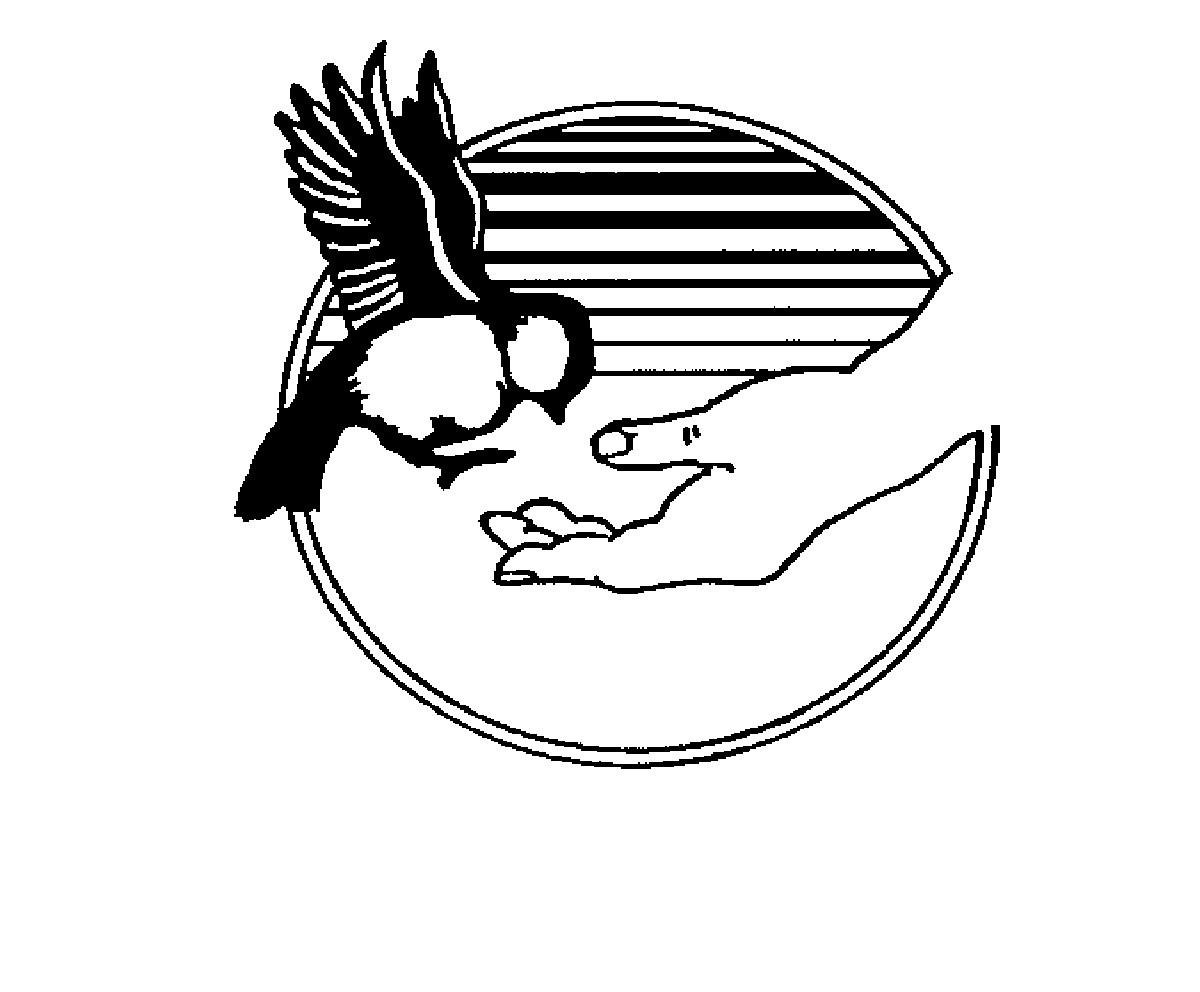
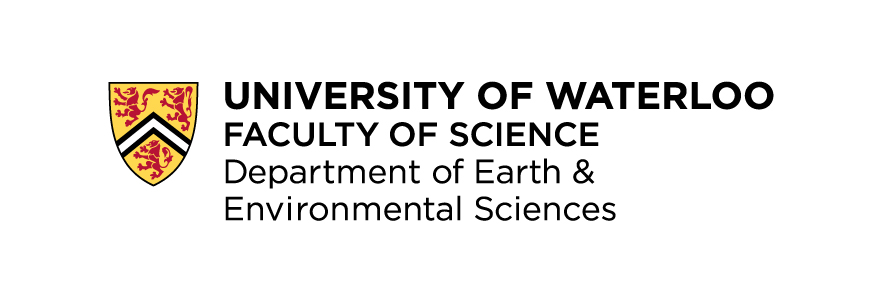
**SES4UI: Earth’s Surfaces and Processes**

