Water Motion and Commotion

In teams, students measure current speed, wave height and wave frequency, and they calculate the tide and make predictions regarding effects of these factors on the movement of a simulated oil spill. Once a "spill" occurs, teams of "environmental experts" measure its movements toward shore and assess its impact on the landscape, biota and human resources.

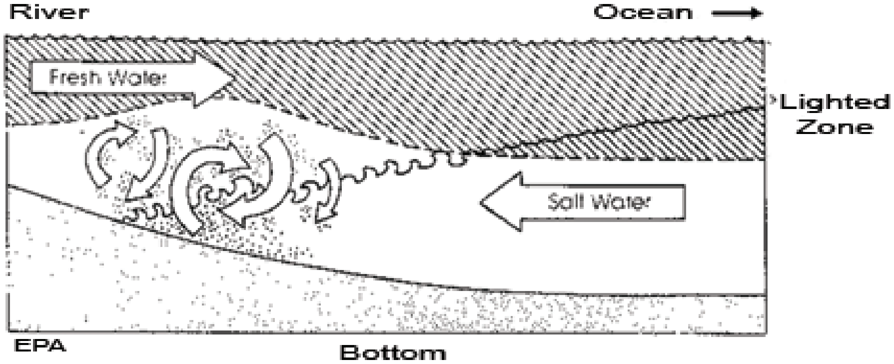
Background

The Chesapeake Bay is a great mixing bowl, receiving runoff from a land area 1-1/2 times the size of Virginia. For every gallon of water entering the bay from its watershed, 30 to 40 gallons of ocean water move in and out of the bay mouth. Both fresh and salt water are in constant motion, mixing together and moving nutrients, fish eggs, shellfish larvae, plankton, minerals, sediments and pollutants.

As in all estuaries, the salinity of the Chesapeake Bay varies greatly with location. At the bay mouth, salinity approaches that of ocean water (30-35 parts per thousand or ppt). Midway up the bay, salinity is about half that of the ocean water, and it continues to decrease further up the bay and its tributaries. Salinity also tends to increase with depth, since salt water is denser than fresh water. As a result, salt water tends to move up the bay along the bottom, forming a salt wedge, along with fresher water flowing out of the bay near the surface. Where the saltwater and fresh water meet, there is often considerable mixing, which stirs up the sediments and resuspends nutrients.

Water movements are grouped into three major categories: waves, tides and currents. A current is the horizontal flow of water. Currents in the bay and the tidal stretches of its tributaries are complex, influenced by water depth, shoreline and bottom contours, tides, rainfall, wind, barometric pressure and many other factors. In a tidal river, speed and direction of currents differ with time and place. Water may flow fast near the shore and slowly near the middle of the channel. Surface waters may flow downstream while water near the bottom may flow upstream. Currents also change with the tide.

Waves are surface disturbances that appear as moving ridges of water. Actually, as a wave passes, the water on the surface moves vertically, and the water below the surface moves mostly in a circular fashion. Wind causes waves, and wave size is primarily determined by wind speed and fetch, the distance wind blows over the water. The greater the wind speed and the longer the fetch, the



Circulation pattern in an estuary

Grade Levels: 6-12

Objectives

Students will investigate possible interrelationships between water motion and dispersion of a hypothetical pollutant by:

- *estimating, measuring* and *calculating* basic characteristics of waves and currents;
- *predicting* the movement of a simulated oil spill;
- *observing* and *predicting* the impact of the spill on the biota, landscape and human activities.

Materials

Per class OR per team:

- two 1.5-meter (m) wooden stakes
- 10-m long measuring tape
- 10-m long piece of string with finger loops in the ends
- meter stick
- grapefruits (1 per team)
- watch with second hand

For popcorn slinger:

- one 5-gallon plastic bucket with cut-out bottom covered with screening
- 25 m of heavy twine or light rope
- 20 liters of plain popped popcorn
- permanent marker

Per team:

- tide chart
- clipboard, pencils, paper
- *Water Motion Worksheet*
- "wettable" footwear, hip boots or waders
- map of Chesapeake Bay region or Virginia
- calculator (optional)

larger the wave. Waves are also affected by tides, currents, weather systems, water depth and shape of the shoreline.

Waves have three aspects that can be easily measured. These are: wavelength, the distance between identical points on two successive waves; wave height, the distance between the lowest point of a wave (trough) and the highest point (crest); and wave frequency, the number of waves to pass a point in a unit of time.

A tide is a special type of wave that is perceived as the vertical movement of ocean waters. Tides are caused by the gravitational pull of the moon with the sun's gravity playing a minor role. These forces "pile up" water into bulges that move as long waves around the planet, creating in the Chesapeake Bay and in many other locations two high tides and two low tides every 24 hours and 40 minutes.

