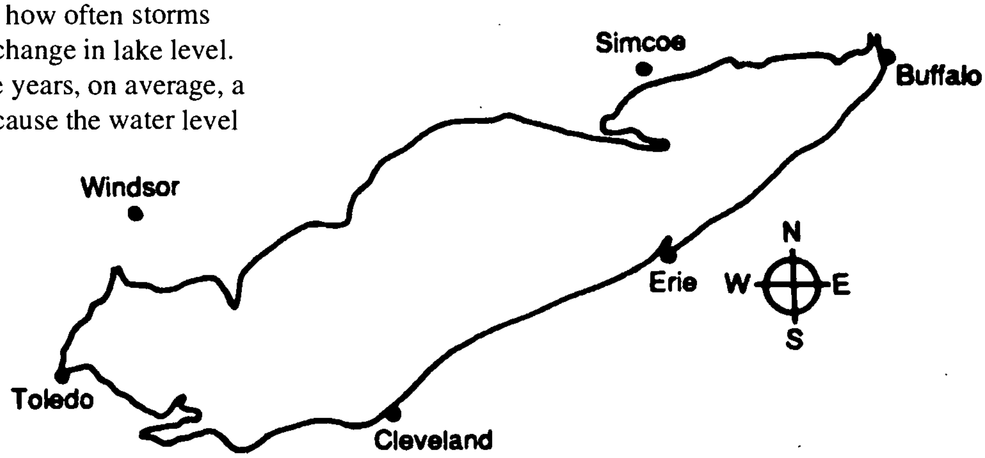


Table 1. Return Frequency of Water Level Drawdown in Lake Erie's Western Basin Due to Storm Surges.

Frequency	Distance Below Normal Level
1.4 years	5 feet
3 years	6 feet
20 years	7 feet

3. Look at Table 1. Use a different colored pen to trace the low water mark of the lake for the return frequency of 1.4 years.

4. Now trace the low water mark for the 3-year return frequency using another color.

5. Based on the lines you have drawn and the data in Table 1, what is the return frequency of the 1979 change in water level?

6. Using data from Table 2, trace the high water mark for the 3.3-year return frequency surge at Toledo.

Table 2. Return Frequency for Positive Storm Surges in Lake Erie's Western Basin.

Frequency	Distance Above Normal Level
3.3 year	3 feet
8.3 year	4 feet
33 year	5 feet

7. Using different colored pens, trace the high water mark for the 8.3- and 33-year return frequencies.

8. Using the scale at the bottom of the map, find out how far inland the floodwaters can come. Write this information on your work sheet.

9. Look at tables 1 and 2. Which problem would bother people living near Toledo the most often, high or low water levels?

10. You are the Port Captain for the city of Toledo. Your job is to make sure commercial boats get safely into and out of the port. You have just been told that a storm tracking out of the northeast has caused the water level at Buffalo to drop by 6 feet. What will happen to the water level in Maumee Bay? A large ore freighter is approaching the port. What directions will you give to its captain?

Answers

5. Over 20 years. Some students may notice the big jump in years between 6 and 7 feet and deduce that the 1979 surge drawdown had well over a 100 year return frequency.

8. About 1 mile.

9. Low water, because it happens more frequently.

Extended Background

Storm surges also occur on the oceans. Any storm can produce them. Hurricanes have been known to cause surges as high as 20 feet. To make matters worse, there are giant waves on top of the surge that can cause huge amounts of damage when the surge reaches shore. They are the reason that people must leave low-lying areas near shore when a hurricane approaches. The people of Holland have spent billions of dollars to build a series of dams to protect their country from storm surges coming from the North Sea and Atlantic Ocean. In 1985, several thousand people were killed by a storm surge that hit the coast of Bangladesh.

The graph on the following page displays the changes in water level in Lake Erie as a storm passed through on December 2, 1985. Notice that the water level at Toledo begins dropping at about 1900 hours on December 1, as the wind moves from the southwest and intensifies. The water level at Buffalo does not begin to rise until about midnight, and then rises rather rapidly, producing the storm surge. It begins to drop at about 0400 hours at Buffalo and begins to rise at the Toledo end at about 0900 hours. Thus, there appears to be a 5 hour lag between the two ends of the lake. This would be about the time it would take for a storm traveling 35 miles per hour to pass over the lake. It took 28 hours for the effect of the storm to pass and for the lake to return to normal, so the period of the wave was about 14 hours. You might want to develop an activity around this graph for your more capable students.

Using the Great Lakes Forecasting System, students can look at recent water movements – surges, seiches, and wind setups – for recent months. Watch GLFS diagrams as Lake Erie responds to the passage of weather fronts and storms. The models are current for March-December of each year (the ice-off period). Use http://superior.eng.ohio-state.edu/ as a source of information on interesting interactions between the hydrosphere and atmosphere!

Online Resources

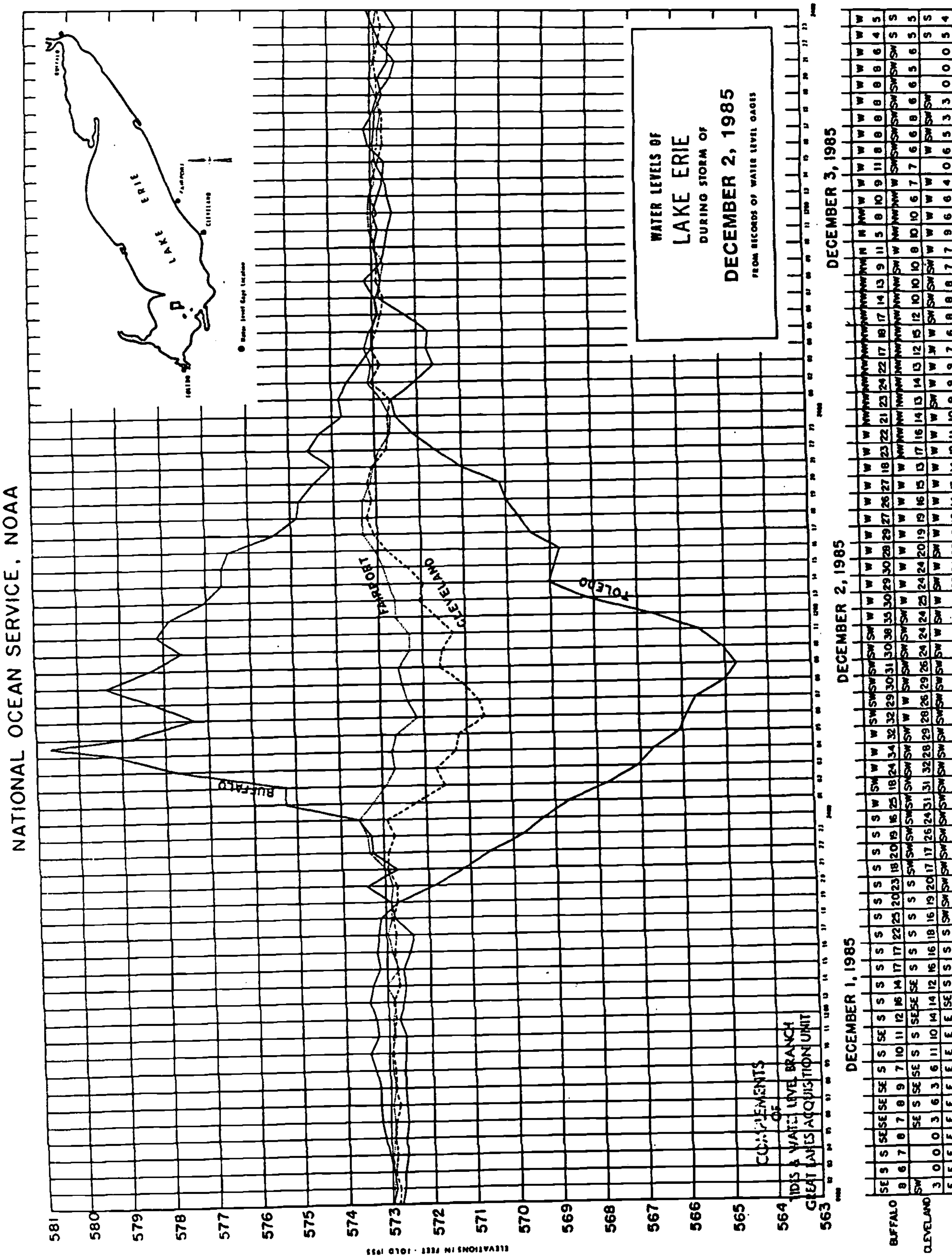
Welcome to the Great Lakes Region
http://www.great-lakes.net/

Great Lakes Environmental Research Laboratory Data and Information Service
http://www.glerl.noaa.gov/data/data.html

Great Lakes Monthly Water Levels
http://www.cciw.ca/glimr/metadata/great-lakes-monthly-mean-wlev/intro.html

Water Fluctuations - Information
http://csx.cciw.ca/dfo/chs/danpd/tcwld/fluctuations.html

Try searching for key words if an address does not work.


NATIONAL OCEAN SERVICE, NOAA
WATER LEVELS OF
LAKE ERIE
DURING STORM OF
DECEMBER 2, 1985
FROM RECORDS OF WATER LEVEL GAGES
BUFFALO
TOLEDO
FAIRPORT
CLEVELAND
LAKE ERIE
DECEMBER 1, 1985
DECEMBER 2, 1985
DECEMBER 3, 1985
COMPLEMENTS OF
TIDES & WATER LEVEL BRANCH
GREAT LAKES ACQUISITION UNIT
ELEVATIONS IN FEET - IGLD 1955
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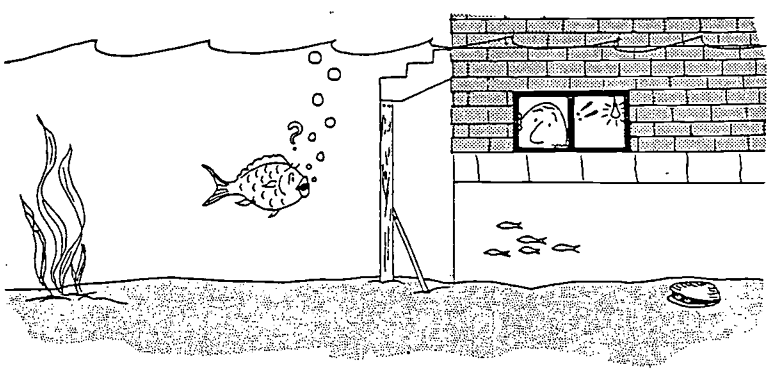
How do the levels of the Great Lakes change?

People like lake shores. There is something about the movement of waves against the beach, the sight of a sailboat on a clear day, and the ability to plunge into the water on a hot summer day that attracts people to the lake. Shores tend to become highly developed. Property values are high. Lakes, however, can be unpredictable. Storm-driven waves can destroy houses, especially if the level of the lake has risen since the houses were built. Is this a problem on the Great Lakes?



Source

Modified from OEAGLS EP - 5 "Changing lake levels on the Great Lakes" by Carolyn Farnsworth, Upper Arlington Public Schools and Victor J. Mayer, The Ohio State University.

Earth Systems Understandings

This activity focuses on ESU 3, 4, and 5 (science process, interacting subsystems and subsystems are evolving).

Materials

- Topographic map of Eastlake, Ohio.
- Graph paper.
- Ruler.
- Pencil.

OBJECTIVES

When you finish this activity you will be able to:

- Determine whether lake levels of the Great Lakes change.
- Determine the effect of an increase in lake level.
- Identify possible causes of changes in lake level.

PROCEDURE

Records of the level of the water in Lake Erie have been kept for over 100 years. Figure 1 is a graph of the average monthly level of Lake Erie measured in meters above sea level. It is for the years 1991 - 93. Figure 2 is a similar record for each of the Great Lakes for a longer period of time.

