Water Wits

aquatic safety, science, and stewardship education program

GRADES 6-8

OREGON STATE MARINE BOARD

Dear Educators,

June 30th, 2015

With thousands of people enjoying activities on Oregon's waterways each year and rising demand for clean water resources, there is a need to educate people early about responsible waterway use. Humans and wildlife both need resilient waterways for health, safety, and survival. That's why we have developed this new K-12 educational curriculum, *Water Wits*!

This program aims to encourage awareness and responsible use of aquatic and marine resources. It goes beyond traditional boating and water safety education to include stewardship messages and scientific principles. It is designed to be interdisciplinary, academically rigorous, interactive, and student-led. We hope that by taking an integrated approach to thinking about water, this curriculum will spark a renewed interest in responsible waterway enjoyment for both educators and students.

Water Wits addresses 3 pillars of aquatic literacy:

Safety: what are the best practices for smart decision-making in, on, and around the water?

Stewardship: how can we reduce our impacts and manage water resources for people and wildlife?

Science: how do physics, engineering, ecology, and the social sciences explain and inform both of these?

The curriculum includes 12 complete lesson plans, divided into grade units (Kindergarten-2nd Grade, 3rd-5th Grade, 6th-8th Grade, and 9th-12th Grade). All lessons are aligned to state and national education standards, including Next Generation Science and Common Core, across multiple subjects. Each unit contains 3-4 lesson plans with suggestions for how to adapt the activity to best suit your student. Lesson plans include a list of aligned standards, background information, detailed instructions, and additional resources including printable worksheets and hand-outs. Each is designed to be completed in one class period, but many offer rich opportunities for extension and suggestions for additional activities are also included.

The *Water Wits* program includes concepts from all subjects: Science, Math, Social Studies, Language Arts, and Physical Education. It also fosters 21st-century skills including collaboration, critical thinking, problem solving, global awareness, and civic and environmental literacy. We encourage you to work with other educators at your school or in the community to create a cross-cutting implementation plan. Doing so will provide you with exciting professional development opportunities and enable you to reach students with different learning styles and interests!

While much of the *Water Wits* curriculum is designed to be academic in nature, the interactive activities and low-cost materials make the lessons adaptable for almost any setting. Determine the age range of your audience and set up the hands-on portions of appropriate lessons at public events, workshops, classroom visits, or your camp site.

For more information and additional support, or if you are interested in adapting this curriculum for your own organization or agency, please contact MariAnn McKenzie, Boating Safety Education Coordinator at mariann.mckenzie@oregon.gov / 503-378-5158.

Thank you for choosing the *Water Wits* program. We hope that you and your students enjoy it!

Randy Henry, Boating Safety Program Manager

Sara S Roberts

Sara Shaw Roberts, Curriculum Writer

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GRADES 6-8
Time: Prep 15-20 mins;
45 mins-1 hr. for activity

River in a Box

Aligned Standards

2014 SCIENCE (NGSS)

- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- MS-PS3-5. Construct, use, and present arguments to support the claim that when kinetic energy of an object changes, energy is transferred to or from that object.

SOCIAL SCIENCE CORE

- Explain how people have adapted to or changed the physical environment in the Western Hemisphere.
- Explain how technological developments, societal decisions, and personal practices influence sustainability in the Western Hemisphere.

COMMON CORE: LANGUAGE

- Engage effectively in a range of collaborative discussions with diverse partners on topics, texts, and issues, building on others' ideas and expressing their own clearly.

COMMON CORE: MATH

- 6.RP.2. Understand the concept of a unit rate associated with a ratio

HEALTH BENCHMARKS

- Explain ways to reduce risk of injuries in and around water.
- Demonstrate verbal and non-verbal communication to avoid unsafe situations in and around water.

Activity at a glance

Students build models of several different rivers including natural and man-made features, and use these to investigate flow physics, boating hazards, and human impacts.

Materials

For each group of 4-6 students:

- River box - **see final page for instructions**
- Sand, pebbles, small rocks
- Pitchers with water
- Bucket
- Plastic boats, Lego pieces, popsicle sticks, broccoli, etc. to represent boats and branches
- Copies of Student Data Sheet (pg. 4)

Background Information

Rivers are dynamic, ever-changing bodies of water that can provide recreation, clean water, and habitat for important species, but also a lot of dangers. Many of these dangers are hidden and nearly impossible to spot by the untrained eye, so it is important that anybody planning on boating down a river is familiar with its physical features and potential hazards.

The way a river behaves and impacts boaters is a result of many factors. These can be either natural or man-made. Surface and submerged obstacles (such as rocks, trees, and branches), narrow channels, and rainfall or landslide events influence the way that the river is shaped and its flow speed. Dams, weirs, spillways, and other man-made structures also determine river behavior and can cause a number of serious hazards.

Sediment, or particles of dirt, sand, or tiny rocks, plays an important role in the size and shape of a riverbed. This means how much sediment is delivered, deposited, or washed away, and the rate of these processes. **Erosion** is the process of sediments being carried away—by wind, water, or debris. **Deposition** is the process of sediment being delivered to the river—by rain, landslides, wind or gravity. The more or faster the erosion, the wider and deeper the riverbed. If deposition is the dominant process, the channel will be narrower and the riverbed steeper. Of course, in a natural system these processes are constantly changing and competing. A river that is low, slow, and calm may be a turbulent roaring river after a large snowmelt, dam collapse, or other event.

Rivers are part of the **hydrologic cycle**, meaning they are driven by the exchange of energy (water) and flow rates. This includes precipitation, runoff, infiltration (the flow of water into the soil) and percolation (the flow of water through the soil due to gravity). All of these determine the river's shape or **morphology.**

Certain features are notorious for causing problems for boaters and need to be carefully researched and avoided. Hazards such as rapids, strainers, holes, submerged debris, and drops may be stationary features or may appear only at certain times. **Know before you go!** Be prepared for hazards by always wearing a life jacket

Objectives

Students will:

- Use a model to represent concepts including erosion, deposition, fluid mechanics, and currents
- Perform a series of experiments to analyze how changing aspects of a river affects the above concepts
- Relate their findings to the importance of water safety and hazard awareness

Image credit: Creative Commons

A river's features and hazards are determined by flow speed, debris and sediment supply, erosion, and more.

Procedures

1. Introduce activity with information from the *Background Information* section. Write down key vocabulary on board.

2. Explain that each group is going to create their own mini-rivers and try to determine how both natural and human-made features impact water flow.

3. Distribute materials and allow student groups to build their model of a river however they want to start. There is no right or wrong way—the variety of their river models will help to illustrate concepts later. Throughout the activity students should record results and observations on the *Student Data Sheet*.

