TBL # 3: Near-surface, SH-wave surveys in unconsolidated, alluvial sediments
Young & Hoyos, 2001

DUE: TBA

Overview

This case history consolidates many of the basic concepts related to refraction seismology within the context of an environmental problem. Your goal is to summarize the case history within the context of the 7-Step process. Both refraction and reflection seismic are discussed, this exercise will focus primarily on the refraction seismic portion of the case history. For non-multiple choice questions, please provide brief answers.

Instructions

Answer the following questions within the context of the 7 step framework. Your answers should be brief, and point form can be used where appropriate.

Resources

- GPG: Seismic

Part 1: Multiple Choise (10 pts)

Setup

1. What motivated the study?
   (a) Leachate from an old landfill is moving down gradient through alluvium toward a reservoir.
   (b) Leachate from an old landfill is moving down gradient through alluvium toward a major river.
   (c) Leachate from an old landfill is being block by shale from reaching a major river.
   (d) Leachate from an old landfill is not dissipating into the earth.

2. What background information is available?
   (a) The top boundary of the alluvium is the Hennessey shale, which leachate won't penetrate.
   (b) The bottom boundary of the alluvium is the Hennessey shale, which leachate will penetrate.
   (c) The bottom boundary of the alluvium is the Hennessey shale, which leachate won't penetrate.
   (d) The Hennessey shale allows the leachate to penetrate through.

Physical Properties

Diagnostic physical property is seismic velocity.

Geophysical Survey

3. Which surveys were selected
   (a) P-wave and s-wave refraction survey (walkaway)
   (b) Reverse shot refraction (delay-time)
   (c) Seismic reflection survey
   (d) All of the above

Data Processing & Interpretation

For questions 4-6 , consider the P-wave refraction data, shown in Figure 2 in the paper.

4. What is the P-wave velocity for the direct arrival? Evaluate this from the arrivals on the seismic section and do not use the number provided in the box. Pay attention to units!!
   (a) 0.35 m/s
   (b) 348 m/s
   (c) 1.6 m/s
   (d) 1600 m/s

5. This refraction event corresponds to the top of the water table. Why does this create an event?
   (a) Water-saturated ground has a lower seismic velocity than unsaturated ground.
   (b) Water-saturated ground has a higher seismic velocity than unsaturated ground.
   (c) Water-saturated and unsaturated ground have the same seismic velocity. The event is therefore noise.
   (d) None of the above.

6. Do you expect to observe this refraction event in the SH refraction data?
   (a) Yes because there is a change in the seismic velocity.
   (b) Yes because there is a boundary there.
   (c) No because SH-waves do not propagate through fluids.
   (d) No because there is no seismic velocity change.

For questions 7-8, consider the SH wave refraction data, shown in Figure 4 in the paper.

7. What is the S-wave velocity for the refracted arrival? Estimate this from the arrival times on the seismic section.
   (a) 0.94 m/s
   (b) 378 m/s
   (c) 940 m/s
   (d) 0.38 m/s

8. In this question, you will estimate the thickness of the top layer using the data in Figure 2. Estimate the thickness of the top layer using the three methods given below. Use the velocities from the previous two questions.

- What is the intercept time? What is the cross-over distance?

- Use either the intercept time OR the cross-over distance to determine the thickness.

Synthesis

9. Overall, what is the important information that was obtained from the refraction surveys?
   (a) The water table was imaged by analysis from the P-wave refraction survey.
   (b) The water table is about 1-2 m below the surface.
   (c) The top of the shale was imaged by the SH-wave refraction survey.
   (d) The top of the shale is about 10-15 m below the surface.
   (e) All of the above.

10. Was the seismic refraction effective in finding the gravel lenses at the base of the alluvium?
    (a) No because the gravel lenses don't exist.
    (b) No because the gravel lenses are too small.
    (c) No because they do not have a refraction on top since their velocity is likely less than the overlying alluvium.
    (d) (a) and (c)
    (e) (b) and (c)

Part 2: Short Answer (10 pts)

In the case history article, the authors make these two observations:

- P-wave reflections may be difficult to obtain because the top of the saturated zone often prevents a very large P-wave impedance contrast that masks reflections from deeper horizons.
- The water table is transparent to the SH-refraction.