Figure 1. Lake Erie Levels 1991-1993

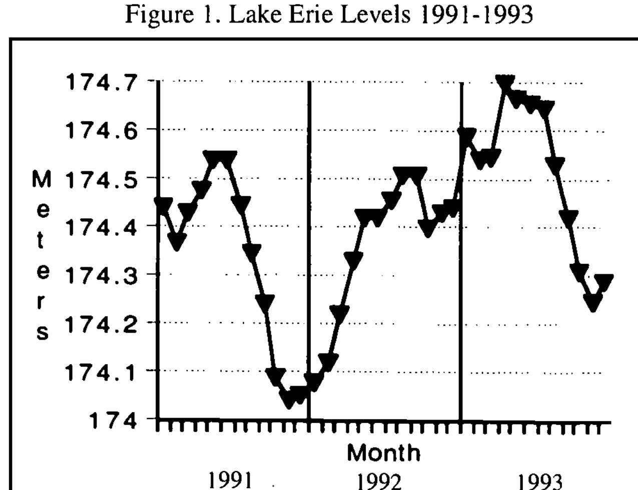
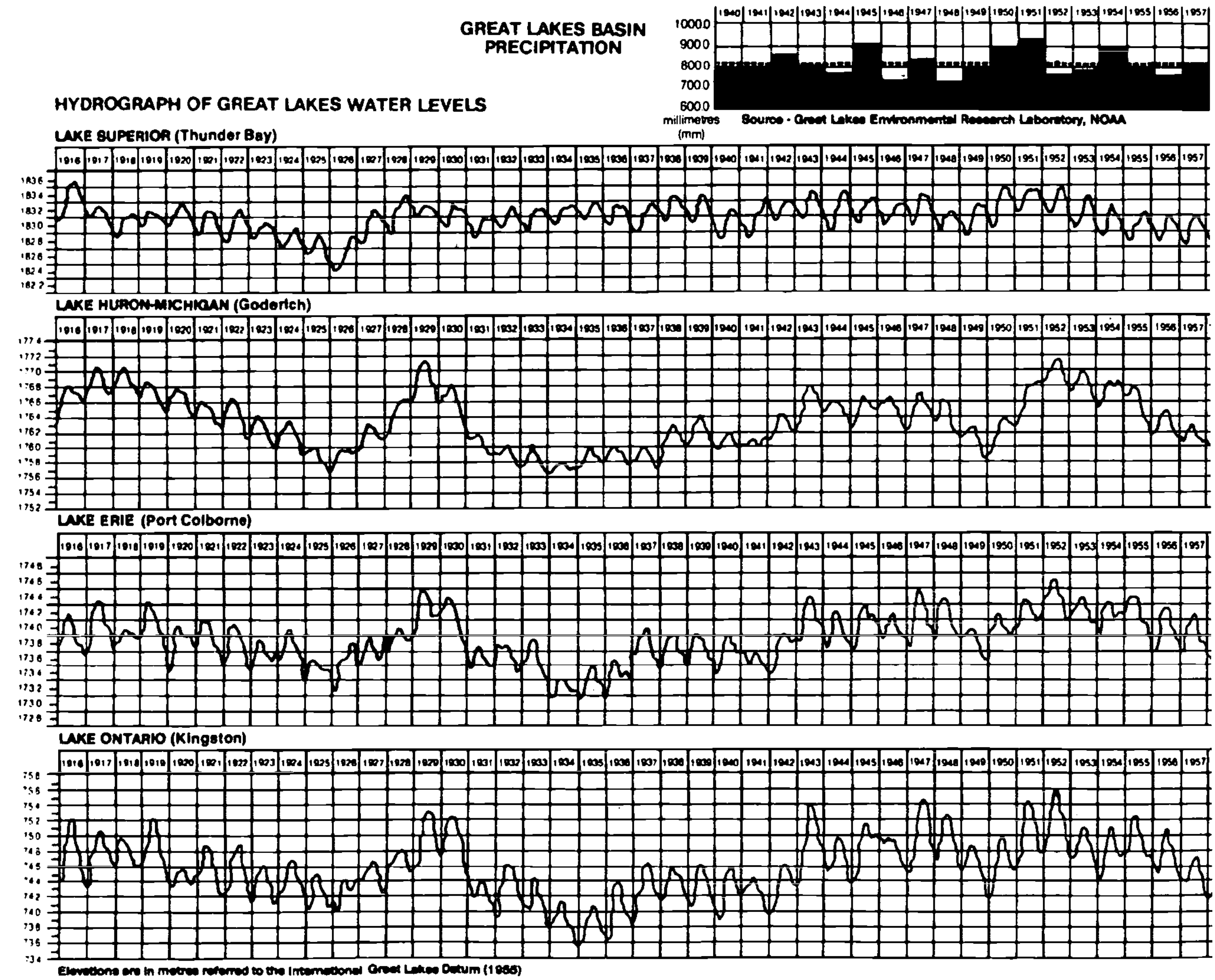
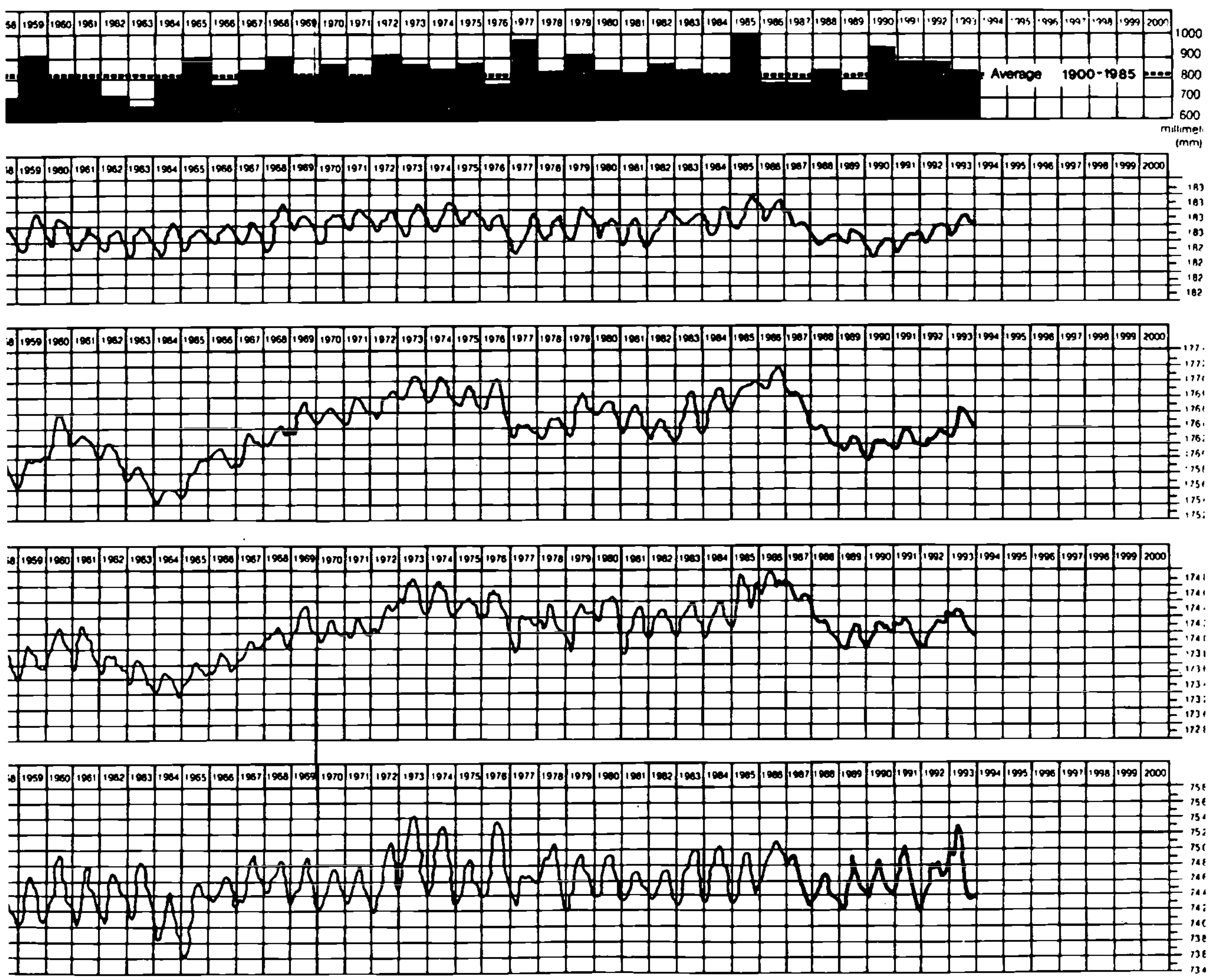


Figure 2. Great Lakes Water Levels and Basin Precipitation.



Elevations are in metres referred to the International Great Lakes Datum (1955)

Figure 2. (Continued)



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Answers

1. 174.7 meters above sea level.
2. 174.25 meters above sea level.
3. Highest water level occurred in spring and the lowest in winter.
4. 0.45 meters
5. Variations in lake levels are due primarily to changes in the amount or rate of precipitation. Note that late winter tends to be a time of low lake levels. Precipita-tion is relatively light at that time of the year, and any that does fall is likely to be held in the snow pack or as frozen ground water. During the spring the combination of runoff from winter and high precipitation tends to produce high lake levels.

6-10 These answers are for Lake Erie. If your students are using the data from another lake, you will need to get the answers from Figure 2.

6. The pattern of lake level differences is repeated in other years, but not always as clearly as for 1993 The reason for this pattern is discussed above.
7. The highest water level occurred in 1986. It was 174.9 meters above sea level.
8. The lowest water level occurred in 1934. It was 173.1 meters above sea level. The difference between the highest and the lowest is 1.8 meters.
9. There does seem to be about a 20 to 25 year pattern. It is repeated twice, between 1930 and 1952 and between 1952 and 1973. Figure TG 1 is a graph of lake levels between 1860 and 1917. Note that this 20 to 25 year pattern does not seem to persist. You might use this as an example to your students of dangers of making generalizations based upon limited data.
10. The longer term variations, though they may not be cyclic, did occur. They are probably related to changes in overall climate in the Great Lakes region.

Use Figure 1 to answer questions 1 - 5. Use your work sheet to record your answers.

1. Determine the highest water level for 1993. What was it?
2. What was the lowest water level for 1993?
3. During what season of the year did the highest water level occur? The lowest water level?
4. What was the difference in meters between the lowest water level and the highest for 1993?
5. What could cause these differences in water level?

Use Figure 2 on pages 58 and 59 to answer questions 6-10. Use the lake that your teacher assigns to you. Record your answers on your work sheet.

6. Is the yearly pattern of lake-level differences repeated? If so, what do you think could cause such a yearly pattern?
7. In what year did the lake have the highest water level? How high was it?
8. In what year did the lake have the lowest water level? What was it? What is the difference between the highest and the lowest?
9. Look at Figure 2. Do you notice similar patterns in other lake levels? If so, how long do they seem to be?
10. Can you think of any possible reasons for these patterns?

You have found that the level of the lake does change. Do you think that such changes would be a threat to buildings along the shore?

To answer questions 11-16, you will work with part of a topographic map of an area of Lake County, east of Cleveland, Ohio. Put your answers on your work sheet.

11. Locate the mouth of the Chagrin River. Draw a topographic profile of the area of houses on the northeast side of the river. Start in the lake. Draw the profile perpendicular to the shore, ending it near Jefferson School.

12. This map was drawn in 1963. Using Figure 2, determine the highest level of water that year. Plot this elevation on your profile.

13. According to Figure 2, what was the maximum height of the lake level in 1973? In 1985? Plot these on your profile.

14. Do you think the changes in lake level caused any flooding in the housing division? If so, where?

Actually, a great deal of damage occurred along the lake shore in the mid-1970s and again in the mid-1980s. It occurred not only from lake levels, but also during storms. Storms actually raise the lake level temporarily, as in Figure 3. Strong winds blowing from the west across Lake Erie have raised the lake level as much as 8 feet at Buffalo, New York.

Teacher's Notes

Students use the 15' quadrangle of Eastlake, Ohio, for this part of the activity. They will find the light (5') contour lines very difficult to read in the portion of the map they are using. In fact, in places the lines converge. It is not important that they locate each line. They should note that the lines tend to group close to the heavier contour lines. They can draw the profiles accordingly.

Answers

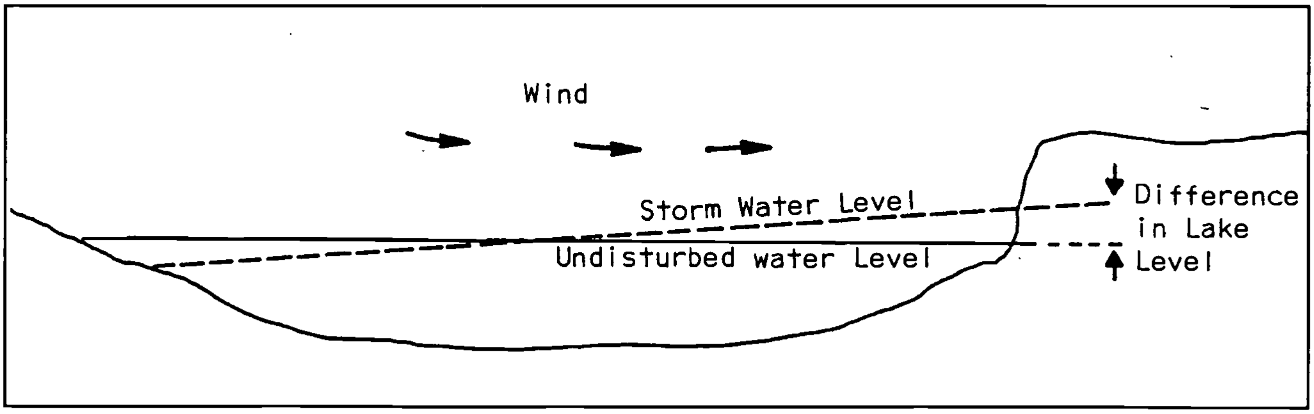
11. See Figure TG 2 for a completed profile. Students should be careful not to use too great a vertical exaggeration; 100 to 150 feet to the inch would be appropriate. The heavy contour line close to the lake shore is the 575 foot line.

12. The highest water level in 1963 was 570 feet above sea level.

13. The highest level in each of the years 1973 was just above 573 feet above sea level.

14. It would appear from the plot on the profile that this three-foot rise in lake level was not enough to flood any of the housing development. The higher lake level, however, would have increased the rate of erosion of the beach and the adjacent cliffs. This would have resulted in undermining the cliffs, landslides, and the accompanying destruction of property.

Figure 3. Profile of a Lake Showing Effect of Wind on Lake Level.



Answers

15. A storm occurring in 1986 would have raised the lake level at this site to 576 feet or possibly more. Therefore, during a storm, extensive flooding could, and did, take place as far back as the slight rise northwest of the roads.

16. High waves accompanying the storm would do a great deal of damage over that area. In fact, this was an area that sustained a great deal of damage during the summer of 1985. Students could count the number of houses in the flat area adjacent to the mouth of the river. There are well over 100 houses. Not all of them, however, actually sustained damage.

Teacher's Notes

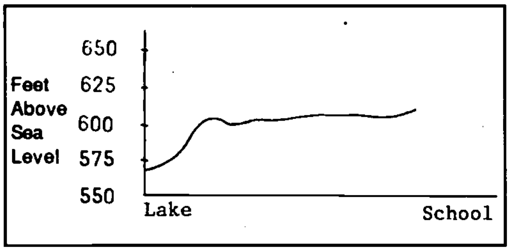
Lake level information is available online at:

http://www.cciw.ca/glimr/metadata/great-lakes-monthly-mean-wlev/intro.html

For more background information you may want to check:

http://csx.cciw.ca/dfo/chs/danpd/tcwld/fluctuations.html

Figure TG 2.



15. If a storm occurring in 1986 raised lake level in the vicinity of the Chagrin River as much as 3 feet, how large an area would have been flooded? Remember the lake level deter mined in question 13 above.

16. If the storm also caused 4-foot high waves, how many houses might be damaged?

17. Use your understanding from this section to predict the effects of lake level changes on a lake near where you live. Discuss.

Most of the damage in such areas is actually the result of the erosion of cliffs along the lake. Storm waves cut at the base of the cliffs. The cliffs collapse into the surf, taking any buildings along with them. In this way, higher lake levels have caused the south shore of Lake Erie to move farther south.

On the Canadian (north) shore of the lake, erosion is three times as rapid as the U.S. side. There are two reasons for this. The Canadian shore is largely underdeveloped farmland, whereas the Ohio side is heavily developed with houses, ports, factories, etc. Buildings and other development tend to slow down the erosion process. Also, the wind tends to come more often from the southwest than from any other direction. This causes greater wave and current action on the Canadian shore.

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Fortner, Rosanne W. and Victor J. Mayer, 1993, *The Great Lake Erie*, Ch. 4: Water Level Fluctuations on the Great Lakes, by Thomas E. Croley, II. Columbus, Ohio, The Ohio State University.