**Groundwater:  
Explore, Understand, and Protect**

**Lab Activity: Soil Classification, Porosity, and Permeability**

****

**Wrigley Corners  
Outdoor and Environmental   
Education Centre**

**Groundwater Geochemistry Remediation Group**

**Introduction**

|  |  |
| --- | --- |
| In the Region of Waterloo, 80% of the approximately 500 000 people are dependent on groundwater. The groundwater is pumped from an aquifer system which is supported by the Waterloo moraine. The moraine is an interlobate moraine which formed at the meeting points of a number of different lobes from the Laurentide glacier. The moraine and the groundwater are precious resources which are well worth studying.  **Aquifers** are underground layers of rock or unconsolidated material that are capable of storing water. An aquifer is **recharged** when water filters through the surface material down into the underground layer of rock or unconsolidated material - changing from **surface water** into **groundwater**. The material present at the surface, called a **substrate**, can influence how easily water can pass into the groundwater system. Material within the moraine can influence the amount of water the aquifer can hold and the ease with which the water can move through the aquifer.  In this lab we examine the **porosity** (the amount of void space in a material) and the **permeability** (the ability of a liquid to flow through a material)  The purpose of this lab activity is to develop a better understanding of the way the Waterloo moraine is structured, thereby supporting our local aquifer system. This lab examines the characteristics of **soil** similar to those found in both the Recharge Zones and the Discharge Zones of the Waterloo moraine. We will be using coarse and fine **gravel**, coarse and fine **sand** as well as **silt**. As part of the lab, we will be using Hubbard Soil sieves to sort and separate the material into various samples, which will then be described using the Unified Soil Classification System (USCS). | http://img.geocaching.com/cache/large/c098e60c-7e8d-421e-8d41-d2c93e8df769.jpg  **Source: geocaching.com/geocache/GC3W0W7\_a-kame-on-the-waterloo-moraine?guid=3910b964-44e6-4eaf-80dc-8432b1ef2167**  Homer Watson Park exposure diagram showing the different layes of earth  **Geology of Homer Watson Park**  **uwaterloo.ca/wat-on-earth/news/homer-watson-park-geology** |

**The United Soil Classification System (USCS)  
  
Background:**Soil classification is important to hydrogeologists and geotechnical engineers alike. The United Soil Classification System (USCS) is a universally accepted classification system which categorizes a sample of soil according to its particle size. A soil sample may contain a narrow range (poorly-graded) or wide range (well-graded) of particle sizes. Sieves are often used to separate different-sized soil particles in a soil sample. This method is standardized by the American Society for Testing and Materials (ASTM) . Using a stack of sieves of gradually decreasing diameter (from the top), a soil sample is placed in the top sieve. The entire stack is shaken vigourously, allowing the various-sized material to separate into their respective sieves. A complete analysis of sieve data would normally include determining the exact mass of material left on each sieve, and calculating the percentage of each size material. Based on these percentages, the soil is classified according to the United Soil Classification System chart. A complete analysis, however, is beyond the scope of this activity.

**Objective:**Students will use the Hubbard sieves to separate glacial till into its respective USCS category.

**Materials:**1 beaker (250 mL)  
Box of glacial till (with lid)  
Stack of sieves (there should be 4 sieves, a bottom-catcher, and a lid; 6 pieces total)  
Wash-towel (optional)  
Stopwatch or Timer

**Procedure:**

1. Obtain a box of glacial till. Shake the box with the lid on vigourously to distribute the various particles evenly.
2. Ensure that the sieves are in the proper order. From the top down: “gravel”, “coarse sand”, “fine sand”, “silt”, “clay” (bottom–catcher). Remove the lid from the top sieve.
3. Using the beaker, open the lid of the glacial till box and scoop one beaker full of the till into the top sieve.
4. Put the lid securely on the top sieve. Lay the wash-towel on a hard, level surface (a workbench is fine). Place the entire stack of sieves on top of the wash-towel (the towel reduces noise while sieving).
5. Set the timer for one minute. Holding on to the top of the stack of sieves, rock the stack of sieves back and forth vigourously on the table. Once one minute has elapsed, stop rocking the sieves. Wait about 15 seconds to allow the particles to completely settle.
6. Remove the individual sieves and complete the worksheet (From the top sieve, remove any gravel that is greater than 1 cm in diameter – you will include this in your analysis). Return the sieved material to the boxes they came from afterwards.