Q11. Based on these observations, draw the reflected and refracted waves for both P- and SH-waves between a shot and a receiver in the figure below.

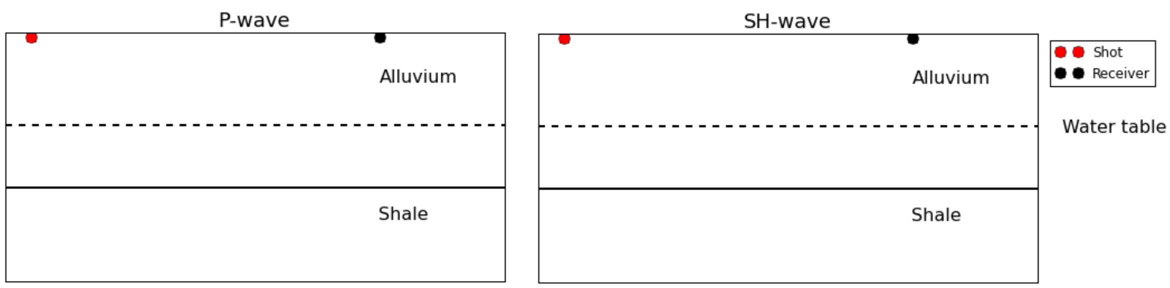

Figure 1

Now, consider the text: "*Soil borings are the Norman landfill commonly encounter a gravelly interval several feet thick at the base of the alluvium, and this zone is associated with high hydraulic conductivity (Scholl and Christenson, 1998). Our SH-refraction survey is unlikely to have seen this interval for two reasons:*

1. *If velocity decreases in the gravel, then a refraction will not exist, or*
2. *If the gravel velocity exceeds that of the shale, a refraction can exist but it may never be a first arrival because it follows a path that is slower than the path along the shale.*

If the gravel layer exists, therefore, it would be a blind zone (Burger, 1992), to SH refractions." Note that the refraction they are referring to is the critical refraction along the top of the gravel lens.

Q12. For item 1 in the above quote, draw a refraction ray path for in the interface between the gravel lens and the shale in the figure (left) below.

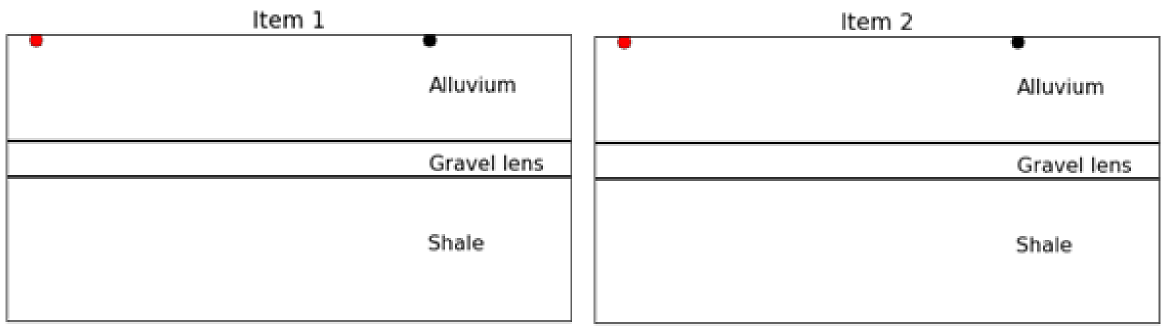

Figure 2

Q13. For item 2 in the above quote, there appears to be a typo in the authors' comment. If they are referring to a critical refraction along the top of the gravel, which two layer velocities are important to consider?

Q14. For item 2, assume that the author meant to say the following:

"If the gravel velocity exceeds that of the alluvium, a refraction can exist, but it may never be a first arrival because it follows a path that is slower than the path along the shale."

Explain why it would never be a first arrival and support your explanation by sketching ray paths for the refracted waves in the figure below. Tip: try using the SeismicApplet too!

Let's dig a bit deeper about this gravel lens. According to the case history, gravel lenses might be expected to exist above the shale and the thickness of these might be about a meter. These are zones of high permeability and sought after if ground water is to be extracted.

