How Can You Find a Shipwreck in Murky Brown Water?

Objectives: Students will be able to describe different types of waves, including light waves and sonar waves, and how they interact with the environment. They will be able to detail how waves differ and how people have harnessed waves for various purposes. They will create a hypothesis that they test in an experiment, practice identifying and interpreting patterns, and interpret their findings in a written text.

Materials: Several balls of different sizes and different materials, a windowless exterior wall (brick, stone, wood, cement block, etc.), safety googles, large handkerchief or similar blindfold, pencils and notebooks for students, graph paper (one page per student), and handouts on pages 4-9, one per student).

Georgia Performance Standards:

CCGPSELA
- ELA GSE4RI1-9
- ELA GSE4RF3, 4a, 4c
- ELA GSE4W1-9
- ELA GSE4SL1-6
- ELA CC9-10W1.d, 2e, 7
- ELA CC9-10SL3
- ELA CC9-10L3

Science
- S8P4a, b, c, e
- SP4a
- SPS9a,b

Social Studies Skills Matrices
- Map and Globe Skills 8, 12
- Information Processing Skills 1, 11, 12, 14, 15

Reading Standards for Literacy in History/Social Studies
- L6-8RHSS2, RHSS4

Writing Standards for Literacy in History/Social Studies, Science
- L6-8WHST1d, e; L6-8WHST2, a-f; L6-8WHST4

Benchmarks for Science Literary Concepts
- Energy Transformations, Motion

Science and Engineering Practices Grades 9-12
- Asking Questions and Defining Problems, Planning and Carrying Out Investigations

Aligns with Next Generation Science Standards (NGSS):

4. Waves: Waves and Information

HS. Waves and Electromagnetic Radiation

HS. Energy

Background

The CSS *Georgia* was an ironclad vessel constructed in Georgia by the Confederacy in 1862. Ironclads were sheathed in iron in an attempt to protect them from enemy vessels firing upon them. Ladies from across the state and the south raised money to fund its construction. The vessel was built of wood and iron railroad rails. This made it too heavy to be propelled by its engine , so the CSS *Georgia* sat in the Savannah River defending the city until December 1864 when Union Major General William T. Sherman took the town on his March to the Sea. Confederate troops sunk the vessel so Union troops would not get it. Several years after the Civil War, and several times during the 20th century, attempts were made to salvage parts of the wreck. During this time, the U.S. Army Corps of Engineers (USACE) dredged the river repeatedly to make the channel deeper. In 2015, the USACE hired underwater archaeologists to excavate the CSS *Georgia* wreck. This was done so that the Savannah River channel could be dredged five feet deeper to allow larger ships coming through the Panama Canal to enter Savannah's port.

How Can You Find a Shipwreck in Murky Brown Water?

Method
Begin with the Brainstorming Session, then conduct the Wall Ball experiment with students. After that, pass out handouts (p. 4-9) for students to read and answer, intermixed with classroom discussion.

Procedure: Brainstorming
1. What phenomenon allows you to see things around you?
Prompts: *Light waves reflecting off of an object enter your eye through your pupil. The lens of your eye focuses the light onto the back of your eye called the retina, which consists of light-sensitive neurons called photoreceptors. These photoreceptors contain chemicals that change the light signals into electrical ones before sending them to the brain.*

2. How do blind people “see” things?
Prompts: *Blind people often use their sense of touch to “see” or feel what something looks like. Receptor cells in a person’s skin respond to mechanical, chemical, or thermal stimuli. The nerve endings in the receptors transduce (convert) the stimuli energy into electrical signals that are sent along the spinal cord to the brain. The brain interprets these sensations based on the properties of the receptors and also on previous stored experiences and recognizable patterns.*

3. What do the above have in common?
Prompts: *Energy; the transfer of energy between different systems including light waves, electrical signals, and/or chemical signals; and pattern recognition.*

4. If the river and ocean water is too murky to see through, and scuba divers can’t possibly touch all of a river or ocean bottom, then how can scientists find and see shipwrecks in a brown-water environment?

