Great Lakes Shipping and Lowered Lake Levels

The Great Lakes have been used as an avenue of transport for goods of all types for hundreds of years. Native Americans, French voyagers, and early pioneers used the lakes to move goods easily from one point to another. Today, nearly 200 million tons of cargo are shipped on the Great Lakes every year. Coal, iron ore, grain, and building materials such as gravel and cement are shipped in bulk. It is the most economical way to ship large quantities of products. However, there are limitations involved in the shipping industry. The formation of ice on the lakes cuts the shipping season by about two months per year. Another limiting factor is water levels. The Great Lakes’ levels fluctuate seasonally and are sensitive to differences in rainfall and evaporation rates which can change from year to year.

Many areas in the Great Lakes are shallow and thus must be dredged seasonally to keep the water levels deep enough for the loaded vessels to pass safely. Many harbors and the locks and canals, as well as the entire western basin of Lake Erie have barely enough water depth to allow fully loaded vessels to pass under normal conditions. Often cargoes have to be tightened because of lower lake levels that result from periodic droughts.

But what if there were a major drop in lake levels that persisted for a long time? Climatologists, using computer models, have indicated that because of the greenhouse effect an atmospheric warming of up to 4.5°C could occur by the year 2055. This would cause very high rates of evaporation in the Great Lakes Basin, lowering the levels of the lakes by as much as 3 m. Such a drop could have serious effects on the shipping industry. On the other hand, warmer temperatures could lessen the impact of winter on the industry — perhaps shipping can continue year-round, making up for losses at other times of the year.

This set of activities will help to show the dramatic changes that can be expected in the critical shipping sector of the economy. Students should be alert to both positive and negative aspects of the changes anticipated.

When a ship is fully loaded, it floats lower in the water than it would with a lighter load. The depth of water displaced is called the draft of the vessel.
Activity A: Will global warming change the economics of the shipping industry?

Changes in lake levels will impact the shipping industry. How much? Will losses be offset by gains in length of season or changes within the industry? This math activity sets the stage for discussion of shipping futures.

Earth Systems Understandings
This activity focuses on ESU #3 (science methods and technology), #4 (interactions), and #7 (careers and hobbies). For a complete listing of the Understandings, see the introduction to this book.

Scenario Reference
#3, What could happen to Great Lakes Shipping?

Materials
- calculator
- copy of the "Impact of Lake Levels on Vessel Carrying Capacity" chart.

Objectives
Students completing this activity will be able to:
- calculate the potential loss of revenue for ship owners if lake levels drop;
- evaluate the economic impact of a shipping season increased to year-round;
- describe the overall economic impact on the Great Lakes shipping industry.

Procedure
1. Examine the data table, noting the following:
   - Vessel Length indicates the five common lengths for Great lakes freighters.
   - Per Trip Carrying Capacity tells what net weight (cargo only) the freighter can haul.
   - Capacity Per Inch of Draft indicates how many extra tons of cargo the vessel would be carrying if it were loaded so that it floated one inch lower in the water.

2. Use the data table to answer the following questions.
   a. A small shipping company uses one of its smaller vessels, 635 feet long, to supply coal from Toledo to Detroit. They charge $2 per ton for this service. How much would they charge for the full load of coal?
   b. How much would the company lose per trip during a drought if the lake level went down two feet and they had to reduce their cargo level? Would these losses have a serious effect on a small shipping company?

Answers
a. 22,064 T x $2 per ton = $44,128

b. 24 inches x 107 tons/inch x $2/ton = $5136 lost per trip. This would be a serious loss, cutting revenue by more than 10 percent.
### Impact of Lake Levels on Vessel Carrying Capacity (net tons)

<table>
<thead>
<tr>
<th>Great Lakes Bulk Carriers</th>
<th>Vessel Length (feet)</th>
<th>Per-trip Carrying Capacity</th>
<th>Capacity Per Inch of Draft*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,000</td>
<td>69,664</td>
<td>267</td>
</tr>
<tr>
<td></td>
<td>806</td>
<td>34,720</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>767</td>
<td>28,336</td>
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<tr>
<td></td>
<td>635</td>
<td>22,064</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>501</td>
<td>13,776</td>
<td>71</td>
</tr>
</tbody>
</table>

*Capacity per inch of draft reflects the incremental tonnage carried at normal loaded draft.

c. An average charge for a shipping company is $6 per ton for carrying iron ore from Duluth, Minnesota, to Cleveland, Ohio. If a company used a 1,000-foot vessel, how much would the total charge be for the trip?