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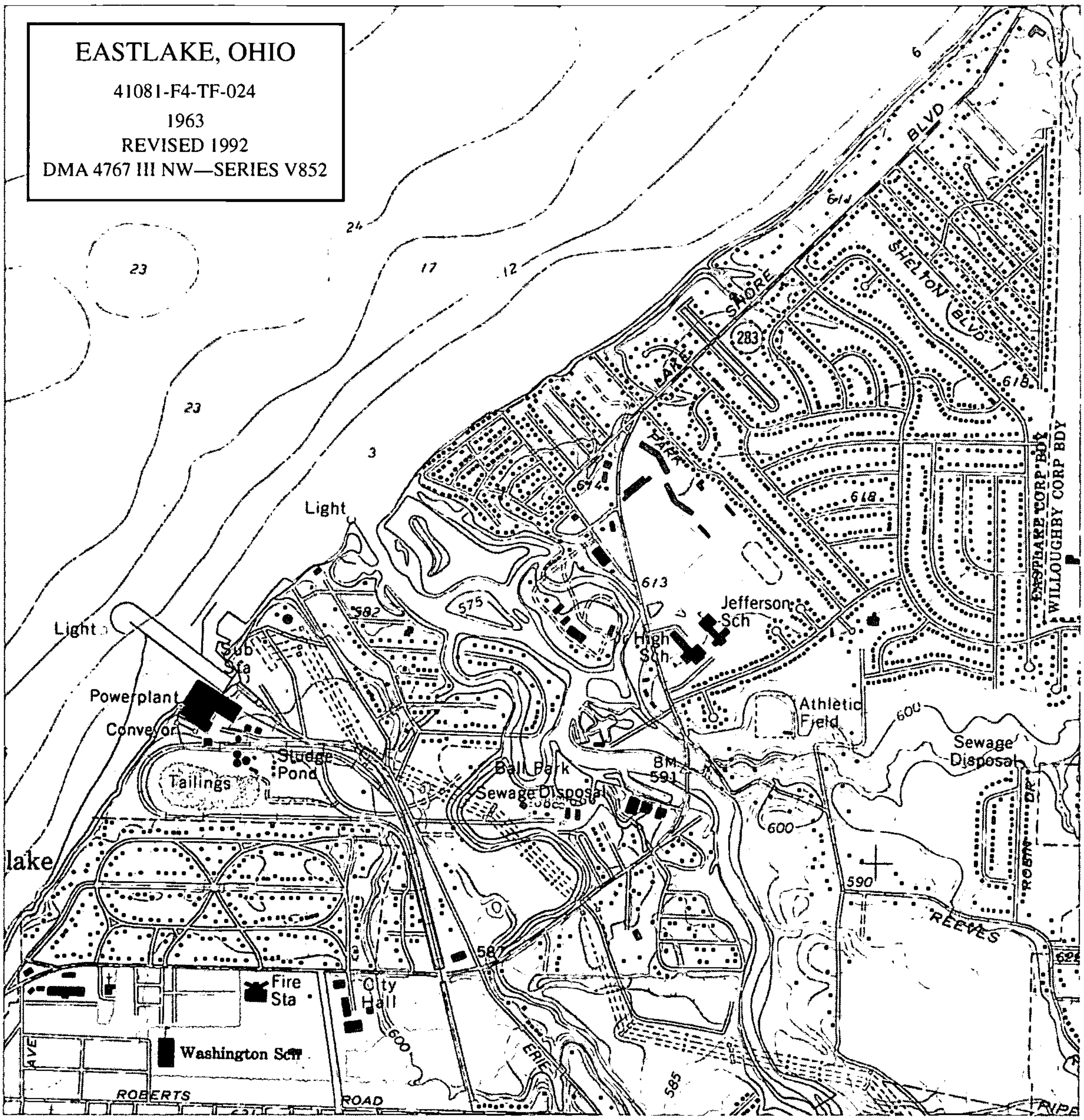

SCALE 1:244000

CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 570.5 FEET

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What would be the result of regulating the level of one of the Great Lakes?

Many people are convinced that all the Great Lakes levels are regulated by the Corps of Engineers. In reality, only lakes Superior and Ontario are regulated. To reduce the problems of erosion, however, some people have suggested that the level of Lake Erie be lowered and maintained at a constant level. The flow of water into and out of Lake Erie could be controlled (regulated) through the use of dams and other devices. In this activity, you will study the effect of regulating the level of Lake Erie upon the levels of the lakes both upstream and downstream from Lake Erie (see Figure 1 on the next page).

OBJECTIVES

When you finish this activity, you will be able to:

- Determine the effect of an increase in lake level.
- Identify possible causes of changes in lake level.
- Identify the effects of regulating the levels of each of the Great Lakes.

PROCEDURE

1. Set up your apparatus as in Figure 2. The tall plastic container will represent Lake Huron, which is upstream from Lake Erie. The cut in the side of the container represents the outlet of the lake. Note that a piece of plastic has been left covering the slit. This can be either opened or closed, thus controlling the flow out of Lake Huron and into Lake Erie. Lake Erie is represented by a larger but lower container. It too has a slit in the side, representing the outlet of the Lake. Lake Erie is sitting in an even larger container, which represents Lake Ontario. The three containers together represent a model of the three Great Lakes.

Source

Modified from OEAGLS EP - 5 "Changing lake levels on the Great Lakes" by Carolyn Farnsworth, Upper Arlington Public Schools and Victor J. Mayer, The Ohio State University.

Earth Systems Understandings

This activity focusses on ESU 2, 3, and 4 (stewardship, science process, interacting subsystems).

Materials

- Three plastic or waxed cardboard containers (lakes), a fourth container (precipitation device) and another to catch

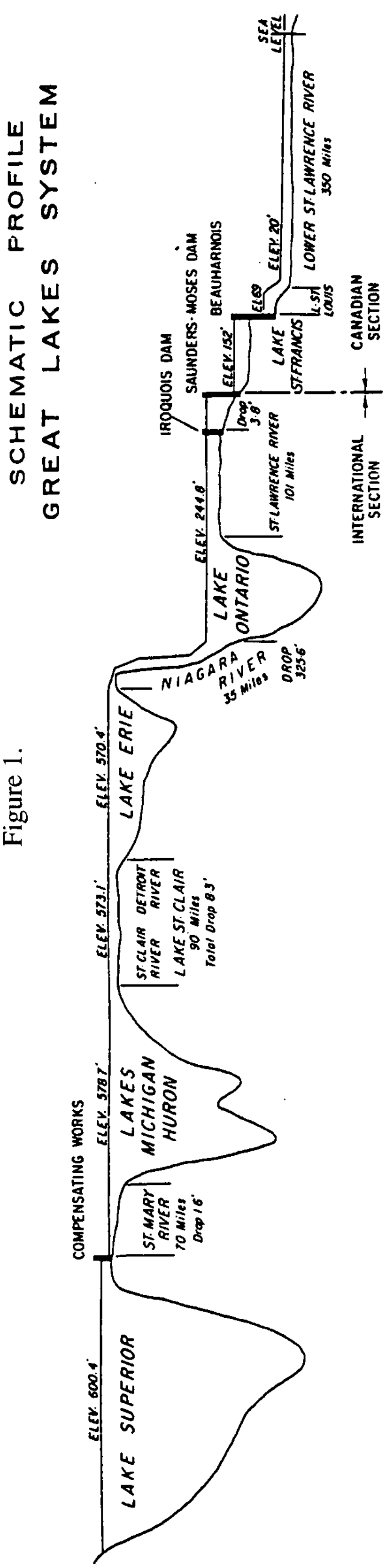
Teacher's Notes

The purpose of this activity is to explore the effect that controlling the level of Lake Erie has upon the levels of the Great Lakes.

Set the apparatus up ahead of time to test it. You will then know that each setup is working so that the students can complete the procedures on their own with minimum supervision from you.

The activity "Out One Lake and In Another - How long does it take water to flow through the Great Lakes?", published in "Lake Effects", uses a very similar equipment set up. The activity focuses on retention time and the flow of water through the Great Lakes. The activity is included in this publication. "Lake Effects" is a quarterly publication for and about Lake Superior education. Published by Lake Superior Center, 353 Harbor Drive, Duluth, MN 55802.

Figure 1.



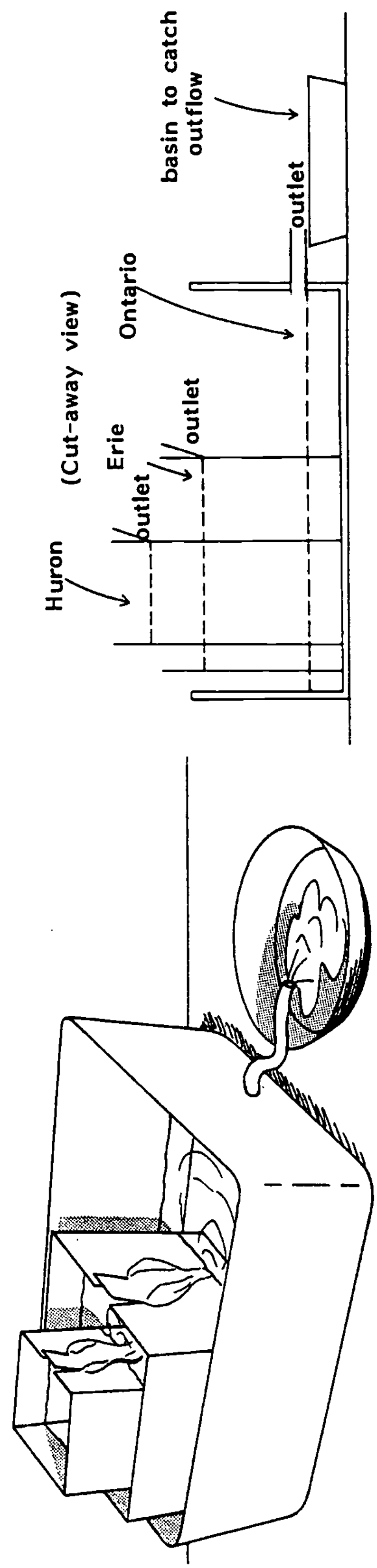
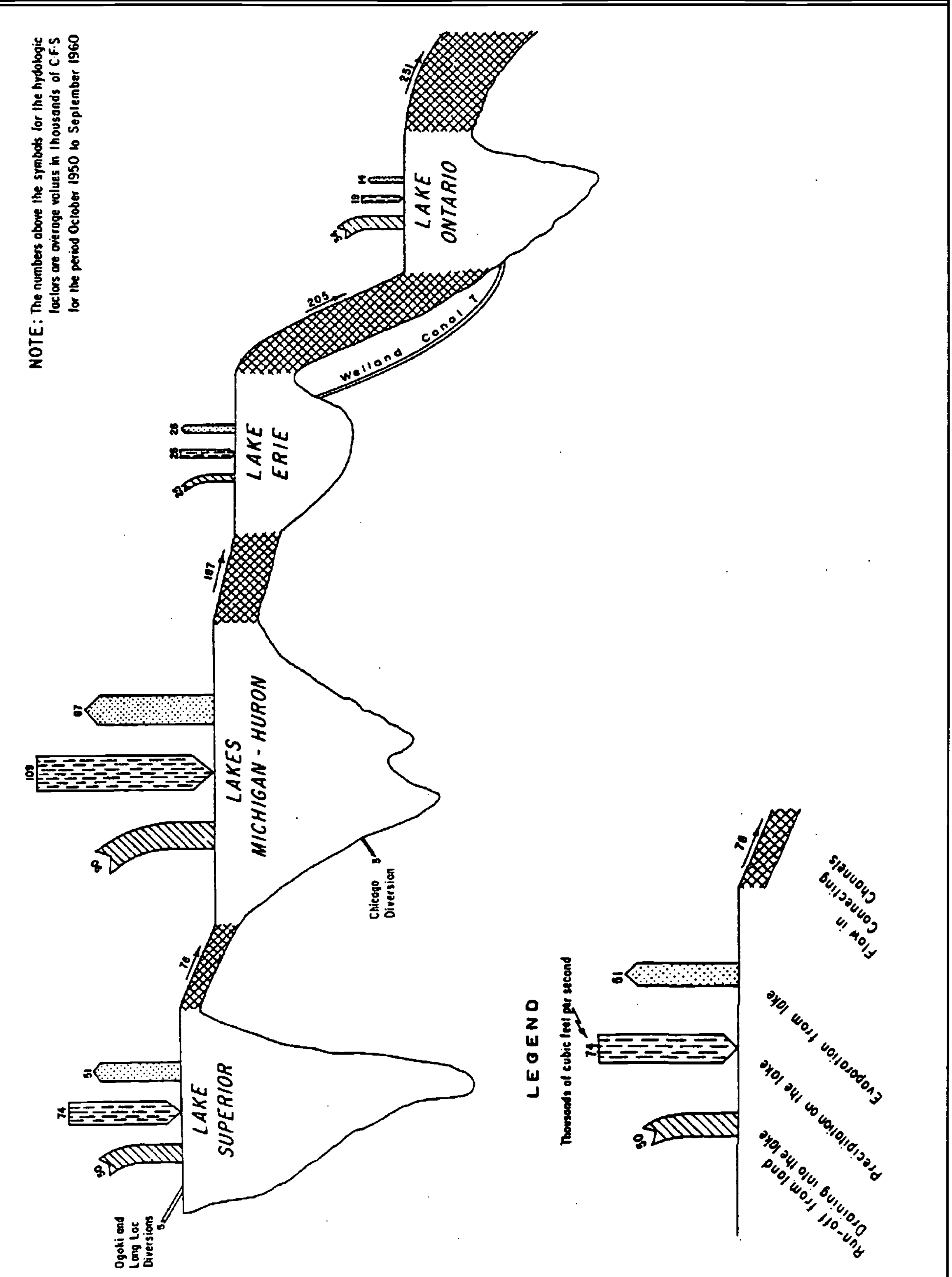


Figure 2. Model of Three Lakes. Dotted lines represent minimum lake levels.

Figure 3. Hydrologic Factors Affecting Water Supplies to Each of the Great Lakes.



2. Fill each of the lakes with water and then wait until the lake level in each lake no longer changes. Mark this level on the outside of each container.

The level you marked is the level that would occur if no water ever entered or left any of the lakes. Of course, this does not occur in nature. The level of each of the lakes at a given time will be determined by the amount of water entering the lakes and any variations in the rate of flow of this water through the lake system.

3. Be sure that the outlets of Lakes Huron and Erie are in the closed position. Some water should still be able to pass through the outlet. This position represents the way the lakes are naturally. The levels are not controlled by dams. Fill the precipitation container with water. The water in this container represents the fall of rain and snow (precipitation) into the lakes and the rivers that feed them. Pour this water into Lake Huron as rapidly as possible, without having any overflow the side of the lake. Mark on the side of each container the maximum lake level.

4. Is the maximum (highest) lake level in all three lakes reached at the same time? Discuss.

5. Fill the precipitation container again. Pour the water into Lake Huron more slowly than you did in Step 3. This represents a lower rate of precipitation than in Step 3. Mark the maximum lake level for each lake. Do the lakes reach as high a level when the rate of precipitation is less? Discuss.