5. Do you always have to see with your <u>eyes</u>? Can you use energy and waves and pattern recognition to “see” in other ways?

Experiment: Wall Ball
Take students outside and stand in the vicinity of a building having a solid wall. Bring a stopwatch or watch with a second hand, several balls (volleyball, rubber ball, two tennis balls, etc.), safety googles, and a handkerchief/blindfold. Have students each bring a notebook and pencil with them. Once outside, ask them if they were blindfolded, how could they use those materials to find or “see” the wall?

Give students time to brainstorm until they eventually determine that they can throw the ball. If it hits the wall, then they have found it. If it hits the wall and bounces back, they can determine how far away the wall is relative to their location, based on how long it takes (in seconds) for the ball to bounce back. Prompt: If different ball throwers stand at the same distance from the wall, what other variables need to be controlled to accurately determine the relative distance of the wall? (The amount of force used to throw the ball; the angle of the person to the wall; the environment – is it snowing, raining, or are there trees or obstacles between the ball thrower and the wall; whether the same type of ball is used by each thrower, etc.)

Instruct students to use points in the discussion, or other ideas, to create their own research question, such as, “Does the force of the ball affect the distance measurement (as recorded in seconds)?” Or “Is the distance affected by the angle of the thrower?” Or “If a thrower tosses two balls at the wall, will they come back at the same rate?” etc. (continued on p.3)

How Can You Find a Shipwreck in Murky Brown Water?

Experiment: Wall Ball (continued from p. 2)

Divide the students into groups of 5-7 people. Then direct the groups to turn one research question into a research hypothesis, such as "The force of the ball affects the distance measurement" or, "The distance is affected by the angle of the thrower", or "If the ball does not bounce back, then there was no wall where the ball was thrown", etc. Then explain that it must be turned into a null hypothesis in order to test it. To do this they must add "no" or "not" to their statement, such as "The force of the ball does not affect the distance measurement" or "The distance is not affected by the angle of the thrower".

Then taking turns, each group selects a group to help them conduct their experiment. The safety goggles and blindfold are placed on each member of the selected group one at a time, after which the bindfolded person is instructed to throw a specific ball in a particular manner, as required by the group's hypothesis. For example in the first hypothesis a group might have one student throw the ball hard at first and then the second time throw it soft, and record the measurements each time. Or the group might have two different students take turns standing at the same place and throwing the ball to the wall, while recording the time it takes the ball to return to that spot. In the second example, a group might have one student throw the ball facing the wall and then throw it again at an oblique angle to the wall, recording the different measurements each time. Have each group record the measurements and other information in their notebooks for their group's hypothesis. Have them determine if their data makes them reject their null hypothesis or fail to reject it. (Explain that they can't say they "accept the null hypothesis", they can only reject it or fail to reject it.)

Back in the classroom have students summarize their experiment in a written narrative. They should write a brief introduction to the topic, then describe their research question and hypothesis and what rationale they use to support it. Students should re-write their null hypothesis and a brief description of the experiment. They should present their data in two ways, such as text, a pie chart, a drawing, a bar chart, graph, table, etc. Students should interpret their data using facts that link to their rationale. They should write a concluding statement about whether they reject or accept their null hypothesis. Students can then present their findings to a small group of the class, revise and refine their presentation, and then present it to the entire class.

Class Discussion

What are other ways you can "see" where something is, without using your eyes or throwing balls?

Prompts: If your eyes see light waves reflecting off of objects and then changes the waves into electrical signals to the brain, can sound waves bouncing off of objects (like the ball bouncing off the wall) be converted into electrical signals that can be measured to determine the distance of an object away from you?

Can those electrical signals then be printed out on a computer in different colors to reflect different distances, showing patterns (like the wall) on the river or ocean bottom? That is what underwater archaeologists do when they use sonar to "see" the bottoms of rivers and oceans.

Did you know that when you see any wave, only energy, and not actual matter is moving? Waves are the *transfer of energy*. For example, sound waves transfer sound energy (acoustic) through air (gases), water, or solids. These waves of energy vibrate molecules within the air, water, or solids, and the vibration makes the sound you hear.

