

The Power of Water : How moving water affects our physical world

By: Jonathan McCabe

Abstract

The goal of these lesson plans is to bring into focus how rivers and streams change the physical environment that they move through and the complications that arise when humans make changes or try to control those systems. Students will use a model to recreate stream features that normally take long periods of time to form. Students will also perform experiments to observe the properties of soil and how humans can mitigate erosion of soils by streams. Students will also run a laboratory experiment that attempts to solve a water contamination problem. Finally, students will take part in an assessment that has them making choices about development along riverfront properties and the implications of that development on erosion, pollution, and water quality. These lesson plans use low cost materials and models that could be constructed in many different ways for a variety of budgets. A field trip to a storm water runoff feature such as a bioswale or channelized riverbed is a nice addition and can further student understanding through visualization.

Project Overview

RET I: Research (Summer 2014)

My research experience was with Dr. Alex Simms in the Sedimentology Lab, Department of Geology, and involved precision dating using radiocarbon techniques for events in the recent geologic past. My project leader, Laura Reynolds, proposed using charcoal deposition history as a proxy for determining dates for significant events in the Carpinteria Marsh. The Transverse Ranges in Southern California are responsible for considerable seismic activity; to include undersea landslides and associated tsunamis. According to historical records, a pair of events in December 1812 resulted in at least one tsunami, which possibly left a depositional record in the Carpinteria Marsh. By recording the abundance of charcoal in vibracore samples from the marsh we are able to create an additional date constraint on this sand facies in order to establish it as a tsunamite and not a storm deposit. A charcoal peak dated to ~1862 is most likely associated with a significant storm event and occurs above the sand facies, indicating that the sand was deposited sometime prior to this date. Charcoal analysis of additional cores from the marsh, as well as further radiocarbon dating, pollen analysis, and X-ray fluorescence (XRF) will help to further constrain this date and contribute to the multi-proxy approach for defining tsunamites.

RET II: Project Rationale (Summer 2015)

In the past, detailed information about water transport and deposition of sediments has not been thoroughly discussed in my district because there was no state standard for 9th grade Earth Science. Adoption of NGSS however, brings back into focus at the secondary school level the role of water in transporting sediments and changing the Earth's surface appearance. My objective this summer was to find practical, low cost ways to present this information to students. Students learn best when they can use multiple senses to explore and observe real world phenomena and the use of physical models allows for this observation on a practical basis.

Learning Objectives:

The goal of my work in this series of lessons is to allow students to observe these changes on the small scale, in the classroom, and then use the scientific method to break down the ‘why’. The second part of my unit looks at anthropogenic causes of change in both river systems and contamination caused by human activities. Additionally, students will explore ways in which humans have attempted to reverse or avoid negative outcomes as a result of our activities. The following labs and activities have been adopted from various sources and hopefully will lead to a fuller understanding of how water and sediments work together to shape the Earth's surface features.

Unit Outline:

Part I Waters Impact on the Earth's Surface

1. Weathering and Erosion, how do rivers move sediment from the mountains to the sea?
2. Chemical vs. mechanical weathering
3. Transportation and deposition: Observing a stream table in action.

Part II Properties of Soil

1. Soil is the result of weathering and erosion
2. How soil works; runoff and infiltration
3. Soil as a resource for life

Assessed Next Generation Science Standards

- **HS ESS 2.5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]
- **HS ESS 3.4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.** [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geo-engineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]

Disciplinary Core Ideas

ESS2.C: The Roles of Water in Earth's Surface Processes

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (HS-ESS2-5)

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS-ESS3-3)
- Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-ESS2-5)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ESS3-4)

Table Of Contents

Part I: Waters Impact on Earth

1. Activity 1: Basic Stream Table Observations
2. Activity 2: Stream Velocity and Erosion
3. Activity 3: Chemical Weathering of Candy
4. Teachers Guide to Using a Stream Table and Activities 1-3
5. Desktop Delta or Flume resources

Part II The Soil and its Relation to Water

1. Teachers guide to Soil
2. Percolation Lab
3. Percolation Lab answer key
4. Sponge Runoff Lab
5. Sponge Runoff lab answer key

Glossary

Mechanical Weathering	Mechanical weathering occurs when physical forces break rock into smaller and smaller pieces without changing the rock's mineral composition.
Chemical Weathering	Chemical weathering is the transformation of rock into one or more new compounds.
Surface Area	A measure of the total area that the surface of an object occupies.
Soil	Soil is the portion of Earth's surface that can support plants. Soil has four major components: mineral matter, or broken-down rock; organic matter, or humus, which is the decayed remains of organisms; water; and air.
Porosity	The amount of open space between soil particles.
Percolation Rate	The rate at which water moves through a soil.
Permeability	The soils capability to allow water to pass through it.
Infiltration	The movement of surface water into rock or soil through cracks and pore spaces.
Runoff	Water that flows over the land surface rather than seeping into the ground.
Meander	A loop-like bend in the course of a stream.
Delta	An accumulation of sediment formed where a stream enters a lake or an ocean.
Bed Load	Sediment that is carried by a stream along the bottom of its channel.

Deposition	The process by which an agent of erosion loses energy and drops the sediment it is carrying.
Floodplain	The flat, low-lying portion of a stream valley subject to periodic flooding.
Alluvial Fan	A fan-shaped deposit of sediment formed when a stream's slope is abruptly reduced.
Cut Bank	A cut bank, also known as a river cliff or river-cut cliff, is the outside bank of a water channel (stream), which is continually undergoing erosion.
Tributary	A stream that empties itself into another stream.
V-Shaped Valley	A valley formed by flowing water, or river valley, is usually V-shaped. The exact shape will depend on the characteristics of the stream flowing through it. Rivers with steep gradients, as in mountain ranges, produce steep walls and a bottom.
Point Bar	A point bar is a depositional feature made of alluvium that accumulates on the inside bend of streams and rivers below the slip-off slope. Point bars are found in abundance in mature or meandering streams.
Stream	The course that water follows over land.
Divide	An imaginary line that separates the drainage of two streams; often found along a ridge.
Channel	The course that the water in a stream follows.
Drainage Basin	The land area that contributes water to a stream.
Capacity	The total amount of sediment a stream is able to transport.
Base Level	The base level of a river or stream is the lowest point to which it can flow, often referred to as the 'mouth of the river'. For large rivers, sea level is usually the base level, but a large river or lake is likewise the base level for tributary streams.
Headward Erosion	Erosion at the origin of a stream channel, which causes the origin to move back away from the direction of the stream flow, and so causes the stream channel to lengthen.
Gradient	The slope of a stream over a certain distance.
Competence	Measure of the maximum size of the particles that the stream can transport. It is proportional to the velocity of the flow.
Groundwater	Water underground in the zone of saturation
Bioswale	Landscape elements designed to remove silt and pollution from surface runoff water. They consist of a swaled drainage course with gently sloped sides (less than six percent) and filled with vegetation, compost and/or riprap.

Denitrification

Process of nitrate reduction (performed by a large group of heterotrophic facultative anaerobic bacteria) that may ultimately produce molecular nitrogen (N_2) through a series of intermediate gaseous nitrogen oxide products.

Activity 1: Basic Stream Table Observations

Objective:

You will be able to identify stream formations and explain the causes of different features using diagrams, observations and key terms. This observation will prepare you for Activity #2.

Background:

Streams are Earth's most important agents of erosion. They can down-cut or erode their channels. They can also transport enormous amounts of sediment. Most of the sediment a stream carries comes from weathering. Weathering produces huge amounts of material that are delivered to the stream by sheet flow, mass movements, and groundwater. Eventually, streams drop much of this material to create many different depositional features. (Prentice Hall Earth Science, 2006)

List of materials:

1. Demo sized stream table
- Projector or smart board (for pictures)
2. Pencil with eraser
 3. Science notebook
 4. Computer with access to google maps

