Impact of Decreasing Great Lakes’ Water Levels on the Shipping Industry
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Subject(s): Algebra, Geometry, Advanced Algebra
Duration: 2 – 1hr class periods

Materials Needed
Per student:
Overhead transparency of grid paper
8.5”x11” map of Lake Superior with scale to match grid paper (source?)

Per class:
Calculator
Scotch tape
Overhead markers

Lesson Overview
Students will estimate the surface area of Lake Superior using Pick’s Theorem:
\[ SA = I(A) + \frac{B}{2} (A) \]
\[ SA = \text{Surface Area} \ (\text{mi}^2) \]
\[ A = \text{Area of 1 grid square} \ (\text{mi}^2) \]
\[ I = \text{Number of interior grid squares} \]
\[ B = \text{Number of border grid squares} \]

Students will then determine how many gallons of water is lost if Lake Superior drops 1” and how much money a 1000’ ship loses due to lower water levels in Lake Superior using dimensional analysis.

Learning Objectives
After this lesson, students will be able to:
1. Use Pick’s Theorem to estimate the surface area of irregularly-shaped objects.
2. Determine how water level in Lake Superior relates to income for the shipping industry.
3. Make data-based predictions about the impacts of changes in water levels in Lake Superior (or in the Great Lakes).

Michigan High School Mathematics Standards and Expectations

L1.1 Number Systems and Number Sense
   L1.1.5 Justify numerical relationships

L1.2 Representations and Relationships
L1.2.5 Read and interpret representations from various technological sources, such as contour or isobar diagrams.

L2.3 Measurement Units, Calculations, and Scales
L2.3.1 Convert units of measurement within and between systems; explain how arithmetic operations on measurements affect units, and carry units through calculations correctly.

L3.1 Mathematical Reasoning
L3.1.2 Differentiate between statistical arguments (statements verified empirically using examples or data) and logical arguments based on the rules of logic.
L3.2 Language and Laws of Logic
L3.2.2 Use the connectives “not,” “and,” “or,” and “if…, then,” in mathematical and everyday settings. Know the truth table of each connective and how to logically negate statements involving these connectives.

A1.1 Construction, Interpretation, and Manipulation of Expressions
A1.1.1 Give a verbal description of an expression that is presented in symbolic form, write an algebraic expression from a verbal description, and evaluate expressions given values of the variables.

A1.2 Solutions of Equations and Inequalities
A1.2.1 Write equations and inequalities with one or two variables to represent mathematical or applied situations, and solve.
    A1.2.9 Know common formulas and apply appropriately in contextual situations.

A2.4 Models of Real-world Situations Using Families of Functions
A2.4.1 Identify the family of function best suited for modeling a given real-world situation.

G1.5 Other Polygons and Their Properties
G1.5.1 Know and use subdivision or circumscription methods to find areas of polygons.

Background
Lake Superior and the other Great Lakes have long been used to transport goods. The most common cargoes carried by ships today include iron ore, coal, salt, grain, and limestone. Ships carry cargo from where it is mined to where it will be processed into goods that we commonly use. Cargo may travel between cities on the Great Lakes, or ships may transfer cargo to trains for transportation to inland locations. When water levels in the Great Lakes go down due to reduced precipitation, it reduces the amount of cargo that a ship can safely transport. While sailing in the middle of the lake will be no problem, low water levels have a significant impact on ships traveling into ports and through channels. For a 1000-foot ship, a 1-inch drop in Lake Superior’s water level (or draft) results in the ship carrying 270 fewer tons of cargo or load. Smaller loads transported results in less revenue for the shipping company and less cargo for the people receiving the load. Smaller ships lose anywhere from 50 to 220 tons per lost inch of draft. There have been times when the largest ships lose 8,000 tons of cargo-carrying capacity per trip. 8,000 tons of iron ore will make enough steel to make 6,000 cars.

Advance Preparation
Youtube videos will be saved as a shortcut on the computer’s desktop so they can quickly be shown on the projector. Overhead copies of grid paper need to be made so that students can lay them over the map of Lake Superior. I will need one copy for each group of 2 students. Also, each group will need a copy of a map of Lake Superior that includes a scale matching the grid paper.

Students will have to have previous knowledge in dimensional analysis. Determining the number of gallons of water for a one inch drop in lake level will take a good base of knowledge in this area. This conversion will take several steps. They will also use dimensional analysis to convert income lost…. again this conversion will take several steps.

Students will need a good base of understanding of equations, recognizing which variable are known quantities, substituting known values for given variables, and using order of operations to solve the equation.

Procedure
1. Watch YouTube videos:
1st video: *Cargo Ship Hits Land* shows a cargo ship running aground. (1 min., 31 sec.)  
http://www.youtube.com/watch?v=qJ_4tK9OSsk

2nd video: *Ship Aground Rescue* shows the rescue of ship workers from their vessel run aground. (Show first 1 minute and 50 seconds) http://www.youtube.com/watch?v=bbAB2Aqiclk

3rd video: *Container Vessel Capsized* shows a news conference with footage of a cargo ship that recently sank in shallow waters. (2 min., 29 sec.)  http://www.youtube.com/watch?v=dGXewDDwMds

2. Lead a discussion with the class about the possible cause of these accidents. What could have been done to avoid such catastrophe? What financial cost does this have and to whom?

