Groundwater Connections

Lesson 2: Porosity & Flow Rate Labs

Porosity/ Flow Rate Labs:

There are a multitude of variations, materials and methods that can be used for these labs. A number of alternatives are noted in the *Resources* section.

NOTE: The instructions for this lab are provided as *Guided Inquiry*. However, depending on students' past experience with inquiry, the labs can be set up as *Open Inquiry,* wherein teams are invited to develop their own methods to test porosity/flow rate and develop their own data tables, given the materials noted in *Class Materials*.

1.0 OVERVIEW

1.1 Description of Lab

This lesson consists of two parts: 1) a lab on ***porosity a***nd 2) a lab on ***flow rate*** of typical sediments found in West Nose Creek watershed. The labs use materials readily available in most science classrooms.

Figure 1. Lab Materials (Photo Credit: C.Farrow).

1.2 Learning Connections

Students will be able to:

- Measure porosity and flow rate of different sediments typically found in the West Nose Creek watershed.
- Explain how flow rate and groundwater flux are related and are both dependent on porosity and connectivity of pore spaces.

1.3 Curriculum Connections

Alberta Program of Studies for Science 8
Unit E: Freshwater and Saltwater Systems
STS & Knowledge Outcomes 1, 2, 3, & 4

Teaching Notes:

Sediments:
Three typical sediments of the West Nose Creek Watershed are used in this lab: sand, silt and gravel. The sand represents sandstone of the Paskapoo Formation and the silt and gravel represents glacial deposits found at the surface near creeks and springs. If silt is not available, use fine sand, course sand, and gravel. Recommendation: If silt is used, set up one container to be monitored throughout the class time. This is due to the amount of time it will take for water to move through silt.

Porosity:
Fraction (%) of open spaces or pores between grains in a given volume of sediment:
(***volume of pores)/ (volume of sediment) x 100***

Flow Rate:
Speed at which a fluid can travel through sediments (mL/s). The speed depends on connectivity of pores and porosity.

Flux:
The rate of flow per unit area of sediment (cm/s).

Permeability:
The ability of a material to allow the passage of liquid through it.

2.0 Preparation and Materials

2.1 Logistics

- If the class is too large for a whole class groundwater flow model demonstration (Lesson 3), the model and two labs could be set up as stations, wherein smaller groups could rotate through each of the three stations.
- Instructions for preparing materials for the *Porosity/Flow Rate Labs,* and *Student Lab Journal* are provided in the Appendices.

2.2 Class Materials

- Porosity Lab (1 set per station):
    - 3 — 500 mL beakers or plastic cups with 150 mL line
    - 150 mL each — Dry fine sand (or silt if available), coarse sand, small gravel
    - 1 — graduated cylinder & access to container of water (or sink)
- Flow Rate Lab (1 set per station):
    - 3 — 250 mL beakers or graduated cylinders
    - 150 mL each — Dry fine sand (or silt if available), coarse sand, small gravel
    - 3 —-plastic cups with holes in bottom (or funnels) with 150 mL line
    - 3 — filter papers or cloth mesh for bottom of plastic cups
    - 1 — stopwatch
    - 3 — containers, beaker, or nearby sink to collect water

2.2 Student Materials

- Student *Lab Journal* (*see,* Appendix II) **and** pencil

3.0 Porosity & Flow Rate Labs

The overall goal of these labs are to help students understand the effects of geology on groundwater storage and flow. This lab explores two major properties of sediments:

- *Porosity*— students will predict, measure, calculate and compare porosity of silt, sand, and gravel.
- *Flow Rate* — students will predict, measure, calculate and compare flow rate of silt, sand, and gravel.

Ask teams to review the *Student Notes* on porosity/flow rate prior to starting the labs and to make predictions about which sediments have the highest porosity and flow rate/flux.

3.1 Lab 1 ~Porosity

- Use the *Lab Instructions* (Appendix I) as guide for the inquiry, followed by a discussion on how groundwater storage differs between the sediments**.** Invite them to record data in *Table 1* of the *Lab Journal*.
- After the exploration, invite students to discuss and identify factors within sediment that might increase porosity (*e.g.,* grain size, arrangement).

3.2 Lab 2 ~ Flow Rate

- Use the *Lab Instructions* (Appendix I) as guide for the inquiry, followed by a discussion on how groundwater flow differs between the sediments**.** Invite them to record data in *Table 2* of the *Lab Journal*.
- After the exploration, invite students to discuss and identify factors within sediment that might increase flow rate and groundwater flux (*e.g.,* porosity, connectivity of pores).