There are sometimes reports of oil spills, chemical spills and other pollutants entering our waterways. Determining where and how a spill will spread is a complex problem, requiring a thorough understanding of tides, currents and waves, among other factors.

Before the Trip:

1. Review the basic concepts of tides, currents and waves with the class.
2. Using a large map of the Chesapeake Bay, show the class the location of the site to be visited. Discuss:
   - *Standing on the shore, which direction (left or right) is down river (toward the ocean)? Why is this direction called down river?*
   - *Are there likely to be tides at the site?*
   - *Predict the height of the waves that will be seen at the site—10 cm, 100 cm, 2 m?*
   - *How can the information from a map help with predicting wave height?*
   - *What are some other things that affect wave height that can't be predicted with the map?*
3. Divide the class into teams of four students.
4. For each team, copy an up-to-date tide chart and the *Water Motion Worksheet*.
5. Practice reading the tide chart, calculating the high and low tides for the particular site where the field trip will occur. (The activity "Telling Tides" teaches how to read a tide chart and to calculate the tidal time differences for each site. The tidal conversions are based on the time difference of the site's tides from those at a designated reference point. Sewell's Point in Hampton Roads is the standard for most southern Chesapeake Bay tide charts, and much of the Potomac River is referenced to tides at Washington, D.C.)
6. For the site, each team calculates the high and low tides that will occur closest to the time of the field trip and enters these on a copy of the *Water Motion Worksheet.*
7. Explain that when they go to the site, each team will be taking measurements of currents and waves and determining the tide. Based on the prevailing conditions at the site's shoreline, they will predict the movement of a simulated oil spill, (i.e., which way it will move, how long it will take to reach shore, if at all, and whether it will stay together or break up).
8. Provide some hypothetical measurements so students can practice the calculations.
9. Make a popcorn slinger following the accompanying directions. Prepare or acquire plain popcorn (no butter or salt).
10. Depending upon resources and equipment availability, either fully equip each team for the field exercises or plan to set up stations between which the teams can rotate.

Credits

Adapted with permission from *Water Water Everywhere...* "Oil is Lighter than Water: Evaluating the Impact of an Oil Spill." Oregon State University Sea Grant College Program, Corvallis, and Oregon Dept. of Education, Salem.

Where

Suitable at all estuarine state parks or any public beach on the bay or a tributary.

Hughlett Point: beach.

When

Any time is suitable; water is warmer in the fall.

Time Required

At the site: Allow at least two hours for entire activity; avoid picking time that coincides with slack tide.

Resources

Chesapeake Bay Foundation

Chesapeake Bay Program 2012 Learn the Issues

EPA 2011 The Great Waters Program: Chesapeake Bay.

2003. U. S. Department of the Interior and U. S. Geological Society. A Summary Report of Sediment Processes in Chesapeake Bay Watershed. Water-Resources Investigations Report 03-4123

Virginia Institute of Marine Science

Hampton River, Hampton Roads, Virginia Tide Chart

http://tides.mobilegeographics.com/locations/2402.html.

At the Site:

1. Select a location along the beach where there is ample room for the students to spread out. Break into teams. If there is room on the beach and there is enough equipment, each team can set up its own station for taking measurements. If space or equipment is limited, teams can rotate stations for measuring current speed and wave action.
2. Each team completes steps 1-4 on the *Worksheet*.
3. After all measurements are completed, each team should discuss results among themselves and make predictions about the direction the simulated spill will move and how quickly it may reach shore if it occurs 25 m from shore, following the questions under No. 5 on the worksheet.
4. Regroup and discuss each team's predictions.
5. After a few practice attempts at throwing the empty popcorn slinger into the water, fill it with popcorn and create the spill. Mark the toss location with a stake.
6. Allow up to 15 minutes to observe the spill and follow its movements. If the popcorn comes ashore, record the time and mark the location with a stake. Measure or pace off the distance between the stakes.
7. Depending upon the local conditions, the spill will break up rapidly, move downstream with the current or come ashore. Assuming that the oil spill came directly ashore at this location, discuss:
   - *How many different types of animals would be covered or affected on land? In the water?*
   - *Could some animals escape the spill? How?*
   - *What animals might not be able to escape?*
   - *How many different types of plants might be affected on land? In the water?*
   - *Would animals that eat these plants be affected?*
   - *What would happen to the shoreline? Beach activities? Swimming? Boating? Fishing?*
   - *Do you think any of the spill would sink? If so, how would it affect the river bottom? The biota living near or on the bottom?*
   - *How would you start to clean up the "spill"?*
   - *How long do you think the spill's impact would last in this area?*
8. After the allotted time is up or the spill has dispersed widely, regroup and gather up all equipment.