All waves can be put in one of two categories, electromagnetic or mechanical.

Light waves can travel through a vacuum like space (like when sunshine travels through space from the sun to the earth). This reveals that light , like X-rays and microwaves, is an electromagnetic wave. These waves periodically move back and forth (oscillate) in electrical or magnetic fields. Other waves, like sound waves, can't travel through a vacuum, but need gas, water, or solids to travel. These are called mechanical waves. For example, sound waves travel from a guitar through the atmosphere (gas) to your ear and you hear music. You can't hear sound waves in outer space because ispace is a vacuum and has no gas/atmosphere.

Why do sound waves travel FASTER in water than in air?

Water molecules are closer together than air molecules. This allows water molecules to bump into each other quicker when sound vibrations hit them.

Sonar uses sound to locate objects underwater. What animals use sonar? Certain bats, whales, dolphins, shrews, and cave swiftlets (birds) use sonar.

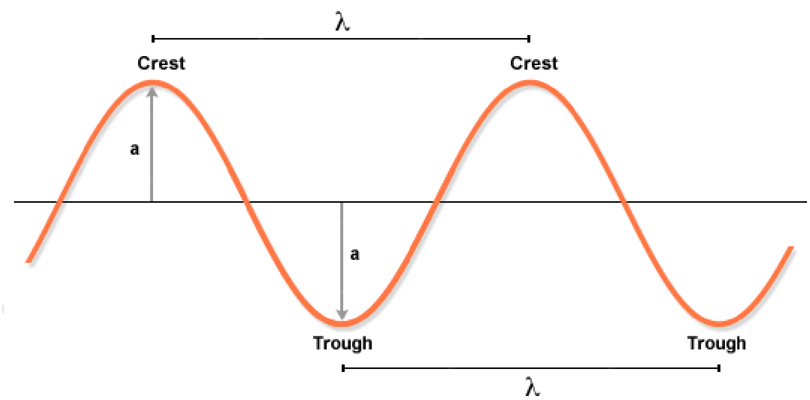
How Can You Find a Shipwreck in Murky Brown Water?

Frequencies

The *frequency* of a wave is the number of waves passing a point in a certain time, usually in one second. That is called a hertz (Hz). So 1 Hz =1 cycle (one wave) a second. Sound waves have different frequencies.

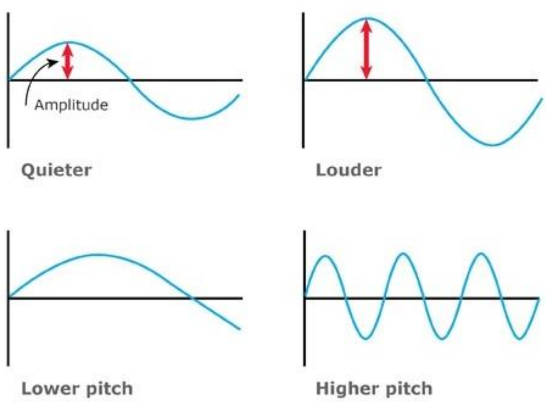
The frequency of the sound wave is chosen based on how far the wave has to travel. Lower frequency waves can travel farther in a medium, such as water, because the motion of these waves is closer to a straight line. Their straight lines travel through the water at a more perpendicular angle, allowing them to penetrate and not lose intensity as quickly as waves at higher frequencies, which have curvier lines.

Higher frequency sonar waves, because they approach the surface of the object at more of an angle, are more likely to bounce off of the object instead of passing through it, allowing for better images. More sound waves that bounce back to the receiver mean better pictures. Therefore, for detailed pictures, a high frequency sound wave is desirable. If the sea floor is so deep that the high frequencies cannot reach, then lower frequency waves may be the better choice.



The *amplitude* of a wave is the distance from the center line to the top of a crest or the bottom of a trough. The greater the amplitude, the more energy the wave is carrying.