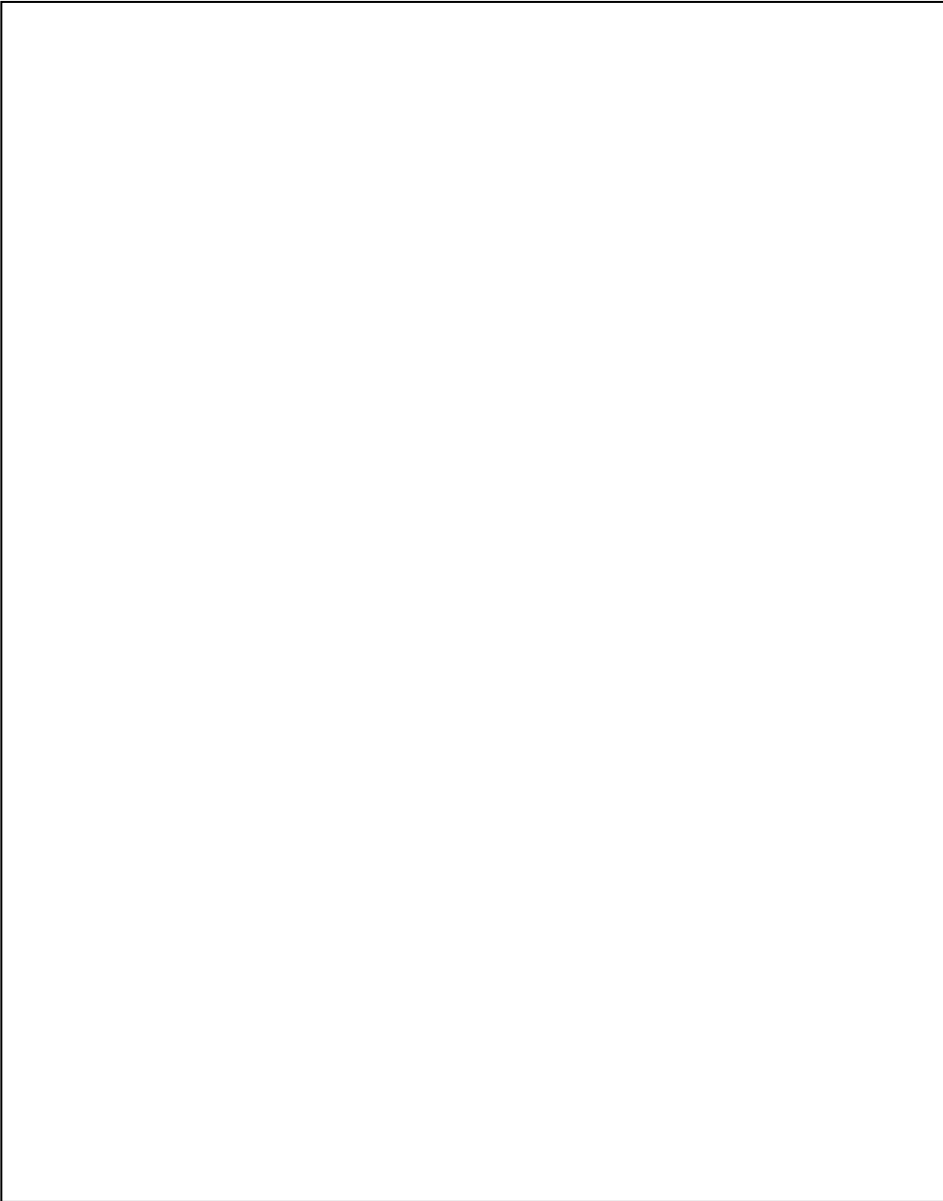
Procedure:

We will be observing features that form over time on the stream table; in addition, there will be video footage of each formation for us to review. You will then need to examine imagery from google maps and identify any features you recognize from our model.

1. **Watch:** the structures that form over a 10-minute time period.
2. **Listen:** as your teacher identifies different features that form while the water is running.
3. Observe: the sample images on the board.
4. **Sketch:** the resulting stream and its formations in the space on page 2.
5. **Label:** the stream with as many of the key terms as possible. Use the provided figures and chapter 6.2 in your textbook, to help with your labeling.
6. Using the computer, navigate to the following coordinates on google maps, identify any features you recognize in the image and sketch them in the boxes provided on page 3.
 - a. 39.318255N , 121.620175W
 - b. 29.521236N , 91.435260W
 - c. 5.626012S , 64.017677W
 - d. 28.443157N , 82.965618E
7. **Check:** Can you label where erosion and deposition would occur in your drawings after observing the running stream table? **Put a "D" for any deposition locations and an "E" for erosion.**

Activity 1: Basic Stream Table Observations

Sketch of the stream table model:



Label each feature on your sketch with the number that matches:

- 1. Meander**
- 2. Delta**
- 3. Cut Bank**
- 4. Point Bar**
- 5. Oxbow Lake**
- 6. Channel**
- 7. V-shaped Valley**
- 8. Divide**
- 9. Tributary**
- 10. Drainage Basin**

Questions:

1. What limitations does our stream table have in modeling a real stream? How is our model similar; how is it different?
2. How would a scientist make the model more accurate?

Activity 1: Basic Stream Table Observations

Stream Sketches:

Coordinate #1	Coordinate #2
Coordinate #3	Coordinate #4

3. What limits do satellite observations have when observing stream systems?
4. What advantages do satellite images have? What can we see here that is not observable from the ground?

Streambed Formations

For use with Activity 1: Basic Stream
Table Observations

What is this?



How about this one?



What is this?



These are called?



Did you see anything like this?



Activity 2. Stream Velocity and Erosion

Objectives:

You will be setting up an experiment to measure how much of an effect stream velocity has on erosion and deposition of sediments.

You will practice the steps of how to conduct an experiment.

Background: In activity 1, you witnessed several processes and formations that are the result of stream transportation of sediment. Sediment is eroded (moved) from the top of a watershed by a stream and its tributaries. That sediment is then deposited at the mouth of the stream, located in the bottom portion of a watershed. The amount of erosion and deposition that occurs can be determined by measuring how large a stream's delta grows over time. This process is dependent upon the velocity of the stream. Velocity is the speed of the water in the stream, usually measured in meters per second. Another key is the amount of water, or discharge involved.

Sediments Removed



Sediments Deposited



List of possible materials:

- Stream table
- Stopwatch
- Plastic gutter
- A ruler or other tool
- Pencil
- Calculator
- Plexiglas sheet
- 250ml beaker
- Dry sand
- Plastic shovel/scooper

Procedure:

1. Examine the **Question** found below and develop a hypothesis from it. What will happen to the sediment in your streambed as you increase/decrease the velocity of the water?
2. Under **Methods**, design an experiment that could test your hypothesis. Your design should include at least the following:
 - Conduct at least three trials with the same stream shape each time at a slow, medium and fast flow (velocity!)

Activity 2. Stream Velocity and Erosion

- Conduct each trial for the same amount of time (Why?!)
 - Measure the “volume” of the delta after each trial in cubic centimeters (length x width x height)
 - Record your data in your science notebook.
3. Construct your defined stream on the stream table (straight and narrow works well) Be sure to set up the experiment exactly the same for each trial to eliminate variables.
 4. Assign the needed roles in your group (these should stay the same through the whole experiment to keep data collection consistent), you may have more than one role!:
 - Flow director
 - Time keepers
 - Delta measurer
 - Data recorder
 - Engineer to keep the same stream size and shape and to redistribute the sediments
 5. Carry out the experiment that you designed under the **Methods** section.
 6. Determine if your hypothesis was correct.
 7. Answer follow-up questions.

Question: How does the velocity of a stream affect how much erosion and ultimately deposition will occur?

What is your **hypothesis**?

Methods:

Explain how you will test your hypothesis.

What are your **independent and dependent variables**?

What will remain **constant** in your experiment?

Observations: Record what happens. Provide any **measurements** in a table. Use a separate sheet of paper if needed.

Activity 2. Stream Velocity and Erosion

Results/Conclusion:

Was your **hypothesis** correct? Explain.

Follow-up questions

1) What do you think would happen if we increased or decreased this stream's slope (make it steeper or flatter) instead of increasing the flow of water?

2) What events in nature did rate of flow represent in this experiment? Hint: Think about weather and climate.

3) How do people try to control rivers and streams in "real life?" How would engineers keep a real stream from changing its size or course?

Weathering and Surface Area

Objectives:

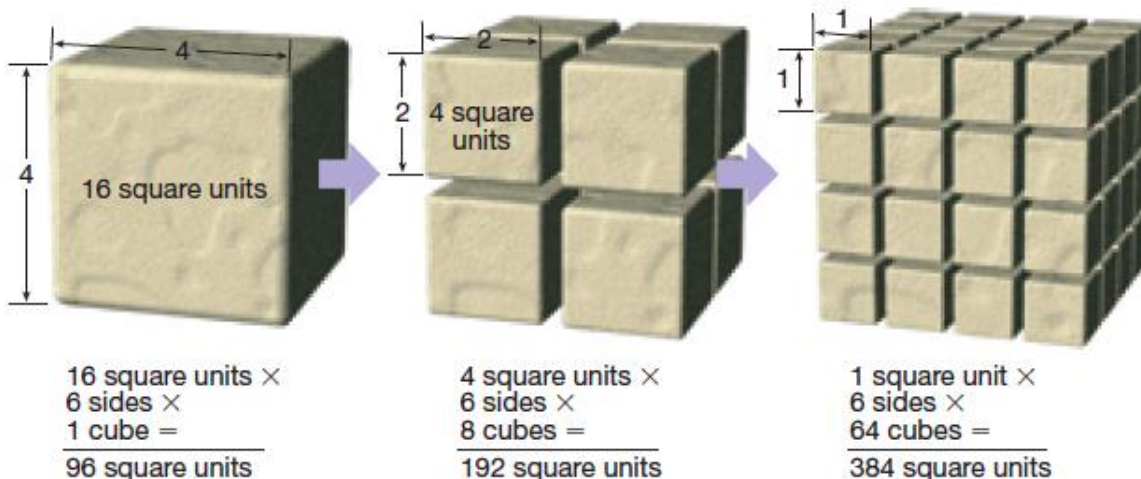
- To understand the importance of surface area when it comes to weathering of rocks and minerals.
- To learn how to design your own independent experiment.

