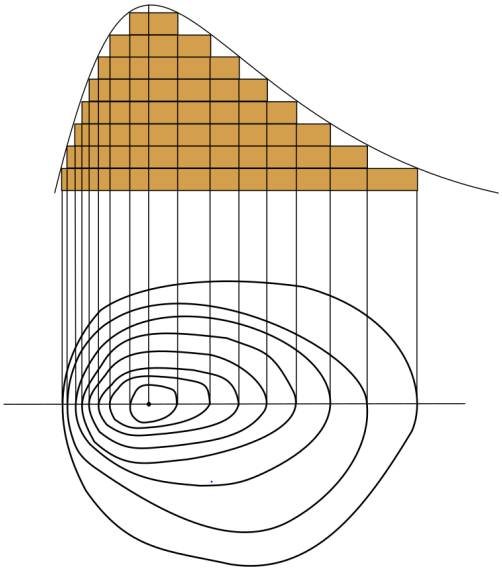
LEEMAN GEOPHYSICAL LLC
CONSULTING & INSTRUMENTATION

Groundwater Flow Lab Activity

Introduction

Groundwater is one of the most vital resources to our existence. In fact 98% of the freshwater on the planet comes from groundwater reservoirs! Pollution can ruin large amounts of this resource. The ways that water and pollutants flow underground can be non intuitive and surprising. In this lab you'll discover how water flows with relation to the pressures surrounding it underground and how pollutants can travel vast distances, only to resurface miles from where they were introduced.

The fundamental variable we are interested in when looking at groundwater flow is pressure. The more water above you, the more pressure you experience, just like when diving in a pool or a lake. The atmosphere above you exerts 1 atmosphere of pressure on you (about 14.7 psi), but only 33 feet of water can exert the same amount of pressure as that column of air. We call pressure from the weight of the water above the hydraulic head. We can connect areas of equal head with lines called equipotential lines (lines of equal potential energy). The flow of water and anything else in it will be from areas of high head to areas of low head. These flow lines, or paths the water will take, are perpendicular to the equipotential lines. This is just like a topographic map where we draw contours lines connecting areas of constant elevation. Rain would flow perpendicular to these lines, i.e. down hill.



Contour lines of constant elevation (bottom) connect areas of constant elevation on a hill (top) much like equipotential lines connect areas of constant hydraulic head. Image: Wikimedia Commons

Often to try to control the movement of pollutants or fertilizers engineers will construct barriers. Other times nature provides barriers to flow by putting rock or a less permeable material that water has a more difficult time flowing through. Remember though that in the real world everything has four dimensions - the three of space and the dimension of time. Water and contaminants will follow the laws of physics, moving from areas of high head to low head in a relentless way.

Understanding how water flows isn't just important for water resources, but it also can even influence when and where earthquakes occur. Water pressures can help jack apart faults and cause them to slip. This occurs both naturally and with man-made injections into faults. When understood, the risks can be managed, but when poorly understood can result in damaging events.

In this lab activity you'll be able to predict and explore the movement of a tracer. Tracers are substances scientists put into water that we can track over time to test and verify our predictions of how the water is moving through the earth. Laboratory experiments like this make it possible for us to understand what is happening in a relatively simple system that we can control and experiment with. It also lets us make observations in just a few minutes that may take days or even years to occur in the real world. What we learn from these analog models can then be applied to the more complex real world and used to predict, understand, and even modify the environment.

Groundwater Flow Lab Activity

Materials Needed

- Assembled flow tank, pump, tubes, etc.
- Food Coloring
- Pipettes
- 5 gallon bucket
- Sand (not included)

WARNING!!! This lab involves the use of electrical equipment around water. Be sure to do this with the supervision of an adult and keep all electrical plugs and outlets well clear of any water!

1. Fill up the flow tank with sand until the sand covers approximately 1 inch (2.5 cm) of the middle dividing plate.
2. Fill the 5 gallon bucket ½-⅔ of the way full with tap water.
3. Connect the hose from one of the high ports of the tank to the port on the water pump.
4. Take the hose from the other high port of the tank and place it in the 5 gallon fresh water bucket.
5. Take the hose from the lower port of the tank and place it in the sink drain or a waste bucket.
6. Place the pump into the 5 gallon fresh water bucket. Your setup should look like this:

7. Plug the pump in - water should start flowing into the flow tank. There is a pump lever to set the flow rate, generally running at full flow works best. The pump cannot push the water up more than a few feet, so if you are having trouble, set the bucket on a chair closer to the level of the tank. The top of the water in the bucket does need to remain below the bottom of the tank though.
8. Let the water saturate the system. The high head side will fill with clean water and that water will drain back into the bucket with the pump. The low head side will fill and begin draining into the waste tank or into your sink drain.
9. Once the system is saturated, you're ready to inject your tracers! When instructed to, using the pipettes, pick up some of the food coloring of your choice and then place the tip of the pipette into the sand and slowly inject the dye. This works best if done right against the front of the tank.