4. Once initial rivers are complete, have students pour a small amount of water starting at the furthest point "upstream" (opposite the hole in the box). What happens to the rocks or obstacles they put in their model? How does the water move around these objects? Encourage sharing aloud of observations.

5. Tell students their next challenge is to build a river that will flow *quickly*. The goal is to design a model that allows water to flow as fast as possible. Allow time for students to build, then again pour water down the river. Was the flow as fast as they expected? Why or why not?

CALCULATE RATE: Advanced students can count the number of seconds it takes water to travel down their river, then calculate the rate of flow in inches per second or other units.

6. Next, instruct students to build a river that flows very slowly. Repeat the experiment and discuss results.

7. After these experiments, help students identify patterns in their results. Note that straight, clean rivers will flow more quickly than meandering rivers with many turns or obstacles. *Why is this?* Have students brainstorm answers.

8. Which type of river will be more likely to experience flooding? (*Answer: meandering, winding rivers will likely accumulate and hold more water rather than quickly routing it downstream*.)

9. Now we will explore how humans have changed the way many rivers operate. Dams, rerouting water flows (known as channelizing), and the filling of wetlands for development are just a few examples. First, build a river with a few meanders, without too many sharp curves or straight paths—this is representative of most average rivers. Then, give students time to experiment with changing river behavior when they do the following:

- Build dams upstream, midstream, and downstream—what happens to the water speed and sediment transportation?
- Add additional streams to the river
- Make the river more narrow using the sand and/or rocks

10. Lastly, identify hazards which may have formed in their model rivers. Did they notice any areas that collected dangerous debris, swift currents, miniature drops or areas of turbulent water around rocks, etc.? Use the pictures on Page 5 to relate these observations to hazards they could encounter on real rivers. Emphasize that these are often unexpected, so it is vital to be prepared.

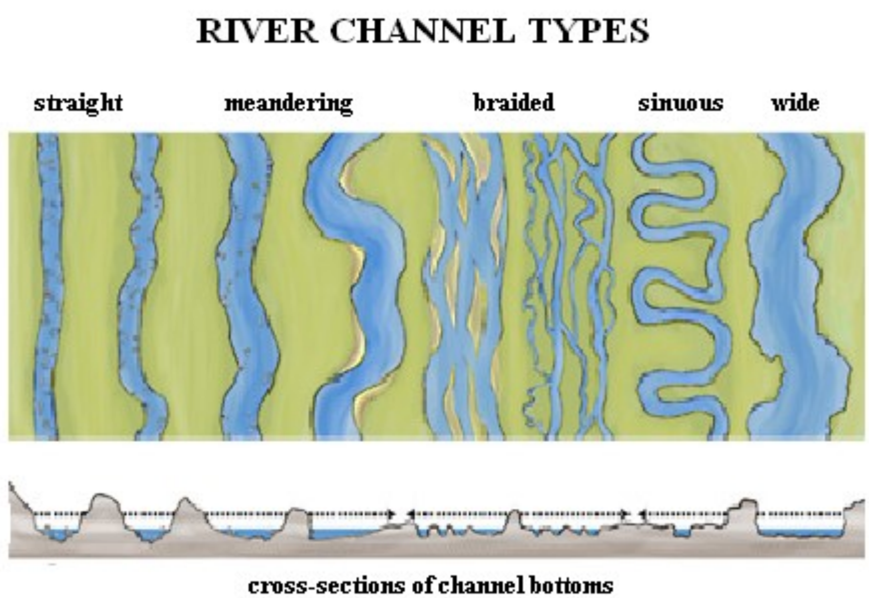
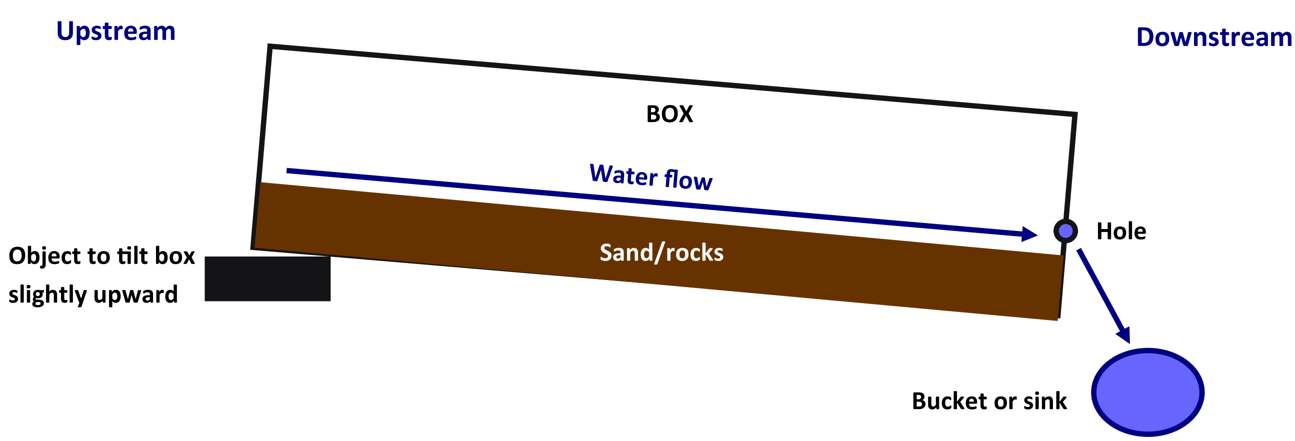


Image credit: Steven Adams/Creative Commons

How to build a River Box

1. Use a plastic, rectangular, waterproof box. It does not need to have a top. It should have enough depth to allow room for sand and rocks and for water flow.
2. Punch or cut a hole into one of the short sides of the box. This will be the “downstream” side of the river. The hole should be approximately 2 inches from the bottom of the box, or just above the desired level of sand. It should be about a quarter-inch in size.
3. Place the “downstream” side of the box over a sink, or on the edge of a table above a bucket. This is where the water will drain into, so if you are using a bucket make sure it is large enough. You may need to have students dump it out if it fills during the activity.
4. Fill the bottom of the box with approximately 1.5 inches of sand or small gravel, at least half an inch below the bottom edge of the hole. Be aware that some sand may wash out of the box. Add some larger pebbles to represent rocks or boulders.
5. Add rocks and pebbles. Add items such as plastic boats, game pieces, and small sticks if desired. These can represent logs, bridges, dams, etc. Add pieces of broccoli to represent fallen trees. Students can make small floating boats out of Legos.
6. Elevate the “upstream” side of the box (opposite the hole) slightly with a binder, piece of wood, or other flat stable object. A couple of inches of elevation should be enough for good water flow.



Additional suggestions

The larger your container, the better it will work as a river model.