The *wavelength* of a wave is the distance from any point on one wave to the same point on the next wave. (Example – from crest to crest or from trough to trough).



Courtesy: University of Walkato

How Can You Find a Shipwreck in Murky Brown Water?

How to See When You Can't: Multibeam Sonar

Did you know that *sound waves* travel farther in water than do *radar* and *light waves*? That makes sound waves perfect for finding things underwater! Underwater archaeologists use sonar, using sound waves, to see the bottoms of rivers and oceans and the shipwrecks that may be there. The National Oceanic and Atmospheric Administration (NOAA) explains sonar well and its descriptions are used throughout this lesson plan.

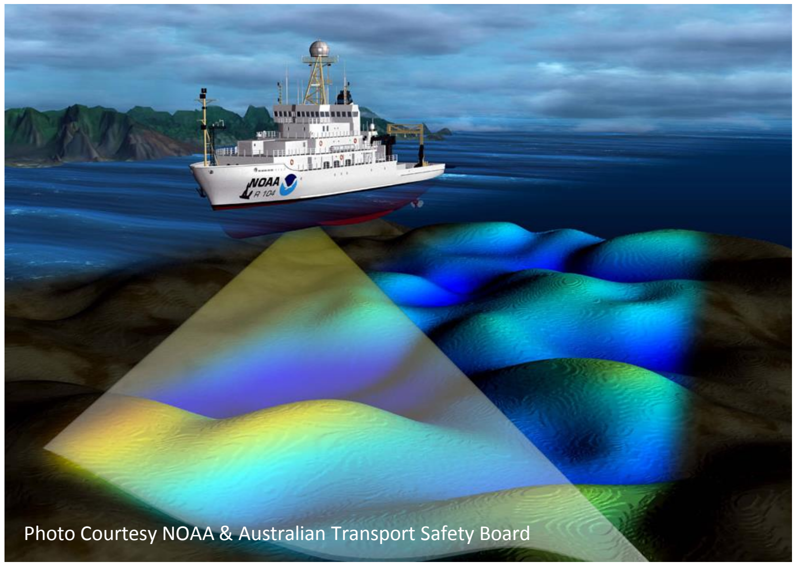
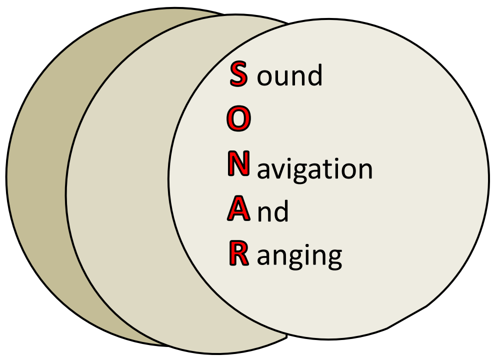
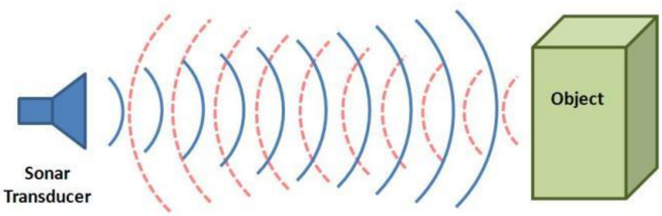


Photo Courtesy NOAA & Australian Transport Safety Board

Sonar transmitters emit a sound (acoustic signal) called a "ping" into the water. If an object is in the path of the sound pulse, the sound bounces off the object and returns an "echo" to the sonar's receiver. The receiver measures the strength of the signal. By determining the time between making the sound pulse and when it was received, the sonar can determine where an object like a wreck is located and how it is positioned. – NOAA



Remember timing the ball when it bounced back from the wall in the class experiment?



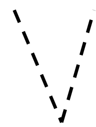
Basic sonar illustration – a transducer generates a sound pulse and then listens for the echo.

Courtesy Wikipedia.