4.0 Reflection & Assessment

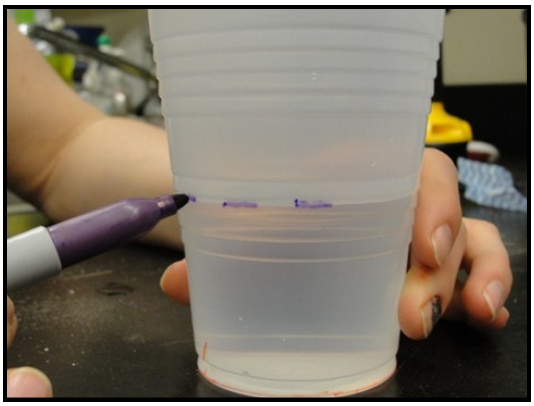
Invite groups to reflect on and discuss how their observations matched or differed from what was discussed in the adapted primary literature article on groundwater research in the West Nose Creek watershed.

Appendix I: Porosity & Flow Rate Lab Instructions p1

A. Preparation

Lab 1: Porosity Lab

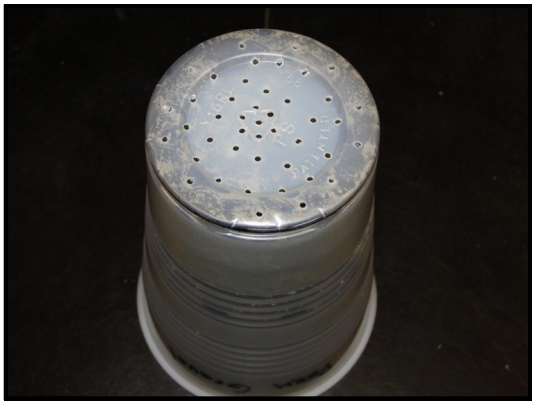
Marking Sediment Fill Line



For each lab station, fill three plastic cups with 150 mL of water. Mark this volume with a line on the outside of the cup. This line will be used as the fill line for sediments.

Lab 2: Flow Rate Lab

Creating Drainage Container



For each lab station, prepare three plastic cups with 150 mL sediment fill line as above and drill numerous small holes in the bottom for drainage.

Cut out filter paper or cloth mesh (j-cloth is used in the picture) to fit in bottom of perforated cup.

Porosity & Flow Rate Lab Instructions p2

B. Performing Labs

Lab 1: Porosity Lab

To calculate porosity of each type of sediment:

- Fill each cup with sediment to the fill line (representing a sediment volume of 150 mL).
- Measure out 100 mL of water in a graduate cylinder and pour just enough water into sediment cup to slightly cover top of sediment. Make sure the sediment is completely wet (all pores are filled with water).
- Record amount of water poured into sediment; this volume represents volume of pore space in between grains of the sediment.
- Calculate porosity (in %):
  [(Volume of Water) / (Volume of Sediment)] x 100

Lab 2: Flow Rate Lab

To compare flow rate of each type of sediment:

- Calculate Area of cup bottom.
  Measuring diameter (d) of bottom, divide by 2 to obtain radius (r), and then calculate Area ($A = \pi * r^2$)
- Fill each cup with sediment to the fill line (representing a sediment volume of 150 mL).
- Measure the diameter (cm) of the bottom of the cup, and calculate the bottom area of the cup (cm^2).
- Measure out 250 mL of water in a graduate cylinder or beaker and **slowly** pour water into sediment cup held above another cup to collect water flowing through. Try to keep the water level just at the sediment surface.
- Record time from start of pouring to time when water stops dripping from bottom of sediment cup (less than 1 drop/second).
- Record amount of water poured through sediment; this represents the flow volume.
- Calculate flow rate (mL/s = cm^3/s):
  (Volume of Water) / (Time of Flow Through)
- Covert the flow rate (cm^3/s) to flux (cm/s):
  (Flow rate, cm^3/s) / (Bottom area, cm^2)

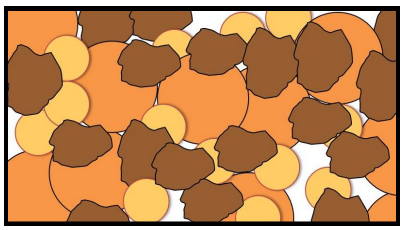
Appendix II: Student Lab Journal p1

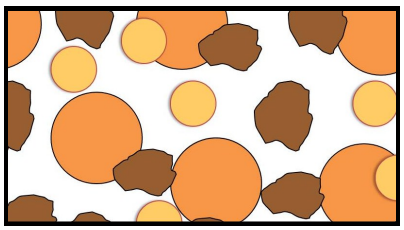
Part 1: Measuring Porosity

Focus Question: *How much water can different sediments hold?*

Porosity is the measure of pore spaces in sediments such as silt, sand, gravel, or rock. It is measured as a percentage of open space (voids) between grains in a given volume of sediment. Porosity determines how much groundwater can be stored in an aquifer (underground layer of sediment that holds water). Predict which of the following sediments (A or B) has a higher porosity and can hold more groundwater?