Instead of making several small river boxes, you can make a large scale model using a rain gutter! Lay it across several tables, or place it on the ground outside. One end of the rain gutter will still need to be elevated to allow water flow. The entire class should be able to fit around the rain gutter. Each student can create their own section of the river or they may still work in small groups to design each section.

STUDENT DATA SHEET

Sketch each of your river models, including the shapes and major manmade and natural features, and record observations below. Discuss the results with your group. How might these different types of rivers and their features impact water currents, sediment transportation, boaters, and wildlife?

Upstream → Downstream

OBSERVATIONS: ______________________________

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Upstream → Downstream

OBSERVATIONS: ______________________________

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Upstream → Downstream

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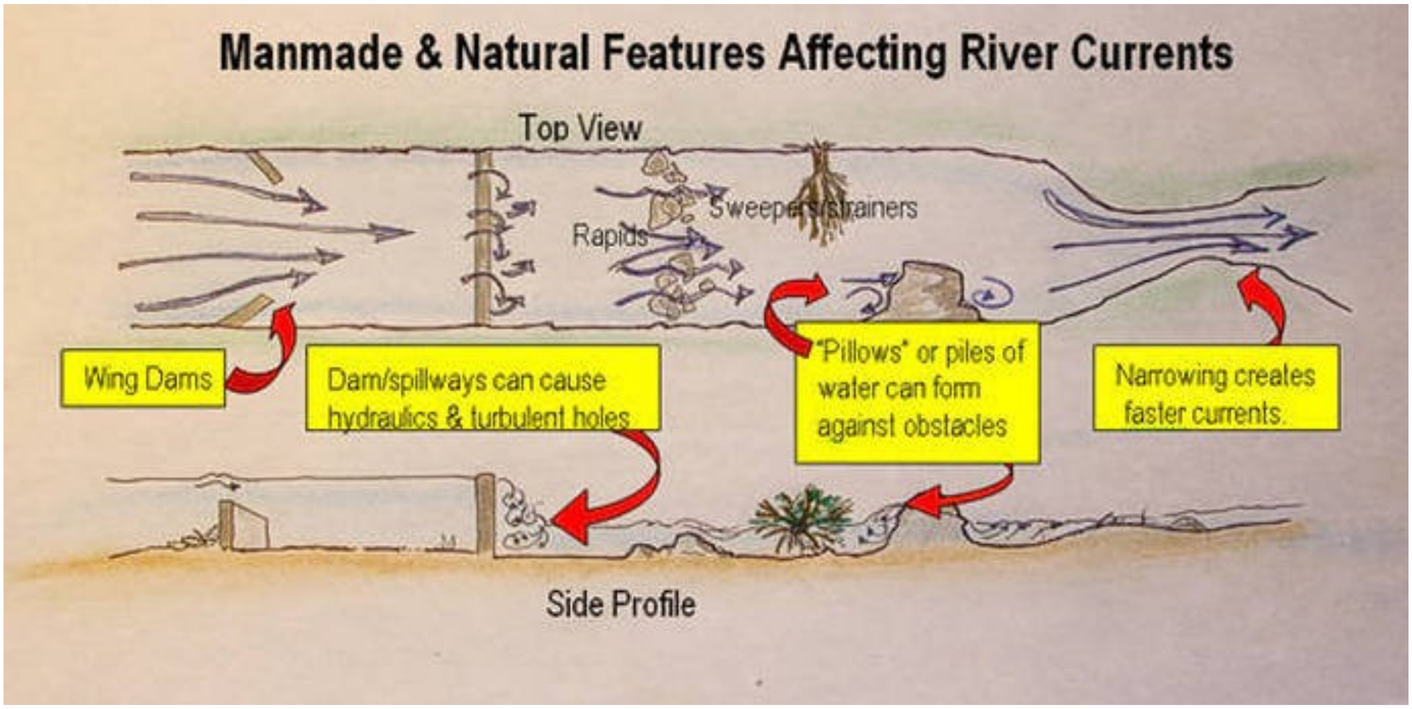

Image credit: www.paddling.net

Resources

Guide to river hazards and how to handle them: http://www.paddling.net/guidelines/showArticle.html?566

Navigation obstructions on Oregon rivers: http://www.oregon.gov/osmb/pages/safety/navigation_hazards.aspx

Video: Why Do Rivers Curve? (2.5 mins) http://mentalfloss.com/article/61170/why-do-rivers-curve

How A River Flows—information and visuals: http://chamisa.freeshell.org/flow.htm

All about Rivers: http://education.nationalgeographic.com/education/encyclopedia/river/?ar_a=1

Impacts of Dams: http://www.americanrivers.org/initiatives/dams/why-remove/

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GRADES 6-8
Time: 10 mins for prep; 1-2 hrs. for activity

Oil Spill Cleanup

Aligned Standards

2014 SCIENCE (NGSS)

- MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
- MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

OR SOCIAL SCIENCE

- Explain how technological developments, societal decisions, and personal practices influence sustainability in the Western hemisphere.
- Investigate a response or solution to an issue or problem and support or oppose, using research.

COMMON CORE: READING AND WRITING

- Integrate information presented in different media or formats as well as in words to develop a coherent understanding of an issue.
- Cite textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
- Write arguments to support claims with clear reasons and relevant evidence.

Continued on following page...

Activity at a glance

Students design and evaluate solutions for the impacts of oil spills in aquatic environments, and investigate the societal dimensions of clean-up efforts.

Objectives

Students will:

- Identify the causes of oil spills
- Infer the impacts of oil spills on wildlife and important water resources
- Create and discuss solutions for a model oil spill in the classroom
- Consider the viewpoints of diverse people when dealing with oil spills in their own communities

Materials

For each group of 4-6 students:

- Water (access to a sink is ideal)
- 1 bowl
- 2-3 tablespoons vegetable oil
- Cotton balls, Q-tips, cotton pads, etc.
- Spoon
- Liquid soap, diluted in a spray bottle
- Small nets or pieces of mesh
- Sponges
- Copies of Student Worksheet (pg. 3)
- Copies of "Clean Boater" handout for students to take home (pg. 5-6)

Image credit: Creative Commons

Oil spills can impact oceans, streams, groundwater, and the people who use these resources.

Background Information

Aquatic wildlife is extremely vulnerable to water pollution, because they cannot survive out of the water and so cannot avoid pollution. A major concern for these organisms is oil spills. In lakes and rivers, oil can come from leaking motorboats or in runoff from nearby roads. In the ocean, huge spills from transport ships can have large-scale consequences. Oil and other pollution can be classified as either **point source**, meaning it comes from a specific place or event, or **non point source**, meaning from multiple or unknown sources. Point source pollution is more easily regulated, though non point source pollutants pose just as much of a major concern as they affect entire communities. For aquatic ecosystems, both of these types of pollution have negative impacts.

