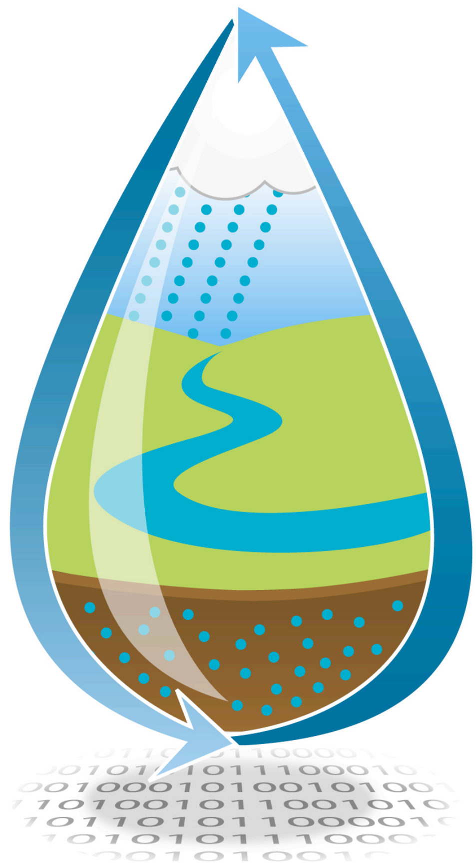

Watershed Dynamics

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Any opinions, findings, conclusions or recommendations expressed in this material are those of the developers and do not necessarily reflect the views of the National Science Foundation.

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Table of Contents

Summary

The Watershed Dynamics project is a partnership between the Office of STEM Education Partnerships (OSEP) at Northwestern University, the GLOBE (Global Learning and Observations to Benefit the Environment) program, and CUAHSI (the Consortium of Universities for the Advancement of Hydrologic Science, Inc.). Each organization represents a group of people interested in hydrology and science education. Working together, curriculum developers at OSEP, the worldwide network of science educators in GLOBE, and scientists and engineers from CUAHSI have created tools and inquiry-driven curricula to support student investigations of the watershed.

Students investigate human impact on the watershed by studying land cover change over time and evaluating its effect on runoff rates and stream discharge. This curriculum promotes the use of authentic scientific data and technology in the high school classroom. Students and teachers learn to use FieldScope, a specialized GIS tool developed by National Geographic, to access live scientific datasets and investigate complex earth system science issues like water availability and human impact on flood frequency. The data used in this investigation were collected and compiled by the U.S. Geological Survey and the Multi-Resolution Land Characteristics Consortium, a partnership among numerous federal agencies. Much of the curriculum is computer-based, but it is supplemented by hands-on activities and (optional) field experiences. The curriculum is aligned to the following frameworks:

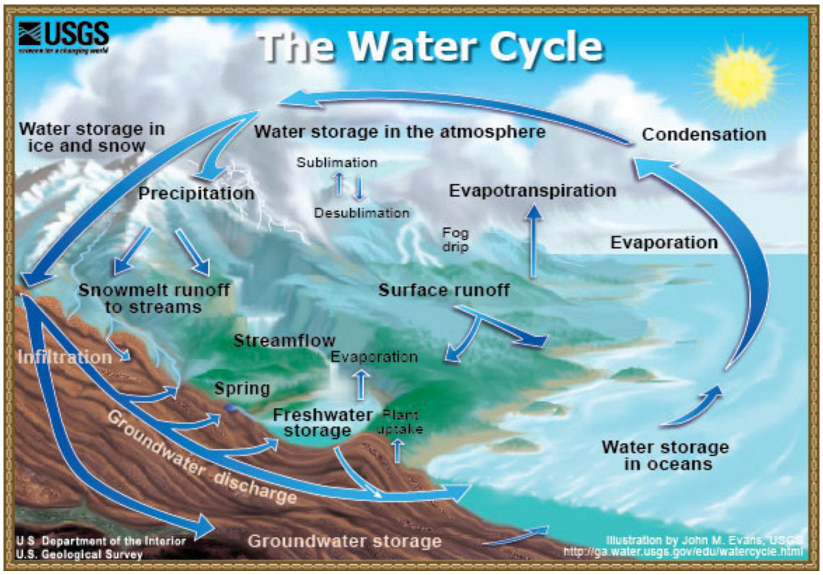
- National Geography Standards
- National Science Education Standards
- AAAS Benchmarks for Science Literacy
- College Readiness Standards
- Illinois State Standards

Human Impacts on the Watershed is the second of two modules in the Watershed Dynamics curriculum. In this module, students complete a series of activities that illustrate the dynamics of a watershed. Students begin by listening to a podcast about how the city of Philadelphia, PA is trying to reduce rainwater runoff pollution. In subsequent activities, students build a 3-D model of a watershed, learn how to measure streamflow, and read hydrographs. Students manipulate computer models to analyze land cover and streamgage data from two different years to explore the relationship between surface type and streamflow. Through these activities, students develop the content knowledge necessary to conduct an investigation using authentic scientific data in FieldScope, a GIS tool developed by National Geographic. Using FieldScope, students investigate a watershed of their choice to understand how human activities within the watershed have been shaped by its hydrology and how human use is impacting the hydrology of the watershed.

Background Information for Teachers

The Water Cycle

Water exists on Earth as a solid (ice), as a liquid, or as vapor and it is constantly in flux between these three states. While the amount of water on Earth is fixed, it is always on the move. Look at the water cycle diagram below.



A general understanding of how the water cycle functions is important background knowledge for this unit; however, two means of water movement are particularly relevant. The Watershed Dynamics materials focus on what happens to water from the time it reaches the ground as precipitation to its arrival in a major stream or river. Whether it is above ground or below, water always travels downhill.

Infiltration

Infiltration is the process by which precipitation (or snowmelt) seeps into the ground after a storm. The amount of precipitation that infiltrates the soil depends on many factors:

- *surface type*: porous surfaces like soil will allow more infiltration than an impervious surface such as ice or pavement
- *intensity and duration of precipitation*: after a storm event, water will continue to seep through the ground towards a streambed for quite a while; the larger the storm, the longer this pulse of subsurface water discharge will persist
- *physical characteristics of the local soil*: soils made of smaller particles, like clay, will allow less water to seep through than soils with larger particles, such as sand. The spaces between round sand particles are much larger relative to the spaces between thin, flat clay particles that tend to layer densely. More water can fit in the spaces between sand particles than clay particles.

- *saturation level*: soil that is already highly saturated from previous storm events will be able to absorb less water, which leads to increased surface runoff
- *type(s) of land cover present*: vegetation slows the movement of water on the surface, thereby allowing more time for the water to seep into the surrounding soil
- *slope of the land*: steeper grades contribute to faster runoff with less time for soil to absorb water
- *rates of evapotranspiration*: water in shallow soils, where plants have their roots, is used by these plants for metabolic processes and later evaporates from the leaves

Subsurface water

Two layers of subsurface water exist. The **unsaturated zone** lies above the water table. In this zone, the spaces between the soil particles (also called pore spaces) contain both air and water. The upper section of this zone is called the soil zone, in which roots, animal burrows, and holes from decayed objects accelerate the process of infiltration. The amount of water present in the unsaturated zone fluctuates over time, depending upon the intensity and frequency of precipitation. In the **saturated zone**, which lies below the plane of the water table, pore space is always filled with water. Water flows down towards this zone once water needs for plants and soil are met. Water in the saturated zone eventually flows into aquifers.

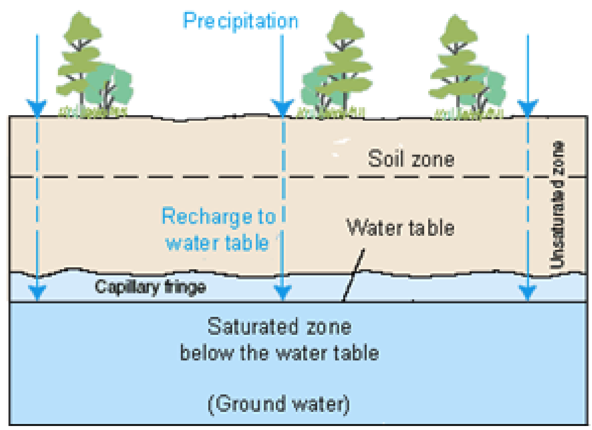


Image: United States Geological Survey

It is important to note that not all water that infiltrates the unsaturated zone will reach an aquifer. Some of this water will be lost as evapotranspiration (where water is taken up by root system of a plant and later released from its stomata into the air) or evaporation directly from the soil. All water flows downhill and will eventually join the nearest body of water if it does not evaporate first. The nearest body of water could be a stream, river, lake or even the ocean. Refer to the water cycle diagram on page *vi*: the arrows depicting the flow of groundwater branch off to represent groundwater discharge (also called resurfacing) where a streambed or lakeshore dips below the plane of the water table.

In the saturated zone, groundwater is still moving – albeit very slowly at times – and it is an important part of the water cycle.

Surface runoff

Surface runoff is the other main form of water movement addressed in the Watershed Dynamics materials. Surface runoff occurs when precipitation falls on a saturated or impervious landscape and, instead of being absorbed by the ground, flows over the surface towards the nearest body of water. There are many factors that affect surface runoff, including:

- *precipitation intensity and frequency*
- *distribution of precipitation over a drainage basin*
- *land use/land cover*
- *soil type*
- *size and shape of drainage basin*
- *elevation, topography*
- *presence of ponds, lakes, sewers, or reservoirs that catch runoff and prevent or delay its travel downstream*

Human activities can significantly impact infiltration and rates of surface runoff by increasing the amount of land covered with impervious surfaces such as roads, houses, and parking lots. In addition, the removal of vegetation and grading of a landscape increase the potential for runoff. These factors combine to increase peak discharges in streams, which in turn increases the severity and frequency of flooding in developed areas.

Of all the activities in the Human Impact module, there are four that specifically address factors that influence surface runoff. These activities build on each other, with the NetLogo Runoff model acting as a synthesis of these variables.

- In Building a Watershed students will observe that **elevation, topography,** and **basin shape** affect surface runoff in the absence of different land cover types.
- In Infiltration Protocol students will observe **how water moves vertically through soil**
- In Just Passing Through students will learn **how water moves through different types of soil** and how this movement alters the soil and water properties
- In the NetLogo model, students will learn **how land cover affects the rate and volume of stream discharge.** This model incorporates data about elevation into its calculation but that is not a variable students can isolate; thus, they are forced to focus on land cover instead.

