How Does Land Use Affect Water Infiltration and Runoff?

Student Activity Sheet

Name _____ Date _____ Class _____

The ways we use our land have changed a great deal over the last 500 years. Many of our forests, wetlands, grasslands, and other wilderness areas have been replaced with houses, farms, pastures, factories, stores, businesses, roads, and streets. These changes in the way we use our land have altered the hydrology of watersheds. ***Hydrology*** is the study of water, where it is and how it gets there. A ***watershed*** is a region of land that drains into a body of water, typically a river or lake. Water not only moves across the surface of land in a watershed (runoff), but it also filters down through the soil and rock to form groundwater. ***Groundwater*** is the water beneath the surface of the ground that has seeped down from the surface and is the source of water for wells and springs. ***Runoff*** is water that does not seep into the ground, but instead flows over the surface of the land.

Changes in land use affect our watersheds. Water may flow in a different direction, more water reaches the rivers, lakes, and oceans, and the water gets to these bodies of water faster without sediments and pollutants being removed by slow infiltration into the soil. The amount of nutrients, sediments, and toxic materials from increased runoff and soil erosion can seriously harm ponds, streams, and groundwater resources. ***Infiltration*** is when water seeps into the soil and rock and recharges an aquifer. An ***aquifer***, or groundwater reservoir, is a section of rock beneath the earth's surface that is soaked with groundwater. Aquifers are often a primary source of water for many communities. Currently, aquifers are being depleted due to the huge water demand of American industries, farms, and families.

Forests have less runoff because leaves and trees slow down the rain before it hits the ground, giving plant root's time to absorb water and time for the water to soak into the earth. When land is paved (by parking lots and roads) or cleared for buildings, the vegetation is removed and the land is covered by blacktop or concrete. There is no longer any vegetation to slow down the rain hitting the ground and since the ground is covered, no water can soak into the soil. Instead, the water runs over the surface, often causing flooding and erosion. Our aquifers are also not being recharged with surface water as fast as they used to be.

The following diagram sums up what you have just learned about how different land uses affect how fast (the rate) water infiltrates or runs off the land. Notice that the rates for runoff are the opposite those for infiltration.

Rates of infiltration for various land uses

<---**Greatest**----------**Smallest**---
>

forest > pasture > crop land > bare earth > buildings > pavement

Rates of runoff for various land uses

<-- -**Greatest**----------**Smallest**--->

pavement > buildings > bare earth > crop land > pasture > forest

You will use a ***model*** in this exercise to simulate or mimic what happens in the real world when we clear natural areas to build roads, parking lots, and buildings.

Objectives:

- Use a model to simulate how various land uses affect rates of runoff and infiltration.
- Become aware of how modern building and development can affect where water flows and its quality.

Materials:

Runoff model	Water
Measuring container	Topsoil or potting soil
Sponges	Quart jar or 2L soda bottle to hold water
Graph Paper	Colored Pencils (optional)

Procedures:

1. Review the vocabulary terms and make sure you understand the introductory material. Ask your teacher to explain anything you have trouble understanding.
2. There is one runoff model but several students will be needed to help your teacher during this demonstration. All of the students will record the amounts of water and make observations about the three models used during this exercise.

3. Using the measuring container, measure out about $^1/_2$ quart or $^1/_2$ liter of water into the water bottle. Place the runoff model on a table so that the tubing will drain all runoff water to the measuring container. (The measuring container must be lower than the model or the water won't flow, so you may want to place the container on the floor.) You may need to tilt the model on the end opposite to the tubing to make sure the water flows well.
4. Sprinkle the measured amount of water over the bare surface of the model (Model 1) and record this amount on the Data Table. Also record the amount of water collected in the container. What does the bare surface (Model 1) represent?
5. Cover the model surface with soil (Model 2). Pat down the soil alittle, so it isn't loose. Sprinkle the same volume of water used for Model 1 ($^1/_2$ quart or $^1/_2$ liter) over the soil covered surface and record the amount collected on the Data Table. What does Model 2 represent?
6. Place sponges over the top of the soil in the model, laying them side by side to cover the model's surface (Model 3). Sprinkle the same measured amount of water over the sponge surface and record the volume on the Data Table. Record the amount of water collected. What does Model 3 represent?
7. Discuss the differences in the amounts of water collected. Make a bar graph of your results. The X axis will be the water poured or collected with the model number and the Y axis will be the amount or volume of water. You will have a total of six bars on your graph, two bars for each model. One bar shows the volume of water that you poured and one bar shows the amount collected. If you are not sure how to make a bar graph, ask your teacher for help. You may want to color the bars for the amount of water poured one color and the bars for the amount collected another color.
8. Answer the discussion questions.

