Case File 2

Bouncing Back: Using ground-penetrating radar to locate buried objects

Locate Mrs. Holloway's car and help solve this cold case.

To: Detective Sergeant Ashanti
Re: Possible new evidence in Holloway case

We have just received new information on this unsolved, high-profile case from several years ago. On May 6, 2000, the wife of billionaire oil tycoon Donald Holloway drove away in her car and never returned. As we never found any evidence of foul play, we believed that Mrs. Holloway left her husband and changed her identity. Recently, Mrs. Holloway's California vanity license plate, OIL GIRL, was found outside a remote gas station along the Desert Highway. This particular gas station happens to be quite close to lands owned by the Holloway oil empire. Also uncovered in recent weeks have been several documents detailing the purchase of some large properties along the road. It now looks like Holloway may have killed his wife and buried her and her car at one of the properties. Sample email is attached.

From: jwinchester@ ZongoReelEstayt.com
Date: May 8, 2000
To: dholloway@hollowayoil.com
Subject: RE: your needs

Mr. Holloway –

Per your request, I have identified four abandoned sites along Desert Highway that would suit your needs. The following locations are very remote and have been untouched for years:

- the old Two Tree golf course
- the 1960s government rocket-testing site (now deserted)
- the construction site on 31st and Desert
- the abandoned Bright Days housing development

Good luck with your latest endeavor.

Forensics Objective

- explore the use of ground-penetrating radar (GPR) to find buried materials

Science and Mathematics Objectives

- detect the presence of an object, using a range finder
- distinguish between different-shaped objects, using a range finder

Materials (for each group)

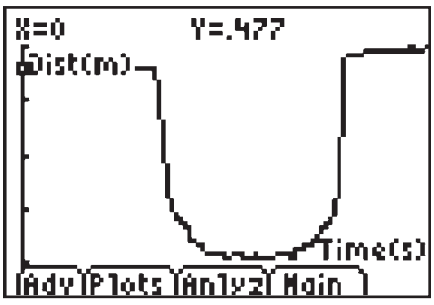
- TI-83/TI-84 Plus™ Family
- Vernier EasyData™ application
- Calculator-Based Ranger™ 2 (CBR™ 2)
- USB cable
- small box or block of wood
- several large boxes, each containing an unknown object

Procedure

1. Attach the USB cable to the CBR 2. Connect the other end of the cable to the calculator's USB port. The EasyData App should self-load. If it does not, press APPS and select **: EasyData**.

2. Set up the CBR 2 to collect one data point every 0.05 seconds for 200 seconds.
   a) Select Setup. Select option **2: Time Graph**.
   b) Select Edit to change the experiment parameters.
   c) Press CLEAR and type **0.05** for the time between samples.
   d) Select Next, press CLEAR, and type **200** for the number of samples.
   e) Select Next. Confirm that the experiment parameters are correct (sample interval = 0.05 seconds, number of samples = 200, experiment length = 10 seconds), and then select OK.

3. Get to know how the CBR 2 displays its data.
   a) Place a block of wood or a small box on your desk. Make sure that there is nothing else on the surface of your desk.
   b) Hold the CBR 2 about a meter above your desktop and toward one end of your desk. Select Start. You will hear a rapid clicking sound from the detector. Slowly move the motion detector, at a constant height above the desktop, from one end of your desk to the other end. Make sure that the light-gray part of the detector is facing the desk and that it passes over the top of the block or box on your desk.
   c) After 10 seconds, the clicking will stop. The screen will say that data are being transferred. Then you should see a display like the one shown below. (Note: It may take a few seconds for the data to transfer. Be patient!)



d) Your display will look like the one shown above only if you have moved the detector slowly, at constant speed, and at a constant height. If you turn your calculator upside down, the image looks more like something sitting on the desktop.
e) Using the arrow keys, you can see how far the desktop and the top of the box were from the CBR 2. (Note: If you do not get a graph like the one on the previous page, repeat step 3b. Make sure that your desk is clear, that the light-gray part of the detector is facing the desk, and that you maintain a constant speed and height above the desk.
f) Select [Main] to return to the Main screen. Repeat steps 3a–d with the box in a different orientation, such as on one of its ends. If you get a message about overwriting stored data runs, select [OK]. Explore the graphs until you are comfortable with how the graph shows the location and shape of the object on your desk.

4. Your teacher will direct your group to move to one of the suspected "burial sites" for the car. Record the location of the site in the Evidence Record.