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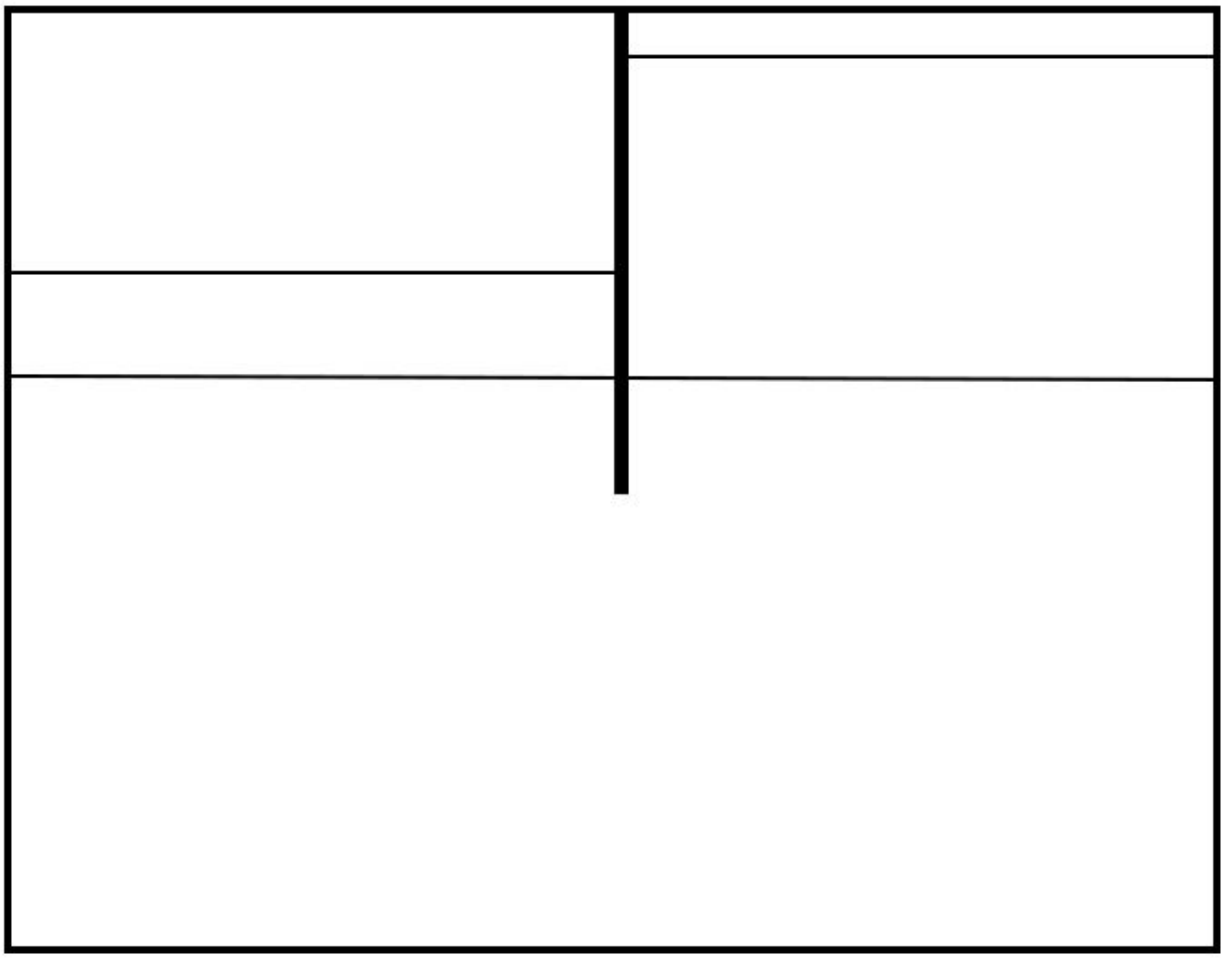
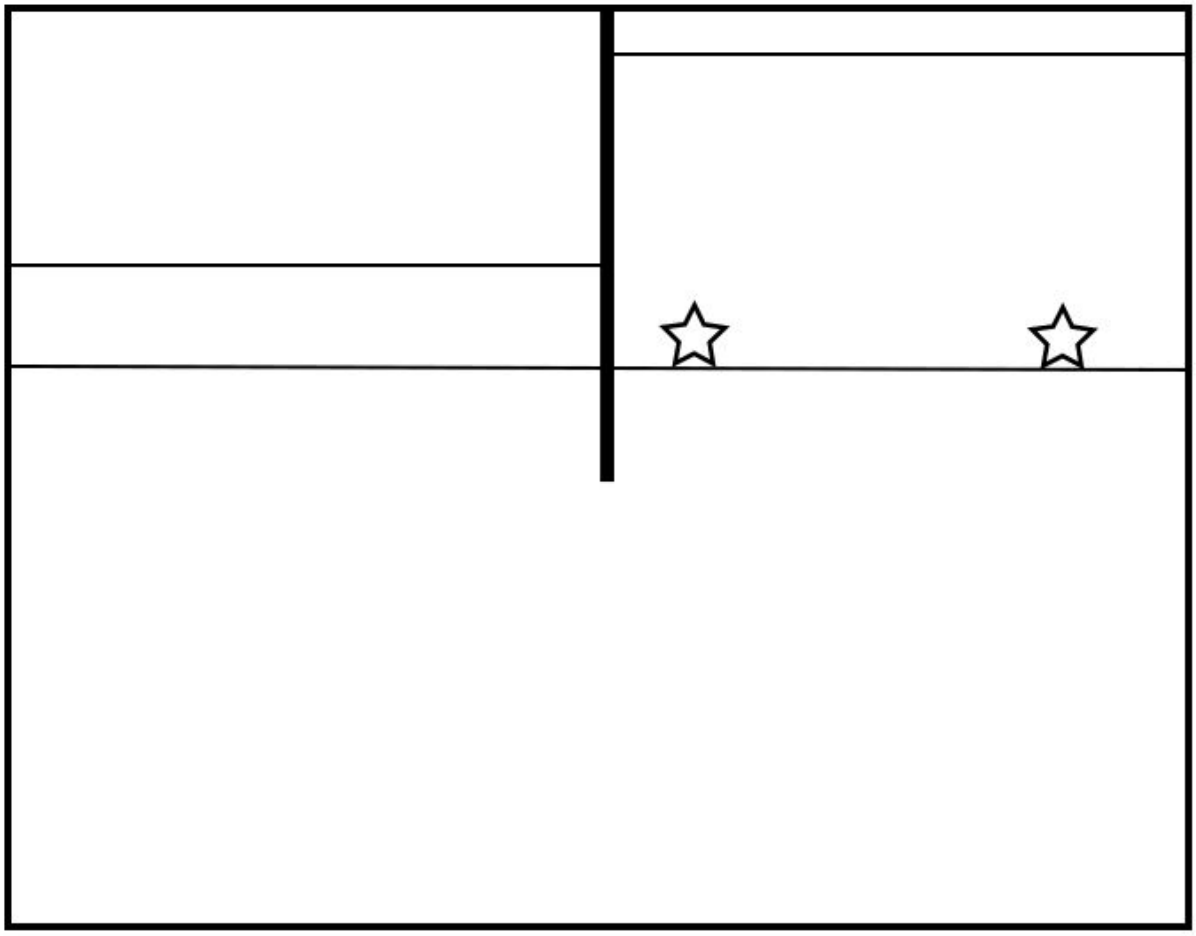
Name:_____