In sonar, the transmitter and receiver are called *transducers* because they convert energy into another form. The ***transmitter converts an electrical signal into an acoustical pulse*** and ***the receiver converts an acoustical pulse into an electrical signal.*** A computer determines how long it takes to receive the returning pulse. The computer translates this into depth measurements. The more time it takes for the pulse to return, the deeper the object is. Assigning different colors for different depths creates a top-side view of the sea floor.

How Can You Find a Shipwreck in Murky Brown Water?

Unlike a side scan sonar, a multibeam sonar has several transducers that allow a wide , fan-shaped area to be surveyed with each pass of the boat. The depth of the water determines the width of the beam. A greater water depth means there is more area for the sound to echo.

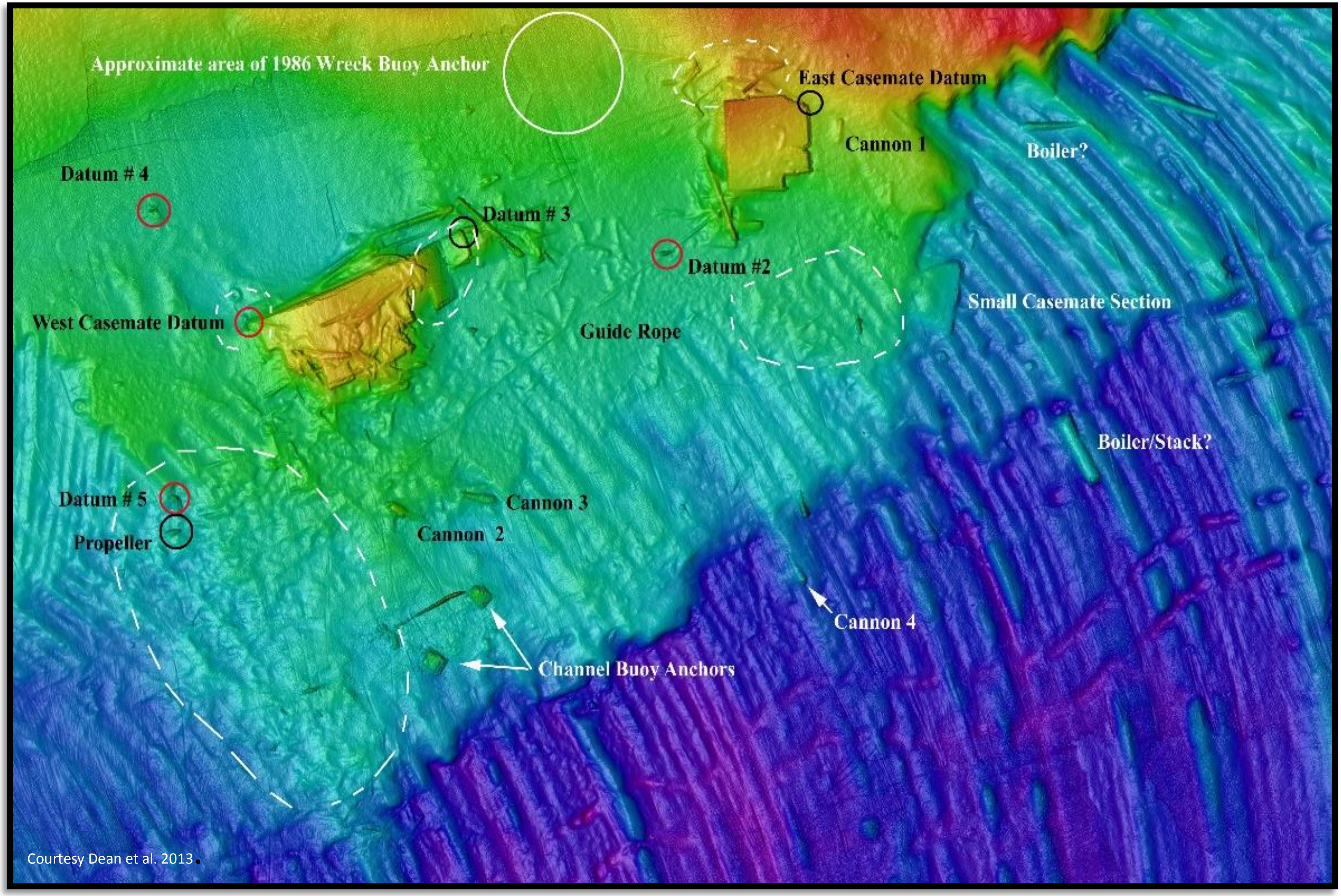


- The sonar pings several times per second. The number of pings and the speed of the boat determines how good the picture of the sea floor will be.
- If the boat is moving very fast and the rate of sonar pings is slow, then the number of times sound is bounced off the seafloor is fewer than if the boat was moving slowly and the ping rate was high.
- Also, if the river or ocean is very deep, then the boat must move slower or use a higher ping rate in order to make a good picture, since it takes longer for the sound pulse to bounce back.
- The ping rate is also limited by the speed of sound in water. There can be only one ping in the water at a time, so the transducer must wait to receive the last ping sent before sending the next one . When the best image is wanted, scientist narrow the sonar multibeam angle and squeeze all 500 beams into a narrower swath!

Why does this work?

It focuses more beams on the bottom of the swath, but also reduce s the angle that the pings on the outer edges of the beam have to travel. This shortens the ping travel time and speeds up the ping rate. So archaeologists get narrow coverage, but a detailed image. *Remember the wall ball experiment? Balls took longer to bounce off the wall when the ball thrower was at an angle to the wall, than when facing the wall.*

Multibeam sonar underwater archaeologists use has a high degree of accuracy. They achieved this by recording the exact time of each ping and measuring the time and angle of its return. This enables them to make detailed 3-D surface models of the river bottom and of shipwrecks, such as the CSS *Georgia*. In order to maintain accuracy, an inertial motion unit keeps track of the sonar transducers' position several times a second, using global positioning satellites (GPS) and measuring the pitch, roll, and heading of the boat to within 0.03 200 times per second (200 hz). They must also correct for the speed of sound in water of various temperatures, density, and salinity.