Background: There are two types of weathering; *mechanical* and *chemical*.

Mechanical, or physical, weathering is the breakdown of rocks or minerals into smaller pieces, while chemical weathering breaks a rock or mineral down by altering a rock or mineral's chemical composition.

Weathering can be affected by several forces, including exposure, particle size, mineral composition, and climate. This activity will look at the role of **particle size** and how fast a material can be weathered.

By breaking a rock into smaller pieces, mechanical weathering increases the rock's surface area that can be exposed to chemical weathering.



List of materials:

- Acid solution (dilute vinegar)
- SweeTARTS™ (the same color)
- Hammer
- Stop watch
- Clear cups or beakers
- Safety goggles (if stronger acid)

Procedure:

1. Break into groups of 3 or 4.
2. Develop a question based on your previous knowledge of weathering of rocks and minerals and the figure above.
3. Turn that question into a hypothesis.
4. Design an experiment that could test that hypothesis with the materials provided to you.
5. Carry out your experiment.
6. Determine if your hypothesis was correct.
7. Answer follow-up questions.

Planning your Experiment:

What is your **question** about weathering of rocks and minerals?

What is your **hypothesis**?

Methods: Explain how you will test your hypothesis.

What are your **independent and dependent variables**?

What will you be keeping **constant** during your experiment?

Provide a sketch of your set-up.

Observations: Record what happens. Provide any **measurements** in a table.

Results/Conclusion:

Was your **hypothesis** correct? Explain.

Follow-up questions

1) Based on the results of your experiment, predict which of these would weather the fastest - a smooth round pebble or a jagged piece of rock. Why?

2) Explain how water could be a form of both mechanical and chemical weathering.

**Activity 4. Weathering and Surface Area
KEY**

Teacher Tips:

Note, in using SweeTARTS™ in the weathering activity, it was found helpful if they used the same colored candy for each treatment. It was found out that a good way to measure how much the SweeTARTS™ had dissolved was by looking at the color of the water that resulted. Also it is important to note that the candy will not dissolve completely, so one of the independent variables should be a set time. Between 5 and 10 minutes was found to be appropriate enough to determine their results.

Materials:

- Acid solution (dilute vinegar)
- SweeTARTS™ (the same color for each group)
- Hammers
- Stop watch (students can use their phones)
- Clear cups or beakers
- Safety goggles (if stronger acid)

Procedure:

1. Break students into groups of 3 or 4.
2. Students may need guidance to develop a question based on previous knowledge of weathering of rocks. This activity is designed to follow a unit on rocks and minerals. Prentice Hall Earth Science (2006) references rocks and minerals in chapters 2 and 3
3. Turn that question into a hypothesis. A good hypothesis could be an If-Then statement. It's ok if students don't actually prove their hypothesis correct!
4. Design an experiment that could test that hypothesis with the materials provided to you.
5. Carry out your experiment.
6. Determine if your hypothesis was correct
7. Answer follow-up questions

Possible Answers below *in italics*

Question:

Which dissolves faster – a solid SweeTARTS™ or a SweeTARTS™ that is broken up into smaller pieces?

What is your **hypothesis**?

If the particle size is smaller (more surface area), then the candy will dissolve (weather) faster.

Methods: Explain how you will test your hypothesis. What are your **controls**? What are your **independent and dependent variables**? Provide a sketch of your set-up.

We will have two cups of acid – CONTROL

A whole piece of candy will be put into one cup and a piece of candy smashed with a hammer will be put in the other – INDEPENDENT VARIABLE

They will both stay in the acid for 10 minutes – CONTROL

After 10 minutes, will we examine the amount of candy left and the color of the water to determine which “weathered” faster – DEPENDENT VARIABLE

Observations: Record what happens. Provide any **measurements** in a table.

The smaller particle size (the broken candy) dissolved faster.

Results/Conclusion: Was your **hypothesis** correct? Explain.

Yes – the SweeTARTS™ that was broken up into smaller pieces dissolved the most

Follow-up questions

1) Based on the results of your experiment, predict which of these would weather the fastest - a smooth round pebble or a jagged piece of rock. Why?

The jagged piece of rock has more surface area and can be weathered faster.

2) Explain how water could be a form of both mechanical and chemical weathering.

Water can continually wash over rock, breaking it down over time like waves hitting the shore (physical), or water can be acidic and dissolve particles like limestone chemically.

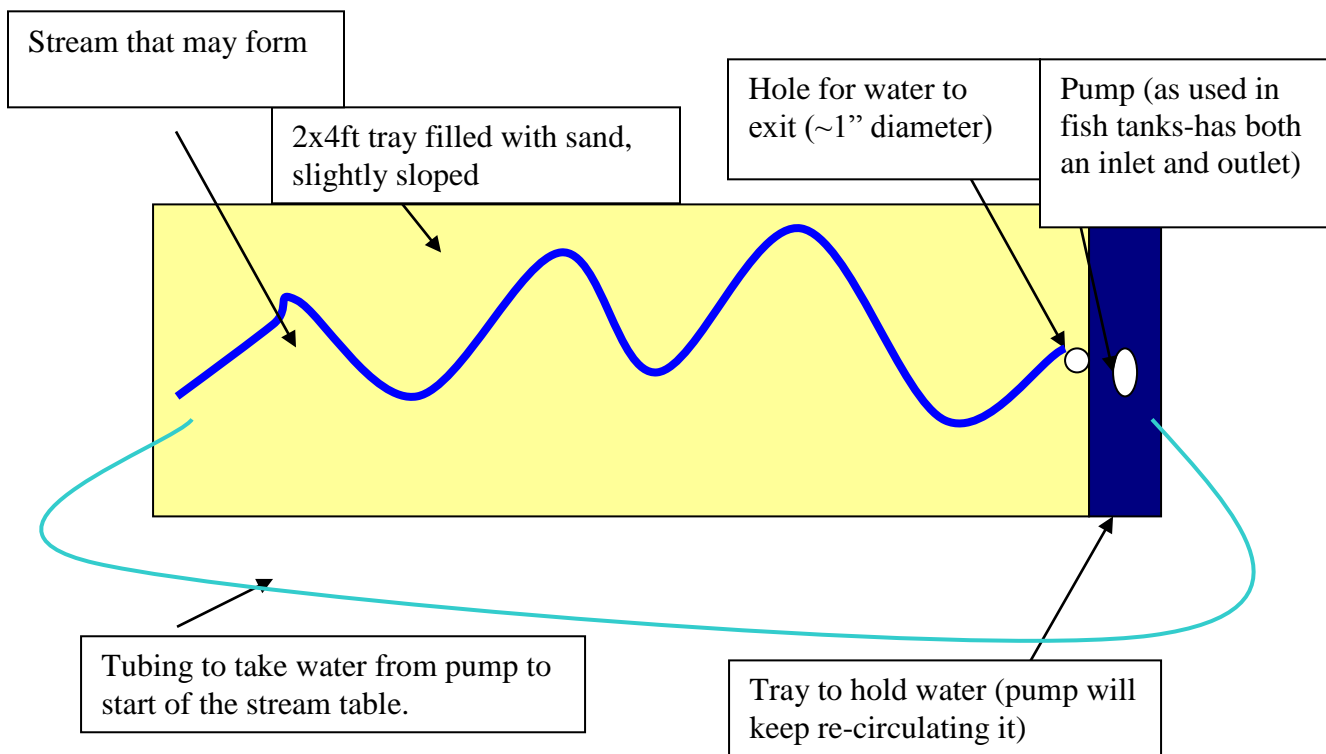
Experiments with Weathering, Erosion and Deposition

For Teachers

1. Overview

The lessons in this unit were adapted from the work of Molly Moffe at Cornell University and Rosemarie Wolf at East High School, Rochester, NY. The first two lab activities are designed to get students looking at how streams form and features that develop as a result of erosion and deposition, at both the macro (streams moving material from high to low elevations) and the micro (features in the stream watershed itself) levels. The third activity of the series will help students explore and understand how surface area relates to the rate of weathering of minerals and rocks. These activities complement an Earth Science curriculum that deals with weathering, erosion and deposition. Its main focus is on water as the driving force of these processes and does not deal with glaciers or wind. These activities are in the form of short-term experiments. If all of the activities in this series are done, it will serve to connect the three processes of weathering, erosion and deposition, which are not always expressed in textbooks.