6. Open the outlet of Lake Huron, keeping Lake Erie closed. Repeat the procedure for the two different rates of precipitation. Describe what happens to the lake levels in Huron and Erie.

7. Now open the outlet of Lake Erie, keeping Lake Huron open also and repeat the procedure for the same two rates of precipitation. Describe what happens to the lake levels of Huron and Erie.

Answers

4. Maximum lake levels were not reached at the same time. Lake Huron overflows first, then Lake Erie, then Lake Ontario. The lag is a function of the flow-through time needed for the water to move from Lake Huron to Lake Ontario.

5. With the lowest rates of precipitation, lake levels do not rise to as high a maximum level. This is analogous to what happens in nature. Students should realize that lake levels are related to the rates of precipitation.

6. Opening the outlet to Lake Huron results in more rapid flow-through of the precipitation, and thus a lower maximum level in Lake Huron and higher maximum lake level in Lake Erie.

7. The maximum lake levels reached in both lakes should be lower than when both outlets were closed. Therefore, by producing an increased outflow in both lakes, their maximum lake levels would be reduced.

8. What happens when only one lake at a time is regulated?

9. How would you design a regulation system that could keep Lake Erie's water level from rising or lowering too much or too fast?

Changes in lake level are related primarily to changes in the amount or rate of precipitation compared to the evaporation rate. These changes follow a yearly pattern (remember your answers to steps 1 through 6 of the activity "Does the level of the Great Lakes change?"). There also seems to be a longer-term cycle.

In this activity you used a model of the lakes to investigate the effects of adding precipitation to lakes upstream from Lake Erie. The flow-through of that precipitation changes lake levels downstream. In nature, the situation is more complicated, because precipitation will be added to all of the lakes directly through runoff from rivers and streams entering the lakes. Figure 3 illustrates the relative importance of each source of water for each of the lakes. Any program to regulate the level of Lake Erie must take into account all sources of water and their possible effects on lake level.

Many people, especially home owners along the lakes, think that the U.S. Corps of Engineers is able to regulate lake levels in locks of the Great Lakes. This is not true. Such regulations would be extremely difficult, as you can see from the results of this activity. The levels of Lake Superior and Ontario, however, can be controlled to a certain degree. This is because the outlets are a part of the St. Lawrence Seaway, and therefore, their flow of water is controlled by dams and canals.

Answers

8. In this model, students regulate a lake only by increasing the outlfow of water. In this case, then, introducing regulation in one lake caused higher lake levels in the lake downstream. In reality, the outlfow from a lake can also be reduced by closing dams, thereby reducing lake level down stream.

9. You should accept any reasonable answer. Systems of dams and deepened and widened channels are most commonly used in regulating lake levels.

Background Information

The two major causes of changes in the levels of the lakes are wind set-up and changes in precipitation. Wind setup is caused by the persistent blowing of wind in a single direction over a prolonged period of time. This causes a "piling up" of water at the downwind end or side of the lake. Wind setup tends to have a short range effect on lake level and can produce daily variations. Changes in the amount and rate of precipitation have longer range effects on lake level. In "How do levels of the Great Lakes change?", students discover annual variation that is due to precipitation. There are longer cycles that are undoubtedly also related to precipitation and in turn to climatic fluctuations in the drainage basin of the Great Lakes.

Lake Erie lake levels could be regulated by controlling the outflow through the Niagara River and/or by controlling the inflow from Lake Huron through the Detroit River. A channel would have to be constructed around the Niagara gorge to carry the necessary outflow during high water seasons. This increased outflow could increase the level of Lake Ontario, causing damage, or if it were passed rapidly through Ontario, it could cause damage on the floodplain of the St. Lawrence River. Controlling the amount of inflow, conversely, would raise the level of Lake Huron and cause damage there. To effectively modify the level of Lake Erie, then, the entire Great Lakes system would have to be controlled. This would be terribly expensive. In 1976, and again in 1986, the International Joint Commission recommended against this because of the high cost and relatively low benefits.

During the 1950s a series of dams and channels were constructed on the St. Lawrence River at the outlet of Lake Ontario. Beginning in 1960 these structures were used to regulate the lake levels in Lake Ontario. Between 1960 and 1974 the level of the lake varied between a low of 241.7 and a high of 247.9; a range of 6.2 feet. If regulation had not occurred, lake level would have varied between 241.4 and 249.1; a range of 7.7 feet. Lake Superior is also regulated. A series of structures that modified the amount of outflow from Lake Superior had been built in the St. Mary's River starting in the late 1800s. In 1921 a systematic plan for the regulation of the lake was implemented.

How do the Great Lakes change through the seasons?

Have you ever been swimming in the ocean or a lake and stepped into a deep area where the water was much colder? Why does colder water stay near the bottom of a lake? Every year, deep lakes in the temperate zones of the world go through water temperature changes as the seasons change. In the Great Lakes, the water may go from an icy winter condition to temperatures as high as 24 °C (75 °F) or more. What is occurring in the lake when this happens, and how are the plants and animals in the lake affected?

OBJECTIVES

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

- Describe how water temperature affects water density.
- Explain how changes in water temperature and density cause stratification of lake waters.

Source

Modified from OEAGLS EP - 28 "Lake Layers: Stratification" by Chris Brothers, David A. Culver, and Rosanne W. Fortner.

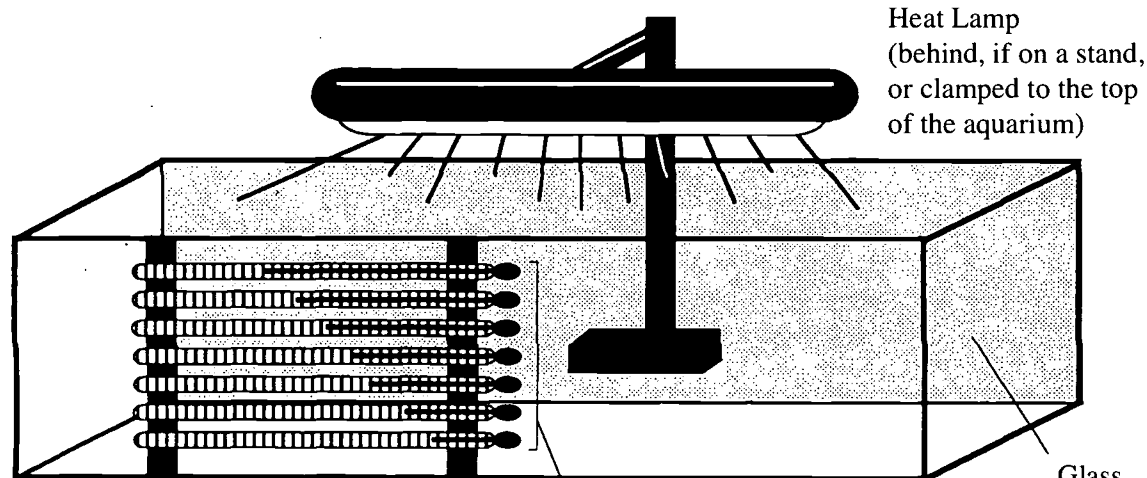
Materials

- Colored ice (frozen with food coloring added).
- An aquarium containing cold tap water.
- Sieve or aquarium net.
- Ice.
- Heat lamp.
- Seven thermometers.
- Rubber bands.
- Two plastic rulers.
- Masking tape.
- Small fan.
- Food coloring.
- 300 ml flask.
- 300 ml beaker.
- Copies of the student data chart and graphs.
- **Safety glasses must be worn at all times during this activity.**

Earth Systems Understandings

This activity focuses on ESU 3 and 4 (scientific process and interacting sub-systems).

Figure 1. Aquarium Setup.



Procedure

A. Set up the aquarium as in Figure 1. Add enough ice (without food coloring), stirring occasionally, to the aquarium to lower the temperature of the water to 4°C near the bottom. You should still have a shallow layer of ice on the surface, where the temperature will be 0°C. Allow the water to come to rest. In the first column of the temperature data chart on your work sheet, record the temperatures of the seven thermometers.

B. Remove the rest of the ice with a sieve or aquarium net as gently as possible. Turn on the heat lamp. **Be very careful not to splash any water on the heat lamp or it could explode.** Record this time as the beginning of the experiment.

C. After 5 minutes, record the temperatures of each of the seven thermometers in the second column of your data chart.

D. As you wait for the 5 minutes to pass, graph depth in cm versus temperature in °C on graph #1 using the data from column #1. What time of year do these temperatures represent? Label the graph with the time of year.

E. At the 12 minute mark, record the temperatures on the seven thermometers in the third column of your data chart. Record the water temperatures again at the 30 minute and 45 minute marks in the fourth and fifth columns of your data chart.

F. While you wait, pour 250 ml of ice water into a 300 ml flask. Weigh the flask.

1. What is the temperature and weight of this water?

G. Empty the flask and refill it with 250 ml of very hot tap water. Weigh the flask with the warm water and record its weight.

2. What is the temperature and weight of this water?

3. Which temperature of water is more dense (weighs more)?

Answers

D. These temperatures represent winter before the spring turnover. Temperatures at most depths should be about 4°C, with the surface water at about 0°C.

1. The water should be about 0-4°C. Specific weight will vary depending on temperature.

2. This water will probably be about 30°C It should weigh somewhat less, depending on the water temperature. Specific weight will vary depending on temperature. Only a sensitive balance will detect the difference based on temperature.

3. The cold water is more dense. Water is most dense at 4°C. It becomes less dense as temperatures increase from 4°C. It also becomes less dense as temperatures decrease from 4°C to 0°C, at which point it freezes. This is why warm layers of water rest on top of cold layers during the summer and why cold water sinks in the fall during fall turnover.

H. Pour the warm water into a beaker or glass jar. Gently add a few colored ice cubes to the warm water.

4. What happens to the colored water from the ice as the ice melts? Why?

Spring turnover occurs when water temperatures at the surface are equal to those at lower depths and water from all depths mixes. The top layers of water may then start to warm slightly.

I. Which column of temperature data best represents spring turnover in your model lake? Use the data from this column to graph depth in cm versus temperature in °C on graph #2. Label this graph "spring turnover."

As summer approaches, the lake continues to warm.

5. Why do surface temperatures increase during the summer, while water temperatures at lower depths remain cold?

During the summer, the lake becomes stratified into three layers of water -- the warm upper layer or *epilimnion*, the cold bottom layer or *hypolimnion*, and the middle layer of rapid temperature change known as the *thermocline*. See Figure 2.

J. Which temperature data column best represents the stratified summer lake? Use the data from this column to graph depth in cm versus temperature in °C on graph #3. What should you label this graph?

6. What is the temperature in the epilimnion? In the hypolimnion? How much temperature difference is there between these two layers?

Wind at the surface of the lake creates waves and stirs up the water, adding oxygen to it in the same way a bubbler works in a fish tank. When temperature layers form in the lake in the summer, the warm surface water (epilimnion) is separated from the cold bottom water (hypolimnion) by the thermocline. The thermocline acts as a barrier. It keeps oxygen in the surface waters from reaching the cold waters of the hypolimnion. Gradually the oxygen in the hypolimnion gets used up.

Answers

4. Ice floats on water because it is less dense than water. As the ice melts, its colored water will sink because it is colder than the warm tap water. Eventually a cold layer of water will form at the bottom of the warm water, illustrating the stratification that occurs in lakes.

I. The data in column two probably best represent spring turnover. The temperatures should be the same over all depths, or slightly warmer at the surface.

5. Surface temperatures increase from warming by the sun and from the surrounding air. Not as much sunlight reaches the lower depths, thus these areas are not warmed as much.

J. Data in column five best represent the stratified summer lake. Temperatures will be warmest at the surface, coldest at the bottom, and may show a sharp drop at some depth in between. This sharp drop occurs at the thermocline. This graph should be labeled "summer stratification."

6. Temperatures in the epilimnion (surface) may be 20°C or higher. Temperatures in the hypolimnion (bottom) may be about 5°C. Temperature differences may be 15°C or more.

Answers

7. These animals may die from lack of oxygen or may be forced to move to areas of the lake where there is more oxygen (surface or near shore waters).

8. Surface water temperatures cool during the fall as less sunlight reaches and warms them. In addition, air over the lake is cooler, and the lake gives up heat to the air.

9. Fall turnover mixes the water in the lake. This mixing resupplies oxygen and other nutrients needed by animals to all depths in the lake.

10. Fall turnover has occurred. There should be no temperature layers in the lake -- temperatures should be fairly similar at all depths.

11. These temperature data represent late fall as water temperatures cool and ice starts to form on the lake.

M. This graph should be labeled "fall turnover" or "late fall."

Online Resource

The Great Lakes Forecasting System has vertical temperature data for Lake Erie available online. Check out: http://superior.eng.ohio-state.edu/

7. What happens to the animals living at the bottom of the lake when there is no oxygen?

As Autumn begins, the surface waters of the lake begin to cool.

8. Why do surface waters of the lake cool off during the fall?

Fall turnover occurs when all the lake water has cooled and has been completely mixed by water movements and wind.

9. How might fall turnover be good for animals living at the bottom of the lake?

K. After you have recorded the 45 minute temperatures, turn off the heat lamp. Turn on the fan and use it to create a strong wind by blowing on the water from one direction. Keep blowing until all the water in the lake is completely mixed. Record the water temperatures in the sixth column of your data chart.

10. What seasonal change in lake temperatures has happened in the fall? Are there any temperature layers in the lake once the water has mixed?

L. Carefully add ice to the surface water to create an ice layer. Try not to mix or disturb the water. Record the water temperatures in the last column of your data chart.

11. What time of year is represented by these temperature data in the last column?

M. Use the data from the last column to graph depth in cm versus temperature in °C on graph #4. What should this graph be labeled?

Extension

All of the Great Lakes stratify to a degree during the summer. Discuss the depths of the Great Lakes, as well as their major bays such as Green Bay. In what kinds of areas would the thermocline go very deep? Hypothesize where (how deep) the thermocline would be in each of the Great Lakes.

Figure 2. Thermal Stratification of a Temperate Zone Lake.