The physical properties of oil make it particularly difficult to contain and remove from water. Because oil is less dense than water, it forms thin layers or **slicks** on the water's surface. This means that the oils are exposed to the wind and easily spread—this can be especially damaging in the ocean, where oils can spread vast distances with nothing to stop them.

A number of solutions have been developed to attempt to mitigate the impacts of oil spills. **Chemical dispersants** similar to household detergents are sprayed from planes or helicopters and help to break up the oils—though sometimes these materials can be just as harmful to wildlife as the oil. **Oil skimmers** (essentially large specialized nets) can be dragged across the surface to separate the oils from the water. **Booms** are floating barriers which are placed around the spill to contain it, though in rough waters these are ineffective as waves simply wash the oil right over the booms. Fire is also sometimes used to burn off the oil, though of course this poses a serious potential danger for humans and wildlife.

Each of these **mitigation methods** has advantages and disadvantages for cost, effectiveness, human safety, and environmental impact. Scientists must carefully consider these factors and many others when designing clean-up techniques.

Aligned Standards

...continued

COMMON CORE: SPEAKING AND LISTENING

- 6-8.7. Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.
- 6-8.1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-level topics, texts, and issues, building on others' ideas and expressing their own.

HEALTH BENCHMARKS

- Identify sources of air and water pollution and how pollution affects health.
- Identify ways that transportation affects environment and health.

Procedures

1. Ask students what impacts humans can have on the environment (directly or indirectly) when they are enjoying waterways. Answers may include pollution, damaging wildlife, etc. If nobody specifically mentions oil, dig deeper on the "pollution" answer: *What types of pollution can occur?* Trash is a common pollutant and a serious concern, but today we are going to focus on a different type of pollution: oil spills.
2. Ask: *What can cause oil spills? How can people help ecosystems recover from spills?* Expand on student answers with additional information from the **Background Information** section. Be sure to go over the bolded vocabulary words and mitigation techniques.

NOTE: For older students or a more challenging design process, refrain from sharing any information about modern mitigation techniques before the activity Instead, let students freely design their solutions. Share the modern techniques after, and relate these to student designs.

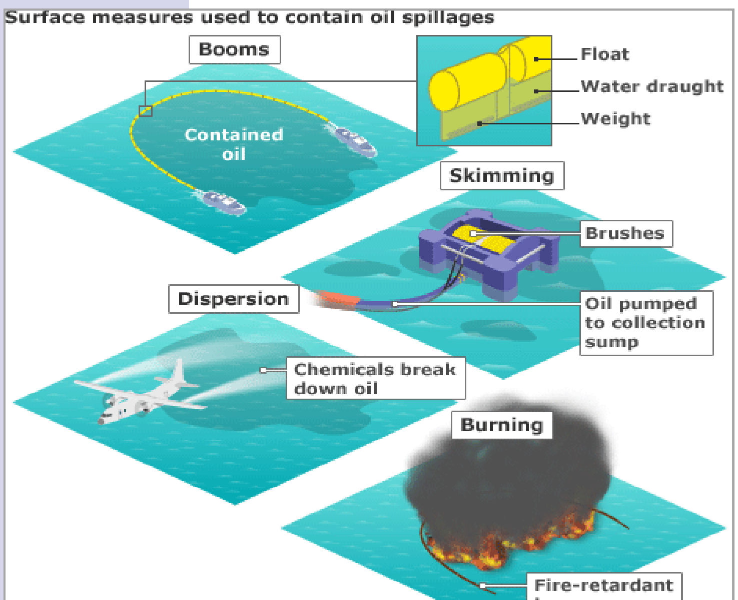

Image credit: BBC/Creative Commons

3. Explain that today, we are going to simulate an oil spill on a lake or ocean. A bowl of water will represent the body of water, while vegetable oil will represent the crude oils and petroleum found in oil spills. *Your task is to design a solution using these materials to mitigate the impacts of your oil spill.*
4. Divide class into groups of 4-6 and distribute the Materials.
5. Allow students to work together to devise and test a clean-up method using the provided materials. Monitor progress and group coherence. Provide guidance if necessary, but encourage independent thinking and group discussion. Give sufficient time to experiment—**the Hands-On portion should be the majority of your class period.**
6. If time allows, have each group present their design, explain their rationale and development process, and defend its success.
7. Discuss all student designs, comparing and contrasting methods used and final products. *Which designs worked the best, and why?*
8. Engage in discussion with students reviewing this activity. *What was the most challenging part?*
9. Wrap up the activity by relating their experiment to the real world. Would their design solutions work in a real body of water? Why or why not?
10. Use the *Community Connections* sheet to encourage students to think about different perspectives in environmental management.

Community Connections: The wreck of the New Carissa

Read the following story about a historical oil spill event off the coast of Oregon. Then use the information provided and your best judgment to explain how you might have reacted.

In 1999, a freighter named M/V New Carissa ran aground on a beach near Coos Bay, Oregon. It was 639 feet long and weighed over 36 tons. Conditions were stormy and the ship's anchor dragged, and by the time the crew noticed this it was too late to navigate away from shore. The ship was abandoned and nobody was injured, but the ship broke into pieces. The fuel tanks began to leak oil onto the beach and into the water, damaging coastal sands and wildlife. To try to mitigate these impacts, it was decided to set the fuel tanks on fire. Napalm, plastic explosives, and other devices were used to ignite the fuel on board. The ship burned for 33 hours, but still did not burn up all of the oil. The bow section was towed out to sea, shot with gunfire and a torpedo to puncture the hull, and sank, trapping the remaining oil within. Efforts to haul the stern section out to sea were not as successful—it remained on the beach for another nine years. Local residents debated whether the stern posed a hazard to human and animal health, and whether it could be more ecologically harmful to further damage the fuel tanks through removal efforts and cause more oil to leak. Some contended that the wreck could become an attraction and generate tourism money that could help the local economy. Eventually, the stern section was dismantled and the metal scrapped. The New Carissa ultimately leaked over 70,000 gallons of fuel oil and diesel on the beach and in the water, and is one of the worst oil spills in Oregon history. Over 3,000 birds were killed, including rare and threatened species. Seals, fish, and valuable oyster beds were also affected.

What would you do?

You are a member of the Coos Bay community and the New Carissa has just run aground on the beach. Everyone is arguing what to do: whether to remove wreckage, leave it on the beach, or find another way to clean up the oil. What do you think should be done, and why?

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Do you think you would have the same opinion if you were a:

Hotel owner? ____

Oyster grower? ____

City Health and Safety Official? ____

(HINT: Think about what each person is interested in, and how the wreckage could help or harm their personal wants and needs.)

Additional Resources

If time allows and you have access to a computer lab, students may use the following resources to research oil spills and the New Carissa wreck before completing the *Community Connections* activity.