These activities require a stream table, either with an automatic pump or a head tank of sufficient size to run a stream for 10 minutes. The table should be at least 2 feet x 4 feet. They can be ordered online from Science Kit & Boreal Laboratories and also WARD's Natural Science. For the adventurous or budget conscious teacher, a table can be built for less than \$100 by following the instructions provided at the end of this teacher guide. The following is a diagram of what one should include.



2. Subject

Earth Science. Based on: Lutgens, Tarbuck 11th ed., 2006. Earth Science. Prentice-Hall, Inc., NJ.

3. Audience

9-12th grade

4. Time required

One lab period per activity

5. Background

In order to use these activities, students should have covered units on rocks and minerals previously. It may be helpful also if they are aware of the different forces that can cause weathering, mainly chemical vs. physical. It may also be helpful if they are aware of other different forces of erosion already, mainly streams, glaciers, waves and wind. However, the class that this was piloted used these activities as an introduction to weathering, erosion and deposition. Their homework consisted reading of the relevant chapters in their text the day before that experiment was to be done, so that they had the relevant background information. These activities are not meant to define important terms. They are meant to supplement the text so that the students can see those terms “in action.”

6. Learning and Behavioral Objectives

The students will learn the following concepts:

- Importance of particle size and the role of surface area in weathering
- Water erosion and the different parts of a stream (meander, tributary, stream bank, flood plain, mouth, delta, etc)
- The processes of erosion and deposition in a stream, including where they occur on both a large and small scale.
- How stream velocity relates to the rate of erosion and deposition
- The sorting of sediment in streams and how that can relate to velocity.

They will also learn to:

- Make good observations
- Learn the different parts of the Scientific Method
- Learn to design a simple experiment with provided materials.

7. Next Generation Science Standards

- **HS ESS 2.5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.** [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

8. Assessment Strategy

Follow-up questions are provided at the end of each activity, including questions related to hypothesis testing.

9. Teaching Tips/Potential Problems

- Completed labs are included at the end of this document.
- Note, in using SweeTARTS™ in the weathering activity, it was found helpful if they used the same colored candy for each treatment. It was found out that a good way to measure how much the SweeTARTS™ had dissolved was by looking at the color of the water that resulted. Also it is important to note that the candy will not dissolve completely, so one of the independent variables should be a set time. Between 5 and 10 minutes was found to be appropriate enough to determine their results.

Activity 1: Basic Stream Table Observations

Objective:

This observation will prepare students for Activity #2. Students will gain experience with the streambed and learn what many of the key features that they will see in pictures will look like in miniature. Students should have practice with the vocabulary terms ahead of time.

Background:

Streams are Earth's most important agents of erosion. They can down-cut or erode their channels. They can also transport enormous amounts of sediment. Most of the sediment a stream carries comes from weathering. Weathering produces huge amounts of material that are delivered to the stream by sheet flow, mass movements, and groundwater. Eventually, streams drop much of this material to create many different depositional features. (Prentice Hall Earth Science, 2006)

List of materials:

1. Demo sized stream table
2. Projector or smart board (for pictures)
3. Pencil with eraser
4. Science notebook

Procedure:

1. Start with a "blank" stream table. (No landforms, no channels)
2. Start the flow of water by turning the valve, adjust the flow to maximum.
3. **Watch:** the structures that form over a 10-minute time period.
4. **Listen:** as your teacher identifies different features that form while the water is running.
5. **Sketch:** the resulting stream and its formations in your science notebook.
6. **Label:** the stream with as many of the key terms as possible. Use the provided figures and chapter 6.2 in your textbook, to help with your labeling.
7. **Check:** Can you label where erosion and deposition would occur in the provided figures after observing the running stream table?



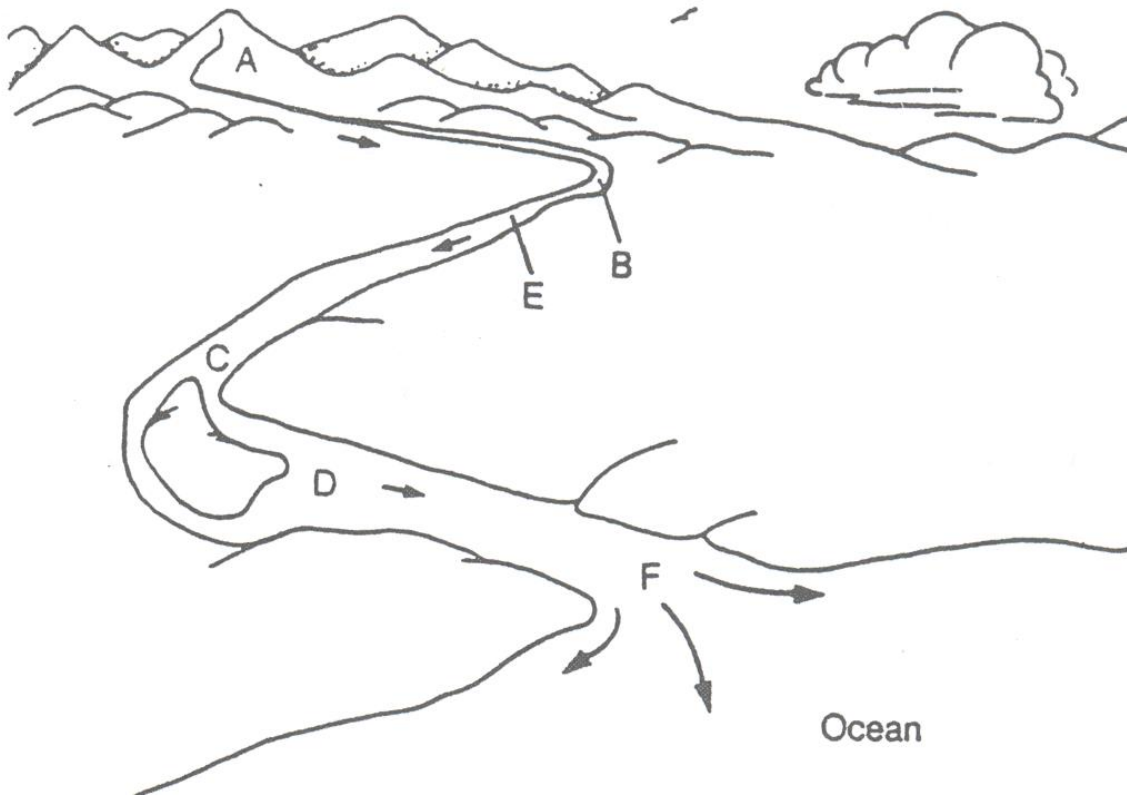
Word Bank of Key Terms:

Meander	Deposition	Cut Bank	Point Bar	Channel
Delta	Floodplain	Tributary	Stream	Drainage Basin
Bed Load	Alluvium	V-Shaped Valley	Divide	Capacity

Stream Sketch:

Run the model once ahead of time and sketch a representation of the stream that develops. The sketch should show as many of the key features as possible.

Each run will produce a slightly different stream and all features may not be present at the same time. It is important for students to take notes and quick sketches of what they see.



Possible features:

Meander Delta Cut Bank Point Bar Oxbow Lake Channel
V-shaped Valley Divide Tributary Drainage Basin

Activity 2. Stream Velocity and Erosion

Topic:

- Erosion and deposition caused by a stream, depending on how fast or slow the stream is flowing.
- Conducting Scientific Experiments

Grade Level: 9th grade Earth Science

Background: Sediment is eroded from the top of a watershed by a stream and its tributaries. That sediment is then deposited at the mouth of the stream, located in the bottom portion of a watershed. The amount of erosion and deposition that occurs can be determined by measuring how large the stream's delta grows overtime.