**The United Soil Classification System (USCS) Lab Sheet**

For this portion of the lab, we will consider six different particle sizes, as indicated on the sieves.

Complete the following list of particle sizes, from largest to smallest:

1. Gravel (>1 cm)  
2. Pea gravel (<1 cm)  
3.   
4.   
5.   
6.   
  
Complete the questions below:  
  
1. Examine each sieve, order the sieves from “most material” (1) to “least material” (6) below. Include an approximate percentage by volume of the amount of each material.

|  |  |  |
| --- | --- | --- |
| Rank | Material | Approximate Percentage (%) |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |
| 6 |  |  |

2. How would you describe the till in terms of gradation? Why?  
(i.e. well-graded, poorly-graded)

*Note: The following two activities involve testing the porosity and permeability of different substrates (different-sized materials) from this same glacial till. The material provided to you in the next two activities has already been sieved and graded according to this exact same method. There is no need to sieve the glacial till in these boxes to use in the porosity and permeability activities.*

**Porosity**

**Background:**  
How much water can a material hold? Porosity is the measure of the void spaces in a material such as soil, sand, or rock. Porosity is measured as a percentage of open space or pores in a material, and can be calculated using a simple formula. An aquifer is an underground layer of unconsolidated material or rock that stores water. The amount of water that the aquifer can store is directly related to its porosity. The substrates (coarse gravel, pea gravel coarse sand, fine sand and silt) in this lab represent aquifers

**Objective:**Students will measure the porosity of 5 different substrates (coarse gravel, pea gravel coarse sand, fine sand and silt) and compare the results.

**Materials**:

5 plastic cups

100 mL of 5 types of substrate (coarse gravel\*, pea gravel coarse sand, fine sand and silt) for each cup

5 graduated cylinders (100mL)

5 beakers (250mL)

Calculator

**Procedure**:

1. Write your predictions ranking the substrates in increasing order for porosity.

Coarse gravel will be used to demonstrate the technique. Because the size of the particles is so large, 500mL of the substrate will be used and placed in a larger container. Water is added as described below.

1. Fill each plastic 100 mL graduated cylinder with one of the following:  
   100 mL pea gravel, 100 mL coarse sand, 100 mL fine sand, 100 mL silt  
   Carefully pour each measured sample into a beaker.
2. Fill another graduated cylinder with 100 mL of water. This is the “Starting H2O Volume”.
3. Slowly pour the water into one of the substrates, until there is a very thin layer of water covering the substrate.
4. Read the remaining volume of water in the graduated cylinder and record the volume as the “Finish Volume”.
5. Subtract the “Finish Volume” from the “Starting H2O volume” to obtain the “Pore Space Volume”
6. Repeat step 3 through 6 for each of the substrates.
7. Complete the calculations for Percent Porosity.
8. Answer the questions and complete the drawings on the back of the lab sheet.

**Permeability**

**Background**:

The Waterloo Aquifer system is supported by the Waterloo Moraine. There are many recharge zones along the western edge of the region. We pump water out of the aquifer to use for drinking water and household, agricultural, and commercial uses. The aquifer naturally discharges through springs and streams into the Grand River. Water in the aquifer is replenished during recharge events. Recharge adds water to the groundwater system when rainfall, melting snow, surface water, or water from a creek or lake soaks in through the soil and till.

**Objective**:

Students will measure the permeability of water through five different substrates (coarse gravel, pea gravel coarse sand, fine sand and silt) and compare the results.

**Materials**:

Modified plastic water bottles

5 different substrates (coarse gravel\*, pea gravel coarse sand, fine sand and silt)

Filter paper or coffee filters

5 graduated cylinders (100 mL)

Stopwatch  
Beakers

**Procedure**:

1. The permeability of coarse gravel will be determined as demonstrated.  
   Note: A sample of 200 mL of gravel will be used with 100 mL of water.
2. One group will be responsible for each substrate. Place a filter cone/coffee filter each water bottle top. Put 100 mL of each substrate into the individual water bottle tops.
3. Place the water bottle top into an empty beaker. Measure 100 mL of water in a graduated cylinder; this is to be filtered through the substrate.
4. **Be ready to start timing the flow.** Slowly pour water into the plastic bottle top with one of the substrates. Pour all of the water in – do not allow the water to overflow.
5. **START TIMING THE FLOW** when the water starts to come out into the beaker.
6. **STOP TIMING THE FLOW** when the drip rate reaches one drop per one second. Record the elapsed time in seconds.
7. Repeat steps 3 – 6, completing the table for Trial 2 and Trial 3.
8. Average the times and complete the calculations **using the average time** (mean). Share your results with the other groups.