General oil spill information:

Environmental Protection Agency—Oil Spill Response information and techniques: www.epa.gov/oilspill

NOAA Office of Response and Restoration—How Oil Harms Marine Environments: http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/how-oil-harms-animals-and-plants.html

Clean Boater Guide—preventing and dealing with oil spills: http://www.oregon.gov/OSMB/Clean/docs/clean_boater_booklet_final.pdf

The New Carissa:

Oregon Department of State Lands: The Wreck of the New Carissa—history and legal actions: http://www.oregon.gov/dsl/LW/Pages/ncar.aspx

Oregon Land Management: The Wreck of the New Carissa—timeline, removal processes, site maps, and photos: http://www.oregon.gov/DSL/LW/Pages/carissa.aspx

Article in The Columbian: "The New Carissa– 15 Years Later" (February 2014): http://www.columbian.com/news/2014/feb/08/the-new-carissa-15-years-later/

Oregon Fish & Wildlife: New Carissa Oil Spill—from response to restoration: http://www.fws.gov/oregonfwo/Contaminants/Spills/NewCarissa/

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OREGON CLEAN BOATER

Every boater loves being on the water. A clean marine environment is a vital aspect of enjoying the boating experience. With 180,000 boats registered in Oregon today, the cumulative actions of boaters can have a significant impact on the health of the marine environment. This guide provides some tips on how to become a cleaner boater and do your part to keep our waterways clean and healthy.

Use a fuel collar or fuel bib

BoatUS

BoatUS

Install a fuel/air separator

BoatUS

GAS AND OIL

Small drips and spills of gasoline, diesel, and other petroleum products add up and can have a serious effect on the marine environment, such as: death of fish, mammals, and birds; cancer, mutations, and/or birth defects; destruction of plant life; and reduction of food supply for marine organisms.

Fuel cautiously

- Fuel your boat slowly and carefully – attend the fuel nozzle at all times.
- Make sure the fuel nozzle connects to the fuel tank to prevent static discharge.
- Only fill the tank to 90% since fuel expands as it warms up.
- Use your hand to check for air escaping from the vent. When the tank is nearly full, you'll feel an increase in airflow. Also listen for a gurgling sound indicating the tank is nearly full.
- Fill portable gas tanks on shore – where spills are less likely to occur and easier to clean up.
- Outboards: close tank fuel vent when boat is not in use to save fuel from vapor loss.
- Built-in fuel tanks: install fuel/air separator in the air vent line from tank to prevent air vent spills.

Two-stroke engine exhaust

Inefficient two-stroke engines release up to 30 percent of their gas/oil mixture unburned directly into the water. For every 10 gallons of gas used, more than two gallons of gas and oil go into the water in the form of a rainbow sheen seen when the motor is idling.

Reduce two-stroke engine use

- Consider replacing a carbureted two-stroke outboard (no longer manufactured) with a quieter, cleaner, and more efficient direct-injection two-stroke engine or a four stroke engine.
- If you have a large outboard you don't plan to replace, consider purchasing a small four-stroke "kicker" to use when trolling or moving short distances. You'll save money on fuel, save wear-and-tear on your larger motor and enjoy a cleaner environment.

When detergents, soaps, and solvents are put on fuel spills, fuel that might otherwise evaporate from the surface is scattered down into the water. This "rainfall effect" causes pollution in all levels of the water, rather than just the surface, and is very difficult to cleanup. Additionally, detergents can contain chemicals that are harmful to marine life.

Handle spills appropriately

- If you have a spill wipe it up with a rag – don't hose it off into the water.
- If fuel is spilled into the water:
  - Call 1-800-OILS-911 and the Coast Guard at 1-800-424-8802 for any spill, large or small, that causes a sheen.
  - Don't use soap or dish detergent - they worsen the problem and their use on spills in the water is against federal law.
- If a spill occurs in a marina, notify the marina management immediately.

GRADES 6-8

Time: 45 mins-1 hr.

Boat Engine-eering

Aligned Standards

2014 SCIENCE (NGSS)

- MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.
- MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

OR SOCIAL SCIENCE

- Investigate a response or solution to an issue or problem and support or oppose, using research.

COMMON CORE: LANGUAGE

- Integrate information presented in different media or formats as well as in words to develop a coherent understanding of a topic or issue.
- Cite textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
- Write arguments to support claims with clear reasons and relevant evidence.
- Engage effectively in a range of collaborative discussions with diverse partners on grade-level topics, texts, and issues, building on others' ideas and expressing their own clearly.

Activity at a glance

Students build a simple engine and perform a series of experiments to demonstrate Newton's Laws of Motion. They then modify their engine design to address common boating safety concerns.

Objectives

Students will:

- Understand Newton's three laws of motion through experimentation
- Build an aeolipile ("Hero's Engine") to represent a boat engine
- Design solutions to improve engine performance
- Apply these experiences to understand safe boating practices

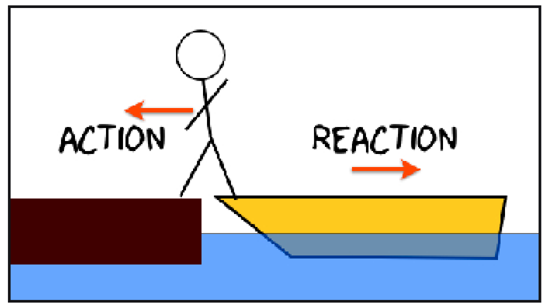


Image credit: wired.com

Newton's Three Laws of Motion explain how boats move and are controlled on the water.

Materials

For each group of 4-6 students:

- 1 plastic cup
- 2 plastic bendable straws
- String (approx. 24 inches)
- Modeling clay
- A skewer or something sharp to poke holes in cup
- Pitcher with water
- Sink or bucket
- Copies of Student Sheets

Background Information

Have you ever stepped off a boat onto a dock and felt the boat get pushed away? If so you have experienced **Newton's Third Law** of Motion: for every **action**, there is an equal and opposite **reaction**. The stepping off of the boat is the action, and the boat responds by traveling some distance in the opposite direction. The amount that the boat travels depends both on the mass of the person and the boat, and the force and speed with which they step off. This is explained by **Newton's Second Law,** which states that the **force** on an object is equal to the **mass** of that object multiplied by **acceleration** (F=ma). **Newton's First Law** states that an object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an external force—in other words, an object tends to keep doing what it's doing. This tendency to resist changes in objects' state of motion is known as **inertia**. Of course, a ball rolling across a flat surface won't keep rolling forever because **friction** will eventually slow and stop the ball, which is considered an external force.