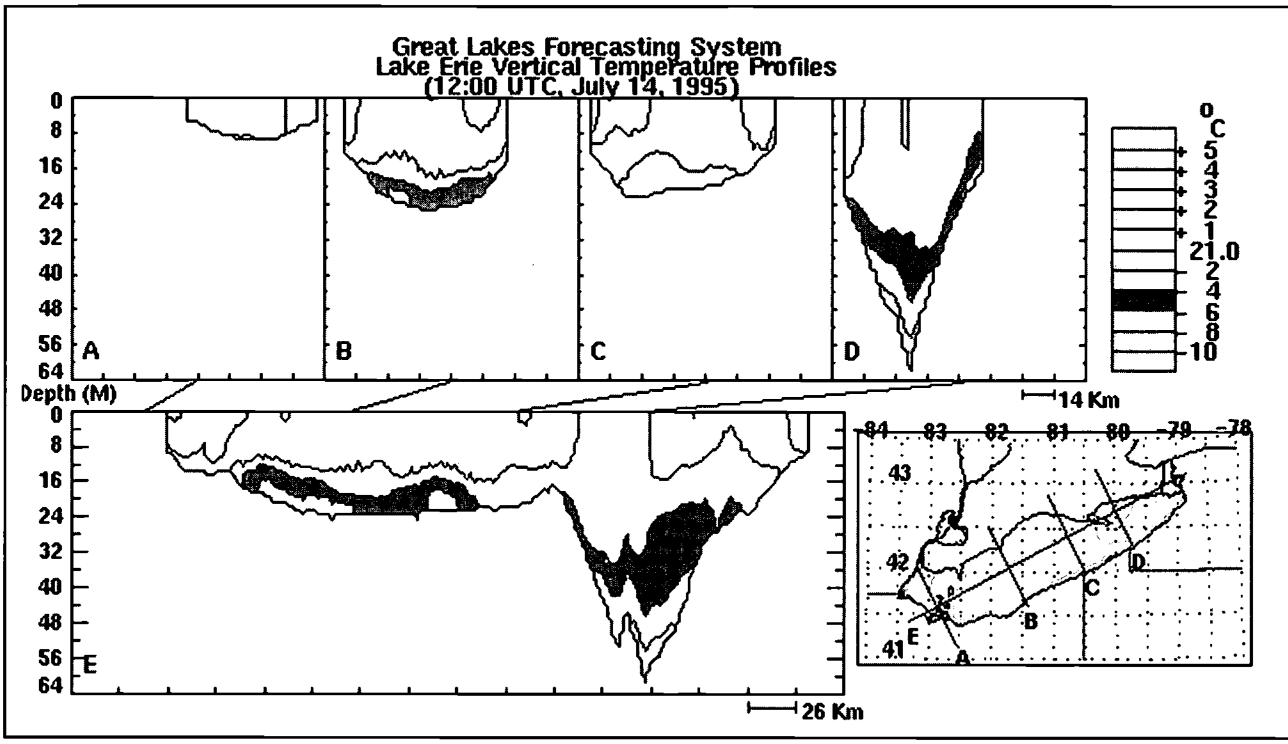


Figure 3. Water Temperature Data Chart (Degrees Celsius).

Depth in cm	Time Columns #1	#2	#3	#4	#5	#6	#7
1							
3							
5							
9							
13							
17							
21							

Figure 4. Water Temperature Graphs.

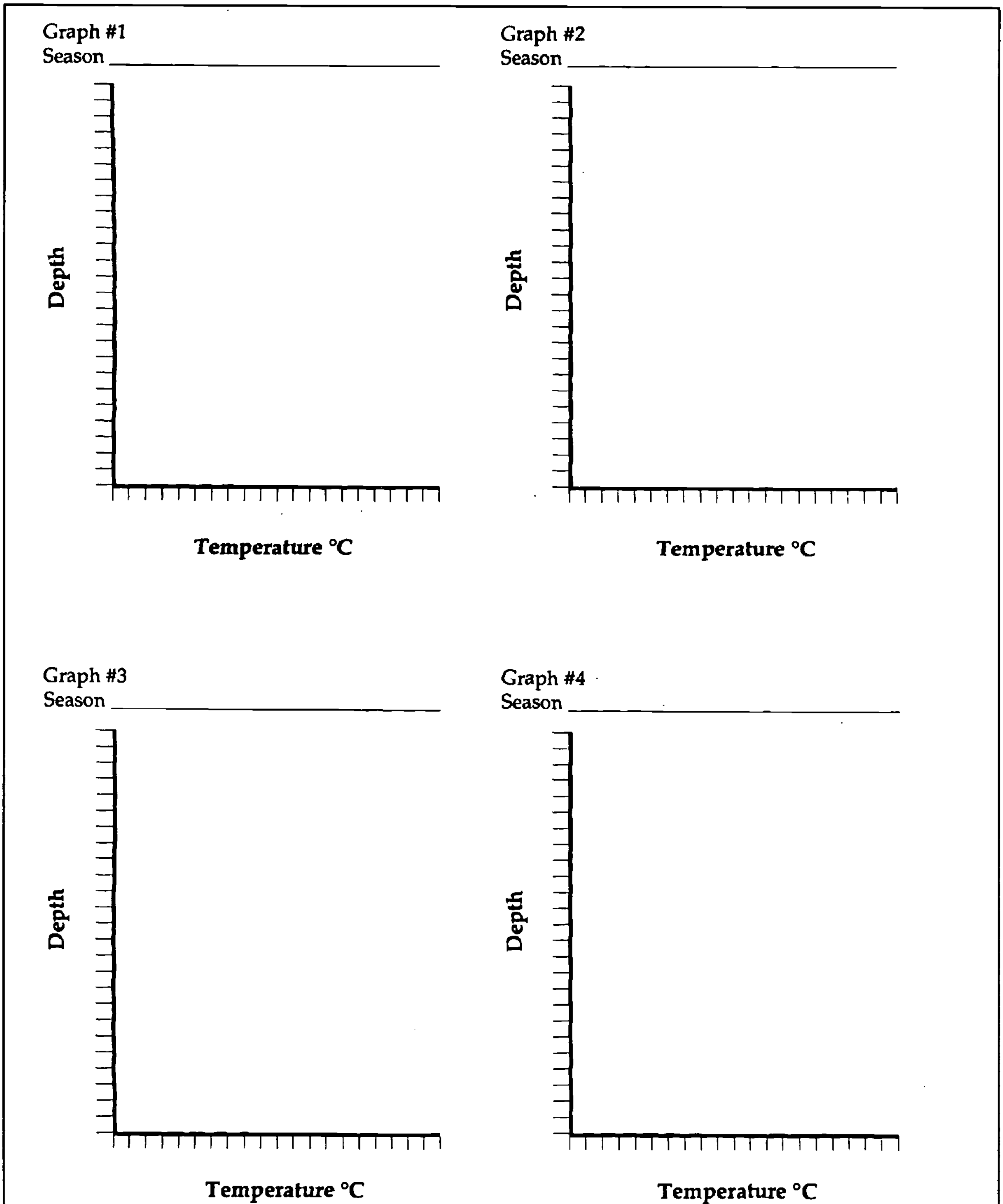
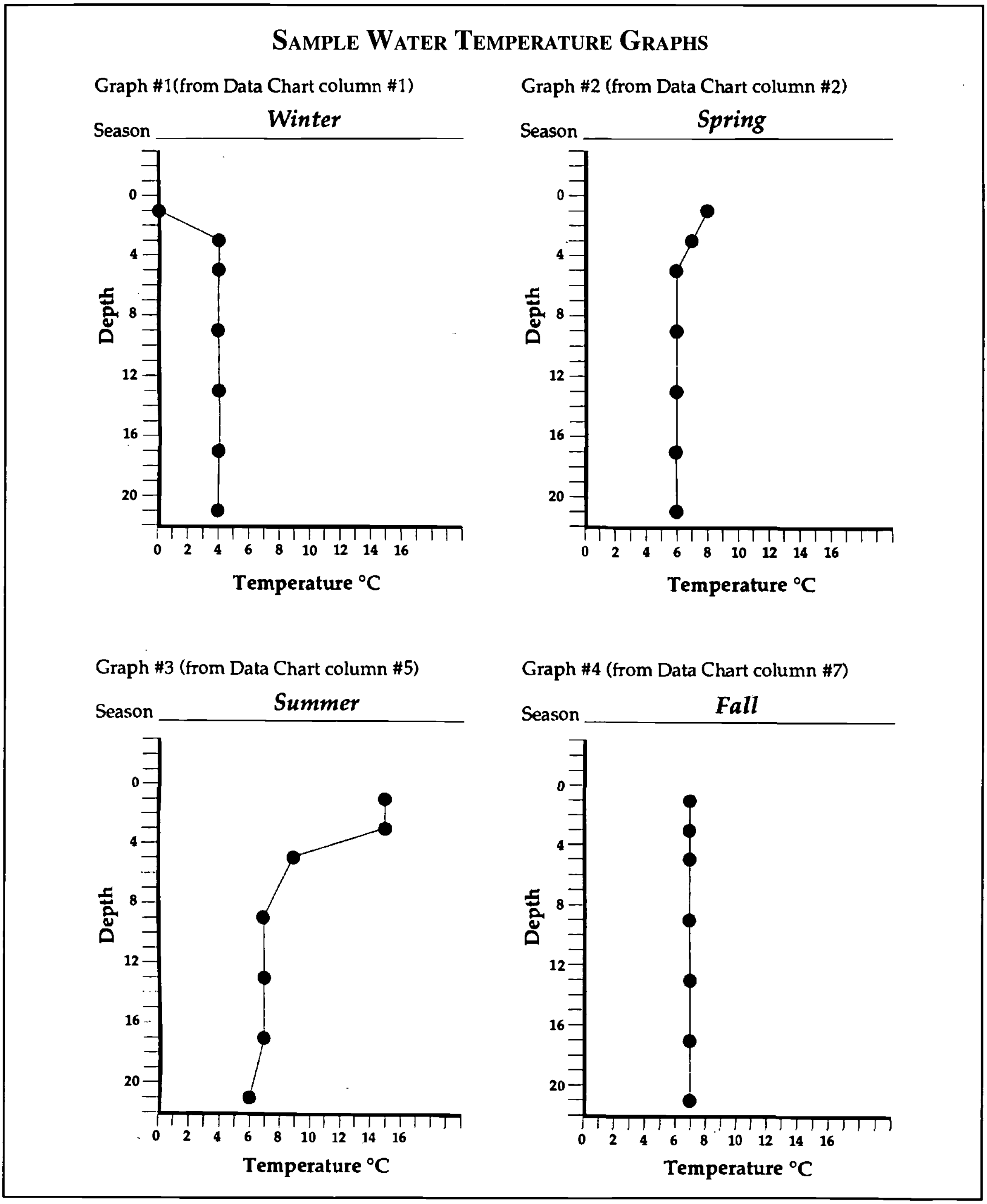


Figure 5. Graphs for the Teacher. Note: Limnologists and oceanographers place 0 depth at the top



How does stratification affect water quality?

Some lakes have water quality problems related to the layering of the lake's waters, which occurs in the summer months. Because of its shallowness, Lake Erie is such a lake. During the summer, the warm surface layer of water does not mix with the colder bottom layer of water. If a lot of algae has grown in the lake, decay of the dead algae on the lake bottom may use up all of the oxygen in the cold bottom water layer. When there is no oxygen in the bottom waters, the water is said to be *anoxic*. Fish and other animals cannot live in these anoxic waters. In the fall, the surface water cools and mixes with the bottom water, resupplying the bottom water with oxygen needed for life.

OBJECTIVES

When you complete the activity you will be able to:

- Describe how stratification of lake waters influences water quality.
- Explain how phosphorus affects oxygen levels in lakes.

PROCEDURE

A. Look at the diagrams of Lake Erie on your worksheet (Figure1). The shaded area on each diagram shows the part of the Lake that was anoxic that year. These parts of the Lake contained no oxygen in the water.

1. In which year do you think the Lake had the largest anoxic area? In which year does the Lake seem to have had the smallest anoxic area?

B. On the anoxia diagrams (Figures 2-6), use the string and ruler method to measure the perimeter of the anoxic part of the Lake in 1930. Stretch the string all the way around the perimeter (outer edge) of the shaded anoxic part. Then stretch the string along the ruler to measure its length in cm. The length of the string is equal to the perimeter of the anoxic part of the Lake. You may want to tape the string in place at your starting point or mark your starting point with your pencil.

Source

Modified from OEAGLS EP - 28 "Lake Layers: Stratification" by Chris Brothers, David A. Culver, and Rosanne W. Fortner.

Earth Systems Understandings

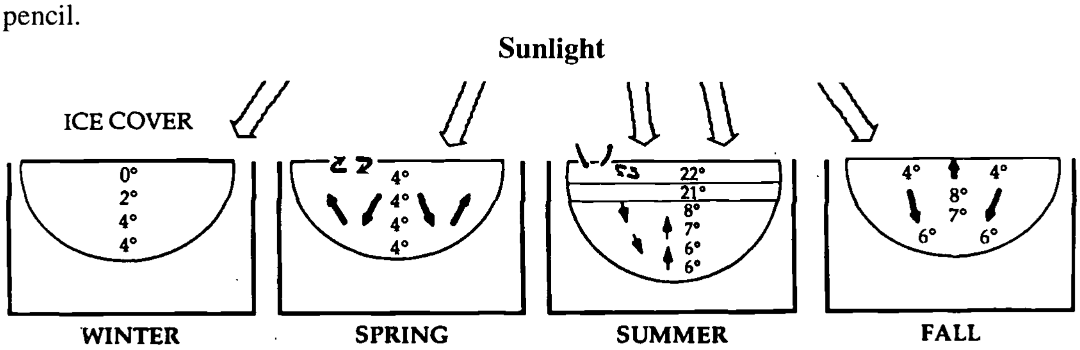
This activity focuses on Earth Systems Understandings 3 and 4 (scientific process and interacting subsystems).

Materials

- Worksheet and diagrams of anoxic areas in Lake Erie.
- Ruler.
- String.

Answers

1. The Lake had the largest anoxic area in 1973. The smallest anoxic area occurred in 1930.



2. What was the perimeter of the anoxic section in 1930 (Figure 2)?

C. Repeat step 2 for the diagrams of the Lake in 1964, 1973, 1976, and 1982 (Figures 3-6). Enter the perimeter of the anoxic part of the Lake for each year in the chart on your work sheet.

D. Using the steps for finding the area of a circle from its circumference, find the area of the anoxic section of the Lake from its perimeter. The formula you should use is $A = C^2/4$.

Although the anoxic section is not a perfect circle in shape, we will use this method to estimate the area of the anoxic part of the Lake from the perimeter you measured. Enter the area of the anoxic part of the Lake for each year in the chart on your worksheet.

3. In which year did the Lake have the largest anoxic area? In which year did it have the smallest anoxic area? How do these results compare to your earlier predictions?

E. Look at the map of Lake Erie divided into its three geographic basins (Figure 7), the Eastern, Central, and Western basins. Match the basins on this map with your map of the Lake showing anoxic areas.

