

Activity 42: Single-Channel Seismic Graphing

Maine Geological Survey



Objectives:

Students will learn the nature of and procedure for using seismographic data; they will graph the results of actual single-channel recordings and use this data to determine the depth to the water table at a specific location.

Time:

This activity will last at least one class period.

Background:

A single-channel seismograph records the time it takes for sound waves to travel from a point of origin, where a hammer strikes an iron plate called the channel iron, to a recording microphone (geophone) located at increasing distances from the point of origin. The procedures for making a seismic survey are as follows.

In looking for sites to do single-channel seismic refraction, the geologist observes gravel pits, bedrock outcrops, and the location of springs and wells. Usually a hard-packed dirt road running along or across the top of a suspected sand-and-gravel aquifer is used as a data gathering site. A softer surface, such as a field, may be used if a suitable hard surface is not available.

The field crew establishes a line and orients it by using a hand held compass. The seismograph is set at one end of the line, called point A for reference, and a 300 foot tape is laid out along the line. One member of the crew does a site sketch and prepares

to read the seismograph. The other crew member uses a 6 or 8 pound sledge hammer and a piece of channel iron to amplify the sound of the hammer striking the ground.

The seismograph is attached by wire to a narrow gauge trigger on the handle of the sledge hammer which instantly registers the time when the hammer strikes the ground. The seismograph has a geophone attached to it which will measure and record a refracted sound wave from the ground. Sound waves travel at different speeds in different materials (media). The denser the material, the faster the sound wave travels. Distinctions between layers of different density, such as dry gravel as opposed to water-saturated gravel, can be made if the geologist has some idea of the composition of the subsurface materials. Some degree of seismic velocity differences always separate layers of different density.

The seismograph reader records the time it takes for each blow of the hammer to return to the seismograph in fractions of a second. The time will increase as the striker moves farther and farther away from the seismograph.

The striker begins at a distance of five feet from the seismograph and strikes the channel iron lying on the ground every five feet for the first forty feet. After this the striker will hit the ground every ten feet. A bedrock reading will usually be encountered somewhere along the 300 foot line.

A bedrock reading is indicated by having five consecutive hits with less than 1 millisecond difference between them. As soon as bedrock readings are observed, the seismograph is moved to the spot where bedrock readings were first noted; this spot becomes point B. The two crew members then repeat the process of taking readings back to point A. This is called a backshot and serves as a check on the original data as well as revealing changes in slope of subsurface layers.

The times and distances are plotted on a graph. Then specific changes in slope ($y=mx+b$) are noted. The value of the x (distance) axis at that specific break in slope can be used to plot the depth of the indicated layer below the surface. In reality the graphing and calculations are done on a computer. See sample data table, graph, and associated calculations. A number of calculations, beyond the scope of this discussion, can be derived from single-channel data.

Materials:

Students will need graph paper, data sheets, pens/pencils, notebooks, and calculators.

Procedure:

After an initial discussion of the techniques involved in seismographic data collection and use, students will be given one or more sets of data to graph. They should use the X axis for the distance in feet, and the Y axis for the time in milliseconds. For graphing purposes the students may wish to divide the time values by 1000 thus giving them whole number and tenths place decimals to graph. They will need to determine scales for BOTH axes before starting to graph.

Once graphs have been constructed, placing a ruler along portions of the line with the same slope will let you locate the positions of the so called break in slope. The first break in slope occurs where the water table currently exists in the subsoil. The distance to the water table from the surface can be calculated as shown in the formula at right, where D is the distance to the water table; X_c , the critical distance, is the value of the X axis at the first break in slope; V_1 is the velocity in the first medium (unsaturated soil); and V_2 is the velocity in the second medium (water-saturated soil). Values for V_1 and V_2 are recorded automatically by the seismograph and are included on the data sheet. See Data Table 1 and graph titled Figure 1. A computer-generated graph is enclosed for the same data; this is Figure 2. While there are a number of methods for determining D (D_1 in some literature), the above formula involves the least amount of higher mathematics and gives very reliable results.

References:

Seismic Refraction Exploration For Engineering Site Investigations, Bruce B. Redpath, 1973, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151.

Activity developed by Alan Lane, in conjunction with the 1991 CREST summer intern program.