These laws of motion govern many things in the world around us every day. Every time you sit in a chair, knock something over, fly in an airplane or high-five a friend, Newton is at work. It is especially important to understand these concepts when boating. Beyond simply stepping off a boat onto the dock, Newton's Laws control the boat's movement, steering, and ability to avoid collisions. These laws help a boat's engine to operate, dictate how quickly the boat can swerve, and the reaction of the boat when it hits the waves. On a sailboat, the wind both pushes and pulls the sail to create movement.

The principles of action and reaction, force, and inertia were understood to some degree before described by Newton. In the first century AD, Hero of Alexandria invented the **aeolipile** (also called Hero's Engine) which was the first known steam engine. The same Laws of Motion which allowed Hero's invention to work are also the basis for today's engine designs.

Procedures

PART 1

1. Introduce the activity by asking if students have ever stepped off a boat onto a dock and felt the boat seem to fly away from their foot behind them. Ask students why that happened? Tell students that Newton's Laws of Motion were behind this event and are the reason for many things in our every-day lives.
2. Use the Background Information and the Resources provided to give a brief overview of Newton's Laws (if students have no previous knowledge of this topic). Use the board to note key terms and vocabulary.
3. Tell students that they will be using Newton's Laws of Motion to build their very own engine. Explain the history and function of a Hero's Engine using the Background Information (there is further information provided on Student Sheet #1).
4. Break students into groups of 4-6 and distribute the building materials. Students will follow the instructions on Student Sheet #1 to build their engines.

NOTE: If you are short on time, or feel that it would be unsafe to allow your students to handle sharp instruments, you may prepare the cups ahead of time by poking the holes yourself.

5. Monitor students carefully for safety concerns while they work, but encourage students to use the directions and diagrams and work as a team to construct their engines.
6. Provide sinks or large buckets for students to test their engines—watch out for water flying around! Students will have to carefully hold their engine above the sink or bucket to avoid spills.
7. Help to troubleshoot any engines that fail to spin. This will likely be due to leaks from the straw holes or not enough water poured into the cup to create the necessary pressure.

PART 2

1. Instruct students to follow the directions to complete Student Sheet #2. Help guide them using the answers provided in the Teacher's Key. You may need to provide additional materials for students to modify their engine designs.
2. Evaluate student understanding and discuss the experience with questions such as:
    - What were some challenges your group faced during the construction process?
    - How does the engine demonstrate Newton's Laws of Motion?
    - Is there anything you would do to change the design if you were to build another engine?
3. Relate the concepts learned to boating safety. Now that students have demonstrated how boat engines work, and learned why boats turn and stop so slowly, remind them that collisions on the water are much more difficult to avoid than in cars. This is why it's so important to operate a boat at a safe speed and stay alert for any obstacles such as other boats, rocks, and swimmers. It is also an important reminder that the best way to be prepared for any accident is to wear a life jacket AT ALL TIMES while the boat is moving, and to encourage friends and family members to do the same!

Sir Isaac Newton (born in England in 1642) was a physicist and mathematician and is regarded as one of the most important scientists of all time. His contributions to science include work in the fields of optics, mechanics, calculus, and astronomy.

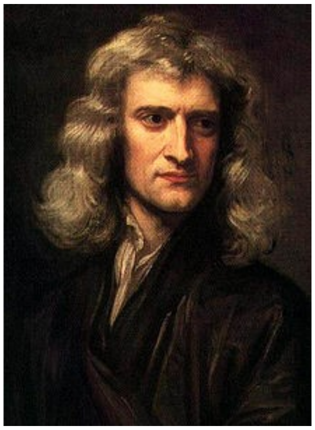


Image credit: Creative Commons

STUDENT SHEET #1

BUILD YOUR OWN "HERO'S ENGINE"!

Hero of Alexandria was the first known inventor of a steam-powered turbine, which he invented in the first century AD and named the "aeolipile". This device consists of a vessel, usually a sphere or cylinder, sitting on an axis and having oppositely bent nozzles projecting from it. When the vessel is pressurized with steam, the steam is pushed out through the nozzles, generating thrust. Because the nozzles point in opposite directions, force is produced along different paths; this combined with the thrust makes the vessel turn on its axis. This invention is the basis of many modern engines, including the ones used in cars and on motor boats.

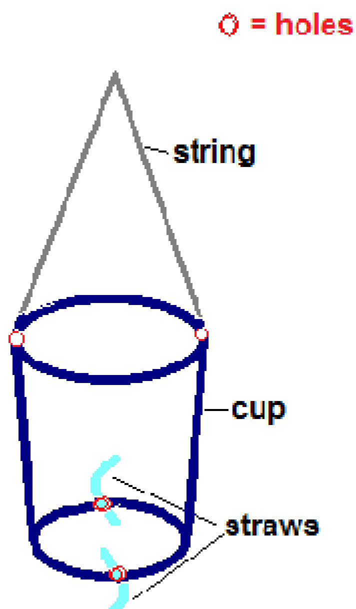
Using a few simple materials we can be "Heroes" and build our own aeolipoles! Instead of using steam to turn the engine, we will be using the power of water pressure.

Image credit: Creative Commons

A sketch of Hero's Engine, showing the vessel pressured with steam from water being heated by fire below.

DIRECTIONS

1. Gather your group's materials: 1 plastic cup, 1 length of string, 2 straws, and a small amount of modeling clay
2. Ask for your teacher's help to poke two small holes near the top of the cup, on opposite sides.
3. Thread the string through the holes and tie the ends of the string in a knot. This will allow you to hold the cup suspended by the string.
4. Ask your teacher to help poke two slightly larger holes, just large enough for the straws to fit through, near the bottom of the cup on opposite sides.
5. Cut each straw about 2 inches below the "bendy" part.
6. Push the end below the "bendy part" of each straw through one of the holes. Turn the straws so that they point towards opposite directions.
7. Divide your lump of modelling clay in half and use each half to firmly seal the spaces between the cup and the straws. Test for leaks by pouring in a small amount of water.
8. Hold your engine away from yourself, over a sink or a bucket. Use a pitcher to slowly pour in water, and watch it spin!



STUDENT SHEET #2

Answer the questions below.

1. Which of Newton's Laws of Motion are involved with making your engine spin, and how? HINT: There may be more than one correct answer.

2. In which direction does your engine spin, clockwise or counter-clockwise?

How would you make your engine spin the other way? Test your hypothesis by modifying your engine design, then record your methods and results:

3. Your engine works much like a boat engine, with the straws representing the propellers, though it is powered by water pressure instead of by fuel combustion. Because boat engines (unlike car engines) are moving through a fluid which is denser than air, they are much slower to react to changes in speed or direction.

How could you modify your design to make your engine spin faster, and thus better allow a boat to swerve more quickly to avoid a collision? Use the space below to describe your methods and sketch a new engine design.