1. In the space below, draw what you believe will happen to the tracer when injected on the high head side of the tank. Injections will be made at the locations marked with arrows. Based on your projections, draw what you think the equipotential lines look like with dashed lines.



2. Make the injections shown where stars are shown below. Use two different colored tracers and inject them right against the front window of the tank. Draw the path of the tracers below. Based on this, draw what you believe the equipotential lines are with dashed lines.



3. How close were your initial predictions? What was correct, what was incorrect?

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4. In the real world things flow in all dimensions, but in the flow tank we've simplified the system. What do you think will happen if you inject the dye in the middle of the sand instead of against the wall of the tank? Try it!

5. Can the two dyes injected ever cross in this system? Why or why not?

6. What would happen if you injected dye on the low head side of the tank? Try it!

7. If engineers were injecting some polluted water on one side of a dam, but the material below the dam was sandy and permeable, what would happen? (Remember the water behind the dam is likely higher than around the dam.)

8. What would happen to the flow lines if we put a horizontal layer of very low permeability material like clay right at the bottom of the divider, isolating the two sides of the system? Optional: If you have the material - try it!

9. What would happen to the flow lines if we put a horizontal layer of very low permeability material like clay a few centimeters below the bottom of the divider? Optional: If you have the material - try it!

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10. Why is it important to observe and understand how water flows in the earth?

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