5. Without looking inside the box, probe each of the suspected burial sites.
   a) Rest the CBR 2 on the top edge of a flap that runs the length of the box, with the light-gray part of the detector facing the bottom of the box.
   b) Practice slowly moving the CBR 2 along the flap at a constant height. You need to move the CBR 2 at a speed that will let you move from one end of the box to the other in about 10 seconds. Practice this until you can move the detector at the correct speed and at a constant height.
   c) When you are ready, select [Start]. If you get a message about overwriting stored data runs, select [OK]. Begin moving the detector just after you begin to hear the rapid clicking noise.
   d) Once the data are transferred, examine the shape of the graph.
   e) Repeat step 5c to see if you get a similar shape again. If not, repeat step 5c until you get a consistent shape. If you are having trouble, ask your teacher for assistance.
   f) Sketch the display shown on the screen into the Evidence Record.

NAME: _____

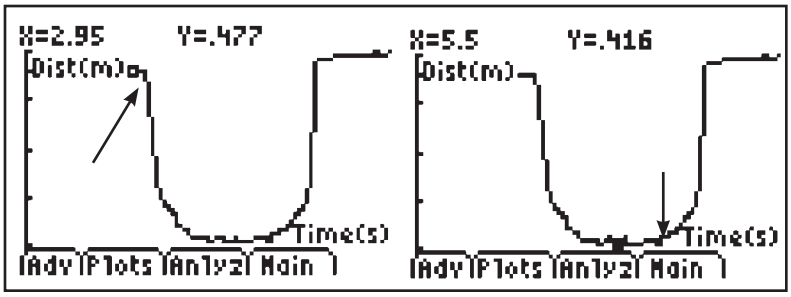
DATE: _____

Evidence Record

Site Probed by Detector	Sketch of Shape Found by Detector

Case Analysis

1. Analyze the sketches that you have made. Which site contains the buried car? Explain your reasoning.
2. Using the screen captures shown below, determine the height of the object. The **X=** is the time in seconds, and the **Y=** is the distance from the CBR 2 in meters. The cursor location is indicated by an arrow. The **X=** and **Y=** values are shown for the cursor location.



3. Why is it important to move the CBR 2 slowly but at a constant speed? What would happen if you didn't move it at a constant speed?
4. What can make the CBR 2 image (or a real GPR image) of an object look different from the actual profile of the object?
5. How could someone get a more complete image of the object if they used real GPR?

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Teacher Notes

Teaching time: one class period

This lab uses the CBR 2™ to determine the presence and height of an object that can't be seen.

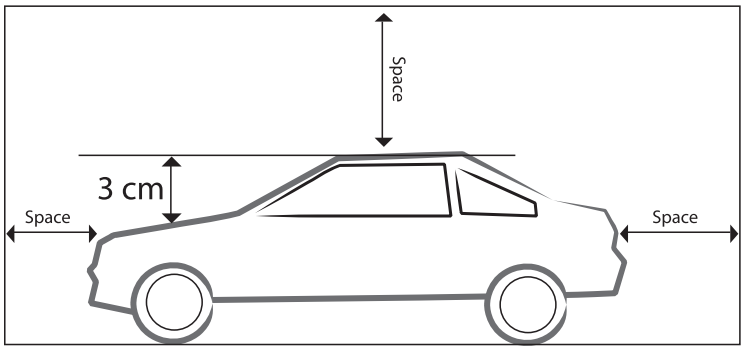
Tips

- Office supply stores sell large boxes. Grocery stores may have some large boxes set out for customers.
- It may prove easier for students to move the CBR 2 smoothly if it is attached to a meterstick.
- If you have access to a *very* large box, you can have the students make several passes over the box with the CBR 2, placing the sensor farther from the edge of the box for each pass. In this way, students can produce a slightly more detailed picture of the bottom of the box. They will also simulate the use of GPR more accurately. However, please note that the CBR 2 transmits and receives signals in a cone of about 8°, so only a *very* large box will work.
- If students are unable to resist the temptation to look inside the boxes, divide the students into groups. Have each group image the object in one of the boxes, and then have the groups trade calculators so that they each have to interpret the display for an object that they did not see.
- If students are having a hard time interpreting the shapes of the various objects, they can repeat step 3 with several different-shaped objects to become more familiar with the way the calculator displays its data.

Lab Preparation

- Obtain at least four large boxes (24 × 12 × 14 in, or higher than 14 in). For each box, tape the top flaps up so that they make the box taller. Students should not be able to see what is inside the box when it is placed on a table. (Hint: The top edge of a flap can be used as a guide for the students to rest the CBR 2 on. This will help to keep the CBR 2 at a constant height as the detector is moved from one end of the box to the other. Placing a long strip of cellophane tape on the edge will help the student to move the detector smoothly.)
- Place an object with a distinctive shape (such as a box, block of wood, large eraser, stapler, roll of tape, or mug) inside each of three boxes. Inside the fourth box, place a model car.