Follow-up:

Hold a group discussion about the movement of the spill with each team presenting its predictions and findings. (Differences in calculations may occur depending on how the measurements were taken in the field.) Discuss the simulated spill's potential impact on different aspects of the environment. *What were the limitations of the activity? What other factors should be considered when environmental experts assess the possible movement and impact of a real chemical or oil spill?* (Consider effects of variations in waves, currents, wind, sun, air temperature, precipitation, boat traffic, etc.) Emphasize the complexity of the problem.

Extensions

1. Try different methods of containing a spill. Students can devise containment equipment.
2. Make a wave jar. Fill a jar with equal parts of vegetable oil and colored water. Replace the lid and turn it slowly end to end. Study wave motion.

Variations

Younger students:
Students make the wave and current measurements. Help them make predictions about the movement of the spill. As students watch the movement of the spill, ask leading questions about the spill and its impact on the environment to develop their observational skills.

Gifted/Advanced:

1. Customize the worksheet by removing formulas and instructions as appropriate for the group. A highly advanced class might be instructed to design its own methods for predicting the location, movement and impact of the spill and make its own measurements, calculations and observations in the field.
2. Research *salt water intrusion* or *salt wedge* formations, how they relate to the circulation of water in the bay and its tributaries, and how this is relevant to various pollution problems.

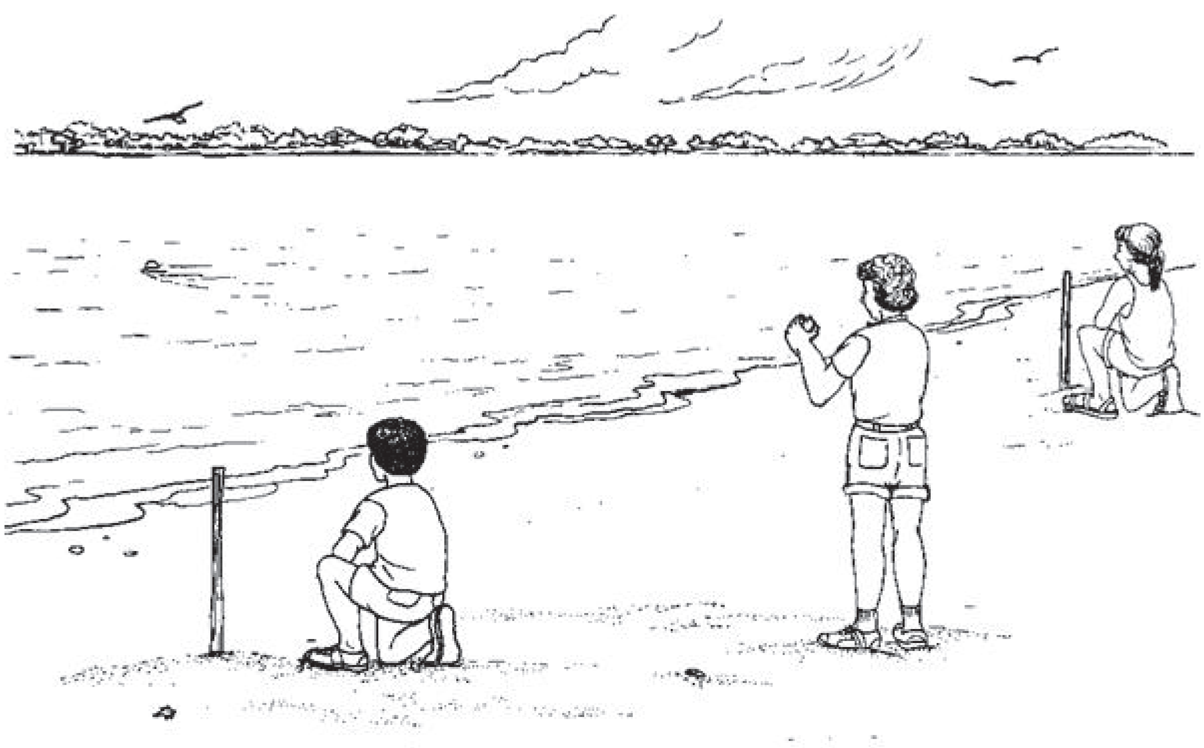
Water Motion and Commotion Worksheet

1. Using the tide chart, determine the following:
   Expected time of low tide: __________ Expected time of high tide: __________
   Present time: __________
   The tide should be rising __________ falling __________ (check one).
   The tide appears to be rising __________ falling __________ (check one).