d. Would this be pure profit for the owners? Explain.

e. Imagine that lake levels dropped by 8 inches. How much less revenue would the company earn per trip in a 1,000-foot vessel?

f. In the global climate change worst case scenario, the atmosphere warms dramatically and the lakes drop 10 feet. How much would the shippers lose per trip in this situation? Would the trip be possible?

g. Many industries in the U.S. and Canada, as well as in other parts of the world, rely on the materials shipped on the Great Lakes. The Lake Carriers would need to charge more per ton of goods delivered if they had to carry less per trip because of lower water levels. What types of goods could we expect to increase in price because of this? Discuss with the class how all our lives would be affected by this change.

c. 69,664 tons x $6/ton = $417,984

d. Fuel costs, debt service, salaries for sailors and office personnel, insurance premiums, upkeep on the vessel would have to come out of these revenues.

e. 8 inches x 267 tons/inch = 2136 tons less. 2,136 tons x $6/ton = $12,816 less per trip

f. 120 inches x 267 tons/inch x $6/ton = $192,240 per trip loss

g. Products dependent on grains (cereal, bread, animal feed), steel products, coal and oil (energy costs), building materials would all increase in price. This could cause people to buy lower-priced imported goods.
h. The companies that are members of the Lake Carrier's Association own a total of 62 vessels. The average number of crew members per vessel is 28, but a total list of 42 must be available to cover vacations and sick leave. Office personnel for the entire association numbers around 500. If all of these workers receive salaries at about the U.S. average of $30-40,000, how much would their yearly gross be?

i. Consider all of the industries totally or partially dependent on Great Lakes shipping and the employees of the shipping industry. How would you characterize the effect that global climate change might potentially have on economies in general?

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**ICE EFFECTS**

The scenario up to this point does not take into account the other effects of warming, namely that ice patterns are likely to change, and there may be the possibility of year-round shipping. If goods are shipped and people are paid year-round, the picture might not be so bleak.

j. The volume of shipping in 1992 was about 105.8 million tons for U.S. flag vessels and 69.8 million metric tons for Canadian flag vessels. One metric ton (or tonne) equals 1.1 U.S. tons. Calculate the total weight of Great Lakes shipping in the ten month 1992 season. This is theoretically 5/6 of what it could be if the lakes were ice-free or at least passable all year. Find the potential shipping volume for a 12-month season.

Of course other costs would also expand to 12 months. The vessel crews should be paid more per year, and insurance and vessel upkeep would increase as well. Discuss with the class whether a 12-month shipping season would be economically feasible for shippers.
OTHER CONSIDERATIONS

Shipping is a business, and in the Great Lakes many people depend on it. It is unlikely that as a business it would sit idly by and let the global warming changes destroy its vitality.

k. Brainstorm with the class how shipping can change to accommodate climate effects. Remember:

- Global warming will not happen overnight but slowly and with some sporadic changes as well.
- Technology does not stand still.
- We can only dredge so deep before we hit bedrock in some areas.
- There is no law that governs the size and shape of Great Lakes ships although the size is constrained by the depth, width, and length of channels and locks.
- Shipping is a business and must make a profit to survive.
- Alternative means of cargo transport may also change.
- The channels in the western basin of Lake Erie would need to be dredged in order for the freighter to get to Huron.

REVIEW QUESTION

The shipping industry will face many challenges with global warming. Make a concept map showing the impact of global warming on shipping, and extend the map to include responses by the industry and others in the region. Will shipping be a winner or a loser in the climate game?

EXTENSIONS

1. Do the OEAGLS (Oceanic Education Activities for Great Lakes Schools) activities related to water transportation:

   EP-013. entitled “Shipping on the Great Lakes” examines the flow of goods from one section of the Great Lakes to another and compares the cost of shipping goods by truck, rail and air.

   EP-020. “Shipping: The world connection” dramatically shows the importance of Great Lakes shipping in world commerce. It examines the extent of trade through the Port of Toledo as an example of the impact of the region, serving nearly two-thirds of the world in one year.
EP-015. The "Ohio Canals" activity details how locks work by having students create a model out of milk cartons.

2. Trace how boats and shipping have changed on the Great Lakes through history. How did different vessel designs adapt to changing water levels before the lakes had locks and dams?

REFERENCES

Cash, Jim. 1994. The current status of shipping on the Great Lakes. The Ohio State University, unpublished MS paper.