DATA TABLE 1

Single Channel Seismic Refraction Analysis - SCSRAP Version 4.0

Site ID: MAH-I
 Description: MD9A1- PACKED S&G; BINGHAM
 Date: 7/17/90

Phone A: 0.0

| Line | Distance (ft) | Traveltime (seconds) |
|------|---------------|----------------------|
| A | 5. | 0.00276 |
| A | 10. | 0.00510 |
| A | 15. | 0.00700 |
| A | 20. | 0.01000 |
| A | 25. | 0.01300 |
| A | 30. | 0.01620 |
| A | 35. | 0.02040 |
| A | 40. | 0.02320 |
| A | 50. | 0.02780 |
| A | 60. | 0.02880 |
| A | 70. | 0.03160 |
| A | 80. | 0.03200 |
| A | 90. | 0.03480 |
| A | 100. | 0.03600 |
| A | 110. | 0.03680 |
| A | 120. | 0.03720 |
| A | 130. | 0.03800 |
| A | 140. | 0.03880 |

| | | | |
|--------|---------|------------------------------|----------------|
| Line A | Layer 1 | Velocity 1 (V ₁) | 1725 ft/second |
| Line A | Layer 2 | Velocity 2 (V ₂) | 5036 ft/second |

CALCULATIONS:

$$D = \frac{X_c}{2} \sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

X_c, from the handwritten graph, is 50 feet, thus

$$\begin{aligned} D &= \frac{50}{2} \sqrt{\frac{5036 - 1725}{5036 + 1725}} \\ &= 25 \sqrt{\frac{3311}{6761}} \\ &= 25 (.699) \\ &= 17.49 \text{ feet} \end{aligned}$$

Thus it is approximately 17.5 feet from ground level to the TOP of the water table at a distance of 50 feet from point A along the line established for this data in Bingham, Maine. Computer-generated graphs and values to the "layer" will be slightly different from those obtained by doing the graphs by hand. They will be very close, however. Students should check their graphs if they are not coming out close to the depth to the water table. Depth values to the water table, calculated by the computer, have been included on the various data sheets; you may wish to remove these before duplication for student use.