This information, and further reading, can be found online at:
http://ga.water.usgs.gov/edu/watercycle.html

NATIONAL SCIENCE EDUCATION STANDARDS	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
Unifying Concepts and Processes										
Evidence, models, and explanation		X	X	X	X	X	X	X	X	X
Change, constacy, and measurement			X	X	X	X	X	X	X	
Science as Inquiry										
Understanding of scientific concepts	X	X	X	X	X	X	X	X	X	X
Abilities necessary to do scientific inquiry			X	X	X	X	X		X	
Understanding of scientific inquiry			X		X	X	X		X	X
An appreciation of "how we know" what we know in science.			X		X	X			X	
Understanding of the nature of science.					X	X			X	
Skills necessary to become independent inquirers about the natural world.			X		X	X	X		X	
Science and Technology										
Understanding about Science and Technology	X						X		X	
Science often advances with the introduction of new technologies. New technologies often extend the current levels of scientific understanding and introduce new areas of research.	X								X	
Science in Personal and Social Perspectives										
Materials from human societies affect both physical and chemical cycles of the earth.	X						X		X	X
Natural and human-induced hazards	X							X		X
Science and technology in local, national, and global challenges	X							X	X	X

AAAS BENCHMARKS FOR SCIENCE LITERACY - HIGH SCHOOL	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
1. The Nature of Science										
1B/H10*** (SFAA): Bias attributable to the investigator, the sample, the method, or the instrument may nto be completely avoidable in every instance, but scientists want to know the possible soureces of bias and how bias is likely to infludence evidence.							X		X	
1B/H2: Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).					X	X	X		X	
1B/H9** (SFAA): To be useful, a hypothesis should suggest what evidence could support it and what evidence would refute it. A hypothesis that cannot, in principle, be put to the test of evidence may be interesting, but it may not be scientifically useful.									X	
1C/H6ab: Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects.	X							X	X	X
4. The Physical Setting										
4B/H6: The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to Earth's warming.									X	

AAAS BENCHMARKS FOR SCIENCE LITERACY - HIGH SCHOOL	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
11. Common Themes										
11C/H4: Graphs and equations are useful (and often equivalent) ways for depicting and analyzing patterns of change.				X			X	X	X	
12. Habits of Mind										
12D/H7*: Use tables, charts, and graphs in making arguments and claims in oral, written, and visual presentations			X				X	X	X	

AAAS BENCHMARKS FOR SCIENCE LITERACY - MIDDLE SCHOOL	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
1. The Nature of Science										
1B/M1b*: Scientific investigations usually involve the collection of relevant data, the use of logical reasoning ,and the application of imagination in devising hypotheses and explanations to make sense of the collected data.			X				X		X	
4. The Physical Setting										
4B/M7: Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the oceans. The cycling of water in and out of the atmosphere is a significant aspect of the weather patterns on Earth.						X	X		X	
9. The Mathematical World										
9D/M4: Comparisons of data from two groups should involve comparing both their middles and the spreads around them.			X						X	
11. Common Themes										
11B/M1*: Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly. They are also used for processes that are too vast, too complex, or too dangerous to study.		X					X			
11B/M4** (BSL): Simulations are often useful in modeling events and processes.				X	X		X			
11C/M10**: Trends based on what has happened in the past can be used to make predictions about what things will be like in the future. However, these predictions may not always match what actually happens.							X		X	

AAAS BENCHMARKS FOR SCIENCE LITERACY - MIDDLE SCHOOL	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
12. Habits of Mind										
12D/M6**: Present a brief scientific explanation orally or in writing that includes a claim and the evidence and reasoning that supports the claim.						X	X	X	X	X

COLLEGE READINESS STANDARDS	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
16-19:										
Select two or more pieces of data from a simple data presentation									X	
Understand basic scientific terminology				X	X		X	X	X	X
Find basic information in a brief body of text	X			X				X	X	
Determine how the value of one variable changes as the value of another variable changes in a simple data presentation								X	X	X
28-32:										
Extrapolate from data points in a table or graph				X			X	X	X	

NATIONAL GEOGRAPHY STANDARDS	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
I-1: How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.		X					X		X	
I-3: How to analyze the spatial organization of people, places, and environments on Earth's surface.									X	
IV-14: How human actions modify the physical environment.	X						X	X	X	X
V-15: How physical systems affect human systems.	X							X		X
VI- 18: How to apply geography to interpret the present and plan for the future.									X	X

ILLINOIS STATE STANDARDS	Activity 1 - Podcast	Activity 2- Building a Watershed	Activity 3a- Streamflow Lab	Activity 3b- Virtual River	Activity 4a- Just Passing Through	Activity 4b-Infiltration Protocol	Activity 5- NetLogo Runoff	Activity 6- Analyzing Hydrographs	Activity 7- FieldScope	Activity 8- Extensions
11 A. Know and apply the concepts, principles and processes of scientific inquiry.										
4a. Formulate hypotheses referencing prior research and knowledge.							X		X	
4b. Conduct controlled experiments or simulations to test hypotheses.		X			X	X			X	
4c. Collect, organize and analyze data accurately and precisely.			X	X	X		X		X	
12 E. Know and apply concepts that describe the features and processes of the Earth and its resources.					X					
E.5 Analyze the processes involved in naturally occurring short-term and long-term Earth events (e.g., floods, ice ages, temperature, sea-level fluctuations).					X	X	X	X	X	
13 A. Know and apply the accepted practices of science.										
4b. Assess the validity of scientific data by analyzing the results, sample set, sample size, similar previous experimentation, possible misrepresentation of data presented and potential sources of error.			X			X			X	

Podcast: *Philadelphia Tackles Rainwater Runoff Pollution*

Purpose

The purpose of this activity is to introduce students to the concept of rainwater runoff and its environmental consequences. This podcast provides a context for the study of runoff that follows in Activities 2-7 of this module.

Overview

In this activity, students will listen to the NPR podcast, "Philadelphia Tackles Rainwater Runoff Pollution." The City of Philadelphia has set a goal to reduce the rainwater runoff that pollutes local rivers and causes flooding. They are focusing on measures to create places where rain is quickly absorbed into the ground, rather than sheeting off pavement.

This activity will take place in three parts. The first part will begin with a "Wordle." This pre-listening activity highlights the major vocabulary that will be addressed in the podcast. It was created using the transcript from the NPR podcast and the online "Wordle" tool: http://www.wordle.net. The second part of the activity involves listening to the 3:30 minute podcast. The third portion involves class discussion and reflection in the form of written responses.

Student Outcomes

- Activate student prior knowledge about rainwater runoff through reflection on experiences they've had with rain events, storms, and flooding events
- Learn about new practices of mediating rainwater runoff pollution and flood prevention in urban areas
- Draw conclusions about how porous pavement can improve water conservation

Time

Less than one class period – 30 minutes

Level

Secondary earth/environmental science (9-12)

Materials and Tools

- Internet access to podcast: http://www.npr.org/templates/story/story.php?storyId=6165654
- Computer speakers
- Internet access to www.wordle.net

Preparation

Prepare students with a pre-listening activity such as a "Wordle." Identify key vocabulary that will be heard in the podcast.

Prerequisites

N/A

Background

Students should be familiar with the terms **water cycle** and **watershed**. Students should also be familiar with factors that influence surface runoff and how storm events and land cover change affect stream discharge. Students should be aware of the disparities among the porosity of various soil and substrate types. They should be aware that cement has less absorptive properties than soil. Because of this, surface runoff in developed/urbanized areas can be much greater when compared to undeveloped land.

Teaching Notes

This podcast is designed as an introduction to the second module of the GLOBE Watershed Dynamics unit, "Human Impacts on the Watershed." Students will use the Wordle activity to make predictions about the content of the podcast they will be listening to in class. The podcast was chosen as an introduction because it gives a real-life example of the relevance of studying the relationship between land cover and rainfall runoff.

Additional Information

Transcript of Podcast: *Philadelphia Tackles Rainwater Runoff Pollution*

LYNN NEARY, host:

The city of Philadelphia has one of the nation's oldest sewage systems; and like many cities around the country, Philadelphia's sewerage can fill up pretty quickly in a rainstorm, leading to flooding and other problems. The city's water department is working on an ambitious plan to change the way water flows through Philadelphia streets.

Brad Linder reports.

BRAD LINDER: Howard Neukrug is standing on an asphalt basketball court in West Philadelphia, but Neukrug isn't here to play. The director of Philadelphia's Office of Watersheds is holding a one-gallon jug of water, which he proceeds to pour onto the middle of the court. At first it puddles, as you'd expect a normal pavement but then...

Mr. HOWARD NEUKRUG (Director, Office of Watersheds, Philadelphia Water Department): You can see in the middle there it's starting to sink in like a sponge into the ground. So it removes the water rather than letting the water puddle and sit there for hours and hours or days and days. The water is going down into a gravel bed underneath here and then eventually infiltrating into the groundwater for West Philadelphia.

LINDER: What Neukrug is looking at is porous pavement. Watershed's Program Manager Joanne Dahme says it starts out like any other pavement material. But the manufacturer doesn't add in the fine particles and binders that make normal pavement waterproof.

Ms. JOANNE DAHME (Program Manager, Office of Watersheds, Philadelphia Water Department): Although looking at it they look like regular asphalt or regular concrete, when you see the rainfall settle on it, you see it quickly disappear. So it's almost like a sand covering that's taking the rain into it and allowing it to go back into the earth.

LINDER: It should cost about the same to produce porous pavement as regular asphalt, but since there's not much demand for the porous surfacing factories have to shut down and reset their machines, which adds to the price. Still, Philadelphia officials think it's worth the money because porous pavement helps with the annoying byproduct of urban life - flooding.

As cities like Philadelphia grows, so do their problems with flooding. Temple University Professor Jeff Featherstone says that's because there aren't enough natural areas to slowly absorb rainwater into the ground.

Professor JEFF FEATHERSTONE (Director, Center for Sustainable Communities, Temple University): You're short-circuiting the natural process. And water hits an impervious surface like a roof or a street or a parking lot and immediately gets discharged off to either a water body or some sort of a storm water facility.