STUDENT SHEET #2

TEACHER'S KEY

Results and Modifications

1. Which of Newton's Laws of Motion are involved with making your engine spin, and how? HINT: There may be more than one correct answer.

*All three of Newton's Laws can be considered to be at play in the engine. The First Law tells us that the engine will remain at rest until acted on by an external force (the water). The Second Law tells us that the stronger the force of the water, the faster the engine will spin (Force=mass * acceleration). The Third Law states that for every action there is an equal and opposite reaction, which is what makes the engine spin: the water being forced by gravity to leave the cup pushes back on the cup in the opposite direction, making it spin.*

2. In which direction does your engine spin, clockwise or counter-clockwise?

Answers will vary depending on which way their straws point.

How would you make your engine spin the other way? Test your hypothesis by modifying your engine design, then record your methods and results:

The straws simply need to be switched around to point in the other direction to make the cup spin the other way. For example, if the straws were initially pointed in a clockwise direction, they need to be turned to point counter-clockwise to make up the cup turn in that direction.

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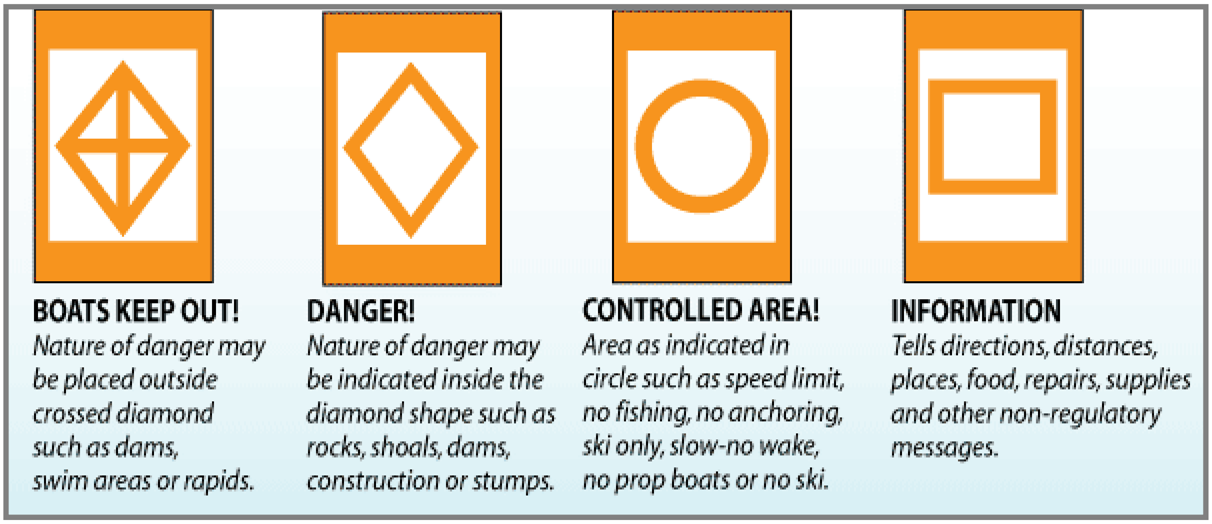
How could you modify your design to make your engine spin faster, and thus better allow a boat to swerve more quickly to avoid a collision? Use the space below to describe your methods and sketch a new engine design.

There are several possible options that could make their engines perform better, i.e. spin more quickly. They could increase the size of the cup to allow more water to be poured in, thereby increasing pressure. The pressure of the water flow could also be increased by making the straw diameters smaller. Making the straws longer or shorter might also change the speed of the engine.

NOTE: If you are able to extend this activity to an additional class period, students may use additional materials to build new engines or modify their existing designs to test the above hypotheses.

The Boating "Rules of the Road"

Navigational aids are similar to traffic signs. They're placed at various points along our waterways to help boaters locate their position and to steer clear of danger. Because it is difficult to stop or turn a boat quickly, it is very important to understand what the signs mean so you can avoid accidents and collisions. **Draw these common sign shapes on the board and discuss their meanings.**



Additional Resources

The Physics Classroom—Newton's Laws: http://www.physicsclassroom.com/Physics-Tutorial/Newton-s-Laws

Physics and History of Propellers: http://www.explainthatstuff.com/how-propellers-work.html

Safe Boating—Know Before You Go: http://www.oregon.gov/OSMB/Pages/safety/safety.aspx

Oregon State Marine Board
Boating Education Program

PO Box 14145
Salem, OR 97309

Serving Oregon's recreational boating public through education, enforcement, access, and environmental stewardship for a safe and enjoyable experience.

For more information please contact MariAnn McKenzie, Boating Safety Education Coordinator:

mariann.mckenzie@oregon.gov
503-378-5158

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www.boatoregon.com

Boating Safety 101

- Make sure all gear and people are balanced
- Don't make sudden movements that could tip the boat over
- Stay seated at all times when boat is in motion
- If your boat does capsize, STAY WITH IT! Most boats will float even when upside-down. And a boat is much easier to spot by rescuers than a person!
- For safety, everyone on board should wear a life jacket at all times — adults AND kids. Children 12 & under must wear one when the boat is in motion— it's the law!

I PLEDGE TO USE THESE SAFE PRACTICES WHEN ON A BOAT.

SIGNED: ____________ ____________ ____________ ____________

DID YOU KNOW?
Life jackets are available to borrow at many Oregon Waterways! For a list of sites, visit:
www.oregon.gov/osmb

Draw a picture of your family having a fun day on the water here!

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1-10-1 Principle—in cold water, you have *one minute* to get your breathing until control and calm yourself, *ten minutes* of meaningful movement, and *one hour* before you lose consciousness due to hypothermia**.**

Acceleration— in physics, is the rate of change of velocity of an object.

Action and Reaction—in every interaction, there is a pair of forces acting on interacting objects. Each reaction is in response to the initial action.

Aeolipile—also known as a "Hero's Engine", it is a simple bladeless steam turbine which spins when the central water container is heated. Torque is produced by steam jets exiting the turbine, much like a rocket engine.

Anglers—Men, women, or children who fish.

Aquatic—of or relating to water.

Balanced and unbalanced forces—If two individual forces are of equal magnitude and opposite direction, then the forces are said to be balanced. An object is said to be acted upon by an unbalanced force only when there is an individual force that is not being balanced by a force of equal magnitude and in the opposite direction.

Ballast—heavy material, such as gravel, iron, or water, placed low in a vessel to improve its stability.

Biofouling—the gradual accumulation of waterborne organisms on the surfaces of structures in water that contributes to corrosion of the structures and to a decrease in the efficiency of moving parts.

Blubber—The thick layer of fat between the skin and the muscle layers of whales and other marine mammals. It insulates the animal from heat loss and serves as a food reserve.