Activity B: What economic costs and benefits might coastal communities experience from lower lake levels? (A tale of two harbors)

To people living on the shores of the Great Lakes, the small seasonal fluctuations in the Lakes’ levels, measured in inches or a couple of feet at most, are of little concern. Lower levels could mean a slightly wider beach or a few exposed rocks near shore. Slightly higher levels could result in waves lapping a few feet further up the beach toward shore. But what would the effects be if there were a drastic change, several meters, in the water level of the Great Lakes? This activity will explore different ways that a small town might be affected and how it might react.

Many communities are dependent upon the Lakes for recreation, shipping and transportation, tourism, and water supply. These communities could be seriously affected by a major lowering of the Lakes’ levels. One such community is Huron, Ohio, located on Lake Erie at the mouth of the Huron River. The Huron River drains an agricultural area with minimal pollution from cities or industry. The town has a population of about 9,000 and has a small port facility for the handling of iron ore, limestone, and grain. It is also a railhead for the further distribution of these products. Important to the local economy are five marinas located within the city limits, serving a large number of Lake Erie recreational boaters.
Another lakeshore community is Green Bay, Wisconsin. This area has been designated as an Area Of Concern (AOC) by the International Joint Commission. The Green Bay area has a population well over 150,000, with the largest concentration of paper mills in the world located along the Fox River. The Fox flows into Green Bay, a large but shallow bay of Lake Michigan. Sediments brought into Green Bay by the Fox River carry toxins such as PCBs, heavy metals, pesticides, and dioxins. The industries causing most of the pollution have existed for a long time, resulting in large accumulations of toxic sediments on the bottom of Green Bay. Some headway has been made in getting cleanup started, but the completed job will take a long time. Add to this scenario the possibility of lowered lake levels because of global climate change, and the city has possibly another very difficult problem. If dredging is needed to deepen the harbor for shipping, some of the toxic-laden sediments could be exposed as dry land.

Both Green Bay and Huron stand to be heavily impacted in a variety of ways, some positive and some negative, if Great Lakes water level drops significantly. In this activity, students may study either community or both. Procedures differ somewhat, but results will be comparable to allow for serious discussion of impacts.

**Objectives**

Students who have completed these activities will be able to:
- use maps and aerial photos to examine and calculate land area changes
- calculate and interpret some economic costs and benefits of lowered lake levels as they would be felt by coastal cities
- analyze the impacts of lowered lake levels on different lakeshore communities.

**Procedures**

If both communities will be studied, divide the class in half so that some investigate Huron and others Green Bay. Depending on time and resources available, it may be necessary to limit discussion to only one of the communities. Set up teams or small working groups.

**Teacher Note:** The directions for the activity are written for students. Measurements are in English units because they appear on maps that way. Conversion information is provided as appropriate.
1. Orienting to the area

Familiarize yourself with the community your team is studying. Look at the aerial photos and the maps provided and answer the following questions. Use map scales as appropriate.

a. What kinds of natural and cultural features do you see? List several. What appear to be the major land uses in the city? Do you see features that could be associated with quality of life in the area? Explain.

b. Approximately how wide is the river where it enters the lake? What kinds of features border the river in its first mile inland?

c. About how many miles of shoreline are bordered by the main part of the city? Is the shore dominated by residences, farms, or other features?

d. What is the maximum depth of the Great Lake in the area of the topographic map segment? What is the depth of the ship channel coming into the river?

2. Finding the new shoreline.

If Great Lakes water level were to drop 3 meters (10 feet) or even half that amount in the next few decades as a result of global warming, as some computer models predict, shallow offshore areas would become dry land.

Look at the topographic map of the community and its shore. Measure how much new land will result by using the following method.

a. Find the soundings, marked in feet, out in the lake or bay. All areas that are 10 feet deep or less could eventually become marshland or dry land. Construct a 10 foot depth contour to determine where the new shoreline would be. If there are no 10s to connect, interpolate the depth between soundings.

b. Further out from shore, the water gets deeper and sometimes much shallower again. These shallow areas should be included in your tracings, since they could appear as islands or peninsulas when water levels drop.

a. Alert students to shapes, shadows and layouts of features that indicate such things as schools (with running track), storage tanks, suburban streets, etc. Green Bay appears to have more industrial development along the shore; wetlands are diked (managed). Huron is residential along most of the shore and has less population density.

b. Huron River: 255 feet wide, bordered by marinas, warehouses (boat storage), and at the mouth some slips for lakers in port. Fox River: about 800 feet wide, bordered by large buildings and grounds (industrial area).

c. Huron: small city, 1-2 miles; residential and natural areas. Green Bay: industry and managed wetlands, also about 1-2 miles visible on these reference images.

d. Huron: 35 feet, ship channel 25 feet Green Bay: 19 feet, ship channel 24 feet.