LINDER: That means when it rains, a massive amount of water flows directly into the Schuylkill and Delaware Rivers and their tributaries, causing them to flood more frequently. But even when they don't flood, that runoff picks up a lot of pollutants on its way to the city's drinking water supply.

Ms. DAHME: (Unintelligible) … like fecal bacteria from animal waste.

LINDER: The Philadelphia Water Department's Joanne Dahme.

Ms. DAHME: You know, when we have storm water runoff, it's picking up with the animals or doing their business on the ground. Periodically, you might have some problems in our sewer systems; they might be what we call like a choke, where you might have some sewage come periodically. So mostly it's that sort of bacteria, the fecal bacteria, that we're looking at.

LINDER: The city has tools besides porous pavement. One neighborhood school, for example, has a rain garden which collects water dropping from the school's roof in a natural setting. In another neighborhood, the city helps establish an urban farm to accomplish a similar goal. Of course, city-owned property is just a drop in a bucket.

Back at the refinished basketball court, Watershed's Director Howard Neukrug says in the next year the city will only be able to reduce about one percent of Philadelphia's runoff. The city is also offering private developers incentives to use environmentally friendly design. Neukrug says the larger goal is to use city construction projects to show developers how to better manage storm water.

Mr. NEUKRUG: If you change one basketball court or two basketball courts, it's nice and it does something good for the community but it doesn't change the world, it doesn't change the environment. By demonstrating that this works on a basketball court, and we can do that all over Philadelphia, then you start to make a change.

LINDER: Neukrug says in another 10 to 20 years the city will have environmentally friendly storm water systems at all its rec centers, basketball courts and other public properties. And there's another benefit - the local kids who play on the court said that as soon as it stops raining, the new pavement's drying up to allow them to shoot hoops. Last year they would have had to sweep the water off the court before they could play.

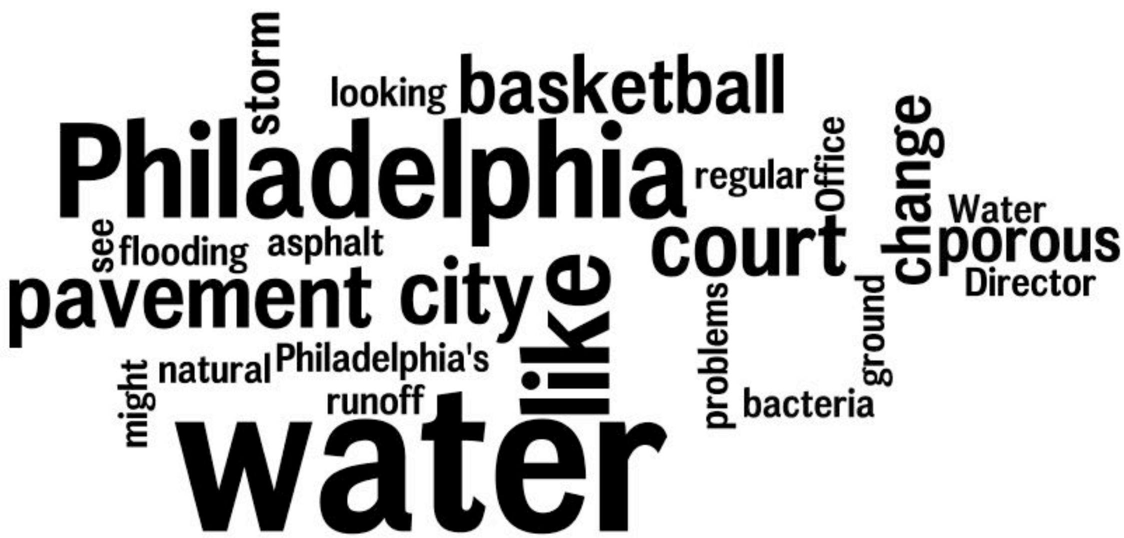
For NPR News, I'm Brad Linder.

NPR transcripts are created on a rush deadline by a contractor for NPR, and accuracy and availability may vary. This text may not be in its final form and may be updated or revised in the future. Please be aware that the authoritative record of NPR's programming is the audio.

Name ______________________________ Date __________ Class ____________

Podcast: *Philadelphia Tackles Rainwater Runoff Pollution*

Part 1: Pre-listening activity via wordle.net



Questions for Pre-listening Discussion:

Q1. In the Wordle above, what are some of the words you recognize?

Q2. What are the words you don't recognize?

Q3. Based on the vocabulary, what do you think the podcast is going to be about?

Part 2: Listen to Podcast Philadelphia Tackles Rainwater Runoff Pollution. It can be found online at: http://www.npr.org/templates/story/story.php?storyId=6165654

Part 3: Reflection

Questions:

Q4. Is there a way to reduce surface runoff in urbanized neighborhoods?

Q5. Describe the effects of porous pavement.

Q6. Are there advantages to using this porous pavement?

Q7. Why isn't the use of porous pavement more widespread? Is it more expensive to make?

Q8. Do you think the implementation of porous pavement could make a difference in water conservation?

Q9. How does the use of porous pavement relate to flooding in urban areas?

Podcast: *Philadelphia Tackles Rainwater Runoff Pollution*

Part 1: Pre-listening activity via wordle.net

Questions for Pre-listening Discussion:

Q1. In the Wordle above, what are some of the words you recognize?

Student answers will vary

Q2. What are the words you don't recognize?

Student answers will vary

Q3. Based on the vocabulary, what do you think the podcast is going to be about?

Students should form some prediction about the podcast that includes the terms above; ideally, they will suggest that the podcast will be about flooding in the city of Philadelphia and pollution it causes.

Part 2: Listen to Podcast Philadelphia Tackles Rainwater Runoff Pollution. It can be found online at: http://www.npr.org/templates/story/story.php?storyId=6165654

Part 3: Reflection

Questions:

Q4. Is there a way to reduce surface runoff in urbanized neighborhoods?

Yes, according to the podcast, there is a material that was used as a pilot test in a basketball court in Philadelphia. It is called porous pavement.

Q5. Describe the effects of porous pavement?

From what we heard, the water pooled normally for a few seconds, but after some time passed it was absorbed into the earth.

Q6. Are there advantages to using this porous pavement?

Yes, it would reduce the amount of water running off into streams and rivers.

Q7. Why isn't the use of porous pavement more widespread? Is it more expensive to make?

Porous pavement is a new material. It is more expensive to make right now because there is not much demand for it and factories have to reset their machines to manufacture it, which takes extra time. Once demand increases, the cost for porous pavement will be the same as for regular asphalt.

Q8. Do you think the implementation of porous pavement could make a difference in water conservation? How?

Porous pavement reduces surface runoff because it allows rainwater to seep down into the ground where it falls. This way, it flows into the local groundwater instead of directly into streams. Less evaporation will occur, and more water will remain in the local water cycle.

Q9. How does the use of porous pavement correlate to flooding in urban areas?

As porous pavement becomes more widespread, the amount of water making its way into rivers and streams via surface runoff will decrease. This will in turn decrease flooding and overflowing of rivers.

Building a Watershed Model

Purpose

Students will build a model to identify the characteristics of a watershed. Students will learn how elevation determines the flow of water within a watershed.

Overview

In this activity, students will work in groups to create a landscape that includes multiple watersheds. Students will observe the relief of the landscape and form predictions about how water will move through the landscape. They will simulate rainfall using a spray bottle and observe how the water flows through the landscape. They will compare their predictions to their observations.

Student Outcomes

- Activate student prior knowledge through reflection on experiences they have had with rain events, storms, and flooding events.
- Practice inquiry investigations and questioning skills by comparing predictions and observations.
- Identify characteristics of a watershed, patterns of water movement within a watershed, and how elevation influences water flow.

Time

1 50-minute class period

Level

Secondary earth/environmental science (9-12)

Materials and Tools

- White plastic tablecloth
- Large, waterproof tray
- Newspaper or magazine pages
- Spray bottles filled with colored water - this represents rain
- Permanent markers
- Masking tape

Prerequisites

- GLOBE Watersheds Human Impact Activity 1: “Philadelphia Tackles Rainwater Runoff Pollution” podcast

Background

Students should be familiar with the basic definition of a watershed. They should also be familiar enough with the water cycle to know that new water reaches the ground in the form of precipitation. Water that does not evaporate or get absorbed as ground water drains into a body of water as surface runoff. A variety of factors influence the amount of surface runoff that flows into a river, including topography and type of land cover present.

Teaching Notes

This activity can be done in groups or as a class, depending on available materials and class size. Once students have built their watersheds, but before they begin to use the spray bottles to create 'rain,' engage them in the following questions:

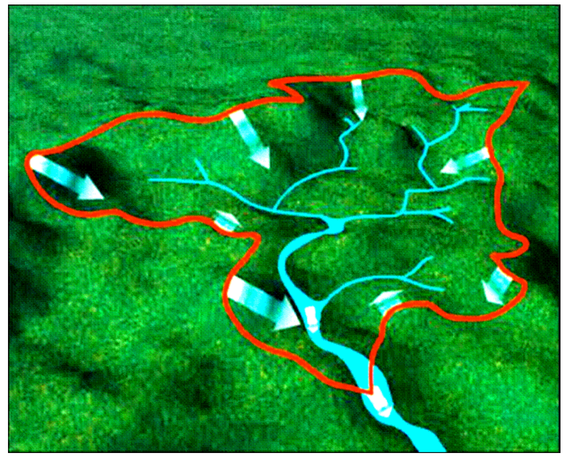
a. Discuss the definition of a watershed. (The areas of land that drain into a body of water—river, lake or pond—is known as a watershed.)
b. What are the highest elevations and lowest elevations on your landscape?
c. Where will water go if rain were to fall?
d. Where will rivers and streams develop?

As indicated in the student guide, students will then use markers to show where they predict water will flow and pool in their watershed. They will also record their predictions in the student guide.

Name ______________________________ Date __________ Class ______________

Building a Watershed Model

Introduction



Let's review the water cycle. We know that new water reaches the ground in the form of precipitation. Water that does not evaporate or get absorbed as ground water drains into a body of water as surface runoff. A variety of factors influence the amount of surface runoff that flows into a river. One major factor is the type of land cover found on the landscape.

What other factors could affect surface runoff?