(A) **(B)**





Objective: Measure porosity of three sediments and determine which can hold more water.

Materials: 3 plastic cups or beakers with 150 mL marked line, 1 — 500 mL beaker of water, 100 mL graduated cylinder, silt, sand, gravel, 3 trays for collecting wet sediments

Procedure:

- Make a prediction as which sediments will have highest and lowest porosity.
- Fill each plastic cup with different sediment up to the 150 mL marked line and record this volume of sediment in *Table 1 (A).* **Note:** this is the "bulk" volume of sediment, not the volume of individual sediment particles.
- Fill the graduated cylinder with 100 mL of water and ***slowly*** pour the water into the cup containing sediment until water just covers the surface of the sediment.
- Record amount of water added to the sediment container in *Table 1 (B).*
- Repeat for each sediment and calculate % porosity of each type of sediment (C).
- Pour sediment mixtures on collecting trays to dry, clean out containers, and return materials.

Sediment	Volume of Sediment (mL)	Volume of Water added (mL)	Porosity (%)
	A	B	C = (B/A)*100
Gravel			
Sand			
Silt			

Discussion:

- Which sediment had the greatest porosity? Why? Did this match your prediction?
- Which sediment would allow for more groundwater storage?
- How do you think mixing gravel and silt would impact the porosity?

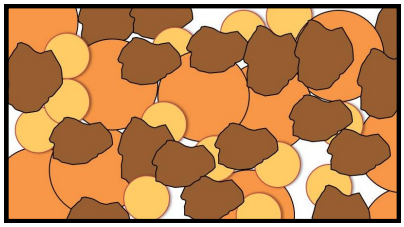
Student Lab Journal p2

Part 2: Measuring Flow Rate

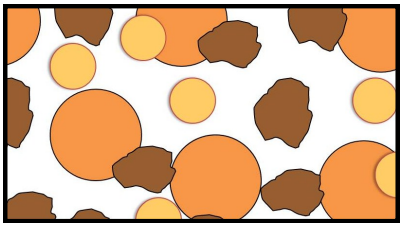
Focus Question: *How fast can water flow through different sediments?*

Flow Rate is the measure of how fast fluids flow through sediments such as silt, sand, gravel, or rock. Flow rate is dependent on porosity and how well pore spaces are connected. When the area of material is taken into consideration, the **groundwater flux** can be calculated, which in this experiment is proportional to the **permeability** and allows for comparison between materials. Predict which of the following sediments (A or B) has a higher flow rate and has a higher permeability?

(A)



(B)



Objective: Measure flow rate of three sediments and determine highest flow rate.

Materials: 3 plastic cups with holes in bottom, filter paper or cloth mesh for bottom of cups, 250 mL beaker or graduated cylinder, stop watch, 3 collection containers, silt, sand, gravel, 3 trays for collecting wet sediments

Procedure:

- Make a prediction as which sediments will have highest and lowest flow rate.
- Calculate Area of cup bottom. Measuring diameter (d) of bottom, divide by 2 to obtain radius (r), and then calculate Area (**$A = \pi * r^2$**)
- Place mesh in bottom of plastic cup and fill with sediment up to the 150 ml marked line.
- Fill beaker with 250 mL of water and ***slowly*** pour all of the water into the sediment cup, while trying to keep the water level right at the sediment surface. At same time, have a second team member hold a collection container under the sediment cup to collect water flowing through and record the total time it takes for the water to flow through cup (start of pouring to last of drop of water draining from cup).
- After flow has stopped (or less than 1 drop/second), pour collected water into graduated cylinder to record volume of water (mL) that flowed through sediment, along with flow time (s).
- Repeat for each sediment and calculate flow rate of each type of sediment (A/B).
- Calculate Flux (cm/s) by dividing Flow Rate (mL/s) or (cm^3/s) by Area of cup bottom (cm^2)
- Pour sediment mixtures on collecting trays to dry, clean out containers, and return materials.

Sediment	A) Volume of Water (mL)	B) Flow Time (s)	Flow Rate (mL/s)	Flux (cm/s)
Gravel				
Sand				
Silt				

Discussion:

- Which sediment had the greatest flow rate? Why? Did this match your prediction?
- Why might it be important for hydrogeologists to be able to determine the permeability of different sediments?

RESOURCES:

Porosity/Flow Rate Lab Simulations

Michigan Department of Environmental Quality Groundwater Module
http://techalive.mtu.edu/meec/module06/index.htm

Wisconsin Department of Natural Resources Groundwater Study Guide
PUB-DG-076 2006
p.7--8, How Groundwater Moves
http://dnr.wi.gov/org/caer/ce/eek/teacher/groundwaterguide.htm

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