4. In which Basin of the Lake are the anoxic areas found?

5. Looking at the map of Lake Erie divided into basins, what is the average depth in each of the three Basins?

Usually only lakes that are deeper than 40 feet or 12 meters stratify into temperature layers during the summer.

6. Which of the three basins in Lake Erie will stratify in the summer?

7. Does the Western Basin stratify during the summer? Why or why not? Will it become anoxic?

Answers

2. The perimeter of the anoxic section is approximately 3.6 cm.

3. The Lake had the largest anoxic area in 1973. The smallest anoxic area occurred in 1930.

4. Anoxic areas are found in the Central Basin. The small black dots in the Western Basin are islands, not anoxic areas.

5. Average depth of the Lake in the Eastern Basin is 80 feet (24 meters), the Central Basin, 60 feet (18 meters), and the Western Basin, 24 feet (7 meters).

6. The Eastern and Central Basin will stratify.

7. The Western Basin does not become anoxic because it does not stratify. It is shallow enough that oxygen is continually mixed and supplied to all depths of the Lake by wind and wave action.

Although the Eastern Basin stratifies during the summer, it does not become anoxic. This is because it is so deep. Deep waters are cold, while shallow waters are warm. Cold water can hold much more oxygen then warm water can.

The supply of oxygen in the cold waters of the Eastern Basin at the beginning of the summer is high. Oxygen at the bottom of the Lake is used throughout the summer by animals living there and in the decay of dead algae. Stratification of the lake's waters prevents more oxygen from reaching the bottom water. Even so, the oxygen supply in the Eastern Basin does not get used up during the summer, because the supply was very high at the beginning of the summer.

8. Is the Central Basin deeper or shallower than the Eastern Basin? Which of the two basins will have warmer bottom waters? Which of the two basins will have less oxygen in its bottom waters at the beginning of the summer? Which of the two basins will most likely become anoxic?

9. What might happen to fish and other animals living in the Central Basin when it becomes anoxic?

The farm fertilizers and the laundry detergents we use both contain a chemical called phosphorus. When fertilizers from farms or sewage containing detergents flows into a lake, phosphorus enters the lake as well. Phosphorus is a nutrient needed by all plants, including algae, to grow. When a large amount of phosphorus enters a lake, it may cause algae to grow and grow very rapidly. The result may be too much algae. The algae may use up the oxygen in the water, both through its own growth and as it decays. See Figure 8.

10. What happens to the lake when growth and decay of algae uses up all the oxygen?

People started putting phosphorus into detergents in the late 1950s. Before that, phosphorus was not used in detergents.

11. Explain the large anoxic areas that occurred in Lake Erie during the 1970s. How can you explain the smaller anoxic areas that occurred in 1930 and 1960?

Answers

8. The Central Basin is shallower than the Eastern one, its bottom waters are warmer, and they contain less oxygen at the beginning of the summer. Thus, the Central Basin is more likely to become anoxic.

9. Fish and other animals cannot live in anoxic waters. They may die from suffocation or they may move to areas of the Lake that still contain oxygen. There may be a change in the kinds of fish living in the Lake from species needing cold, high oxygen waters (trout and whitefish) to fish that can survive in warmer waters with less oxygen (carp).

10. The lake becomes anoxic.

11. Large anoxic areas in the 1970s probably resulted from large amounts of phosphorus from laundry detergents entering the Lake. The smaller anoxic areas in 1930 occurred before phosphates came into use. Although phosphates were being used by 1960, not as much phosphorus had entered the Lake by 1960 as had by the 1970s.

In 1978, laws were passed by many states located in the Great Lakes Basin to limit the amount of phosphorus that could be used in detergents.

12. Why do you think laws banning phosphorus in detergents were passed?

The amount of phosphorus entering Lake Erie has been reduced nearly 60 percent in the past twenty years.

13. Relate this information to the fact that the size of anoxic areas in the Lake seems to have decreased since 1976?

In January of 1990, the State of Ohio joined other Great Lakes states that have reduced phosphorus in detergents.

14. Predict the size of the anoxic area of Lake Erie in the 1990s if phosphorus continues to be reduced in the Lake.

Answers

12. Such laws, called phosphorus bans or limits, were passed to reduce the amount of phosphorus entering the Lakes. It was hoped that by reducing the amount of phosphorus entering the Lakes, algae growth and anoxic areas could also be reduced.

13. Reducing the amount of phosphorus entering the Lake has contributed to a reduction in algae growth in the Lake. With less algae growth, smaller areas of the Lake became anoxic during the 1980s.

14. As less phosphorus enters Lake Erie, anoxic areas of the Lake should decrease in size. However, phosphorus will still be entering Lake Erie from farm runoff and other sources.

Note: In more recent years, data on anoxia have been collected differently, and equivalent diagrams cannot be constructed. There is evidence of smaller anoxic areas in the 1990s.

Extension

1. Nutrients in the Great Lakes are addressed by activities in both the "Environmental Issues" and the " Life in the Great Lakes" ES-EAGLS collections. The activities relate to eutrophication and water quality in the Great Lakes. Students investigate the impact of nutrients in a lake by observing algae growth in samples of lake water and plot the amounts of nutrients reaching a lake following a storm to learn about the role of wetlands in improving water quality.

2. Have students check the phosphorus content of the detergents their families use. Most brands include this information in the list of ingredients. Which detergents contain the most and the least amounts of phosphorus? How important is this in the students' minds? Can one family make a difference?

3. Have students do research on the farming practices used in their area. What is no-till agriculture? Are any farmers using it? What are the advantages and disadvantages of no-till? Students could interview farmers or county Soil and Water Conservation District staff to find out.

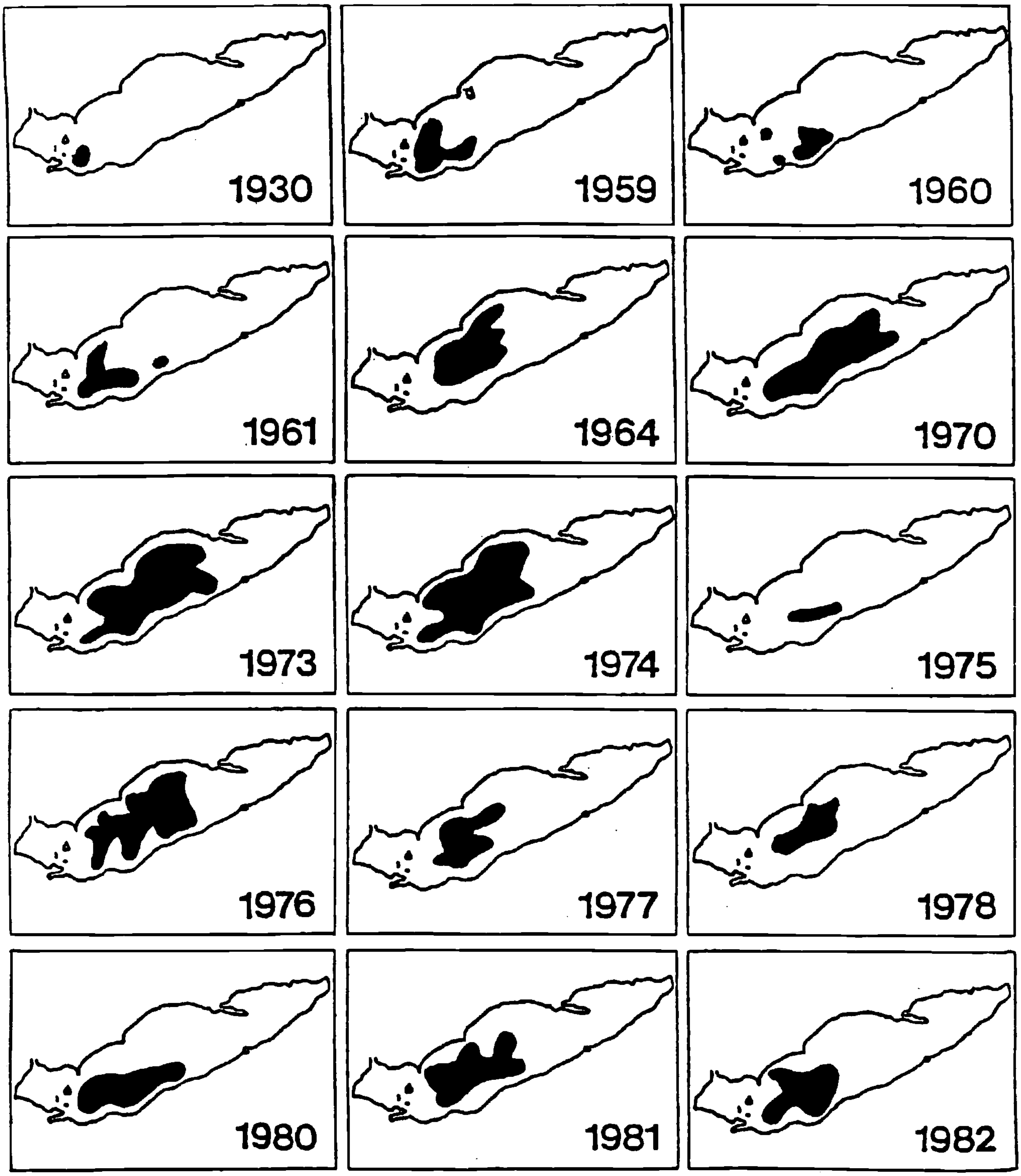
Online Resources

Use GLIN of GLIMR and search for nutrient information.
GLIN: http://www.great-lakes.net
GLIMR: http://www.cciw.ca/glimr/intro.html

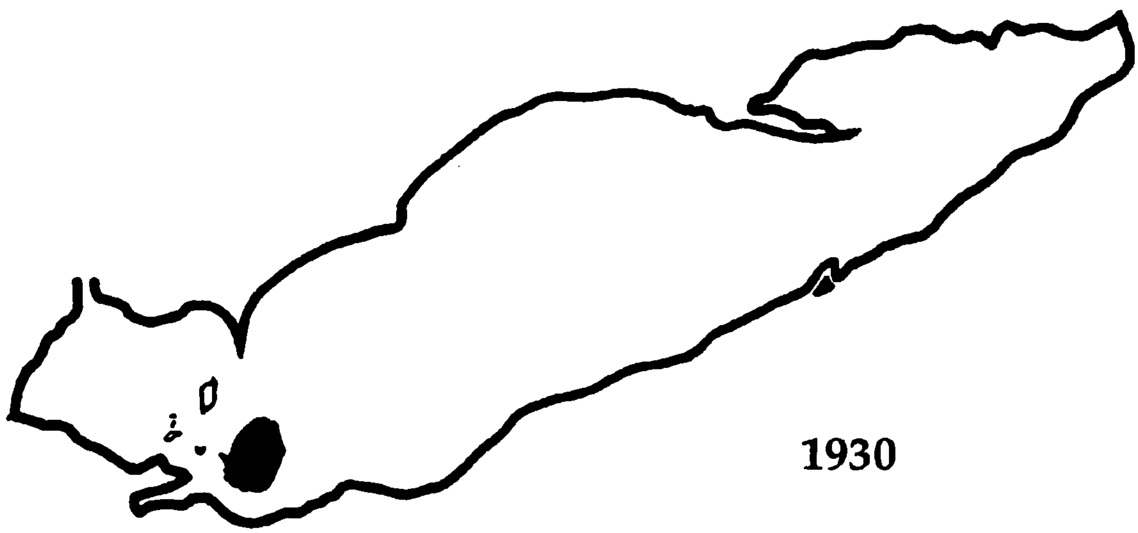
Reference

Herdendorf, Charles E. "Recovering from Phosphorus Enrichment." *The Great Lake Erie.* 1993. Rosanne W. Fortner and Victor J. Mayer, editors. Ohio Sea Grant, Columbus, OH.

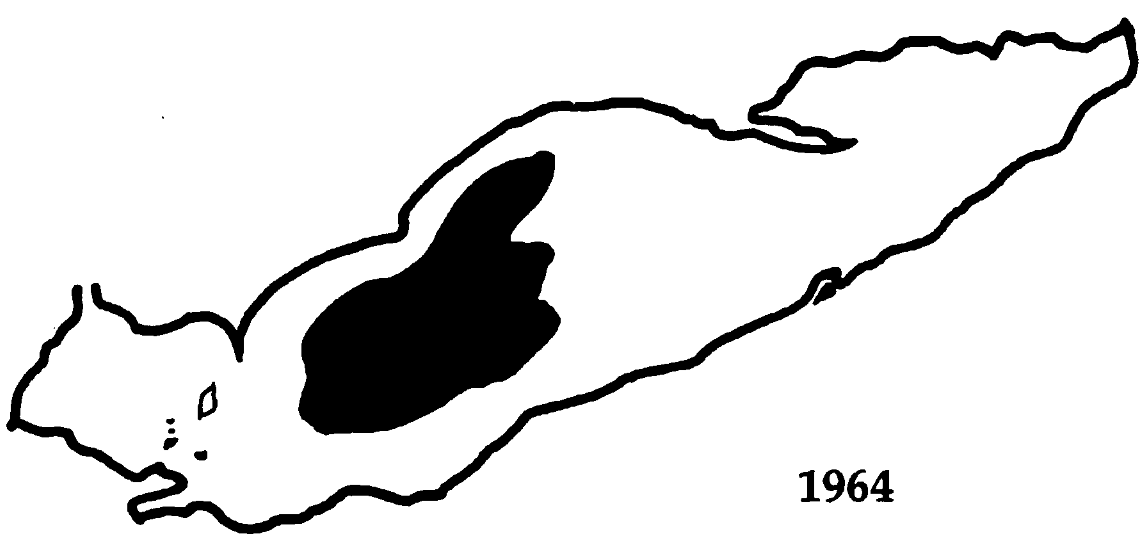
Figure 1. Anoxia Diagrams of Lake Erie 1930 - 1982.



Figures 2 and 3. Anoxia Diagrams of Lake Erie.