Boat—all watercraft used or capable of being used as a means of transportation on the water, including a seaplane on the water (not in flight) but NOT including boathouses, floating homes, air mattresses, beach and water toys, or single inner tubes.

Booms—a temporary floating barrier used to contain an oil spill and prevent it from reaching the shoreline. Booms help to concentrate oil in thicker surface layers so that skimmers, vacuums, or other collection methods can be used more effectively.

Buoyancy—the ability or tendency to float in water or air or some other fluid.

Capsize—to overturn in the water.

Catch limits—also known as bag limits; laws imposed on fishermen restricting the number of animals within a specific species or group of species they may kill and keep. Size limits and fishing seasons sometimes accompany catch limits.

Chemical dispersants— a common tool used after oil spills to break up oil slicks on the water surface into smaller particles and increase the oil's rate of degradation by wind or wave action.

Cold water immersion—When one's body completely enters cold water. The definition of cold water is variable. For practical purposes, significant risk of hypothermia usually begins in water colder than 77° F.

Density—the degree of compactness of a substance.

Deposition—the geological process in which sediments, soil and rocks are added to a landform or land mass. Wind, ice, and water, as well as sediment flowing via gravity, transport previously eroded sediment, which, at the loss of enough kinetic energy in the fluid, is deposited, building up layers of sediment.

Drought—a prolonged period of abnormally low rainfall; a shortage of water resulting from this.

Equilibrium—a state in which opposing forces or influences are balanced.

Erosion—A type of weathering in which surface soil and rock are worn away through the action of glaciers, water, or wind.

Force— In physics, something that causes a change in the motion of an object.

Friction—the resistance that one surface or object encounters when moving over another.

Habitat—the natural home or environment of an animal, plant, or other organism.

Hydrologic cycle—the storage and movement of water between the *biosphere* (the regions of Earth occupied by living organisms), *atmosphere* (the blanket of gases surrounding the Earth), *lithosphere* (the rigid outer part of the earth, consisting of the crust and upper mantle), and the *hydrosphere* (all the waters on the earth's surface, such as lakes and seas).

Hyperventilation—a condition characterized by abnormally prolonged and rapid breathing, resulting in decreased carbon dioxide levels and increased oxygen levels that produce faintness, tingling of the fingers and toes, and, if continued, alkalosis and loss of consciousness.

Hypothermia—a medical emergency that occurs when your body loses heat faster than it can produce heat, causing a dangerously low body temperature.

Incapacitation—occurs within 5 – 15 minutes in cold water. Vasoconstriction decreases blood flow to the extremities in an effort to preserve heat in the core, thereby protecting the vital organs but allowing the periphery to cool. Within this critical time frame you will lose meaningful movement in your hands and feet, and then your arms and legs.

Inertia—a tendency to do nothing or to remain unchanged.

Invasive species—an organism (plant, animal, fungus, or bacterium) that is not native and has negative effects on our economy, our environment, or our health.

Involuntary reaction—there are two types of involuntary reactions, *autonomic* and *reflex.* The autonomic nervous system controls the body's internal environment without conscious intervention and helps to regulate vital functions. A reflex is an involuntary response to a stimulus, such as withdrawing your hand from a hot surface before you become aware of the heat.

Irrigation— is the watering of land to make it ready for agriculture.

List—a nautical term for when a boat tilts towards one side.

Marine mammals—a diverse group of species including whales, polar bears, dolphins, and otters that rely on the ocean for their existence. All of these species have the five characteristics of mammals: they are warm-blooded, have hair or fur, give birth to live young, nourish their young with mother's milk, and breathe air.

Mass—a measure of the number of atoms in an object. The basic unit of measurement for *mass* is the kilogram.

Mitigation—The elimination or reduction of the frequency, magnitude, or severity of exposure to risks; the minimization of the potential impact of a threat or warning.

Morphology—the shapes of river and stream channels and how they change over time.

Native species—an organism (plant, animal, fungus, or bacterium) that is naturally found in a region. These can be either endemic (found only within a particular region) or indigenous (found both within the region and elsewhere).

Natural resources—anything that people can use which comes from nature. People do not make natural resources, but gather them from the earth. Examples are air, water, wood, oil, wind energy, hydro-electric energy, iron, and coal.

Newton's First Law—every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force.

Newton's Second Law—The acceleration of an object as produced by a force is directly proportional to the magnitude of the force, in the same direction as the force, and inversely proportional to the mass of the object.

Newton's Third Law—For every action, there is an equal and opposite reaction. The statement means that the size of the forces on the first object equals the size of the force on the second object.

Non-point source pollution—water and air pollution from many diffuse and sometimes unknown sources.

Oil skimmers—a machine that separates a liquid from particles floating on it or from another liquid, such as oil.

Organic materials—matter composed of organic compounds that has come from the remains of organisms such as plants and animals and their waste products in the environment.

Overfishing—a non-sustainable use of aquatic or marine resources in which the supply of fish and other animals is depleted or exhausted.

Plankton—small and microscopic organisms drifting or floating in the sea or fresh water, consisting chiefly of tiny plants and algae, small crustaceans, and the eggs and larval stages of larger animals.

PFD—Personal Flotation Device

Point source pollution— a single identifiable source of air, water, noise or light pollution.

Porous—having minute spaces or holes through which liquid or air may pass.

Reservoir—a large natural or artificial lake used as a source of water supply.

Resource manager—a person who develops conservation and rehabilitation plans for nature reserves, land, rivers, and other natural resources, so that people can use these resources in an ecologically sustainable way.

Shock—lasts for only about a minute after entering the water and refers to the effect that cold water has on your breathing. Initially, there is an automatic gasp reflex in response to rapid skin cooling; this can lead to hyperventilation. If the head goes underwater, water may be breathed into the lungs during the gasp.

Slicks—a film or layer of oil floating on an expanse of water, especially one that has leaked or been discharged from a ship.

Stakeholders—people who can affect, be affected by, or have personal interest in an issue.

Strainer—a common river hazard consisting of sticks or branches. Water passes through these but solid objects like boats or people do not, similar to a kitchen strainer. Even boaters wearing life jackets can drown if they are washed into a strainer, because they can get trapped underwater against the branches by tons of water pressure.

Sustainable—capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage.

Town Hall Meeting—an informal public meeting at which community members discuss issues and concerns.

Vectors—a pathway by which non-native species are transported or carried to new environments. This can include currents, boats, humans, or other organisms.

Volume—the amount of space that a substance or object occupies, or that is enclosed within a container.

Water scarcity—the lack of sufficient available water resources to meet the demands of water usage within a region.

Woody debris—large wood that falls into a stream or river, including logs, branches, and root balls. This debris can cause dangerous hazards in rivers for boaters.

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