In this activity you will predict how water flows into rivers and streams. You will be making a model of a landscape that includes multiple watersheds. You will use newspaper to form hills and valleys and a plastic tablecloth to represent the surface of the earth. After you write down your predictions about how you think the water will flow in your model, you'll use a spray bottle to simulate a rainstorm. The purpose of this model is to explore the factors that determine how rivers and streams are formed.

Materials and Tools

- White plastic tablecloth
- Large, waterproof tray
- Newspaper or magazine pages
- Spray bottles filled with colored water - this represents rain
- Permanent markers
- Masking tape

Procedure:

1. Create your landscape. Crumple pieces of newspaper and arrange them on the tray. Design your landscape so that the newspaper forms taller mounds around the outer edges of the tray, and the shorter mounds in the middle.

2. Lay the white plastic tablecloth over the crumpled newspaper. Secure the tablecloth along perimeter by taping it to the tray.

3. On your model, use a marker to label the areas of high elevation with an "H." Label the low elevation areas with an "L."

4. Discuss the following questions with your classmates and teacher:

   a. What is the definition of a watershed?
   b. What are the highest elevations and lowest elevations on your landscape?
   c. Where will water go if rain were to fall?
   d. Where will rivers and streams develop?

5. Using a different color, draw on the tablecloth where you predict the rivers and streams will form. Use arrows to show which direction you predict the water will flow. Draw circles where you think the water will form puddles.

6. In the box labeled "Prediction" draw a bird's eye view of the model, using "H" and "L" to indicate the areas of high and low elevation. Each group member should draw his or her own map.

7. In this same space, draw where you predict water will flow in your model. Use arrows to show water flow and circles to show where you think the water will form puddles.

Predictions

8. Obtain a spray bottle from your teacher. Holding it about 5 inches above the plastic tablecloth, spray for several minutes until you see a continuous flow of water in your model. This is your model "run." Take turns running the model. Each group member should begin his or her turn by spraying the model in a different place on its surface.

9. Draw another elevation map of your model in the box labeled "Observations" on the next page. Draw what you observed during the model runs. Use arrows to show where the water flowed and circles to show where puddles formed.

Observations

Questions:

Q1. In your own words, define the term watershed.

Q2. What do all watershed boundaries have in common?

Q3. How can there be two watersheds right next to each other?

Q4. Describe what you observe about the way water flowed over the surface of your model. What type of land cover do you think most closely matches this kind of surface? Explain your response.

Q5. Did the arrows you drew in your predictions landscape align with where the water actually flowed?

Q6. What is a model? What is the purpose of building models?

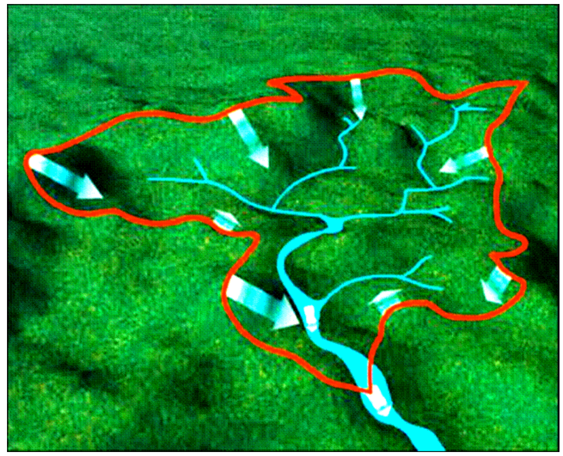
Q7. In your model, what determines where the water flows?

Q8. What changes to the land could be made to slow the flow of water into the rivers and streams? What changes to the land would increase flow into the river?

Q9. Suppose this model were to represent farmland – a different type of land cover. How would that change the way water flows across the surface?

Name ____________________ Date __________ Class ____________

Building a Watershed Model



Introduction

Let's review the water cycle. We know that new water reaches the ground in the form of precipitation. Water that does not evaporate or get absorbed as ground water drains into a body of water as surface runoff. A variety of factors influence the amount of surface runoff that flows into a river. One major factor is the type of land cover found on the landscape.

What other factors could affect surface runoff?

In this activity you will predict how water flows into rivers and streams. You will be making a model of a landscape that includes multiple watersheds. You will use newspaper to form hills and valleys and a plastic tablecloth to represent the surface of the earth. After you write down your predictions about how you think the water will flow in your model, you'll use a spray bottle to simulate a rainstorm. The purpose of this model is to explore the factors that determine how rivers and streams are formed.

Materials and Tools

- White plastic tablecloth
- Large, waterproof tray
- Newspaper or magazine pages
- Spray bottles filled with colored water - this represents rain
- Permanent markers
- Masking tape

Procedure:

1. Create your landscape. Crumple pieces of newspaper and arrange them on the tray. Design your landscape so that the newspaper forms taller mounds around the outer edges of the tray, and the shorter mounds in the middle.

2. Lay the white plastic tablecloth over the crumpled newspaper. Secure the tablecloth along perimeter by taping it to the tray.

3. On your model, use a marker to label the areas of high elevation with an "H." Label the low elevation areas with an "L."

4. Discuss the following questions with your classmates and teacher:

    a. What is the definition of a watershed?
    b. What are the highest elevations and lowest elevations on your landscape?
    c. Where will water go if rain were to fall?
    d. Where will rivers and streams develop?

5. Using a different color, draw on the tablecloth where you predict the rivers and streams will form. Use arrows to show which direction you predict the water will flow. Draw circles where you think the water will form puddles.

6. In the box labeled "Prediction" draw a bird's eye view of the model, using "H" and "L" to indicate the areas of high and low elevation. Each group member should draw his or her own map.

7. In this same space, draw where you predict water will flow in your model. Use arrows to show water flow and circles to show where you think the water will form puddles.

Predictions

8. Obtain a spray bottle from your teacher. Holding it about 5 inches above the plastic tablecloth, spray for several minutes until you see a continuous flow of water in your model. This is your model "run." Take turns running the model. Each group member should start his or her turn spraying the model in a different place on its surface.

9. Draw another elevation map of your model in the box labeled "Observations" on the next page. Draw what you observed. Use arrows to show where the water flowed and circles to show where puddles formed.

Observations

Questions:

Q1. In your own words, define the term watershed.

The area of land that drains into a body of water—river, lake or pond—is known as a watershed. Watersheds are outlined by ridges of high elevations, or divides.

Q2. What do all watershed boundaries have in common?

They are always located at the top of hills and mountains and encircle the water body.

Q3. How can there be two watersheds right next to each other?

A ridge separates the two areas.

Q4. Describe what you observe about the way water flowed over the surface of your model. What type of land cover do you think most closely matches this kind of surface? Explain your response.

The water flowed over the surface, none of it seeped in. Small streams flowed into each other to form larger streams, and the water collected in low-lying areas. This matches the kind of runoff described in the podcast—so this model represents developed land.

Q5. Did the arrows you drew in your predictions landscape align with where the water actually flowed?

Student answers will vary.

Q6. What is a model? What is the purpose of building models?

A model is a simplified representation of a real-world system or phenomenon. People build and manipulate models to so they can better understand how these systems work.

Q7. In your model, what determines where the water flows?

Students should observe that the water always flows downhill. Topography determines the path of water in this model.

Q8. What changes to the land could be made to slow the flow of water into the rivers and streams? What changes to the land would increase flow into the river?

Decreasing the height of the high elevations – flattening the landscape—would slow the flow of water over the model. Creating more high-elevation spots on the landscape – more places with a steep slope—would increase the rate of flow. Students might also refer to changes in land cover that would change rates of water flow.

Q9. Suppose this model were to represent farmland – a different type of land cover. How do you think that would that change the way water flows across the surface?

Water would flow more slowly over farmland than developed land because it would encounter more surface friction from planted crops than it does over the simulated paved surface. Water could also infiltrate the soil, which would reduce surface runoff and lead to decreased puddling (potential flooding) in low-lying areas.

Measuring Streamflow Lab

Purpose

In this activity, students will learn how to determine streamflow of a nearby river or stream using both high-tech and low-tech methods.

Overview

Students will calculate stream velocity of a nearby river or stream in two ways: 1.) Drop an orange into the river and time its travel over a given distance. 2.) Use PASCO equipment to measure streamflow. Streamflow information is vital for making predictions about the movement of water within rivers and streams. Streamflow is calculated by determining the volume of water in the stream and how fast the water moves. In this activity, students will measure velocity and they will estimate stream discharge.

Student Outcomes

- Activate student prior knowledge through reflection on experiences they've had with rain events, storms, and flooding events.
- Practice inquiry investigations & questioning skills, including site description
- Explain factors that can influence rates of stream discharge.
- Make predictions about how streamflow may change with land cover modifications.
- Describe how to measure stream velocity.
- Identify areas in a stream where velocity is different from other areas; how stream morphology affects streamflow

Time

2 50-minute class periods
Day 1: Assign and discuss groups
Day 2: Conduct lab at field site

Level

Secondary earth/environmental science (9-12)

Materials and Tools

- PASCO GLX
- PASCO Stream velocity flow meters – at least 3
- Tape measure
- Orange
- Stopwatches – at least 2
- Student Guides – 1 per student
- Digital camera (optional)

Procedure:

Low-Tech: Orange Dropping
Choose a location where it will be safe for students to measure the stream velocity. Discuss with class the setting and strategy of activity. Assign students to groups ahead of time:

- Group 1: Measurement. Students will measure out a 30-meter distance along the riverbank.
- Group 2: Start Marker. This student will stand at the upstream end of the 30-meter length and mark the start position for the timers.
- Group 3: End Marker. This student will stand at the downstream end of the 30-meter length and mark the end position for the timers.
- Group 4: Orange Dropper. This student is responsible for dropping the orange in the river upstream of the start marker.
- Group 5: Orange Catcher(s). The orange catchers should be positioned just past the downstream end of the 30 meters.
- Group 6: Timer(s). Student(s) will start timing when the orange passes the start marker and stop timing when it passes the end marker.
- Group 7: Data Collectors. Collect times at each trial and each location of stream.