List of materials:

- Stream Table
- Defined streambed (rain gutter, or other long, narrow channel)
- Calculators
- Plexiglas with a 30cm by 30cm grid drawn on it. (for measuring the size of the delta that forms)

Procedure:

1. Examine the **Question** found below and develop a hypothesis from it.
2. Under **Methods**, design an experiment that could test your hypothesis. Your design should include at least the following:
 - Conduct at least three trials with the same stream shape each time at a slow, medium and fast pump speed
 - Conduct each trial for the same amount of time (Why?!)
 - Measure the "volume" of the delta after each trial in centimeters (length x width x height)
 - Record data
 - Return the sediments to the top of the watershed after each trial (Why?!)
3. Construct your defined stream on the stream table (straight and narrow works well)
4. Assign the needed roles in your group (these should stay the same through the whole experiment to keep data collection consistent):
 - Pump operator
 - Time keepers
 - Delta measurer
 - Data recorder
 - Engineer to keep the same stream size and shape and to redistribute the sediments
5. Carry out the Experiment that you designed under the **Methods** section.
6. Determine if your hypothesis was correct.
7. Answer follow-up questions

Answer Key

Question: How does the velocity of a stream affect how much erosion and ultimately deposition occurs?
What is your **hypothesis**?

My hypothesis is that the faster the water flows, the more erosion will occur and the larger the delta will grow.

Methods: Explain how you will test your hypothesis. What are your **controls**? What are your **independent and dependent variables**?

We will construct one sized and shaped stream to run 3 trials because the shape of a stream (straight vs. meander) can affect its velocity and how long it is can change the amount of erosion– CONTROL

We will have three trials; one slow, one medium and one fast speed - INDEPENDENT VARIABLE

Each trial will be for the same amount of time; One minute – CONTROL

The volume of the delta will be measured in centimeters and recorded after each trial – DEPENDENT VARIABLE

The “sediments” will be returned to the top of the “watershed”, so that there is the same amount of sand present for each trial - CONTROL

Observations: Record what happens. Provide any **measurements** in a table.

Trial #	Volume of Delta
#1 (slow)	
#2 (medium)	
#3 (fast)	

Results/Conclusion: Was your **hypothesis** correct? Explain.

Yes – the faster the speed, the larger the delta

Follow-up questions

1) What do you think would happen if we increased or decreased this stream’s slope (make it steeper or flatter) instead of the speed of the pump?

Increasing the slope would cause more erosion, too.

2) What events in nature did the speed of the pump represent in this experiment? Hint: Think about weather and climate.

Rainfall and snowmelt

3) How do people try to control rivers and streams in “real life?” How would engineers keep a real stream from changing its size or course? **Dams and levees**

Activity 3. Weathering and Surface Area

KEY

Objectives:

- To understand the importance of surface area when it comes to weathering of rocks and minerals.
- To learn how to design your own independent experiment.

Background: There are two types of weathering; mechanical and chemical. Mechanical, or physical, weathering is the breakdown into smaller pieces, while chemical weathering breaks a rock or mineral down by altering a rock or mineral's chemical composition. Weathering can be affected by several forces, including exposure, particle size, mineral composition, and climate. This activity will look at the role of particle size and how fast a material can be weathered. See Figure 9-2

FIGURE 9-2 – as found in Student Handouts

List of materials:

- Acid solution (dilute vinegar)
- SweeTARTS™ (the same color)
- Hammer
- Stop watch
- Clear cups or beakers
- Safety goggles (if stronger acid)

Procedure:

1. Break into groups of 3 or 4.
2. Develop a question based on your previous knowledge of weathering of rocks and minerals and Figure 9-2.
3. Turn that question into a hypothesis.
4. Design an experiment that could test that hypothesis with the materials provided to you.
5. Carry out your experiment.
6. Determine if your hypothesis was correct
7. Answer follow-up questions

Question: Which dissolves faster – a solid SweeTARTS™ or a SweeTARTS™ that is broken up into smaller pieces?

What is your **hypothesis**?

The smaller the particle size, the faster it will dissolve.

Methods: Explain how you will test your hypothesis. What are your **controls**? What are your **independent and dependent variables**? Provide a sketch of your set-up.

We will have two cups of acid – CONTROL

A whole piece of candy will be put into one cup and a piece of candy smashed with a hammer will be put in the other – INDEPENDENT VARIABLE

They will both stay in the acid for 10 minutes – CONTROL

After 10 minutes, will we examine the amount of candy left and the color of the water to determine which “weathered” faster – DEPENDENT VARIABLE

Observations: Record what happens. Provide any **measurements** in a table.

The smaller particle size (the broken candy) dissolved faster.

Results/Conclusion: Was your **hypothesis** correct? Explain.

Yes – the SweeTARTS™ that was broken up into smaller pieces dissolved the most

Follow-up questions

1) Based on the results of your experiment, predict which of these would weather the fastest - a smooth round pebble or a jagged piece of rock. Why?

The jagged piece of rock has more surface area and can be weathered faster.

2) Explain how water could be a form of both mechanical and chemical weathering.

Water can continually wash over rock, breaking it down over time like waves hitting the shore (physical), or water can be acidic and dissolve particles like limestone chemically.

Desktop Delta

For more “desktop delta” or “flume” resources see:

http://serc.carleton.edu/NAGTWorkshops/sedimentary/models/desktop_delta.html#plans

Teacher Background

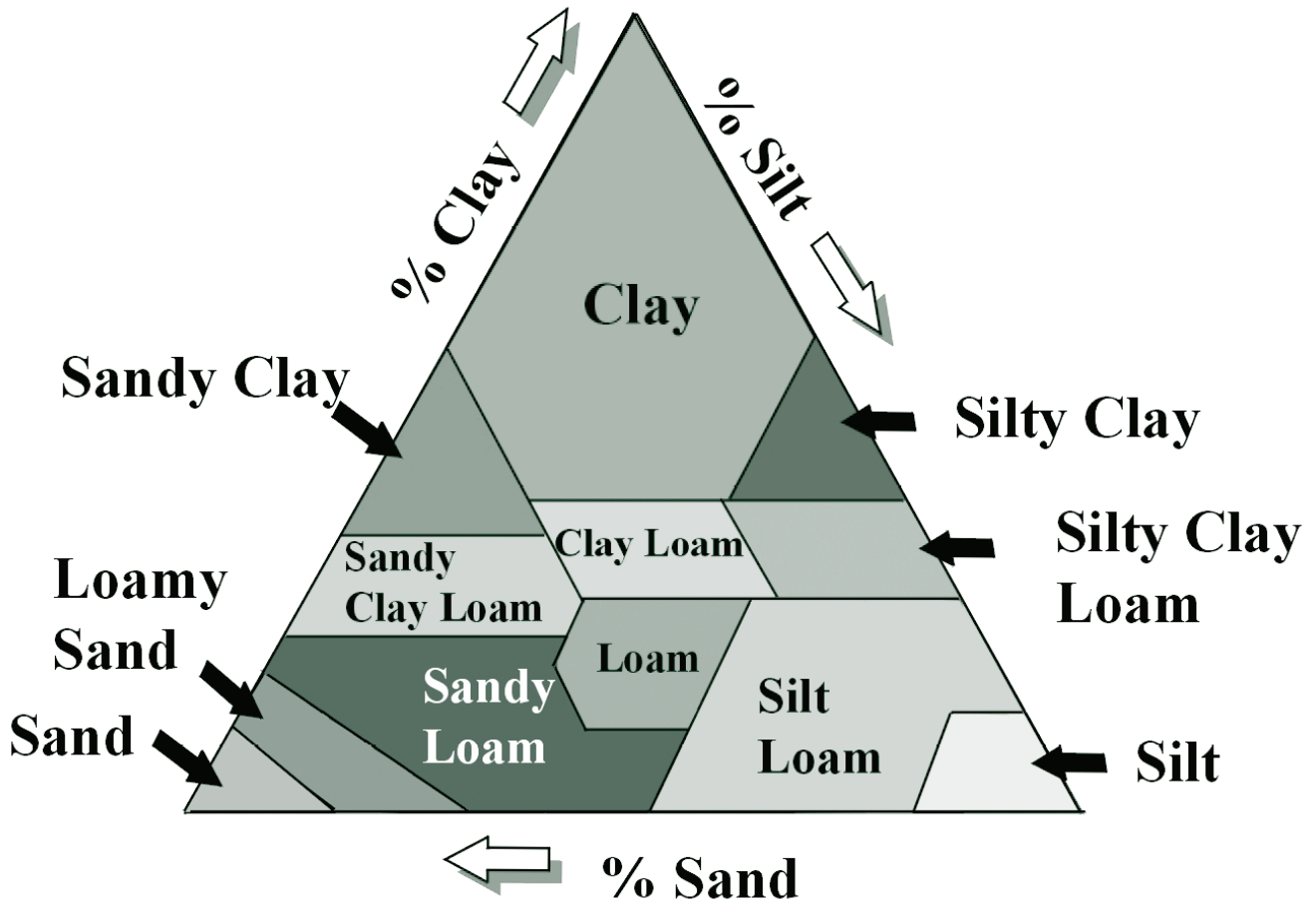
Properties of Soil

We generally don't think much about soil. In fact, "soil" can have a negative connotation. We call it dirt and wash it off our clothes and our bodies. In reality, the soil is essential to our survival and that of nearly every organism on Earth. Our planet is mostly made of rock with an iron-nickel core. Plants and animals, including us, occupy a thin veneer on its surface. Our existence is possible because of a thin layer of soil that comes between the planet's rocky interior and us.