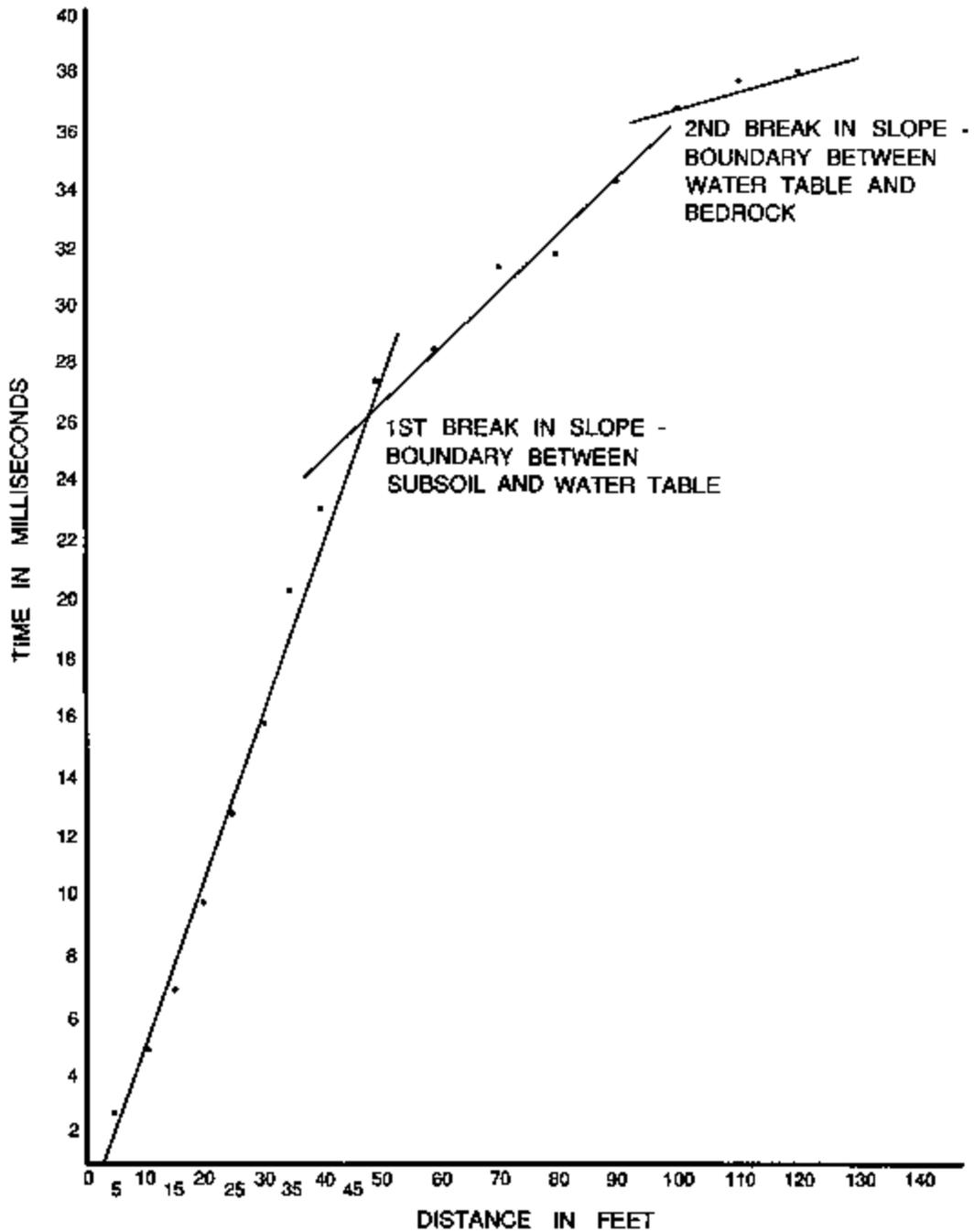


Figure 1. Once graphs have been constructed, placing a ruler along portions of the line with the same slope will let you locate the positions of the so called break in slope. The first break in slope occurs where the water table currently exists in the subsoil.

Single Channel Seismic Refraction Analysis - SCSRAP Version 4.0

Site ID: MAH-K
 Description: MD9A1- S&G; BINGHAM
 Date: 7/17/90

Phone A: 0.0

| Line | Distance (ft) | Traveltime (seconds) |
|------|------------------|-------------------------|
| A | 5. | 0.00184 |
| A | 10. | 0.00460 |
| A | 15. | 0.01040 |
| A | 20. | 0.01460 |
| A | 25. | 0.01780 |
| A | 30. | 0.02120 |
| A | 35. | 0.02240 |
| A | 40. | 0.02280 |
| A | 50. | 0.02360 |
| A | 60. | 0.02600 |
| A | 70. | 0.02840 |
| A | 80. | 0.03040 |
| A | 90. | 0.03200 |
| A | 100. | 0.03360 |
| A | 110. | 0.03600 |
| A | 120. | 0.03680 |
| A | 130. | 0.03960 |
| A | 140. | 0.04200 |
| A | 150. | 0.04520 |
| A | 160. | 0.04760 |
| A | 170. | 0.04800 |
| A | 180. | 0.04880 |
| A | 190. | 0.05200 |
| A | 200. | 0.05400 |
| A | 210. | 0.05500 |
| A | 220. | 0.05600 |
| A | 230. | 0.05700 |

$V_1 = 1566$ ft/sec

$V_2 = 5216$ ft/sec

Depth to water table is 11.9 feet

Data Table 1. Sample data table from single channel seismic refraction analysis.

Single Channel Seismic Refraction Analysis - SCSRAP Version 4.0

Site ID: MAH-G
 Description: MD9A1- GRASSY; BINGHAM
 Date: 7/17/90

Phone A: 0.0

| Line | Distance (ft) | Traveltime (seconds) |
|------|------------------|-------------------------|
| A | 5. | 0.00384 |
| A | 10. | 0.00730 |
| A | 15. | 0.01040 |
| A | 20. | 0.01360 |
| A | 25. | 0.01640 |
| A | 30. | 0.01780 |
| A | 35. | 0.01900 |
| A | 40. | 0.02000 |
| A | 50. | 0.02240 |
| A | 60. | 0.02400 |
| A | 70. | 0.02480 |
| A | 80. | 0.02840 |
| A | 90. | 0.03000 |
| A | 100. | 0.03080 |
| A | 110. | 0.03280 |
| A | 120. | 0.03560 |
| A | 130. | 0.03880 |
| A | 140. | 0.04120 |
| A | 150. | 0.04200 |
| A | 160. | 0.04200 |
| A | 170. | 0.04800 |
| A | 180. | 0.04900 |
| A | 190. | 0.05000 |
| A | 200. | 0.05000 |