High-Tech: GLX flow meters
- Groups will be assigned Pasco flow meters: Groups will safely walk to varied locations of stream to measure flow using Pasco meter.
- Group 1: Stand at center of stream
- Group 2: Stand at stream banks
- Group 3: Stand mid-way between center of stream and banks

Prerequisites
- GLOBE Watersheds Human Impact Activity 1: "Philadelphia Tackles Rainwater Runoff Pollution" podcast
- Activity 2: Building a Watershed Model

Background
Students should be familiar with how the shape and topography of a watershed affects streamflow. Students should understand how surface runoff is generated and how land cover can influence surface runoff and ultimately stream discharge.

Teaching Notes

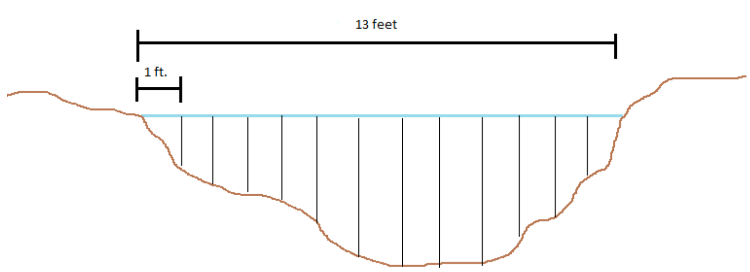
The day before the class visits the site, mark out safe areas along the river where students can make their measurements. Ensure there are enough supplies for this activity and that the PASCO flow meters are working properly. Additional information on the GLX stream velocity flow meters can be found in "PASCO_stream_flow_copy.pdf."

You will want to assign the groups and go over the activity the day before heading into the field. The actual field activity should take no more than one class period

During this activity, students will calculate the discharge rate for the stream in cubic feet per second (cfs)—this is the total volume of water per second that passes a certain point. Students will need to measure the average velocity (feet per second, f/s) and the cross-sectional area of the stream (ft^2) in order to calculate the discharge rate.

To find the average velocity of a stream, students will use the "six-tenths rule," which states that the average velocity for the entire depth profile of a stream can be measured at six-tenths of its total depth. This measurement is taken 60% of the way down the water column. The Virtual River activity (or the included transcript) provides a very good explanation of how to measure velocity rates and includes the derivation of the six-tenths rule.

To measure the cross-sectional area of the stream, students will need to measure the width of the stream and divide it into smaller, evenly-spaced segments (see diagram below). These sections can be 1 foot wide, 3 feet wide, or more—depending on the size of the stream you are measuring. The smaller the width of these sections, the higher your resolution, and the more accurate your calculations will be. Students will measure the depth of each of these sections and calculate the cross-sectional area of each one. Then, students will add these areas together to find the total cross-sectional area of the stream. Students will record all measurements in a table provided in the Student Guide.



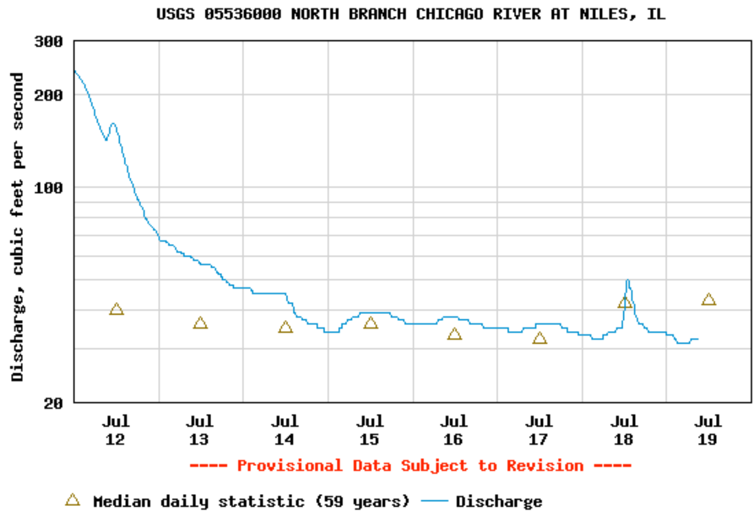
There are four activities in this unit designed to help students understand how water flows through streams and soils. The two outdoor activities, "Monitoring Streamflow Lab" and "Infiltration Protocol," can be done if you have access to a stream and can take your class on a field trip. If this is not possible, there are two analogous indoor activities: "Virtual River" and "Just Passing Through." The former is an online resource that simulates streamflow and teaches more in-depth concepts about streamflow and river dynamics. It is an excellent way to reinforce and build upon concepts from this lab and should be assigned for homework if there is not time in class. "Just Passing Through" is an indoor simulation of the different rates at which water percolates through various soil types. It also demonstrates how a substrate can change chemical and physical properties of the water that flows through it.

Name ______________________________ Date __________ Class ______________

Measuring Streamflow Lab

Introduction

Imagine you are walking down to the banks of your local stream. What do you hear? Is it a lazily flowing river or a gurgling brook? What factors can influence how fast a stream flows? What happens when the velocity of a stream increases? The greater the velocity of a stream, the greater the erosive and carrying power it has. When there is more sediment in the water the water becomes muddy looking or more "turbid." Greater turbidity leads to a decrease in aquatic plants and animals. This fact is due to decreased levels of sunlight penetrating the water.



Is the velocity of a stream constant over time? How much does it vary? What causes stream velocity to change? The United States Geologic Survey (USGS) maintains streamgages on hundreds of streams across the country. These streamgages provide real-time and historical data for the locations where they are installed. These data allow us to look at changes in velocity that result from storms, droughts, and other events. USGS data is available as graphs or tables. A graph showing stream discharge over time is called a hydrograph.

In the photo to the right, students from Maine East High School in Park Ridge, Illinois, use a flow meter to measure stream velocity. You will be using two methods to measure stream velocity in this activity. First, you will record the time it takes for an orange to travel a 30-meter distance down the stream in different parts of the streambed. Then, you will repeat the experiment using a PASCO flow meter.

Materials & Equipment:

- PASCO GLX
- PASCO Stream velocity flow meter
- Tape measure
- Orange
- Stopwatch
- Digital camera (optional)

Procedure:

Low-Tech: Orange Dropping

1. Choose a location where you can safely wade into the water to measure the stream velocity. You will be assigned one of the following roles in this investigation: measurement, start marker, end marker, orange dropper, orange catcher, timer, or data collector.
2. In the space below, record information about the characteristics of the location.
3. If a camera is provided, take pictures to document the location.
4. Measure a distance of at least 30 meters along the river.
5. Position the start marker at the start of the 30 meter length. Position the timers at the downstream end of the 30 meter stretch.
6. Position the orange dropper in the center of the stream, just upstream of the start end of the 30 meters. Carefully use a meter stick to test the flow of water before stepping into it.
7. Position the orange catchers just past the downstream end of the 30 meters.
8. When the orange passes the Start Marker, the Start Marker needs to shout out "Start." The timers should start their stopwatches **when the orange passes the start marker**. When the orange passes the 30 meter end line, the timers should stop their stopwatches.
9. Timers announce their times and recorders record them in the data table.
10. Perform at least three trials.
11. Repeat the process along the stream banks and mid-way between the center of the stream and the banks.

Questions:

Q1. Describe the stream you are measuring. Include details about the soil type, vegetation, surrounding land cover and its size and speed. Is it wide or narrow? Does it flow quickly or slowly?

Q2. Enter your results in the table below.

	Time (seconds)				
Location	**Trial 1**	**Trial 2**	**Trial 3**	**Distance**	**Average velocity** (distance/time)
Center of stream					
Stream banks					
Mid-way					

High-Tech: GLX flow meters
These measurements should be taken in the same location as the previous activity.

1. Turn on the GLX.
2. Connect the flow meter to port 1 at the top of the flow meter.
3. Submerge the flow meter in the flow in the center of the stream 6/10's of the way from the top of the stream to the bottom. Align the sensor so that it is parallel to the flow direction of the stream. The meter must be properly aligned to measure the true maximum velocity.
4. Read off the velocity from the graph on the GLX.
5. Record in the data table.
6. Perform at least three trials.
7. Repeat the process along the stream banks and mid-way between the center of the stream and the banks.
8. Collect an additional data point by lowering the probe into the stream near the center of the stream so that the probe is just above the stream bed.

Q3. Record your GLX Streamflow data in the table below.

	Time (seconds)			
Location	**Trial 1**	**Trial 2**	**Trial 3**	**Average velocity** (time/distance)
Center of stream				
Stream banks				
Mid-way				
Stream bed				

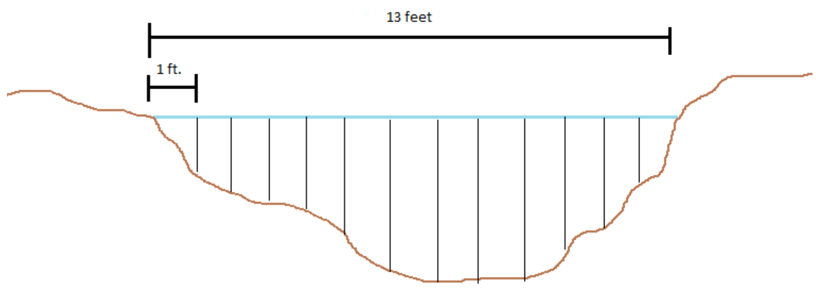
You can see from your data in the table for Question 3 that the stream flows at different rates depending upon whether you are measuring at the water's surface or near the streambed. Scientists have figured out that the average velocity for any location in a stream can be measured at six-tenths (0.6) of the depth at that spot. This is called the **six-tenths rule.**

How will you figure out what the **average velocity** of this stream is?

Calculating Stream Discharge

Now you have measurements for the stream **velocity**. Typically, however, hydrologists (scientists who study how water moves) measure the **discharge** of a stream. Discharge is the total volume of water per second that is flowing past a fixed point in the stream.

To measure the cross-sectional area of the stream, you and your classmates will need to measure the width of the stream and divide it into smaller, evenly-spaced segments (see diagram below). These sections can be 1 foot wide, 3 feet wide, or more—depending on the size of the stream you are measuring. The smaller the width of these sections, the more accurate your calculations will be. You will measure the depth of each of these sections and calculate the cross-sectional area of each rectangle. Then, add these areas together to find the total cross-sectional area of the stream. Make a table in the space below to record your measurements.



AREA of stream cross-section **x** stream **AVERAGE VELOCITY = DISCHARGE**

Create a data table to calculate cross sectional area:

Questions:

Q4. Complete the table below to calculate the discharge rate of your stream. Refer to the equation above to calculate the discharge rate.