Students are allowed to determine for themselves how far to measure. If measuring from the city limits, they could calculate approximately how much shoreline would be added to each city and compare these numbers.

The images included for this activity are from previous years. If students desire more recent photographs, they should obtain them. This will enable them to discover what industries/structures/land use exist currently in these cities.
3. Determining land acquisition.

a. Obtain a transparent copy of the included grid page. Based on the scale of the map, one square is equal to 1,000,000 sq ft (1000 ft x 1000-ft box). Place it over the map of the newly exposed lake bottom (from Part B), and count the squares to determine how far lakeward, on the average, the amount of new land extends.

b. How many square miles of land would the lakeshore city acquire?

c. Notice the difference in scale between the topographic map and the aerial photo of your city. Sketch in the approximate position of the new shoreline on the aerial photo. Estimate how many homes or other property segments in the city would have a "new and bigger" backyard.

d. Try to imagine what the area would look like from the air if the water level dropped 10 feet. Sketch in the new landforms on your copy of the aerial photo.


Discuss who could or should benefit from the sale of this new land. Should current lakeshore landowners automatically acquire the new land without paying for it? Should the city own it and use it for the good of all? These are questions that people may have to find solutions for in the next few decades.

One factor in the decision will be the property value. In 1993 the value of near-shore property was as follows:

- Huron: $250,000 to $300,000 per acre
- Green Bay/Fox River: $150,000 per acre

While the figures may be related to zoning decisions made by the cities, they may also indicate aesthetic value or desirability for certain uses. The dollar value here should be calculated based on the answer to C2.

Conversions:

One sq mile = 640 acres = 27,878,400 sq ft.
5. Keeping the Harbor Open

Great Lakes freighters require a depth of about 25 feet for safe navigation in protected waters such as Huron Harbor. Currently, the Army Corps of Engineers is responsible for the clearing of sediment, brought downstream by rivers, from the harbor and approach channel located in the Lake. This is an expensive procedure requiring the use of a large floating dredge. If lake levels dropped the projected 10 feet, dredging an additional 10 feet would compensate for the lower water levels and would suffice to keep the freighter traffic moving.

a. Using the map provided, find the areas that represent the approach channel and turning basin for lake freighters using the harbor. Also locate the “slips” (docking areas) where freighters load or unload their cargoes of grain, limestone or iron ore.

b. With the scale on the map, measure and calculate
   a. average width of entrance channel multiplied by one mile (to cover access to the harbor from the lake)
   b. total area of slips and turning basins in the harbor.

c. Calculate the total square feet of the area that would need to be dredged (approximately).

d. If lake level dropped 10 feet, how many cubic feet of sediment and rock would have to be removed to maintain the depth of the harbor? Charges for dredging are based on how many cubic yards are removed. To convert cubic feet to cubic yards, divide your answer by 27.

e. Dredging first removes sand and mud, but then it may reach bedrock. Dredging sand and mud costs about $5 per cubic yard. However, the present channels are already down to bedrock in most areas. The cost to break up the bedrock and remove it is about $75 per cubic yard. Calculate the cost for dredging if all the dredged material is bedrock.

Remember that in many coastal areas of the Great Lakes the sediments have toxic chemicals in them, and these would be disturbed by dredging. Dredged sediments may be put into a safe disposal site within concrete or steel walls, out from the shore. Both aerial photos show the locations of such containments. Discuss the issues that arise when potentially toxic sediments are stored in this way.

Answers will vary in this section, but will generally come out to a ratio of 1:4, with Green Bay's challenges and opportunities being four times that of Huron's.
CONCLUSION

These exercises demonstrate some of the types of effects that global climate change could have on shoreline and port communities. Imagine the disruption on a worldwide basis if projected global warming occurs. Remember that in most coastal areas, sea level will RISE, probably with even greater consequences than the Great Lakes drop in water levels will cause. Be sure students discuss the personal life-style changes that would help to prevent global warming from increasing. Activities on RESPONDING will assist.

REVIEW QUESTIONS

1. What are some ways that people living in a lakeshore town such as Huron or Green Bay would be affected by a 3-meter drop in Lake Erie’s level? Rank the issues involved on a scale where 10 = most significant. Which of the issues, when resolved, will determine whether the community is a winner or loser in the global warming story?

2. Do you feel that the Federal government would pay the large sum of money needed to deepen Great Lakes harbors? Think of the size of a given harbor, the use it gets, and the large amount of money. If the Federal government wouldn’t pay this sum, what would it mean to the port city to lose its shipping terminal and its marinas?