$V_1 = 1398$ ft/sec

$V_2 = 5295$ ft/sec

Depth to water table is 8.4 feet

Data Table 2. Sample data table from single channel seismic refraction analysis.

Single Channel Seismic Refraction Analysis - SCSRAP Version 4.0

Site ID: MAH-T
 Description:
 Date: 8/8/90

Phone A: 0.0

| Line | Distance (ft) | Traveltime (seconds) |
|------|------------------|-------------------------|
| A | 5. | 0.00392 |
| A | 10. | 0.00840 |
| A | 15. | 0.01220 |
| A | 20. | 0.01520 |
| A | 25. | 0.02060 |
| A | 30. | 0.02400 |
| A | 35. | 0.02580 |
| A | 40. | 0.02700 |
| A | 50. | 0.02840 |
| A | 60. | 0.03040 |
| A | 70. | 0.03240 |
| A | 80. | 0.03400 |
| A | 90. | 0.03640 |
| A | 100. | 0.03880 |
| A | 110. | 0.04080 |
| A | 120. | 0.04160 |
| A | 130. | 0.04480 |
| A | 140. | 0.04680 |
| A | 150. | 0.04920 |
| A | 160. | 0.05160 |
| A | 170. | 0.05520 |
| A | 180. | 0.05400 |
| A | 190. | 0.05520 |
| A | 200. | 0.05480 |
| A | 210. | 0.05680 |
| A | 220. | 0.05880 |
| A | 230. | 0.06120 |
| A | 240. | 0.06400 |
| A | 250. | 0.06640 |
| A | 260. | 0.06840 |
| A | 270. | 0.06880 |
| A | 280. | 0.06920 |
| A | 290. | 0.07040 |
| A | 300. | 0.07120 |

$V_1 = 1143 \text{ ft/sec}$

$V_2 = 5673 \text{ ft/sec}$

Depth to water table is 11.7 feet

Data Table 3. Sample data table from single channel seismic refraction analysis.

Single Channel Seismic Refraction Analysis - SCSRAP Version 4.0

Site ID: MAH-J
Description: MD9A1- S&G ROAD; BINGHAM
Date: 7/17/90

Phone A: 0.0

| Line | Distance (ft) | Traveltime (seconds) |
|------|------------------|-------------------------|
| A | 5. | 0.00300 |
| A | 10. | 0.00590 |
| A | 15. | 0.00760 |
| A | 20. | 0.01060 |
| A | 25. | 0.01260 |
| A | 30. | 0.01500 |
| A | 35. | 0.01800 |
| A | 40. | 0.02000 |
| A | 50. | 0.02440 |
| A | 60. | 0.02680 |
| A | 70. | 0.02840 |
| A | 80. | 0.02800 |
| A | 90. | 0.03000 |
| A | 100. | 0.03400 |
| A | 110. | 0.03520 |
| A | 120. | 0.03760 |
| A | 130. | 0.04000 |
| A | 140. | 0.04240 |
| A | 150. | 0.04320 |
| A | 160. | 0.04360 |
| A | 170. | 0.04440 |

$v_1 = 2001 \text{ ft/sec}$

$v_2 = 5083 \text{ ft/sec}$

Depth to water table is 15.1 feet

Data Table 4. Sample data table from single channel seismic refraction analysis.

Name _____



Activity 42: Single-Channel Seismic Graphing

Maine Geological Survey

Student Sheet

Purpose:

To introduce the students to single channel seismic mapping and to have them calculate the depth to the water table for real seismic data.

Materials:

You will need graph paper, data sheets, pens/pencils, notebooks, rulers, and calculators.