The seismic reflection survey indicates a reflector about 9 meters away from the origin (see figure below). To an untrained eye, this feature might not even be noticed when looking at the seismic image. However, closer scrutiny shows it is distinctive. The question is whether we can expect to see separate reflections from the top and bottom of the gravel lens. The frequency of seismic wavelet is 67 Hz.

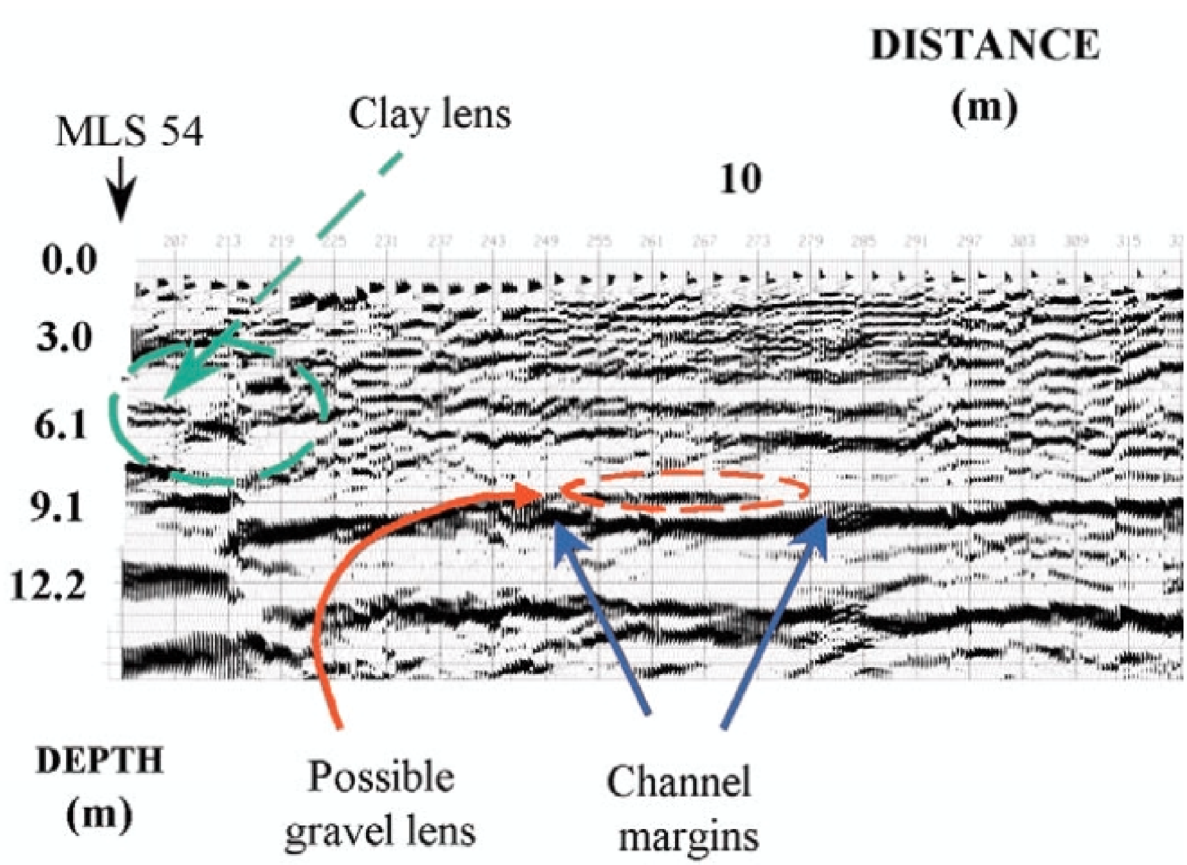

Figure 3

Q15. What is the minimum layer thickness that you can reasonably detect?

- Use the equations $L = \lambda/4$ and $\lambda = v/f$, where L is the thickness, λ is the wavelength, v is the velocity, and f is the frequency.
- Assume the velocity for the gravel lens is 200 m/s.
- See GPG: Seismic Vertical Resolution for more details

Q16. Now look at the seismic section in *Figure 3.* What are the units of the vertical axis? Seismic data are recorded in time. How could they have made this switch?

Q17. What is the distance between the two reflections in the seismic section? How does this compare with your minimum layer thickness? What confidence does this give you that you might be able to see the top and bottom of the gravel layer?