Data Table

	Amount of Water Poured	Amount of Water Collected
Model 1 (Bare)		
Model 2 (Soil)		
Model 3 (Sponges)		

Discussion Questions:

1. How have changes in the way land is used affected the hydrology of watersheds over time?

2. Do you think there is more or less runoff now than there was 200 years ago? Why or why not?

3. What are some ways people are using land differently now? What effects do you think they have on the watershed and the environment?

4. If you were building a house, what are some things you could do so you could still use your land but also continue to recharge the aquifer?

Vocabulary

Hydrology: The study of water on the earth and in the atmosphere, including how and when water moves.

Watershed: A section of land that drains into a body of water, typically a river, lake, or the ocean.

Groundwater: Water beneath the surface of the ground that has seeped down from the surface and is the source of water for wells and springs.

Runoff: Water that does not penetrate beneath the surface but instead runs over the surface of the land.

Infiltration: When water seeps into the ground and rocks to recharge the aquifer.

Aquifer: A groundwater reservoir beneath the earth's surface containing rock that is filled with groundwater.

Model: A small example that simulates or mimics a real process or activity.

Teacher Strategies

Check the tubing connection for leaks on the runoff model and reseal it if necessary. The tube opening on the inside of the pan should be covered with a piece of screen. Make sure the screening is securely fastened. The soil has been provided in this kit, but you can experiment with and use different materials (such as gravel, sand, or sod) to see what the rates of infiltration or runoff will be.

Review the introductory material with your class and be certain to completely review the vocabulary words before the demonstration. You may want to leave the words on the board throughout the activity. You may also put the "Rates of Filtration and Runoff" diagrams on the board to illustrate how the rates of infiltration and runoff compare for the different land uses. Actively involve your students with the demonstration: have them measure and sprinkle the water, collect and measure the runoff water, or add the soil and sponge materials to the model. You may also want to have one student record the results in table form on the board so that all the students may later copy the data on their individual data tables.

In the procedural write-up, the students are asked what each version of the model represents. You can go over this after the demonstration or give your students a chance to figure it out on their own. The following describes what each model version represents:

- Model 1: This simulates pavement or concrete covered surfaces; rain falling on these surfaces would all runoff, so that nearly all the water poured should be collected from this bare surface.
- Model 2: A moderate amount of murky water should be collected from the bare soil. This model shows how bare, unplanted soil can erode and the effect of erosion on surface water quality.
- Model 3: This model illustrates how plants greatly increase infiltration to the soil and the aquifer. Most of the water stayed behind in the plants or soil, so that little water should have been collected from this model.

The students are asked to make a bar graph of their results. Your students may need a review of this type of graph and graphing skills. Have one bar represent the amount of water poured and one bar to represent the amount recovered for each of the three models. If colored pencils are available, color the bars for the water poured one color and the collected another color. It may help to draw a sample graph on the board.

Answers to Discussion Questions:

1. Hundreds of years ago land use was very minimal, so the hydrology wasn't altered much. More and more people settled on the land and used land to build towns and to grow crops. Eventually many areas became cities, using land for buildings, industry, parking lots, and streets. The hydrology has been affected by pollution, high runoff rates and erosion of the land.
2. More, because there are more streets, parking lots, and bare land than years ago. The effects of runoff will be greater the more people there are.
3. Development is an ongoing process in America due to population growth and our expanding economy. As forested lands are replaced by pavement and cement, runoff and erosion increases. Growth of the world's population has also increased the need for more productive farms, resulting in the use of fertilizers, pesticides, and herbicides. These chemicals increase the possibility of our water supply being polluted or poisoned. As runoff increases, less water is able to filter down to the aquifers. The level of water in aquifers will decrease and water shortages will occur.
4. You could limit the amount of trees you cut around your house lot. Planting trees, shrubs, and plants will help water infiltrate the soil so that the aquifer is continually recharged. A gravel or shell driveway will reduce surface runoff and erosion. If you don't use chemicals (insecticides or herbicides) on your lawn, the pollution of the groundwater and the watershed will be lessened.