This multibeam sonar map reveals portions of the Civil War ironclad shipwreck sunk in 1864 and resting on the bottom of the murky Savannah River in Savannah, Georgia. What patterns to you see in the sonar map?

How Can You Find a Shipwreck in Murky Brown Water?

Examine the multibeam sonar map. Imagine that you are an archaeologist interpreting the data on the map. Red and yellow colors are shallower depths than blue and purple. “Casemate” is the top of the ship. What patterns do you see?

1. **Is the shipwreck whole or broken in pieces?**

1. **How can you tell this was likely a war ship?**

3. **What do you think created all those lines and furrows in the deeper purple, blue, and part of the green sections?**

Review the handouts and previous class discussions to determine the answers to the following.

4. **Did underwater archaeologists use sound or light waves in their multibeam survey?**

5. **What factors did they need to consider at the beginning of field work and why ?**

6. **What type of waves are sonar waves and what do they need in order to transfer energy?**

7. **The CSS Georgia shipwreck was found in the Savannah River, which is a tidal river. That means during high tide water from the Atlantic Ocean is pushed upstream into the river. During low tide fresh water flows downstream. Knowing this, what do underwater archaeologists have to consider when using the multibeam sonar here?**

How Can You Find a Shipwreck in Murky Brown Water?

Answers

Examine the multibeam sonar map. Imagine that you are an archaeologist interpreting the data on the map. Red and yellow colors are shallower depths than blue and purple. “Casemate” is the top of the ship. What patterns do you see?

1. **Is the shipwreck whole or broken in pieces?** It is at least two pieces, the west casemate on the left and the east casemate on the right.

2. **How can you tell this was likely a war ship?** The map shows four cannons that were on the ship.

3. **What do you think created all those lines and furrows in the deeper purple, blue, and part of the green sections?**
   Those long lines are scars in the river bottom. They were made over many years when the river bottom was dredged to keep the channel deep enough for boats to travel without getting stuck, especially during low tide. Notice how the scars go into parts of the shipwreck. Some of the scars were made when boats accidentally dragged the nearby buoy anchor and its chain across the wreck and river bottom. This also damaged the wreck.