Depth of stream in center of channel	
Width of stream	
Average velocity at 0.6 depth	
Discharge rate (include units)	

Q5. How similar were the velocities you recorded in each of the trials for the orange dropping method? For the GLX flow meter method?

Q6. How does the data collected by timing the distance traveled by the orange compare to the data you collected with the flow meter?

Q7. Compare the velocity of the stream from the center out toward the stream banks. Explain why you think stream velocity varies according to the pattern in your data.

Q8. Compare the velocity of the stream at the surface of the water and near the stream bed. Explain why you think stream velocity varies according to the pattern in your data.

Q9. What factors influence stream velocity?

Q10. How does stream velocity affect discharge?

Q11. How do you think the velocities would be different if you measured them immediately after a heavy rain event? Why might this be?

Q12. How might building a strip mall about a block away affect the stream velocities? Why would they be different?

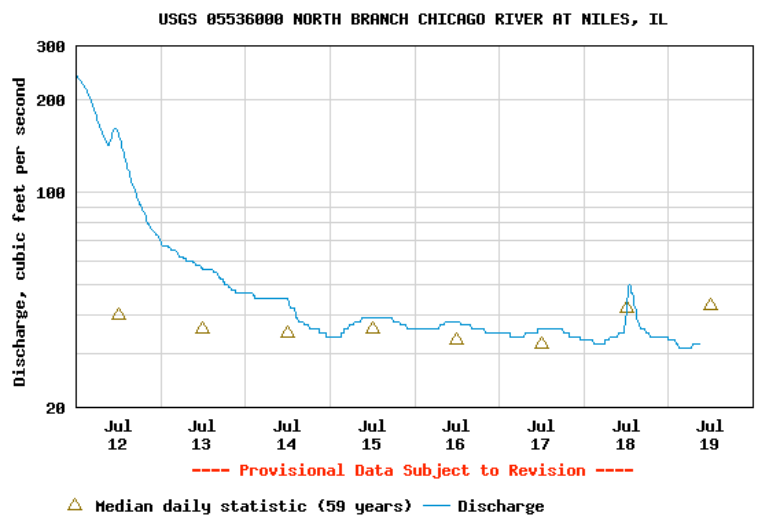
Q13. Discuss any sources of error in your data and suggest ways to correct for them in the future.

Measuring Streamflow Lab

Introduction

Take a walk down to the banks of your local stream. What do you hear? Is it a lazily flowing river or a gurgling brook? What factors cause the velocity of a stream to increase? What happens when the velocity of a stream increases? The greater the velocity of a stream, the greater the erosive and carrying power the stream has. When there is more sediment in the water the water becomes muddy looking or more turbid. Greater turbidity leads to a decrease in aquatic plants and animals. This fact is due to decreased levels of sunlight penetrating the water.

Is the velocity of a stream constant over time? How much does it vary? What causes stream velocity to change? The United States Geologic Survey (USGS) (water.usgs.gov) maintains streamgages on hundreds of streams across the country. These streamgages provide real-time and historical data for the locations where they are installed. The available data allow us to look at changes in velocity that result from storms, droughts, and other events. USGS data is available as graphs or tables. A graph showing stream discharge over time is called a hydrograph.



In the photo to the right, students from Maine East High School in Park Ridge, Illinois, use a flow meter to measure stream velocity. You will be using two methods to measure stream velocity in this activity. First, you will record the time it takes for an orange to travel a 30-meter distance down the stream in different parts of the streambed. Then, you will repeat the investigation using a PASCO stream velocity flow meter.

Materials & Equipment:

- PASCO GLX
- PASCO Stream velocity flow meter
- Tape measure
- Orange
- Stopwatch
- Digital camera (optional)

Procedure:

Low-Tech: Orange Dropping

1. Choose a location where you can safely wade into the water to measure the stream velocity. You will be assigned one of the following roles in this investigation: measurement, start marker, end marker, orange dropper, orange catcher, timer, or data collector.
2. In the space below, record information about the characteristics of the location.
3. If a camera is provided, take pictures to document the location.
4. Measure a distance of at least 30 meters along the river.
5. Position the start marker just upstream of the start of the 30 meter length. Position the timers at the downstream end of the 30 meter stretch.
6. Position the orange dropper in the center of the stream, just upstream of the start end of the 30 meters. Carefully use a meter stick to test the flow of water before stepping into it.
7. Position the orange catchers just past the downstream end of the 30 meters.
8. When the orange passes the Start Marker, the Start Marker needs to shout out "Start." The timers should start their stopwatches **when the orange passes the start marker**. When the orange passes the 30 meter end line, the timers should stop their stopwatches.
9. Timers announce their times and recorders record them in the data table.
10. Perform at least three trials.
11. Repeat the process along the stream banks and mid-way between the center of the stream and the banks.

Questions:

Q1. Describe the stream you have selected. Include details about the soil type, vegetation, surrounding land cover and its size and speed. Is it wide or narrow? Does it flow quickly or slowly?

Student answers will vary but should include details about all of the above characteristics of the study site.

Q2. Enter your results in the table below.

	Time (seconds)				
Location	**Trial 1**	**Trial 2**	**Trial 3**	**Distance**	**Average velocity** (time/distance)
Center of stream					
Stream banks					
Mid-way					

High-Tech: GLX flow meters
This activity should be done in the same location as the previous activity.

1. Turn on the GLX.
2. Connect the flow meter to port 1 at the top of the flow meter.
3. Submerge the flow meter in the flow in the center of the stream 6/10's of the way from the top of the stream to the bottom. Align the sensor so that it is parallel to the flow direction of the stream. The meter must be properly aligned to measure the true maximum velocity.
4. Read off the velocity from the graph on the GLX.
5. Record in the data table.
6. Perform at least three trials.
7. Repeat the process along the stream banks and mid-way between the center of the stream and the banks.
8. Collect an additional data point by lowering the probe into the stream near the center of the stream so that the probe is just above the stream bed.

Questions:
Q3. Record your GLX Streamflow data in the table below.

	Time (seconds)			
Location	**Trial 1**	**Trial 2**	**Trial 3**	**Average velocity** (time/distance)
Center of stream				
Stream banks				
Mid-way				
Stream bed				

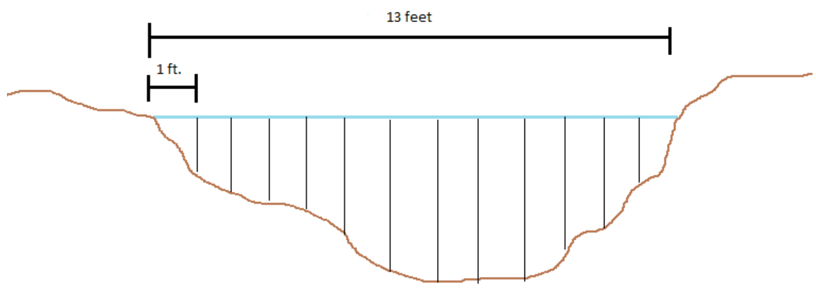
You can see from your data in the table for Question 3 that the stream flows at different rates depending upon whether you are measuring at the water's surface or near the streambed. Scientists have figured out that the average velocity for any location in a stream can be measured at six-tenths (0.6) of the depth at that spot. This is called the **six-tenths rule.**

How will you figure out what the **average velocity** of this stream is?

Calculating Stream Discharge

Now you have measurements for the stream **velocity**. Typically, however, hydrologists (scientists who study how water moves) measure the **discharge** of a stream. Discharge is the total volume of water per second that is flowing past a fixed point in the stream.

To measure the cross-sectional area of the stream, you and your classmates will need to measure the width of the stream and divide it into smaller, evenly-spaced segments (see diagram below). These sections can be 1 foot wide, 3 feet wide, or more—depending on the size of the stream you are measuring. The smaller the width of these sections, the more accurate your calculations will be. You will measure the depth of each of these sections and calculate the cross-sectional area of each rectangle. Then, add these areas together to find the total cross-sectional area of the stream. Make a table in the space below to record your measurements.



AREA of stream cross-section **x** stream **AVERAGE VELOCITY = DISCHARGE**

Create a data table to calculate cross sectional area:

Questions:

Q4. Complete the table below to calculate the discharge rate of your stream. Refer to the equation above to calculate the discharge rate.

Depth of stream in center of channel	
Width of stream	
Average velocity at 0.6 depth	
Discharge rate (include units)	

Q5. How similar were the velocities you recorded in each of the trials for the orange dropping method? For the GLX flow meter method?

Students may find that the flow meter has better repeatability than the orange dropping method, but it will depend on their individual reaction times and technique.

Q6. How does the data collected by timing the distance traveled by the orange compare to the data you collected with the flow meter?

Students should discover that the stream velocities measured by timing the orange will be roughly similar to the stream velocities calculated by the flow meter.

Q7. Compare the velocity of the stream from the center out toward the stream banks. Explain why you think stream velocity varies according to the pattern in your data.

Students should see that the center has a higher velocity. When the water comes into contact with the banks, there is more friction, which slows the water down. In the center, there is less friction to slow down the water, therefore it moves faster farther away from the banks.

Q8. Compare the velocity of the stream at the surface of the water and near the stream bed. Explain why you think stream velocity varies according to the pattern in your data.

Answers should include the idea of friction once again. There is more friction at the streambed than at the surface, therefore an increased velocity at the surface should be observed.

Q9. What factors influence stream velocity?

Answers should include volume of water in the stream, stream morphology, storm events, and/or surface runoff. Frequency and intensity of rain events will influence the velocity of streamflow. Discharge will increase after a storm due to a surge in volume from surface runoff. Over time, changes in land cover will influence stream discharge.

Q10. How does stream velocity affect discharge?

The higher the stream velocity, the greater the discharge there will be due to the increased volume of water in the body of water.

Q11. How do you think the velocities would be different if you measured them immediately after a heavy rain event? Why might this be?

Water makes its way to the stream or river through surface runoff after a storm, causing increased discharge of water through the stream. Thus, stream velocity would increase after a rain event due to a higher volume of water in the stream. How quickly the stream velocity increases is influenced by its surroundings: surface runoff in a developed environment will reach the stream much more quickly than runoff in undeveloped areas.

Q12. How might building a strip mall about a block away affect the stream velocities? Why would they be different?