Approximate time: One class period

Target audience: Science; Grades 6-8

Extensions:

Grades 4-6

1. Students can design layouts for residential, commercial, and industrial land uses. They should keep in mind that the more vegetation and uncovered (e.g., unpaved) land you have, the greater the infiltration rate will be. Students can share their designs and discuss their reasoning behind their design.
2. Since the soil is a natural filter for pollutants, this activity will help students understand the process of filtration. The students will devise a filtering system that will clean a dirty cup of water. Show students a cup of muddy water and have them design a filtering method to clean the water with the materials provided. You may even want to add several drops of food coloring to the water to represent some pollutant. Give groups of student's two to three

Styrofoam cups, two to three sheets of paper, towels, sand, charcoal, gravel, cotton, and aluminum foil. Have your students collect the filtered water in a separate cup and measure the amount reclaimed. Record the amounts of water they started and finished with and have them note how clean the water appears after filtering. Hints: poke holes in the cup and place a paper towel in it to keep sand from falling out. They can also make a funnel out of aluminum foil and line with a paper towel and fill with sand and gravel.

Grades 9-12

1. Students can run experiments to determine the rates at which water will soak into various types of soil. Use the runoff model from the described activity as a template to create a copy for each group of students. Have your students work in groups of four to five with each group experimenting on their own runoff model. Select samples of soil that vary in the degree of compaction (i.e., sand, rocky soil, or packed clay). Following are examples of soil materials you may wish to use:

   - fine grained sand
   - peastone (or small sized gravel)
   - crumbled asphalt
   - bark chips
   - topsoil
   - clay
   - coal chips (crumbled charcoal)
   - leaves (compost)

   Students are to construct a model by first partially filling the container with sand, topsoil, or clay, then placing a layer of peastone, crumbled asphalt or bark chips. Students can make a variety of combinations to simulate actual conditions. If time permits, have your students experiment with several combinations of soil materials. Then they will push a coffee can (with the top and bottom cut off) about two centimeters into the filling. Make sure that the end of the tubing is placed into some type of measuring container. Next the students will pour 500 ml of water into the can. If the water leaks around the edges of the can, rotate and push the can further into the soil filling until it stops leaking. Students should record the time it takes for the water to be absorbed into the soil sample and how much water is collected in the measuring container as runoff. Students create a data table (such as the one below) and calculate the per cent runoff (water collected through the tube) as well as the per cent absorbed. For example, if students collect 280 ml after infiltration:

   $\frac{280\text{ ml}}{500\text{ ml}}$ = 0.56 or 56% runoff, meaning that 44% was absorbed (100-56=44).

Data Table

Model Type	Runoff Water	Percent Runoff	Percent Absorption	Time
sand with asphalt cover	280 ml	56%	44%	4 minutes

Your students should plot their data, with time plotted against percent absorption. If they have time to try more than one soil combination, plot each model type with a different color pencil. If the students only have time for one model, have one group prepare a base graph on which each group can plot their data in a different color. Have your students compare their plots and discuss the results. Using information they have gathered, students can answer the questions that follow.

Questions:

a. Which model had the highest and lowest percent runoffs? Place model types in increasing order from least runoff to highest.
b. Explain what you think would happen to various areas around your home to water runoff during a thunderstorm (backyard, driveway, pool surround, woods, garden road). If runoff is high in some of these areas, predict where the water will go.

2. Different areas of the country have different soil compositions. Using research information gathered from the conservation districts, the R.I. DEM, the U.R.I. Extension, and etc., determine the soil composition of the area where you live. Describe what you think the expected infiltration and runoff of water will be based on the soil type and the information you have learned in this activity.
3. After first receiving permission from their parents, students will dig a hole with a shovel on their property. They should create a hole two feet in diameter and about 8 inches deep. They will then record the topsoil depth and the depth of the underlying layers. The students will use this data to create a diagram of the soil strata they found. They will then perform a simple "percolation test": fill the hole with a gallon of water and record the time it takes for the soil to absorb the water. Using the knowledge they have gained from this exercise, students can answer the questions that follow.

   Questions

   a. RI requires a percolation test before building permits are issued. Why is this so?
   b. Due to soil conditions,where do you feel building should not be permitted? Explain.

c. Underground aquifers provide drinking water to individuals and towns. If aquifers are drained, what would happen to the soil layers above the area? What would happen to runoff?
d. What does the depth of topsoil tell about the "health" of soil? Why is topsoil very advantageous?