The weathering of rock slowly produces soils. Constant exposure to wind and rain cause the rocky crust to slowly break down into smaller particles. It can take centuries to produce fertile topsoil. As rainwater seeps into cracks, temperature extremes cause the water to freeze. The rock expands, contracts, and fractures. These weathering actions are helped along by organisms that live on and in the soil. Soils are composed of inorganic material derived from rock and organic material derived from living and dead organisms. Both are important to support plant growth. Some scientists believe that without life, soils are just dirt.

As weathering breaks down inorganic material, particles of various sizes are produced. Soil texture refers to the relative proportions of different-sized particles found in the soil. Scientists classify soil particles into three categories. The smallest particles, which measure less than 0.002 millimeters, are called clay.¹⁶ Clay is important in holding nutrients. Clay particles form plate like structures that act like magnets, holding nutrients until they are displaced by another element, absorbed by a plant root, eaten by a soil microbe, or chemically absorbed into the soil. The next largest particles are called silt. Silt particles range in size from 0.002 millimeters to 0.06 millimeters. Sand refers to the largest particles. Sand grains range in size from 0.06 millimeters to 2 millimeters. Soils vary in their proportions of clay, silt, and sand. Soil scientists classify different soil types using the soil triangle. Each side of the soil triangle represents the amount of a soil component, clay, silt, or sand. The relative amounts of these three particle sizes intersect within the triangle and determine to what type of soil those proportions correspond.

Figure 1. The soil triangle is used to classify soil types.



The ability of a soil to accept and retain water is largely determined by the relative amounts of clay, silt, and sand present. Porosity refers to spaces in the soil that can hold either air or water. Permeability is defined as the rate at which water can travel through soil. Table 8 lists properties of particle size that relate to soils' interactions with water. Soils with desirable properties for farming are called loams. Loamy soils typically contain about 50 percent air space, which allows root systems to "breathe" (i.e. obtain O₂ for respiration). The solid half of soils is about 90 percent minerals and 10 percent organic material. Usually, loamy soils have names that more accurately reflect their composition, such as clay loam or silt loam.

Properties of Soil Particles

Property	Clay	Silt	Sand
Porosity	Mostly small pores	Mostly small pores	Mostly large pores
Permeability	Slow	Slow to moderate	Rapid
Water-holding capacity	Large	Moderate	Limited

Although the organic fraction of most soils is small in volume compared to the mineral fraction, it plays an important role in supporting plant growth. The organic material is composed of living organisms, plant roots, and plant and animal residue. A single gram of healthy topsoil may contain 100 nematodes (small roundworms), 1 million fungi, and 1 billion bacteria.²⁴ Present in smaller numbers may be earthworms and a wide variety of insects. Organic material contains a significant amount of nutrients and it, together with plant roots, helps:

- Decrease erosion
- Increase water infiltration and storage
- Act as a pH buffer (to maintain an acid-base balance)
- Decompose organic material, releasing nutrients
- Recycle carbon, nitrogen, and other nutrients
- Retain available nutrients such as metal ions.

The soil is a “bank” for nutrients that are taken up by plants, and these nutrients must be replenished for continued plant growth. Before the advent of modern agriculture, farmers relied solely upon tillage to break down existing organic material and release existing soil nutrients. This practice is still used in many less developed countries.

TEACHERS GUIDE

Soil Percolation Lab

BACKGROUND INFORMATION:

Most of the rain that falls on land soaks into the ground. The rest runs off into streams and rivers. How well rain soaks into the ground depends on a number of factors including: the slope of the land, the amount of open space between the soil particles, (its porosity), and the soil or rock's capability to allow water to pass through it (permeability).

The shape of the particles, how tightly the particles are packed, and how many different sizes of particles there are determine **porosity**. These characteristics and changes in the amount and rate that water soaks in can vary among different soil layers.

This activity will demonstrate the variation in the rate that water moves through various soil layers by testing the rate at which water moves through clay, topsoil and sand. The rate that water moves through a soil is called the **percolation rate**.

Define the following words

Porosity: *the amount of open space between particles*

Permeability: *the soil or rocks capability to allow water to pass through it*

Percolation rate: *The rate that water moves through the soil*

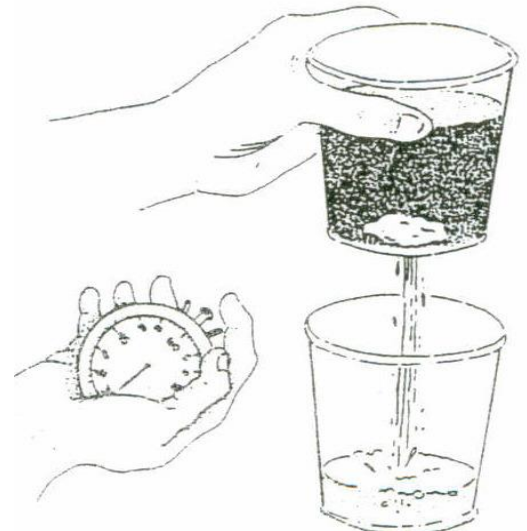
HYPOTHESIS: Develop a one-sentence prediction for the outcome of this experiment.

Answers will vary:

I predict that the percolation rate of the sand will be the fastest because the pore space appears to be the largest.

MATERIALS:

- 3 samples (topsoil, sand, clay) water
- 1 graduated cylinder
- 1 stopwatch/cell phone
- 1 cup (use same cup for all 3 samples)
- 1 pencil
- 1 plastic beaker
- tweezers
- 3 cotton balls/pads



TEACHERS GUIDE

PROCEDURE:

- 1) Gather your materials
- 2) Carefully poke a hole with a pencil through the bottom of the cup.
- 3) Place a cotton ball over the hole in the cup.
- 4) Use a beaker to measure 100mL of soil and place it in the cup.
***Use topsoil or sand first, test the clay last.*
- 5) Measure 50 mL of water in the graduated cylinder.
- 6) With one group member ready to start timing with a stopwatch, pour the water through the sample all at once, while holding the paper cup over the beaker.
- 7) WHEN WATER STARTS TO DRIP FROM THE BOTTOM OF THE CUP, time the flow of water for 30 seconds.
- 8) After 30 seconds, measure the collected water by pouring the contents of the beaker into the graduated cylinder and recording the volume in your data table.
- 9) Determine the percolation rate of the sample by dividing the amount of percolated water by the amount of time (30 sec.)
EX: 30 mL percolated through a sample in 30 sec.
 $30\text{mL}/30\text{ sec.} = \text{percolation rate}$
Percolation rate = 1 mL/sec.
- 10) Remove the cotton ball with a pair of tweezers and throw it away.
- 11) Empty the used sample into the appropriate used sample bucket at the front of the room.
- 12) Repeat steps 3-11 for the remaining 2 samples.