Student responses should include a connection between land usage and surface runoff. Developed land cover will increase the surface runoff into a stream causing an increase in discharge.

Q13. Discuss any sources of error in your data and suggest ways to correct for them in the future.

Student answers will vary, but could include differences in reaction times for orange dropping activity, the angle at which they held the flow meter, etc.

Virtual River

Purpose
Students will learn about basic stream terminology, how streams flow, and how stream velocity is measured.

Overview
Virtual River is an online, interactive activity developed by California State University that will introduce students to streamflow, discharge, stream velocity at depth, and how such measurements are taken in the field. Students are asked to consider river models and do simple calculations to complete data tables during the activity. Students will receive a Certificate of Completion and a final copy of their data table generated by the website when they finish the activity.

Student Outcomes
- Describe how to measure and calculate stream velocity.
- Identify areas in a stream where velocity is different from other areas.
- Identify factors that influence stream velocity.
- Explain how stream velocity affects discharge.
- Understand scientific terminology relevant to the measurement of stream discharge

Time
1-2 50 minute-class periods (may assign for homework)

Level
Secondary earth/environmental science (9-12)

Materials and Tools
- Computers with internet access – ideally 1 per student
- Virtual River website: http://www.sciencecourseware.org/VirtualRiver/

Prerequisites
- GLOBE Watershed Dynamics Human Impact Activity 1: "Philadelphia Tackles Rainwater Runoff Pollution" podcast
- Activity 2: Building a Watershed Model
- Activity 3a: Streamflow Lab (optional)

Background

Students should be familiar with the concepts of streamflow and discharge, and they should understand the factors that influence the volume and direction of surface runoff. To successfully complete this activity, students will need to plot and interpret simple graphs of their data and perform basic calculations.

Teaching Notes

This activity should be done as a follow-up to "Streamflow Lab" as it reinforces the concepts learned in that activity. "Virtual River" also introduces new material such as the six-tenths rule, which states that the average velocity of a stream can be measured at six-tenths of its depth. In addition, students will learn about the forces of friction acting on the water traveling in a streambed and how they affect stream velocity in different parts of the stream.

A transcript of the activity has been prepared, complete with student questions, in the document "Virtual River Transcript and Questions." At the end of the activity students have the option to print out a 'Certificate of Completion'; this may be turned in to teachers as proof that students completed the activity.

Virtual River

This activity can be found online at: http://www.sciencecourseware.org/VirtualRiver/

Click on the link for "River Discharge."

Page 1:

The goal of this exercise is to introduce you to some basic concepts about how rivers work.

The term **river** describes water moving through a well-defined channel.

This is a picture of Herd Creek in eastern Idaho with water flowing through its well-defined channel. The channel here is about 7 meters wide.

Where do rivers get their water?

Page 2:

Streams can gain much of their flow from groundwater springs. Here is a picture of a spring in Idaho which produces a moderate size creek – Tom's Creek -- that flows off to the right.

Rivers also get their water during storms. This is especially true when the underlying soil is saturated and the rain can no longer seep into the ground. This picture of a hillside in California shows that the soil has become saturated with water ponding at the surface. Notice that some channels are starting to form and the standing water is beginning to move downhill.

Page 3:

Discharge
The amount of water flowing in a stream is called its **DISCHARGE**, which is the volume of water moving in a stream during a given time interval. Time is usually expressed as seconds, but volume can be in cubic feet (ft^3) or cubic meters (m^3). So, discharge can be either cubic feet per second (ft^3/s, also termed cfs) or cubic meters per second (m^3/s). We'll be using the metric system for our determinations, but at the end of this activity you have the opportunity to convert from m^3/s to cfs.

[animated graphic of fish swimming in river]

Click "Start" to observe the block of water move downstream at a rate of 1.0 meters per second. (It takes 10 seconds for the cubic meter block to move 10 meters.) The example stream above is confined to a 1 meter square channel. Discharge here then, is 1.0 cubic meters/s. Later in this exercise you will determine the cross-sectional area of a stream and the stream's velocity through that area. By multiplying the area times the stream's velocity, you will be able to estimate the stream discharge.

Answer these questions:

1. Discharge is an important concept. What statement best describes stream discharge?
   a. It's a measure of stream volume per distance traveled.
   b. It's a measure of stream velocity.
   c. It's a measure of how much water is moving past a certain location along the stream each second.
2. If the stream above were moving twice as fast, what would the discharge be?
   a. cubic meters/s
   b. 0.5 cubic meters/s
   c. 1.5 cubic meters/s

Page 4

Stream Terminology
But, natural stream channels don't have a square meter cross-section shape and their velocity values vary a lot from spot to spot. As we shall see over the next few pages, a stream's cross-section can be complicated such that carrying out velocity measurements can be challenging. Before we consider how velocity values and channel shape are determined, let's examine a few terms used to describe streams.

Notice that there is a right and left bank of the stream. The sides of a stream are named (right or left) relative to a view downstream. The arrow shows the direction of flow, which in the diagram on the right is away from us.

Answer these questions:

3. In this diagram, which side of the river is the **left** side? (A or B)

Page 5

In order to measure discharge, we need to measure both the **area** of the cross section and the **velocity** of the water. (We'll measure the area later.) Remember that velocity has the units of speed which can be expressed as either **feet per second**, or **meters per second**.

In a stream, velocity is measured by using a **velocity sensor** attached to a **wading rod**. Below (left) is a picture of a wading rod with the velocity sensor attached. The sensor has a set of cups (or a propeller device) that spins in moving water. The faster the cups spin, the greater the stream's velocity.

(The following relates to photos embedded in the website) Above John Stamm, a hydrologist, is holding a wading rod with a velocity sensor attached to the lower part of the rod. The sensor is connected by a wire to a digital display meter held by Professor Stamm.

Above is a close-up of the velocity sensor (top) and its digital display meter (bottom).

Page 6

Below, two students are measuring **velocity** near the right bank of a muddy stream. They mark their "position" in the stream by using a **tape measure**. Their position is the point where the wading rod touches the tape. The rotating cups are down in the water spinning like crazy.

You might ask "*At what depth should they place the spinning cups to measure the velocity?*" At the surface of the water? At the bottom of the stream? Where? Let's find out.

Page 7:

The animation on the left is a look inside a flowing stream. Notice the particles flowing past your view.

4. Which part of the stream is flowing fastest?
   a. Near the top
   b. In the middle
   c. At the bottom of the stream

Page 8:

That's right!

The water in a stream moves fastest near the surface and slowest near the bottom where the flow is slowed by friction from the roughness of the bed material.

To compute the discharge of a stream, we need to compute velocity, which, as you now know, changes with depth. To make the best estimate of a stream's velocity hydrologists use the **average** velocity of a stream.

The question is *"where is the average velocity measured?*" Is it near the middle, or nearer the top, or nearer the bottom?

Click the "Next" button to find out.

Page 9:

Determining the Average Velocity of a Stream
For each of the four layers use the stop watch to time the movement of particles from one post to the other. The wooden posts are 5.0 meters apart. (Some of the values have been measured and recorded for you.)

Make each measurement twice to the nearest 0.2 seconds. Record your data in the table below. Then record the average of the two times.

Page 10:

Students calculate stream velocity

Page 11:

Making a Depth verses Velocity Graph
To visualize the relationship between the depth of water in the stream and its velocity let's plot up the velocity and depth data that you collected.

Use your mouse cursor to drag the symbols representing each of the four points from the table on the right to the graph on the left. When the depth and velocity coordinates on the graph match those from the table release the mouse button. You may not be able to plot each point perfectly. Point # 1 has already been plotted for you.

Page 12:

The Velocity verses Depth curve for streamflow.
The blue line connects the points you just plotted. The blue line curve tells us that there is a definite and measurable relationship between the velocity of a stream's flow and the depth at which the measurement is taken.

Rather than measuring velocity at many depths to determine the average velocity, let's use the curve to determine the velocity at many different depths and then calculate the average of those numbers.

Page 13:

The interactive graph to the left shows that streams flow fastest near the water surface and slowest near the bottom of the stream. Use your mouse to move the "crosshairs" and read the velocity at different depths. Record your results. The velocity data from your prior measurements is already displayed.

Page 14:

The 6-tenths rule.
That's right. The average velocity for this hypothetical stream is 0.29 m/sec. (Your value may have been slightly different.) This value is for a very rapidly flowing stream.

Rather than make a number of measurements at various depths to estimate the average velocity, let's use the graph to figure out approximately what depth in a stream would have the "average" velocity.

This is a very important concept. The graph can tell us that there is a certain depth at which we could make just one measurement to estimate a stream's average velocity.

Move the cross hairs to the depth where the velocity in the stream is closest to the average velocity. What is that relative depth value?

Page 15:

The SIX-TENTHS Rule
That's right! The average velocity at any location in a stream can be estimated by measuring the velocity at six-tenths of the depth of the stream at that location. This is called the **six-tenths rule.**

If the stream is 3.2 meters deep, the average velocity at that spot can be estimated by measuring the velocity at 3.2 m times 0.6, which equals 1.92 m

Answer these questions.

5. At what depth should a velocity sensor be placed to estimate a stream's average velocity if it's 12.5 meters deep?
6. Same questions as above, but for a stream that's 2.0 meters deep.

Page 16:

Working with a very simple stream
Next we will estimate the discharge of a simple stream where the velocity changes with depth, but stays constant from side to side. Below is a **cross section** of such a stream. There is a "wading rod" tool, which you can move back and forth. Attached to the rod is a velocity sensor (a propeller device), which you can move up and down. The velocity and depth sensor readings can be seen below to the left.

Questions:

7. What is the velocity value at a sensor depth of 0.30 m at 6.2 m on the tape measure?
8. How does the velocity at 9.1 m on the tape (also at a sensor depth of 0.3) compare with that at 6.2 m and 0.30 sensor depth?

Page 17:

Determining a stream's depth, width, velocity and discharge: For this stream, the average velocity is the same (provided the depth is the same) no matter what position on the tape it is measured. Answer the questions below.