3. Earth System scientists use data in the form of images as well as numbers. Evaluate the types of images used here for their value to scientists (e.g., what can be learned from them, what advantages do they have over other technologies, what are their limitations?).
EXTENSIONS

1. Hold a town council meeting with students assigned to represent different interest groups (city officials, local conservation groups, realtors, shoreline homeowners) who would be responsible as a group to decide to what use the "new land" would be put.

2. The marsh areas bordering the Fox and Huron Rivers could become dry land if lake levels drop significantly. Many species of fish use these areas for spawning. How might the Lake's food chain be disrupted if marshes like these disappear? Use activities in other parts of this volume as a start to finding your answers.

3. The Green Bay area communities have developed and are implementing a Remedial Action Plan (RAP) to clean up pollution problems and restore Green Bay to full uses of the water. Write to the Wisconsin Department of Natural Resources for information about the status of the RAP, and discuss the difficulties of implementing such a plan.

Information sources

- City Hall, Huron, OH
- U.S. Army Engineer Districts, Buffalo and Detroit
- Green Bay RAP
Green Bay aerial view
Huron aerial view
Activity C: How can we map changes in water level?

The current concerns with global warming have prompted an awareness of secondary problems such as changes in water levels of major lakes and oceans. We can address this problem with an activity designed to increase student awareness of the effects of changing water levels. This activity is also helpful in teaching students how to interpret and use contour maps.

Objectives

When students have completed this activity, they will be able to:

- create and interpret a contour map;
- describe how contour maps can be used to study changes in water levels and land elevations;

Procedure

1. Cut off the top of a 2-liter bottle about 15 to 20 cm from the top. We will use the bottom section without the colored plastic bottom cup. Use a bottle that will stand without a bottom cup.

2. Use clay to form a hill and any other landscape features you choose in the bottom of the bottle. You may choose to leave one area depressed as to simulate a pond or lake.

3. Make marks on the side of the container to indicate 1 centimeter increments from the bottom to the top.

4. Record the level of the land/clay in accordance with the marks on the side of the container. How many centimeters does your clay landscape rise from the bottom of the container?

5. Slowly pour water into the container and onto the clay landscape. Add water until it becomes level with the first centimeter mark from the bottom of the clay. Describe how much of the clay landscape is now covered with water.

6. Put two or three small marks on the rim of the bottle. These will correspond to marks that will be made on the transparent sheet to help keep its position constant.

Earth Systems Understandings

This activity addresses ESU #3 (science methods and technology) and #4 (interactions). Refer to the introduction of this book for a full description of the understandings.

Global Change Scenario

#1. What will happen to water resources?

Materials

(for each group of four students)

- 2-liter soft drink bottle
- small plastic house/hotel piece, as from a monopoly game (optional)
- lump of clay, enough to fill the bottom of the 2-liter bottle
- clear overhead transparency or plastic sheet
- metric ruler
- overhead transparency marker or grease pencil
- container for holding water
7. To construct a contour map, place a blank transparency on top of the container. Draw a circle on it to indicate where it touches the rim of the container, and mark your registry points from the rim as well.

8. Look straight down from above the bottle (not at an angle) and draw a line on the transparency where the water meets the clay (the shoreline).

9. Take off the transparency and add more water to the bottle until it is level with the second centimeter mark. Replace the transparency in exactly the same location (lining it up with the dots and rim circle). Draw another line on the transparency as in Step 8 to indicate the new water level.

10. Continue adding water a centimeter at a time and drawing the contour line (where the water meets the clay) until the clay is completely submerged.

11. The finished transparency can be traced onto a sheet of paper for future reference.

**INTERPRETING THE MODEL**

After constructing your contour map, answer these questions.

A. How can contour maps be useful to geologists, farmer, marina owners, boaters, or others whose work is directly related to the coastal landscape?

B. If the water level decreased 1 centimeter in elevation on your model, how much more land was exposed? Figure out how you could determine this mathematically and defend your answer.

C. If a contour map has an area in which the contour lines are very close together, what does this indicate?

D. How are flat areas shown on a contour map?

E. Describe how a lower water level, such as what the Great Lakes will likely have with global change, has different effects on steep versus flat areas.
EXTENSIONS

Drain off most of the water. Place a miniature house or hotel (possibly a small game piece) at some location you would consider "safe" from drastic changes in the water level of a lake. Describe the location you chose, and indicate it on your transparency contour map. A more complex terrain could be constructed in a larger container.

Sample of a contour map created by this method