3. After handing out a map of Lake Superior to each group, I will have the group guess the surface area of Lake Superior. After a short while of confusion and frustration, I will introduce Pick’s Theorem to the class and explain how it can be used to help find the lake’s surface area.

4. Groups will receive an overhead grid paper and tape it to over the map of Lake Superior. Then, using the overhead markers, the students will trace the outline of Lake Superior on the grid paper. Next, each group will count the number of squares the shoreline of the lake passes through. This number will be “B” in Pick’s theorem (the number of border squares). The students will then count the number of grid squares contained completely inside of the lakes shoreline. This number will be “I” in Pick’s theorem (the number of interior squares). Using the scale on the map, each group will next calculate the area of each grid square. This number is “A” in Pick’s Theorem. Finally, each group can plug their information into the equation to come up with their calculated value for the surface area of the lake. Each group will turn in their map, overhead with tracing on it, work, and answer they calculated. I will also have each group jot down their “guess” on their worksheet.

5. Before leaving class, each student will be told that they will have to look up the actual surface area of Lake Superior as homework this evening. They should print their information from the site they use along with referencing the site.

6. Day 2: Each group will take their values from yesterday’s lesson to help find the number of gallons of water that 1 inch of Lake Superior holds. We will have a discussion of how we might go about finding this answer. They will have the surface area of the lake (2 dimensions) from their work….1 inch of depth gives us a 3rd dimension so we can now calculate volume. Students need to realize that they have to work in the same units so a conversion will have to be made before volume can be calculated. All conversions needed to get the volume in gallons will be given to the class.

1 mile = 5280 ft

1 ft = 12 inches

1 ft3 ~ 7.48 US gallons

Students will then calculate the volume of the lake in gallons.

7. Once completed, we will have a short discussion of how much water this is. On the board, I will convert the water volume to weight.

1 gallon ~ 8.35 pounds
2000 pounds = 1 ton
1 ton is approximately the weight of a Volkswagon Beetle
8. Next, we will briefly discuss how and why low water levels result in a ship carrying less cargo. Finally, I will have the class calculate how much money a 1000’ iron ore ship loses when Lake Superior loses one inch of water. In addition, the class will calculate how many cars are NOT produced due to the reduced cargo. Again, all needed conversions will be given to the class:

1 inch drop in lake level = 270 tons of iron ore NOT carried
1 ton of iron ore sells for approximately $60
1.333 tons of iron ore is needed to make enough steel to build one car

9. For homework, students will be asked to research changes in the water level of Lake Superior over the past ten years. They should find the average long term depth of the lake to compare with recent years. They will bring in a printout of their results along with citing the website they used.

**Assessment of Student Learning**

Day 1: Students will turn in all of their work from the day’s activity including: the map of Lake Superior, the overhead grid paper with lake traced, all work and calculations involved in using Pick’s Theorem to find the surface area of the lake, and their guess of the lake’s surface area. All students will turn in their findings of the actual surface area of the lake at the start of day 2.

25 points possible:

- Participation in activity and discussions 5 pts
- Tracing of Lake Superior on overhead 5 pts
- Calculation of surface area using Pick’s Theorem 10 pts
- Print off of actual lake’s surface area and citation 5 pts

Day 2: Students will turn in their findings for number of gallons of water for one inch depth in Lake Superior along with all of their work. Also they will turn in their findings for the cost to the ship for one inch loss of depth in the lake along with all of their work. Finally, they will have to turn in their finding for the actual lake depth the next day.

20 points possible:

- Participation in discussions and class work 5 pts
- Results of the number of gallons conversion 5 pts
- Results of the cost to a ship 5 pts
- Print off of actual lake levels 5 pts

**Extensions**

1. Draw a poster of Lake Superior and label all of the shipping ports.
2. Research the depth and volume of Lake Superior and compare it to the other Great Lakes.
3. Research other cargoes hauled by ships in the Great Lakes and calculate the lost income of a one-inch drop in water level. Compare these values to the iron ore values we found in class.
4. Research ships that ran aground in Lake Superior. When and how did it happen?

**Resources**

Stonehouse, Fred. Personal communication. Maritime Historian [www.frederickstonehouse.com](http://www.frederickstonehouse.com)

Glen Nekvasil, Lake Carrier’s Association [www.lcaships.com](http://www.lcaships.com)

NOAA. Annual average water level and long-term mean level in meters, retrieved February 24, 2011.
Lake Carriers Association. *U.S.-Flag Shipping on the Great Lakes* (brochure) and *Map of U.S. and Canadian Great Lakes Ports* (brochure). Describes major cargoes and provides a useful map of shipping and receiving ports.


You Tube Videos:

http://www.youtube.com/watch?v=qJ_4tK9OSsk

Ship Aground Rescue, posted by widehorizons June 8, 2007, retrieved on February 24, 2011. 
http://www.youtube.com/watch?v=bbAB2AqiclK

http://www.youtube.com/watch?v=dGXewDDwMds