OBSERVATIONS AND DATA ANALYSIS

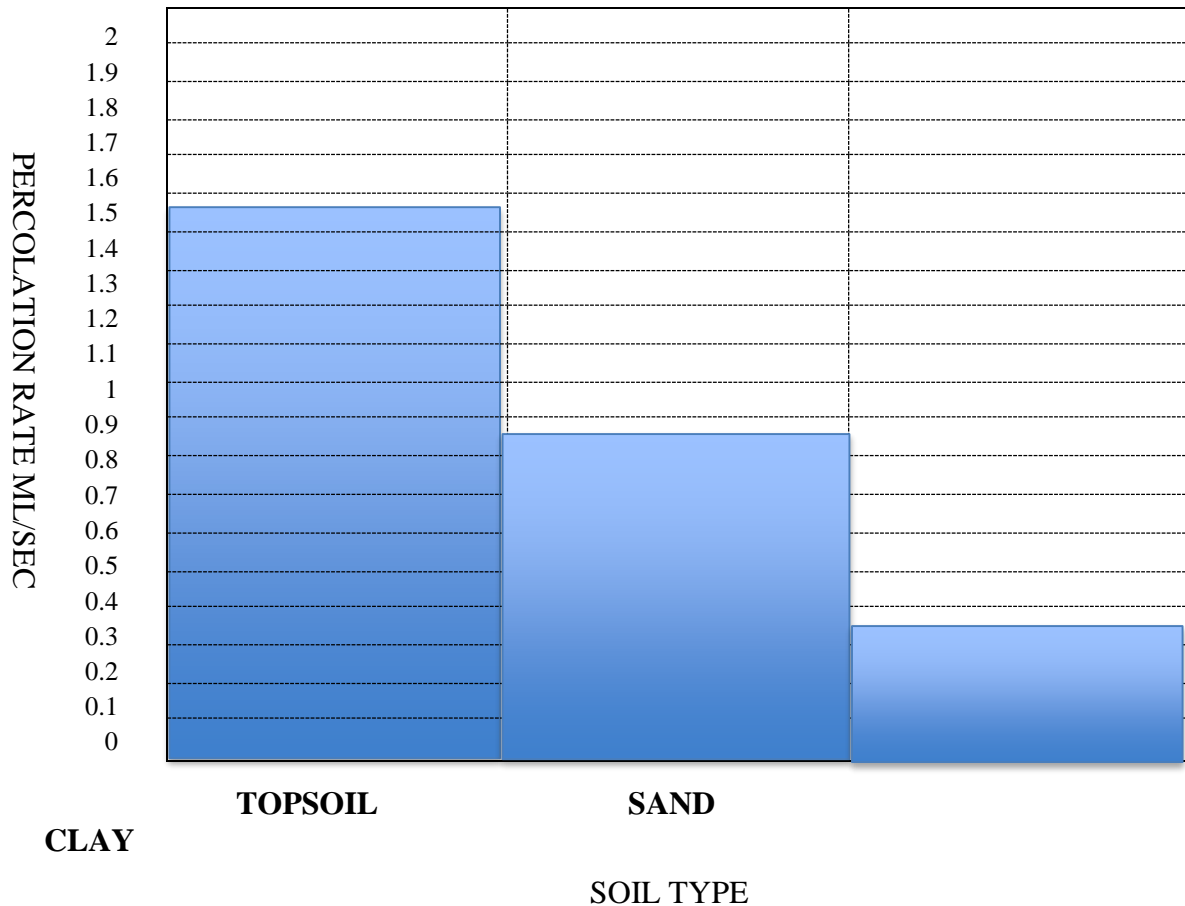
Data will vary, below are some sample values that could be possible. This will depend on your soil samples and where you got them

Data Table

SAMPLE	WATER VOLUME (mL)	(mL/sec)	PERCOLATION RATE (mL/sec)
Topsoil	45	/30 sec.	1.5
Sand	25	/30 sec.	.83
Clay	10	/30 sec.	.33

Create a bar graph with the results from your data table

TEACHERS GUIDE



QUESTIONS:

1) In this experiment, what was the independent variable?

The amount of water

2) What was the dependent variable?

The type of soil

3) What could we have used as an appropriate control for this experiment?

A precise mixture of the three soil types

4) Was your hypothesis correct or incorrect?

Yes, the topsoil had the greatest space between particles and allowed the water to flow through.

5) List 3 possible sources of error that could have affected your results.

Answers will vary, some possible ones are listed below

a) *The water was poured too fast and created a hole in the soil sample*

b) *The soil sample was accidentally compacted in the cup, reducing pore space*

c) *The sample was already wet, which resulted in more water passing through the sample instead of being retained.*

TEACHERS GUIDE

CONCLUSION: Answer the following questions based on the activity using complete sentences.

6) Which soil component had the fastest percolation rate?

The topsoil had the fastest percolation rate

7) Why does the soil component from question #1 percolate the quickest? What properties/characteristics does it have that may contribute to its percolation rate?

The topsoil has the largest pore space, which gives it greater permeability.

8) Which soil component had the slowest percolation rate?

The clay

9) Why does the soil component from question #3 percolate the slowest? What properties/characteristics does it have that may contribute to its percolation rate?

The clay was slowest because it has the smallest pore space of the three samples, this gives it the lowest permeability.

10) List at least 3 people or occupations that may find knowing the percolation rate of various soil components to be useful. For each, explain how they would use this information.

a)

b)

c)

11) Suppose you are a farmer and you have 2 samples of soil—one is mostly sand and the other is mostly clay. You want to grow soybeans in one of these 2 soils. What questions would you need to ask before choosing the soil in which to plant your soybeans? (Write at least 2 questions).

Questions will vary, here are some possible ones

1. *How much water do soybeans need? If they need large amounts of water then I will need a soil with good permeability to allow water to get to the roots.*

2.

Soil Percolation Lab

BACKGROUND INFORMATION:

Most of the rain that falls on land soaks into the ground. The rest runs off into streams and rivers. How well rain soaks into the ground depends on a number of factors including: the slope of the land, the amount of open space between the soil particles, (its porosity), and the soil or rock's capability to allow water to pass through it (permeability).

The shape of the particles, how tightly the particles are packed, and how many different sizes of particles there are determine **porosity**. These characteristics and changes in the amount and rate that water soaks in can vary among different soil layers.

This activity will demonstrate the variation in the rate that water moves through various soil layers by testing the rate at which water moves through clay, topsoil and sand. The rate that water moves through a soil is called the **percolation rate**.

Define the following words

Porosity: _____

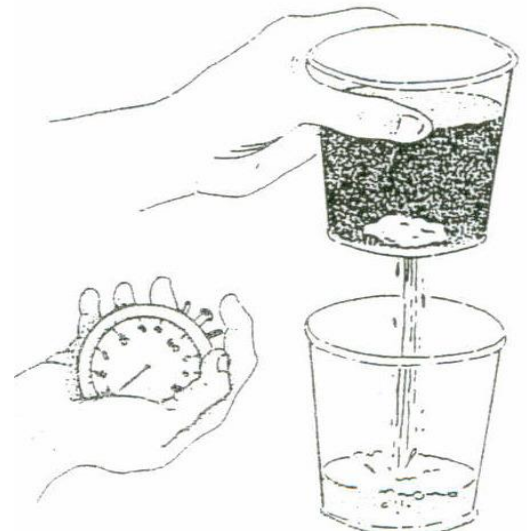
Permeability: _____

Percolation rate: _____

HYPOTHESIS: Develop a one-sentence prediction for the outcome of this experiment.

MATERIALS:

- 3 samples (topsoil, sand, clay) water
- 1 graduated cylinder
- 1 stopwatch/cell phone
- 1 cup (use same cup for all 3 samples)
- 1 pencil
- 1 plastic beaker
- tweezers
- 3 cotton balls/pads



PROCEDURE:

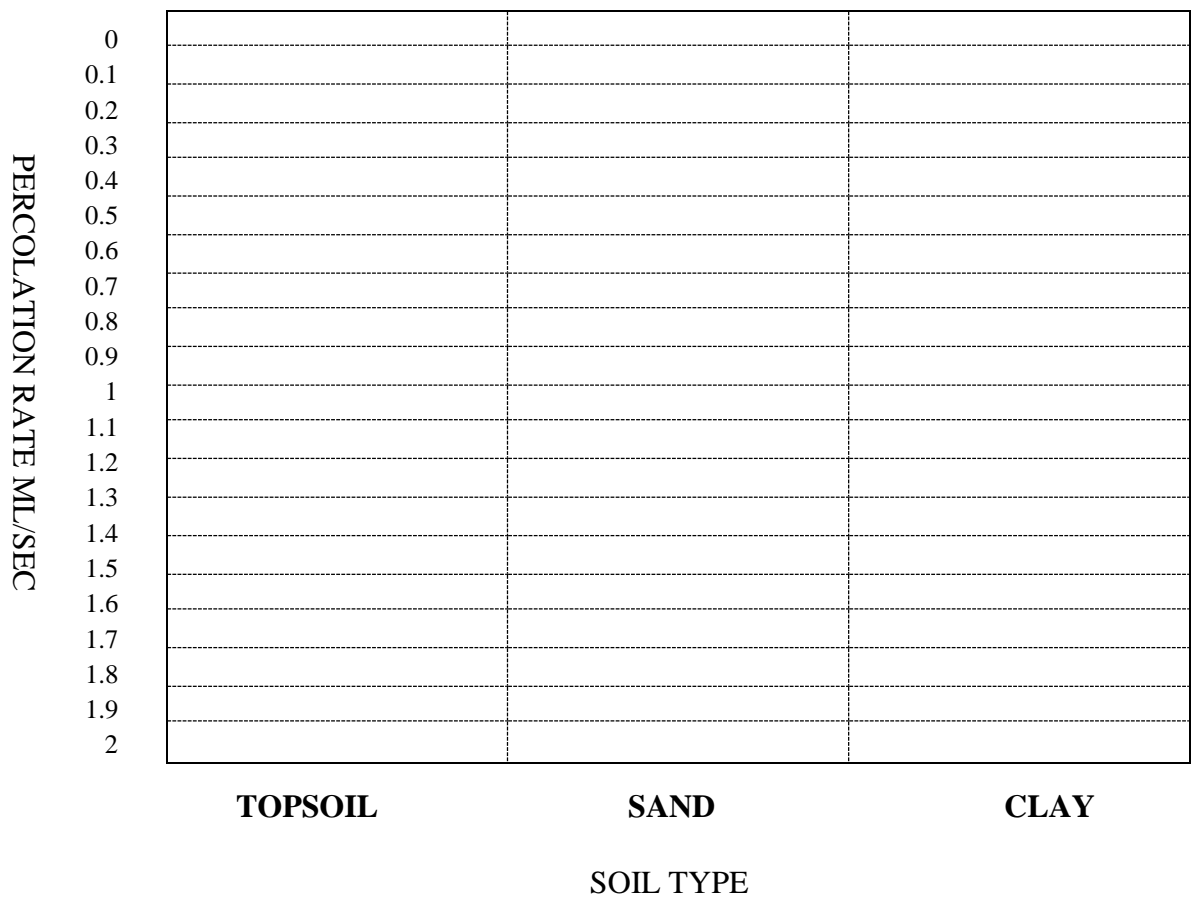
- 1) Gather your materials
- 2) Carefully poke a hole with a pencil through the bottom of the cup.
- 3) Place a cotton ball over the hole in the cup.
- 4) Use a beaker to measure 100mL of soil and place it in the cup.
*** Use topsoil or sand first, test the clay last.*
- 5) Measure 50 mL of water in the graduated cylinder.
- 6) With one group member ready to start timing with a stopwatch, pour the water through the sample all at once, while holding the paper cup over the beaker.
- 7) WHEN WATER STARTS TO DRIP FROM THE BOTTOM OF THE CUP, time the flow of water for 30 seconds.
- 8) After 30 seconds, measure the collected water by pouring the contents of the beaker into the graduated cylinder and recording the volume in your data table.
- 9) Determine the percolation rate of the sample by dividing the amount of percolated water by the amount of time (30 sec.)
 EX: 30 mL percolated through a sample in 30 sec.
 $30\text{mL}/30 \text{ sec.} = \text{percolation rate}$
 Percolation rate = 1 mL/sec.
- 10) Remove the cotton ball with a pair of tweezers and throw it away.
- 11) Empty the used sample into the appropriate used sample bucket at the front of the room.
- 12) Repeat steps 3-11 for the remaining 2 samples.