2. Determine current speed (V):
   - Throw a grapefruit straight out from shore, about 20 meters. (A good heave will do.)
   - Watch the grapefruit to determine the direction of the current.
   - Several meters downstream of the grapefruit, push two stakes into the sand on the beach, exactly 10 meters apart and both equidistant from the water's edge.
   - Two people act as spotters. Each sits about a meter inshore from a stake and sights over it, across the water, in a line perpendicular to the shore. The spotters wait for the grapefruit to cross their lines of sight.
   - A third person, with a watch or stopwatch, begins timing when the first spotter indicates when the grapefruit reaches his/her line of sight and stops timing when the grapefruit reaches the second spotter's line of sight. Record the time (t) in seconds it took the grapefruit to travel the distance (d) of 10 meters:

   time (t) = __________ seconds
   distance (d) = 10 meters
   current speed (V) = d/t

   current speed (V) = 10 meters/__________ second
   current speed (V) = __________ meters/seconds

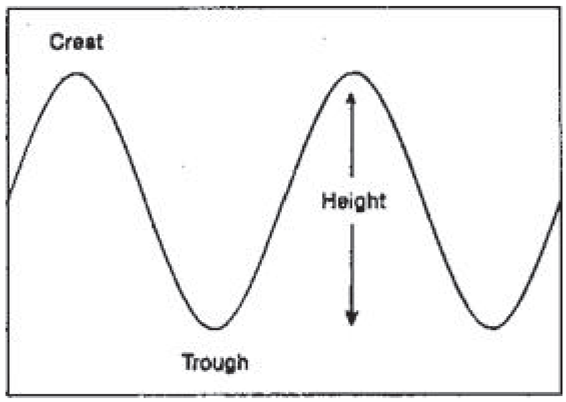


3. Determine the wave frequency (f):
   - The measurer wades out knee deep and holds a meter stick vertically in the water with one end on the bottom.
   - On a signal from a timer on shore, the measurer counts the number of waves that pass the meter stick for two minutes.
   - Record this number below.

   Number of waves in two minutes: __________ Frequency (f) = number / 120 seconds = __________waves per second

4. Determine wave height (h):

- One person, the measurer, wades out to where individual waves can be identified (no farther than knee deep) and holds a meter stick vertically in the water with one end on the bottom.
- The measurer bends over and calls out the high (wave crest) and low (wave trough) water line measurements in centimeters as a wave passes.
- Another person on shore records these measurements below. Repeat five time. Subtract trough height from crest height to get the wave height for each pair of measurements and record. Add the wave heights together. Divide this sum by 5 to determine the average wave height.



Measurement (cm)	1	2	3	4	5
Crest					
Trough					
Wave Height					

Sum of wave heights = ___________

Divide above sum by 5 = ___________

Average Wave Height: ___________

5. Before the spill occurs, predict the following:
   - *How fast (minutes) will the spill (first piece of popcorn) reach the shore?*
   - *Which direction will the spill move?*
   - *Where will the spill come ashore? (Distance in meters down beach from where popcorn is thrown.)*
   - *Will the spill stay together or break up?*

6. After the spill, record the following:

Time of spill: ___________ Spill was ___________ meters from shore.

Time first popcorn reached shore: ___________

First popcorn reached shore ___________ meters from toss location.

How To Make a Popcorn Slinger

1. Assemble all materials required for the popcorn slinger as indicated in “Materials” in the sidebar.
2. Mark off 5 m intervals on the 25 m line with a permanent marker. Firmly tie the 25 m line to the bucket handle.
3. Contact a popcorn concessionaire (listed under “Popcorn” in *Yellow Pages*) for stale plain popcorn or pop a two-pound bag of corn to make the necessary 20-24 liters.
4. At the site, first practice throwing the bucket empty. Grab the rope near the bucket and start twirling the popcorn slinger over your head. When the bucket has gathered momentum, let it fly out over the water. After landing, the weight of the bucket will pull it under the water and the buoyant popcorn will be forced out. Before hauling the bucket in, let it sink beneath the surface so as not to disturb the spill.
5. Once you feel the comfortable tossing the bucket, fill it with about 20 liters of popcorn and take a strategic position (dock, breakwater, large rock, etc.) from which to toss the popcorn. Make sure the line is secured on shore to prevent loss of the slinger. Keep the line tangle-free to avoid hindering the bucket’s flight. If you have trouble making the slinger work, someone can wade out into the water and pour the popcorn out.
6. Count the marked intervals as the bucket is hauled in to determine the spill’s distance from shore.

Standards of Learning: Science: 6.1, 6.2, 6.3;LS.1; PS. 1, PS.9, PS.10; ES. 3, ES. 10, 6.7, 6.9, Algebra I: A.2, A.5, Geometry: G.13

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