You can make a car from blocks of wood. The motion detector works best on objects with flat surfaces. Make sure that the hood and trunk are at least 3 cm shorter than the top of the car.



- If you are using a box that is 24 in long, the car should be no more than 20 cm long. If the bottom of the box cannot be detected on both sides of the car, the students will not get a good image of the car.
- Label the boxes with the four suspected burial sites for the car. You may elect to place the boxes at different locations in the room and have student groups go there to collect their data with the CBR 2.
- Students will need to practice on a small block of wood or box to learn how the motion detector displays shapes.
- You may want to leave one of the boxes empty.

Background Information

Ground-penetrating radar (GPR) is a technique that is used frequently by geologists and archaeologists to locate objects and features below the ground. It has also become common to use GPR in forensic investigations. GPR utilizes the same principles as other kinds of radar. Pulses of electromagnetic radiation (often in the frequency range of radio waves) are sent into the ground. These pulses tend to reflect off interfaces in the subsurface—places where two distinctive materials (such as dirt and oil, or rock and water, or soil and metal) meet. The reflected rays travel back to the GPR device, which records the time it takes for the waves to reflect back and the intensity with which they are reflected. With some computer processing, it is possible to create an approximate image of subsurface structures.

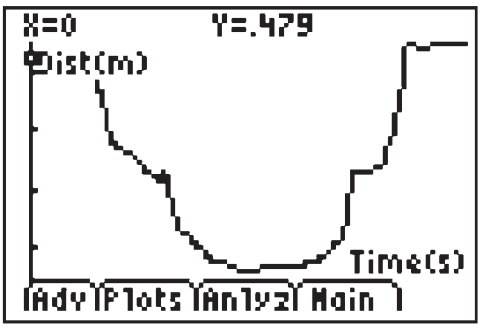
Although GPR is a powerful tool, it does have some limitations. The waves tend to attenuate rapidly in water, making it difficult to accurately image saturated soils. The detectors also pick up reflections from surface and near-surface materials, such as trees. Good filtering can remove these “ghost” images, but in general, GPR is best at imaging objects that are 50 cm to 1.5 m in depth. As with all types of radar and sonar, there is a trade-off between resolution and penetration: One can detect deep large objects or shallow small objects but not small objects that are very deep.

Resources

http://www.du.edu/~lconyers/SERDP/GPR2.htm
This Web site provides an in-depth look at how GPR can be used in archaeology. It also contains some basic theory and methodology for GPR.

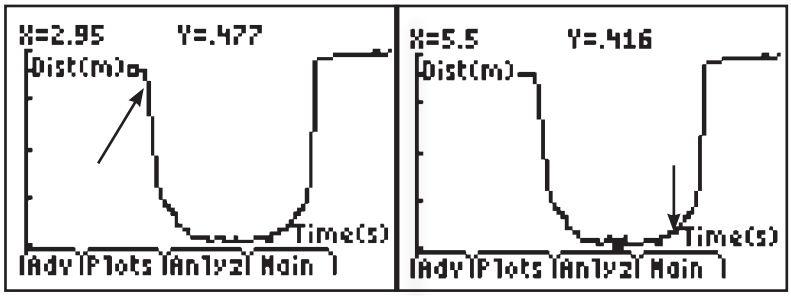
Sample Data

The shapes the students obtain depend on the objects they are investigating. Below is an example of what a car may look like on the CBR 2 screen.

Site Probed by Detector	Sketch of Shape Found by Detector
(Burial site containing a car)	

Case Analysis Answers

1. Analyze the sketches that you have made. Which site contains the buried car? Explain your reasoning.
   Student should explain that the shape of the car is different from the other shapes observed; it has contours similar to those of a car.
2. Using the screen captures shown below, determine the height of the object. The **X=** is the time in seconds, and the **Y=** is the distance from the CBR 2 in meters. The cursor location is indicated by an arrow. The **X=** and **Y=** values are shown for the cursor location.



   The height of the object is 0.061 m, or 6.1 cm.
3. Why is it important to move the CBR 2 slowly but at a constant speed? What would happen if you didn't move it at a constant speed?
   It is important to move the CBR 2 at constant speed so that time can be used as an estimate of distance or location. If you change the speed of the CBR 2, the horizontal profile will be out of proportion.
4. What can make the CBR 2 image (or a real GPR image) of an object look different from the actual profile of the object?
   The CBR 2 image won't match the profile of the object if the CBR isn't held at a steady height and moved at a steady speed. Also, the CBR can pick up only the top surface of the object. If an object is complex, many parts of its profile will not be picked up. In addition, other objects between the intended object and the sensor will interfere with the profile of the intended object.
5. How can someone using a real GPR get a more complete image of the object?
   Making many different transects and then piecing those transects together makes a three-dimensional image.