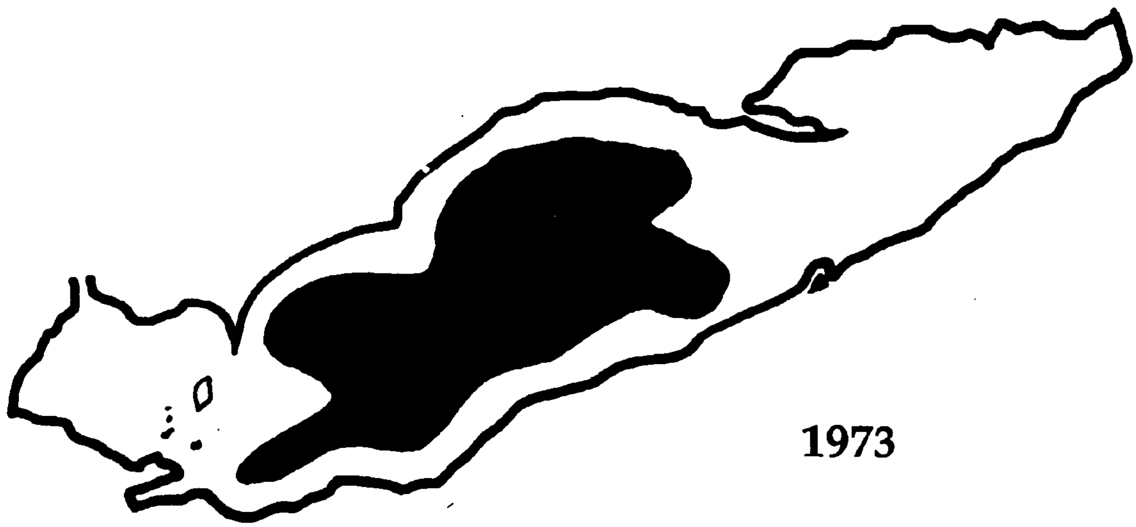


1930

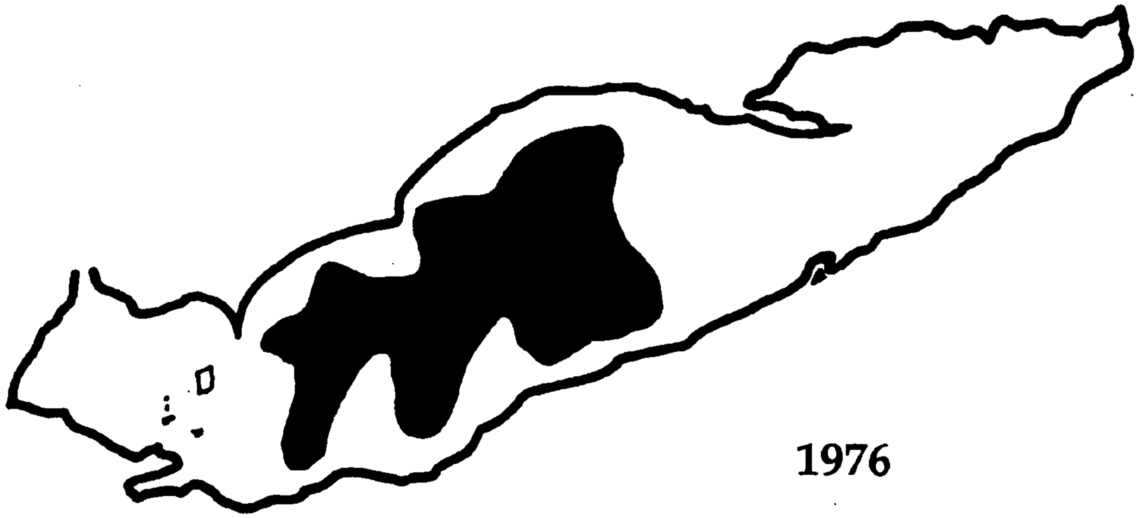


1964

Figures 4 and 5. Anoxia Diagrams of Lake Erie.



1973



1976

Figure 6. Anoxia Diagram of Lake Erie.

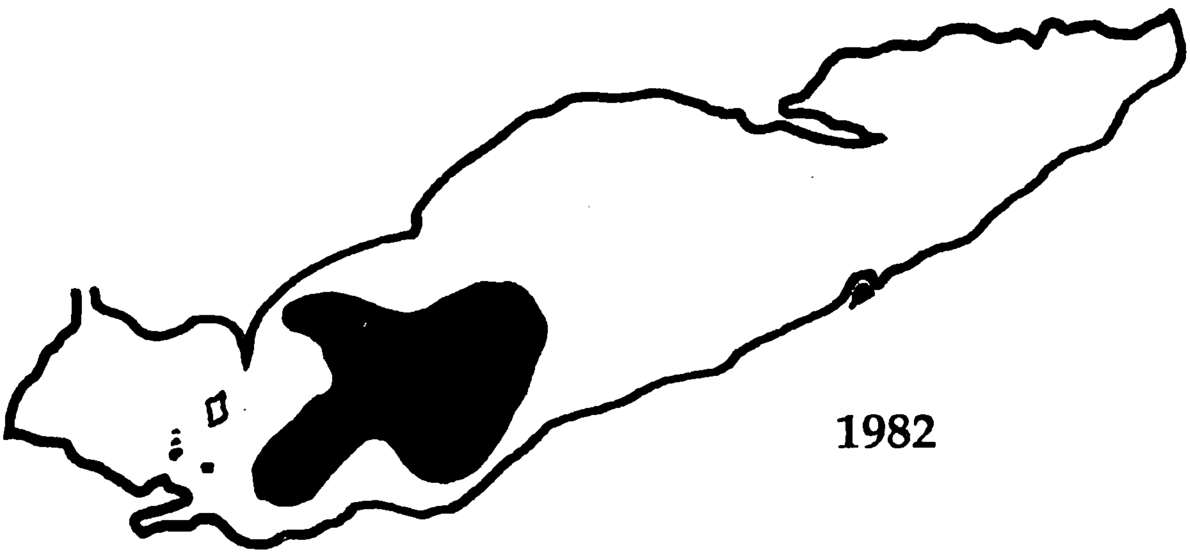


Figure 7. Three Basins of Lake Erie.

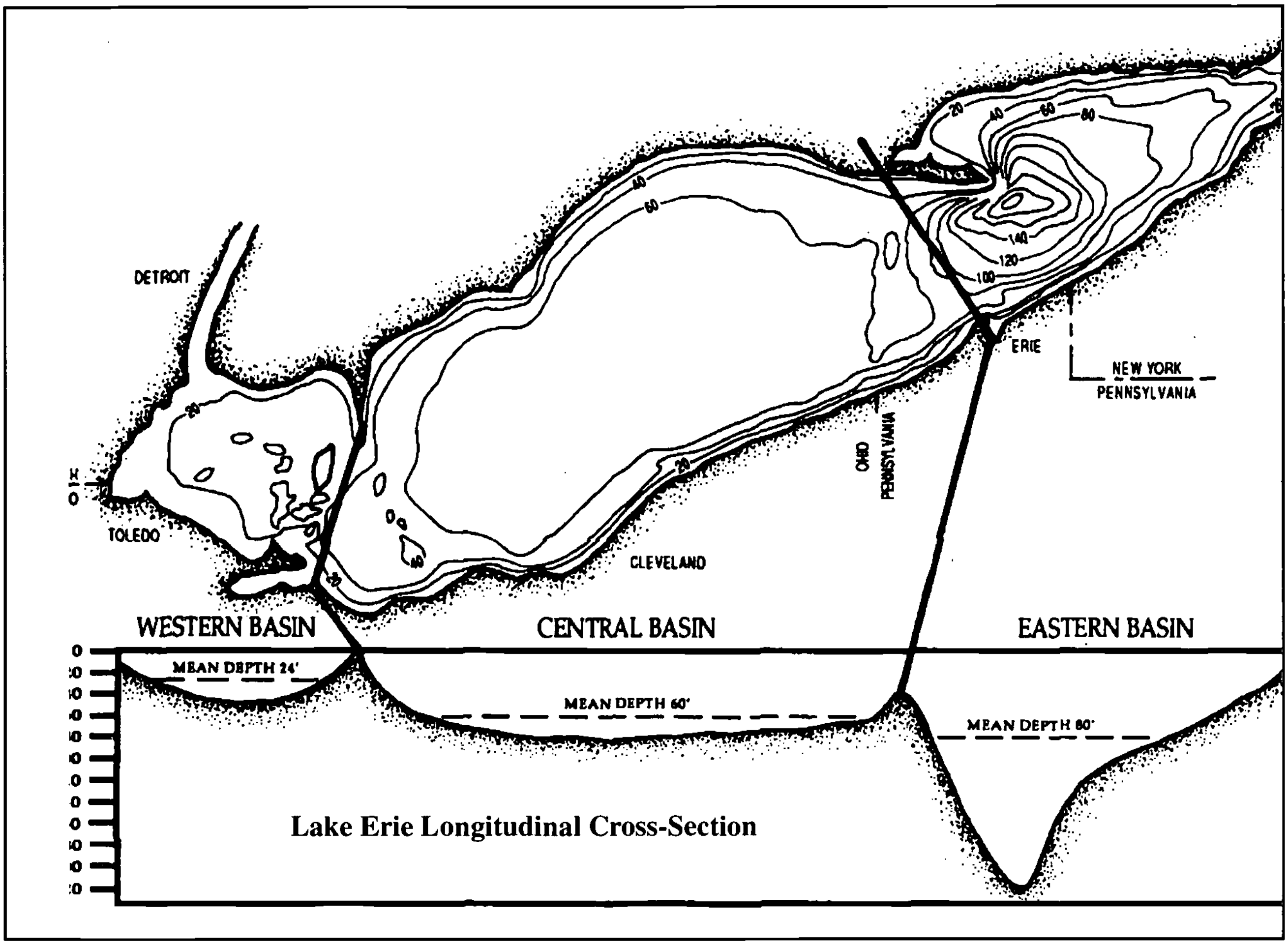
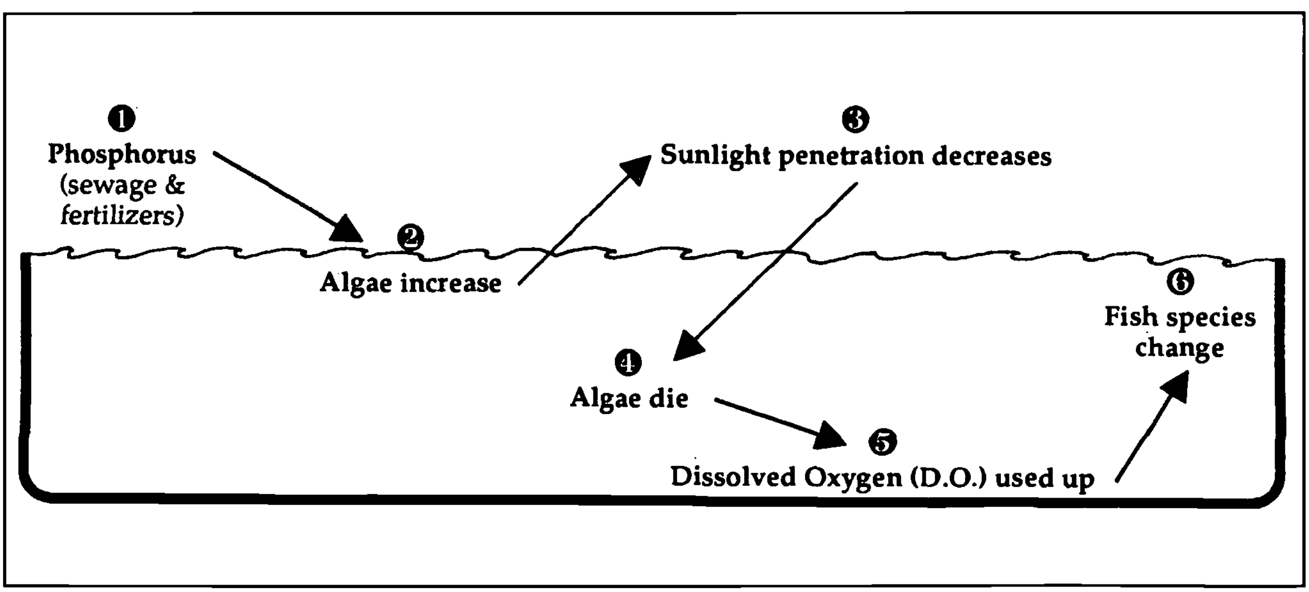


Figure 8. Cultural Eutrophication (Accelerated aging of lakes).



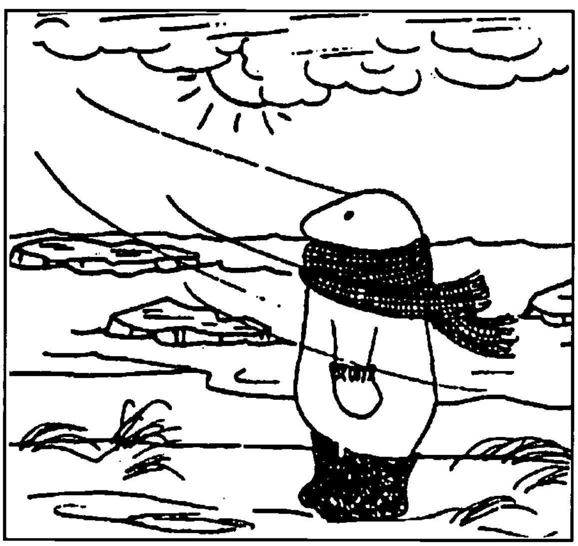
What factors impact ice coverage on the Great Lakes?

What impacts do you think ice on the Great Lakes might have on the surrounding area? Ice actually has a considerable impact. Shipping is shut down for a part of the year. Fish spawning can be impacted. Shoreline structures can be damaged. Even the climate itself is impacted by the ice coverage.

OBJECTIVES

In this activity you will demonstrate the ability to:

- Develop a hypothesis identifying the major factors involved in ice coverage of the Great Lakes.
- Design an investigation of relationships in the Earth System.
- Evaluate your hypothesis and suggest other investigations related to it.



Authors

Richard Meyer and Rosanne W. Fortner, The Ohio State University

Earth Systems Understandings

This activity focuses on ESU 3 and 4 (scientific processes and interacting subsystems).

Materials

- Handouts.
- Pencil or pen.
- Graph paper.
- Other materials depending on investigations developed.

Teacher's Notes

After students have recorded their own perceptions of ice coverage of the Great Lake and then compared them to actual data, they will be asked to develop an investigation that will test factors that they believe influence ice coverage on the Great Lakes.

The format that this activity takes is very open ended, and you can modify it to fit your style. Some possible variations include:

a. The class selects one investigation after a discussion and everyone does this investigation in groups or individually.

b. Students conduct their approved investigations outside of class in groups or individually.

After investigations are conducted, reports can be written, oral or in a conference style where each group would report results and conclusions. Then the class would try to determine what factors are most important in ice coverage of the Great Lakes from the data collected.

PROCEDURE

Part I.

You already have some knowledge about the Great Lakes and the freezing of lakes / water. Use your knowledge to predict how the Great Lakes freeze. Complete *Table 1. Predictions.* on the next page with your predictions.

Table 1. Predictions.