Review the handouts and previous class discussions to determine the answers to the following?

4. **Did underwater archaeologists use sound or light waves in their multibeam survey?** The multibeam survey was a sonar survey tool that used sound waves, which travel well through water.

5. **What factors did they need to consider at the beginning of field work and why ?**
   They had to make adjustments for water characteristics such temperature, salinity and density. They also had to adjust their sonar equipment based on the depth of the river bottom, the rate of pings, the current, and the speed of the boat.

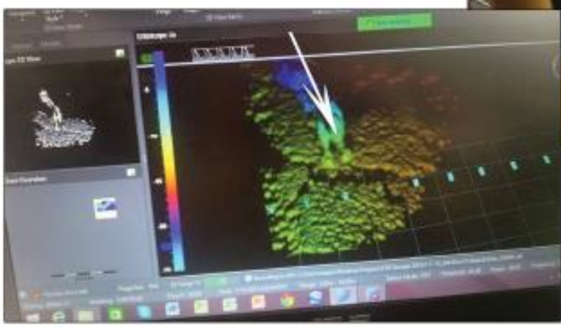
6. **What type of waves are sonar waves and what do they need in order to transfer energy?** They are mechanical waves that need matter, such as gas/air, liquids, or solids to produce sound.

7. **The CSS Georgia shipwreck was found in the Savannah River, which is a tidal river. That means during high tide water from the Atlantic Ocean is pushed into upstream into the river. During low tide fresh water flows downstream. Knowing this, what do underwater archaeologists have to consider when using the multibeam sonar here?** They must take into account the increased salinity during high tide when salt water dominates the water around the wreck. They must consider low tide when the water is fresh, and they must realize that during portions between low and high tide the river may be brackish – part fresh and part salt water. All of these things can make the sonar pings bounce back at angles and rates that are not true. In addition, the fluctuating tides raise and lower the river levels by as much as 6-7 feet. This will impact the way they configure the size of the sonar swath and the angle of the sonar beams in order to get an accurate image.

How Can You Find a Shipwreck in Murky Brown Water?

Military personnel and archaeologists use an array of technology to monitor divers' movements underwater and help them record and retrieve artifacts in very low visibility. (U.S. Navy, Explosive Ordnance Disposal Group Two)

See these two plumes (by white arrow)? They're a Navy Diver and an EOD tech, rigging a confederate cannon for recovery. (U.S. Navy, Explosive Ordnance Disposal Group Two)



On-scene commander Chief Warrant Officer 3 Jason Potts goes over UXO (unexploded ordnance) recovery plans with Julie Morgan, Technical Project Manager and District Archaeologist for US Army Corps of Engineers, and Stephen James, Archaeologist and Co-Principal Investigator for Pan-American Consultants, Inc. (U.S. Navy, Explosive Ordnance Disposal Group Two)

Resources

Australian Transport Safety Board
"Multibeam Sonar Fact Sheet",
https://www.atsb.gov.au/media/5147105/collecting_multibeam_sonar_data.jpg
accessed March 28, 2016.

Dean, Martin, Mark Lawrence, Stephen James, Jr., Gordon Watts, and Mike Rice
2013 "High Resolution Multi-beam Sonar Survey", Panamerican Consultants, Memphis, Tennessee.

Museum of Underwater Archaeology
CSS *Georgia*
http://www.themua.org/cssgeorgia launched April 5, 2016 with new additions to follow.

National Ocean and Atmospheric Administration (NOAA)
"How Multibeam Sonar Works"
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/multibeam/multibeam.html accessed, March 8, 2016.

National Ocean and Atmospheric Administration (NOAA)
"National Ocean Service", http://oceanservice.noaa.gov/facts/sonar.html March 8, 2016.

Sound Scapes
3 Minute video about sound waves for download
http://oceanservice.noaa.gov/facts/sonar.html March 28, 2016.