Answer the questions and complete the drawings on the back of the lab sheet.

**Porosity Lab Sheet**Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question**: Which substrate (coarse gravel, pea gravel coarse sand, fine sand and silt) has the highest porosity? Why?

**Prediction**:

**Data Table:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Substrate:** | **Starting H2O Volume (mL)** | **Finish Volume (mL)** | **Pore Space Volume (mL)** | **Substrate Volume (mL)** | **Percent Porosity (%)** |
| **Coarse Gravel** | 300 | 63 | 227 | 500 | 45.4 |
| **Pea Gravel** | 100 |  |  | 100 |  |
| **Coarse Sand** | 100 |  |  | 100 |  |
| **Fine Sand** | 100 |  |  | 100 |  |
| **Silt** | 100 |  |  | 100 |  |

**Calculations:**  
*Pore Space Volume = Starting H2O Volume – Finish Volume (what is left in the graduated cylinder)*

*% Porosity = (Pore Space Volume / Substrate Volume) x 100%*

**Conclusions**:

1. Which substrate has the highest porosity? Which substrate has the lowest porosity?
2. How does the data support or contest your prediction?

**Complete the drawings on the back of this page.**

Color in the pore spaces between the particles to see which has the highest porosity.  
Answer the questions below.

1. Which has the most open space? Which would hold the most water? Why?
2. List the factors that affect or influence the porosity of a substrate.

**Porosity Lab Sheet (continued)**

**A:** 

**B:**

**Permeability Lab Sheet**  
Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question**: Which substrate (coarse gravel, pea gravel coarse sand, fine sand, or silt) has the highest permeability? Why?

**Prediction:**

**Data Table:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Substrate:** | **Elapsed Time to Reach One Drip per One Second (seconds)** | | | **Average (Mean) Time (seconds)** |
| **Trial 1** | **Trial 2** | **Trial 3** |
| **Coarse Gravel** |  |  |  |  |
| **Pea Gravel** |  |  |  |  |
| **Coarse Sand** |  |  |  |  |
| **Fine Sand** |  |  |  |  |
| **Silt** |  |  |  |  |

**Calculations**:

*Permeability = volume of water (mL) divided by time (minutes)*

*To convert from seconds to minutes, divide total number of seconds by 60.*

Coarse gravel: 300 mL / \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ minutes = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mL per minute

Pea gravel: 100 mL / \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ minutes = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mL per minute

Coarse sand: 100 mL / \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ minutes = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mL per minute

Fine sand: 100 mL / \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ minutes = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mL per minute

Silt: 100 mL / \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ minutes = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mL per minute

**Conclusions**: (look over your data and your background information and write your answers below:

1. Which substrate had the greatest permeability (was most permeable)?
2. Which substrate had the least permeability (was least permeable)?
3. How does the data support or contest your prediction?
4. How does porosity relate to permeability?
5. Combining what you have learned about **porosity** with what you’ve learned about **permeability,** why would rock be a poor filter for water?
6. Which material would make a good filter? Explain why.
7. Which material would make a good aquifer? Explain why.

**Permeability Lab Sheet (continued)**

8. Complete the two mazes below. Show the paths water can take between the particles by using a blue crayon or

colored pen or pencil.

**A:**

**B:**

9. Which allows water to flow more freely? Explain.

10. The Waterloo Moraine supports an aquifer that is complex in that there are many layers of glacial till. Given what you have learned about porosity and permeability, why would pollution such as road salt and pesticide use be a major concern within the aquifer recharge zone?

**Inventory of Materials:**

* 5 beakers (400mL)
* 5 beakers (250mL)
* 6 graduated cylinders (100mL) (3 plastic, 3 glass)
* 1 SEPM grain size ruler
* coffee filters
* stack of 4 sieves + lid + bottom catcher
* 9 waterbottle bottoms
* 9 waterbottle tops
* 1 plastic funnel
* separated till
  + gravel
  + pea gravel
  + coarse sand
  + fine sand
  + silt
* 1 box of till
* 2 cardboard boxes