Predictions Lake:	#1-5 First to last to start freezing	Month it reaches max. ice coverage	#1-5 First to last to start melting	% of lake frozen in normal winter	% of lake frozen in severe winter
Lake Erie					
Lake Huron					
Lake Michigan					
Lake Ontario					
Lake Superior					

Part II.

6. What different conditions do you think influence the formation of ice on the Great Lakes? What factors did you consider in making your predictions?

7. Take a look at Table 2 (provided by your teacher) and then revise your predictions, if needed. Why do you suppose your answers differed from the information in Table 1? [Alternatively, use the Great Lakes Ice Model developed for computers by the Great Lakes Environmental Research Laboratory.]

8. Compare your list of factors in question 6 to lists made by other students in the class. Taking into consideration what you found in Table 2, hypothesize factors that you think might affect ice conditions on the Great Lakes and list them.

9. Discuss these factors with your teacher and class.

Answers

9. Brainstorm ideas. Some possible factors that might work well for investigation development in the next part of this activity are depth of the water, the volume of the lakes, wind patterns, and location of the lake (southern lakes are closer to warmer conditions).

Computer Program Source

A DOS or MAC version of "Great Lakes Ice Simulation" is available from: Publications, NOAA, Great Lakes Environmental Research Laboratory, 2205 Commonwealth Blvd, Ann Arbor, MI 48105-1593

Part III. Investigation Planning

10. Select one factor that you believe affects ice conditions on the Great Lakes and design an investigation that you can conduct to test your hypothesis that the factor you chose affects ice conditions. **Complete the form below and get it approved by your teacher before conducting your experiment.**

A. If ______________________ is a factor affecting ice formation then I expect the following to happen in my investigation ____

____

B. Materials needed:

____

____

____

____

C. Procedure: ____

____

____

____

____

____

____

____

____

____

D. Data - What data are you going to collect? (What will you record?) ______________________

Signatures: ______________________ __________ ______________________ __________

Student or Team Date Teacher Date

Answers

There are a variety of answers possible to questions 13 and 14. The following are provided as a starting point for discussion.

13.

a. Ice will form first in shallow harbors because of a faster heat loss for the volume of water. Thus, the shipping season will be shorter or icebreakers will be needed.
b. Ice formation will be later.
c. Ice formation insulates the water below and slows heat loss to the atmosphere. This means that the lake cannot warm the air (serve as a heat source) the way it does before the ice forms. Temperature moderation will cease, and temperatures along the shores will be colder than normal.
d. With ice covering the lake, evaporation will be slowed, and the lake will not contribute extra humidity to the atmosphere.
e. With no extra humidity being added to a storm system moving over the lake, there will be no added lake effect snow storms.

14.

a. Shipping season may be lengthened.
b. Evaporation levels may increase.
c. Lake levels may be lowered with increased evaporation.
d. Precipitation rates may increase with increased evaporation. We are not sure what will happen.

Evaluation

Have students draw a concept map of the interactions that they see as a result of question 13 or 14.

Other Resources

For more information, you may want to get a set of Global Change in the Great Lakes Scenarios and/or GLIMCES - Great Lakes Instructional Materials for the Changing Earth System. Both are from Ohio Sea Grant Publications, 1541 Research Center, 1314 Kinnear Rd, Columbus, OH 432121194. (614)292-8949

Part IV. Investigation Results

10. Produce a chart or graph of the data you collected in your investigation.

11. Did the results come out as you expected? If not, why not?

12. What other investigation would you like to do based on the results of this one?

Part V.

Record your thoughts about each of the following and then discuss them with your class.

13. When there is ice on the Great Lakes, how would it affect:

a. shallow harbors.

b. deep harbors.

c. temperature of air above the lake.

d. humidity of the air above the lake.

e. "lake effect" winter storms.

14. Some scientists predict that global warming could increase the average world temperature by 1.5 to 4.5° Celsius. How do you think global warming might affect the Great Lakes in regards to:

a. length of shipping season (currently about 10 months).

b. evaporation rate of lake water.

c. lake levels.

d. precipitation rates.

Table 2. From Phillips, D.W. and J.A.W. McCulloch. 1972. *The Climate of the Great Lakes Basin.* Climatological Studies Number 20. Environment Canada. Toronto.

Ice Coverage and the Great Lakes

Normal winter ice events	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Early Ice Cover	Jan 20 - 30	Jan 25 - Feb 5	Jan 25 - Feb 5	Jan 15 - 25	Jan 25 - Feb 5
Mid - Season Ice Cover	Feb 25 - Mar 5	Feb 20 - 28	Feb 25 - Mar 5	Feb 1 -10	Feb 15 - 25
Maximum Ice Cover	Mar 25 - Apr 5	Mar 15 - 25	March 20 - 30	Feb 20 - 28	Mar 10 - 20
Early Decay (melting) Period	April 1 - 10	Mar 20 - 30	Mar 25 - Apr 5	Feb 25 - Mar 5	Mar 15 - 25
Percentage of Lake Covered By Ice at Maximum:					
Mild Winter	40	10	40	50	8
Normal Winter	60	40	60	95	15
Severe Winter	95	80	80	100	25

Framework for Earth Systems Education

UNDERSTANDING #1: Earth is unique, a planet of rare beauty and great value.

- The beauty and value of Earth are expressed by and for people of all cultures through literature and the arts.
- Human appreciation of Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation of Earth through their responsible behavior and stewardship of its subsystems.

UNDERSTANDING #2: Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

- Earth is vulnerable, and its resources are limited and susceptible to overuse or misuse.
- Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- When considering the use of natural resources, humans first need to rethink their lifestyle, then reduce consumption, then reuse and recycle.
- Byproducts of industrialization pollute the air, land, and water, and the effects may be global as well as near the source.
- The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

UNDERSTANDING #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

- Biologists, chemists, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- Direct observation, simple tools, and modern technology are used to create, test, and modify models and theories that represent, explain, and predict changes in the Earth system.
- Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- Scientific study may lead to technological advances.
- Regardless of sophistication, technology cannot be expected to solve all of our problems.
- The use of technology may have benefits as well as unintended side effects.

UNDERSTANDING #4: The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

- The subsystems are continually changing through natural processes and cycles.
- Forces, motions, and energy transformations drive the interactions within and between the subsystems.
- The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- Each component of the Earth's system has characteristic properties, structure, and composition, which may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface.
- Weathering, erosion, and deposition continuously reshape the surface of the Earth.
- The presence of life affects the characteristics of other systems.

UNDERSTANDING #5: Earth is more than 4 billion years old, and its subsystems are continually evolving.

- Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up Earth have been recycled many times.
- Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
- Evolution is a theory that explains how life has changed through time.

UNDERSTANDING #6: Earth is a small subsystem of a Solar system within the vast and ancient universe.

- All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
- All bodies in space, including Earth, are influenced by forces acting throughout the solar system and the universe.
- Nine planets, including Earth, revolve around the Sun in nearly circular orbits.
- Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
- The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
- The rotation of Earth on its axis determines day and night.

UNDERSTANDING #7: There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

- Teachers, scientists, and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
- Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
- Scientists from many cultures throughout the world cooperate and collaborate using oral, written, and electronic means of communication.
- Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
- Many people pursue avocations related to planet Earth processes and materials.

The development of this framework started in 1988 with a conference of educators and scientists and culminated in the Program for Leadership in Earth Systems Education. It is intended for use in the development of integrated science curricula. The framework represents the efforts of some 200 teachers and scientists. Support was received from the National Science Foundation, The Ohio State University, and the University of Northern Colorado.

For further information on Earth Systems Education, contact the Earth Systems Education Program Office, 2021 Coffey Road, The Ohio State University, Columbus, OH 43210.

Ohio Sea Grant Education Program

The Ohio Sea Grant Education Program has focused on the development of curriculum materials to enhance the quality of science education, the infusion of these materials into the classroom, and teacher training. Materials developed emphasize real-world issues including, most recently, the impact of global climate change on the region.

Earth Systems - Education Activities for Great Lakes Schools (ES-EAGLS)

ES-EAGLS are designed to take a concept or idea from the existing school curriculum and develop it in a Great Lakes context, using teaching approaches and materials appropriate for students in middle and high school. The activities are characterized by subject matter compatibility with existing curriculum topics, short activities lasting from one to three classes, minimal preparation time, minimal equipment needs, standard page size for easy duplication, suggested extension activities for further information or creative expression, teachability demonstrated by use in classrooms, and content accuracy assured by critical reviewers.

Each title costs $8.00

Land & Water Interactions in the Great Lakes EP-082
Great Lakes Climate & Water Movement................EP-083
Great Lakes Shipping EP-084
Life in the Great Lakes EP-085
Great Lakes Environmental Issues EP-086

The Great Lakes Solution Seeker

This compact disk will help educators teach their students about the Great Lakes by providing online or simulated Internet connections to comprehensive data sources, resources, graphics, and activities. The data and activities work best on Macintosh system 7.0 or higher. Most sections are also usable with Windows 95. EP-081 *$10.00*

Global Change in the Great Lakes

Ten scenarios (2-4 pp. each) and an introduction explain climate models and are packaged in a file folder. The scenarios describe the scientific community's prevailing interpretations of what may happen to the Great Lakes region in the face of global warming but are written in terms the general public can understand. The scenarios explore water resources, biological diversity, shipping, agriculture, airborne circulation of toxins, estuaries, eutrophication, recreation, fisheries, and forests. EP-078 *$6.00*

Great Lakes instructional material for the changing earth system. Provides integrative activities on global change to educators and decision-makers and must be purchased with EP-078 (above). Printing donated by Brunswick Marine. Cost includes EP-078 and additional postage charge. EP-080 *$9.00*

Summary of the global change scenarios (above) for the Great Lakes region. 2 pp. FS-057 *free*

Oceanic Education Activities for Great Lakes Schools (OEAGLS)

OEAGLS (pronounced "eagles") were developed from 1985 to 1991 for students in middle school grades. The ES-EAGLS (see above) are modifications of OEAGLS. Refer to that series description. Each OEAGLS title consists of a student workbook and a teacher guide.

Each title costs $3.00

Yellow Perch in Lake Erie EP-009
Shipping on the Great Lakes EP-013
Geography of The Great Lakes EP-014
Ohio Canals EP-015
The Great Lakes Triangle EP-017
Knowing the Ropes EP-018
We have Met the Enemy..EP-021
It's Everyone's Sea: Or is it? EP-022
A Great Lakes Vacation EP-024
Storm Surges EP-025

OEAGLets

Three activities provide students in primary grades with activities relevant to Lake Erie. The activities apply to all primary subject areas. *Each title costs $5.00*

Lake Erie - Take a Bow EP-031
Build a Fish to Scale EP-032
A Day in the Life of a Fish EP-033

Additional Educational Materials

Holling C. Holling's *Paddle-to-the-Sea* published by Houghton Mifflin Company. 28 pp. EP-076/B *$10.00*

Supplemental curriculum activities to accompany Holling C. Holling's Paddle-to-the-Sea. 168 pp. of activities for grades 3-6: science, social studies. EP-076 *$10.00*

The great Lake Erie. Sixteen experts present different facets of the importance of the Great Lakes to North America and the world. Written in 1987 and reprinted by Ohio Sea Grant in 1993. 148 pp. EP-079 *$10.00*

The Ohio Sea Grant Education Program: Development, Implementation, Evaluation. EP-075 *$8.00*

Abstracts of research in marine and aquatic education: 1975-1990. Brief review of the topics addressed in marine and aquatic education research, including knowledge and attitude testing of various groups, models of program evaluation, and comparisons of impact of education techniques. 24 pp. EP-077 *$2.00*

Costs cover publication, postage, and handling.

Make payment payable to The Ohio State University in U.S. dollars. Mail your request and payment to: Ohio Sea Grant Publications, The Ohio State University, 1314 Kinnear Road, Columbus, OH 43212-1194. ›ne 614/292-8949 or e-mail (cruickshank.3@osu.edu) if you have any questions or would like to place a large order.

Other ES-EAGLS

Land & Water Interactions in the Great Lakes

Geography and Technology

- How well do you know the Great Lakes?
- What can GLIN tell us about land and water interactions?

History of Land and Water Interactions

- When did the rocks in the Great Lakes basin form?
- How were sedimentary rocks in the Great Lakes basin formed?
- How did rocks and rivers shape the Great Lakes?
- What evidence of glaciation exists in the Great Lakes region?
- What evidence of glaciation and geologic processes can be found on Great Lakes beaches?

Land and Water Interaction Today

- What causes the shoreline to erode?
- Can erosion be stopped?
- How fast can a shoreline change?
- How much land has been lost?
- What natural wonders of the Great Lakes relate to land and water interactions?
- How can a concept map represent land and water interactions?

Great Lakes Shipping

Great Lakes Shipping

- What products are carried on the Great Lakes?
- What is the most economical form of transportation?
- Which transportation method uses the least energy?

World Connection

- Where go the boats?
- How do ships go from one lake to another

Language

- How have ships and sailing influenced our language?

Great Lakes Triangle

- What is the Great Lakes Triangle?
- How can disappearances within the Triangle be explained?
- What happened aboard the *Edmund Fitzgerald*?

Canals

- How were early canal routes determined?
- How did the canals affect Ohio?

Life in the Great Lakes

Organisms in the Lakes

- How does a dichotomous key work?
- What are the characteristics of some Great Lakes fish?
- How do fish get their names?
- How are shorebirds adapted for feeding?
- What do scientists know about invader species of the Great Lakes?

Ecological Relationships

- Who can harvest a walleye?
- What does a biomass pyramid tell us?
- What is a food web?
- What factors affect the size of a natural population? (A Great Lakes fish example)
- How can a natural fish population be managed?

Estuary Values and Changes

- What is the role of plants in an estuary?
- How does the estuary serve as a nursery?

Great Lakes Environmental Issues

Resources and Reactions

- How big is a crowd?
- Who owns the resources of the Great Lakes?
- How (environmentally) insulting can we get?
- How skillfully can you read science articles?

Toxins in the Great Lakes?

- How much is one part per million?
- Which fish can we eat?
- How should the public heath be protected?
- How do toxins move through the food chain?
- How big is the problem of airborne toxins?
- Where do all the toxins go? (internal view)
- Where do all the toxins go? (external view)
- Could we live without chlorine in the Great Lakes?

Watershed and Basins Issues

- What can we learn about water quality in a river?
- What happens when nutrients enter a lake?
- What is the status of the Great Lakes Areas of Concern?

Oil Pollution

- Where does oil pollution come from?
- How can an oil spill be cleaned up?
- How does an oil spill affect living things?
- What if . . .? (a Great Lakes investigation)

Sea Grant
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http://www-ohiosg.osc.edu/OhioSeagrant

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