Procedure:

Single-channel seismic work helps geologists obtain a clear picture of underground soil, rock, and water layers without doing a lot of expensive and time-consuming drilling. Sound waves are recorded and measured as they move through the ground. The sounds are produced by hammering on a piece of iron with a sledge hammer. They are recorded by microphones, called geophones, attached to a machine called a seismograph. A computer takes the seismograph data and prints out graphs of the path the sound waves took to reach the geophones; the computer will also calculate the depths to the water table, the upper surface of water-saturated ground, and bedrock. The material below the water table is called an aquifer. The precision and accuracy of aquifer mapping has increased greatly in recent years mainly because of the widespread use of seismographs.

In this activity you will be given data obtained from a real seismic survey of an area near Bingham, Maine. You will graph this data using the X axis for distance in feet, and the Y axis for time in milliseconds. You will want to divide the original values for time by 1000; this will give you whole numbers and one-place decimals to graph for the most part.

After you have graphed the data, take a ruler and identify the three areas of the graph where the slope of the line is different. Draw straight lines along these areas. A typical arrangement might look like the graph in Figure S1.

The spot on the graph where a change in slope occurs is called a break in slope. The first break in slope on any graph of seismic data usually represents the boundary between the subsoil and the aquifer. This point has been circled on the above diagram. Circle this point on YOUR graph and drop a perpendicular from the break in slope to the X axis. The value of the X axis at this point is called X_c , and this distance is known as the critical distance. Using the following formula at right, you can calculate the distance down to the water table. D is the depth of the top of the water table below the surface of the earth. The velocities, V_1 and V_2 , are given by the computer on the data table. When you have graphed your data and done the calculations for D , you should check with your instructor to see if you are correct in your calculated distance to the water table.

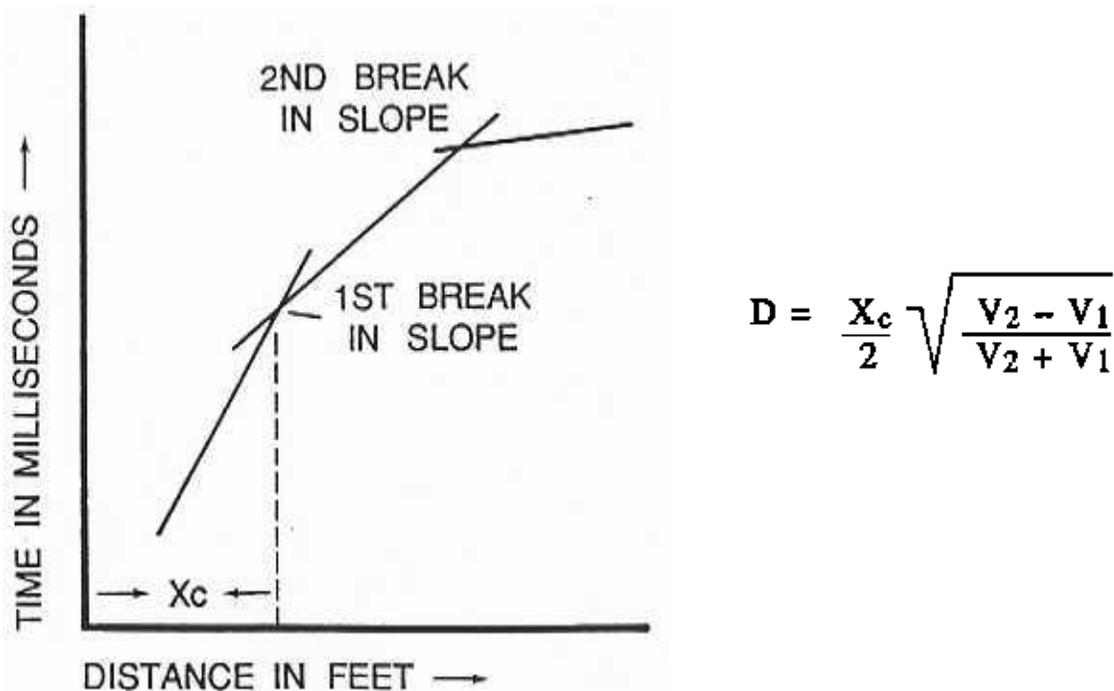


Figure S1. Stylized seismic data graph.