OBSERVATIONS AND DATA ANALYSIS

Data Table

SAMPLE	WATER VOLUME (mL)	(mL/sec)	PERCOLATION RATE (mL/sec)
Topsoil		/30 sec.	
Sand		/30 sec.	
Clay		/30 sec.	

Create a bar graph with the results from your data table



QUESTIONS:

- 1) In this experiment, what was the independent variable?
- 2) What was the dependent variable?
- 3) What could we have used as an appropriate control for this experiment?
- 4) Was your hypothesis correct or incorrect?
- 5) List 3 possible sources of error for that could have affected your results.
 - a)
 - b)
 - c)

CONCLUSION: Answer the following questions based on the activity using complete sentences.

6) Which soil component had the fastest percolation rate?

7) Why does the soil component from question #1 percolate the quickest? What properties/characteristics does it have that may contribute to its percolation rate?

8) Which soil component had the slowest percolation rate?

9) Why does the soil component from question #3 percolate the slowest? What properties/characteristics does it have that may contribute to its percolation rate?

10) List at least 3 people or occupations that may find knowing the percolation rate of various soil components to be useful. For each, explain how they would use this information.

a)

b)

c)

11) Suppose you are a farmer and you have 2 samples of soil—one is mostly sand and the other is mostly clay. You want to grow soybeans in one of these 2 soils. What questions would you need to ask before choosing the soil in which to plant your soybeans? (Write at least 2 questions).

1.

2.

Runoff and Infiltration: Where does rainfall go?

Runoff: water that does not soak into the ground but instead runs over the surface... *where does it go? (Name three places)*

Infiltration: When water seeps into the soil and rocks from the surface ... *where does it go? (Name three places)*

Materials:

1 of the following: Plastic bottle, pipette, eye dropper

Optional: Ring stands with clamps

2 types of sponges, small pores/large pores

Plastic bin to catch runoff

250ml beakers

Plastic sheet (acrylic, binder divider or similar) to simulate pavement

Soil is like a Sponge

1. A drizzle: Use plastic pipettes, eye droppers, or a small soda bottle rainfall simulator set at a drizzle and hold it over a sponge. Where is the water going? Write down your observations:

2. A rainstorm ... a flood: Fill beaker with water, and first very, very slowly pour it onto sponge. Then keep on increasing speed at which you are pouring (you may need to refill the beaker!) Experiment with different speeds. Where is the water going when you pour slowly? How is this different when you pour fast? Write down your observations:



Slow:

Fast:

3. What do you think would change if the pores in the sponge (in the soil) were much, much smaller? (Try this out with a fine-pored sponge)

4. Explain the differences in runoff and infiltration you have observed so far in your own words – how does the sponge show what happens when rain falls on soil?

5. Paving a road: Cover the sponge with plastic, and pour water onto it again. Where is the water going?

Write down your observations:

How does paving over the soil affect runoff and infiltration?

6. In what ways are people using land differently now than 200 years ago? Do you think there was more or less runoff 200 years ago? Why?

7. What effects do you think runoff can have on the environment? How could runoff play a part in pollution? How would it affect streams, rivers and lakes? How would it affect the groundwater?

Runoff and Infiltration: Where does rainfall go?

Runoff: water that does not soak into the ground but instead runs over the surface... *where does it go? (Name three places)*

Infiltration: When water seeps into the soil and rocks from the surface ... *where does it go? (Name three places)*

Wetlands, rivers, lakes, the ocean, floods in a city, ... (there are more right answers)

Materials:

1 of the following: Plastic bottle, pipette, eye dropper

Optional: Ring stands with clamps

2 types of sponges, small pores/large pores

Plastic bin to catch runoff

250ml beakers

Plastic sheet (acrylic, binder divider or similar) to simulate pavement

Soil is like a Sponge

1. A drizzle: Use plastic pipettes, eye droppers, or a small soda bottle rainfall simulator set at a drizzle and hold it over a sponge. Where is the water going? Write down your observations:

Students should find that the water goes into the sponge, and maybe that some is dripping out of the sponge at the bottom.

2. A rainstorm ... a flood: Fill beaker with water, and first very, very slowly pour it onto sponge. Then keep on increasing speed at which you are pouring (you may need to refill the beaker!) Experiment with different speeds. Where is the water going when you pour slowly? How is this different when you pour fast? Write down your observations:



Slow:

Most, if not all water will be going into the sponge, and flowing out the bottom. A small amount may flow over the top and run off the sides.

Fast:

Most of the water will flow over the top of the sponge and off the sides, it will be harder to see that some is still flowing through the sponge.

3. What do you think would change if the pores in the sponge (in the soil) were much, much smaller? (Try this out with a fine-pored sponge)

More water would run off in a sponge with smaller pores, less water would infiltrate.

4. Explain the differences in runoff and infiltration you have observed so far in your own words – how does the sponge show what happens when rain falls on soil?

Small amounts of water can go into and through the pores in the sponge, but larger amounts poured faster can't all fit into the pores at once. So the pores are filled up with water, and the rest of the water flows over the top. When the pores are smaller, less water fits into them, and it flows slower, so even more water will run off over the top. The same thing happens with soils... water from a light drizzle will be absorbed, but when there's a rainstorm, the soil pores become full, and some water will run off. Soils with smaller pores at the surface will cause more runoff.

The teacher may especially need to help students think this explanation through – this seems to often be the hardest part for students. Make sure that students are gaining the connection to the real world during this exercise.

5. Paving a road: Cover the sponge with plastic, and pour water onto it again. Where is the water going?

Write down your observations:

How does paving over the soil affect runoff and infiltration?

All the water runs off the surface, none is able to get through the plastic (pavement), and therefore no water goes into the soil.

6. In what ways are people using land differently now than 200 years ago? Do you think there was more or less runoff 200 years ago? Why?

Some possible answers: More roads, larger roads, roads are paved now, more buildings, more flat ball fields, fewer wetlands, more mechanized agriculture, larger agricultural fields, less forested land, ... There is more runoff now, because so many more surfaces are covered, paved, compacted, or flattened now than 200 years ago

7. What effects do you think runoff can have on the environment? How could runoff play a part in pollution? How would it affect streams, rivers and lakes? How would it affect the groundwater?

Many possible answers here: erosion of agricultural land, fertilizers and pesticides can be washed away; sediment, nutrients, pesticides, chemicals from cities such as gasoline and oil, can all be washed into rivers and lakes and pollute these. More runoff can create floods. With more runoff there is less groundwater recharge, so this can contribute to the groundwater level going down, etc