Questions:

9. What is the maximum depth of water in this hypothetical stream?
10. At what actual depth should the velocity sensor be set to record the average velocity? (Remember that the average velocity is best measured at 6/10$^{th's}$ of the total depth.)
11. What is the average velocity of this stream, as measured by the virtual stadia rod and velocity sensor?
12. What is the distance on the tape of the left edge of stream? (Note that the edge of the stream is NOT at "0.0" on the tape.)
13. What is the distance on the tape of the right edge of the stream?
14. Compute the width of the stream. (This is the difference between the right and left sides.)
15. Discharge is computed as the volume of water in the stream passing by in one second. **DISCHARGE = DEPTH** times **WIDTH** times **AVERAGE VELOCITY.** (Keep in mind that for this very simplistic stream the velocity at a fixed depth is constant from side to side. Water velocity in a real stream varies not only with depth, but from side to side.) What is the discharge of this stream? (Calculate to TWO decimal places in cubic meters per second)

Page 18:

Sure! The discharge determined for the hypothetical stream on the prior page is a little less than 0.9 cubic meters per second. This calculation was pretty easy: it's just the product of the rectangular cross sectional area and the average velocity from bank to bank which is a constant value.

Real streams are not as simple. Cross sections are irregular because the water depth varies from side to side. Also a stream's velocity varies from spot to spot because of the frictional effects of the sides and bottom of the channel.

Furthermore, a complex stream commonly flows in sinuous paths called **meanders**.

Meanders are a product of the stability of stream banks, which are controlled by the bank's vegetation, the size of the sediment within the banks, and the power of the water in the stream (which increases as discharge increases).

Page 19:

More about real streams
Meandering is produced by both erosion and deposition of sediment.

Riffles (straight sections between bends) and **point bars** (on the inside of a meander bend) are places where sediment is deposited and temporarily stored. **Pools** and **cutbanks** (on the outside of a bend) are places where sediment is eroded or removed. Stream erosion and deposition generally occur during periods of flooding. An imaginary line connecting the deepest parts of a stream channel is called a **thalweg**.

Move your mouse cursor over the points marked "X" on the left diagram to find descriptions of some of the features of a meandering stream. Then respond to the questions below by matching the red letter in the image on the right with its corresponding term.

Page 20:

Stream Channel cross sections
The previous page shows us that streams have complicated channels with deep pools and shallow riffles. In a real stream the channel's cross section can be quite complicated.

How do we measure discharge where the channel geometry is complicated? We divide the stream into several smaller sections called **verticals**. Each vertical has its own depth, width, and velocity.

Below is a diagram showing verticals for a stream and students measuring water velocity in the middle of a vertical.

Above we see two students measuring water velocity in the middle of a vertical. The measuring tape is used to determine the location of the middle of each vertical.

A reasonable question to now ask is "How many verticals should be used to accurately determine a stream's discharge?"

Page 21:

If we use only a few verticals, we could miss the high-velocity band of water, and our discharge measurement will be too low. Using at least 20 verticals gives us a good chance of getting a measurement in the high velocity area and therefore having a more accurate measurement of discharge.

Less than 20 verticals can be used, but at the expense of accuracy.

If a stream is 30 meters wide, and we want to compute discharge in a stream using 20 verticals, how many meters wide would each vertical be?

Page 22:

Instructions: Hang in there! You're almost finished. Measure the width of this stream by using the mouse to drag across the stream. Set the number of verticals to 10 or more. (If you use less, the discharge you calculate will be too inaccurate.) You will only have to measure the area of 5 of these, as the program will measure the rest. Click the Read To Measure button to advance to the next page.

Page 23:

Converting Cubic Meters per Second to Cubic Feet per Second (cfs)
The total discharge you determined for this stream is 4.012 cubic meters per second. Recall that discharge often is reported in units of cubic feet per second (cfs). It's important to be able to convert from one set of units to the other.

The conversion from feet to meters is 0.3048. In other words, one foot equals 0.3048 meters.

Page 24:

Congratulations! You have successfully completed this activity about river discharge.

Determining discharge is just the first step in understanding rivers. You can learn more about other important river processes, such as floods and erosion, by completing the other lessons in this virtual lab. (You'll find a link on the next page.)

Enter information below to get a certificate of completion

Page 25:

VERY NICE WORK!

Summary of Discharge Data for this Hypothetical River

Vertical Number	Width (meters)	Depth (meters)	Average Velocity (m/sec)	Area of Vertical (sq m)	Discharge of Vertical (cubic m/sec)
Total Discharge					(Value here) cu m/sec
					(Value here) cu ft/sec

Just Passing Through Learning Activity

Purpose:

To develop an understanding of some of the relationships between different types of soil and water, including how water affects these different soils when flowing through it.

Overview:

Students time the flow of water through different soils and observe the amount of water held in these soils. Students will also observe the filtering ability of soils by noting the clarity of water before and after it passes through the soil.

Student Outcomes:

- Students will be able to identify some of the physical and chemical changes that occur as water is poured through soil.
- Students will be able to design grade level appropriate experiments that test soil and water properties.
- Students will be able to apply the Scientific method.
- Students will be able to explore the concepts of Earth as a System.
- Students will apply the “re-use” conservation concept by salvaging disposable items for experimentation.

Science Concepts:

Earth and Space Science

- Soil consists of weathered rocks and decomposed organic material.
- Soils have properties including color, texture, structure, and density.
- Water circulates through soil changing its properties.

Scientific Inquiry Abilities:

- Identify answerable questions.
- Design and conduct an investigation.
- Use appropriate mathematics to analyze data.
- Develop descriptions and explanations using evidence.
- Communicate procedures, observations and explanations.

Level:

Primary; however this activity could be enhanced and used as an introduction to soil science for upper secondary. It could also serve as an introduction to experimental design.

Time:

One class period; additional class periods may be necessary if including additional activities (See "Further Investigations"); this activity can also be used as an introductory activity, thereby needing only 15 to 20 minutes.

Materials and Tools:

*Materials needed for each group of 3-4 students**

# of Items	Items
1	1.5-litre clear water bottles (empty)
1	2-litre clear soda bottles (empty)
1	0.5 litre clear water bottles (empty)
1	Panty hose or other material with small mesh size
1	Small rubber bands
1	100 mL graduated cylinder or other volumetric measuring device
500 cm^3 (approximate)	Different types of soil (For example, sand, non-clumping clay cat litter, potting soil, mulch, etc.)
1	Newspaper or small white paper plates
1	Stop watch (or watch with second hand)
1	Scissors

Optional materials for "Further Investigations"
Distilled (or De-Ionized) water
Salt
Vinegar
Baking soda
pH Paper or meter (see Hydrology Chapter of the **GLOBE Teacher's Guide** or manufacture's instructions for proper use)
Conductivity (TDS) meter (see Hydrology Chapter of the **GLOBE Teacher's Guide** or manufacture's instructions for proper use)
Alkalinity Test Kit (see Hydrology Chapter of the **GLOBE Teacher's Guide** or manufacture's instructions for proper use)
NPK Test Kit (see Soil Chapter of the **GLOBE Teacher's Guide** or manufacture's instructions for proper use)
Locally-available plant seeds

*Teachers can also present this activity to the class using different soil types in several 2-litre bottles as a whole-class activity.

Prerequisites:

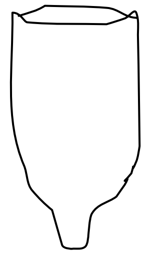
None

Preparation:

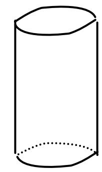
Teachers can prepare the materials themselves, or they may direct their students to do the preparation.
Preparation Time: 20 to 30 minutes

1. Empty and rinse all bottles and remove labels.
2. Cut off bottom of 2-litre bottles, leaving at least 2/3 of the original bottle (**Diagram A1**).

3. Cut off top of 1.5-litre bottles, leaving at least 2/3 of the original bottle (**Diagram A2**).

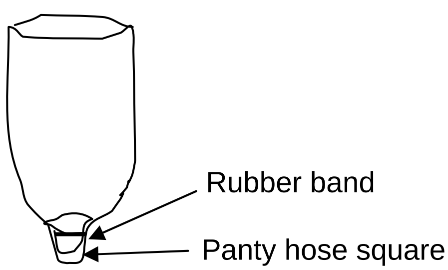


Cut 2-litre soda bottle (inverted)
Diagram A1

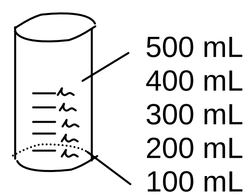


Cut 1.5-litre bottle
Diagram A2

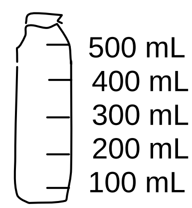
4. Discard (or recycle) bottoms of 2-litre bottles (tops of 1.5-litre bottles can be cut to act as trowels).
5. Cut panty hose into (approximately) 5 cm by 5 cm double-layer squares (by beginning your cutting at the toes of the panty hose, sections can be cut off providing you with immediate double layered pieces).
6. Place each double-layered panty hose section over the mouth of each 2-litre bottle. Slip a small rubber band over each panty hose square and onto the threaded part of mouth of the 2-litre bottle (rubber bands may need to be doubled to provide snug fit). This will ensure that the panty hose section is fastened securely to the 2-litre bottle (panty hose should extend beyond the rubber band and can be tugged on to tighten against the 2-litre mouth). The panty hose will act as a filter (**Diagram B1**).
7. Measure out 100 millilitres of water and pour into the bottoms of the cut 1.5-litre water bottles; mark level of water with a permanent marker; continue until 200, 300, 400, and 500 mL levels are also marked on the bottle bottoms. These will act as beakers (**Diagram B2**).
8. Measure out 100 millilitres of water and pour into the 0.5-litre water bottles; mark level of water with a permanent marker; continue until 200, 300, 400, and 500 mL levels are also marked on the bottles. These will act as graduated cylinders (**Diagram B3**).



Cut 2-litre bottle
Diagram B1

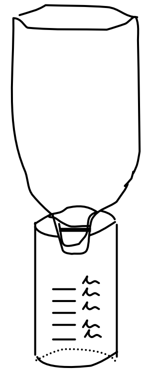


Cut 1.5-litre bottle
mL levels marked
Diagram B2



0.5 Litre water bottle
mL levels marked
Diagram B3

9. Choose soil and/or soil-like substances (potting soil, mulch, sand, clay cat litter, etc.) or have substances for students to choose.
10. Set 2-litre bottles into the openings of the cut 1.5 mL bottles (**Diagram C**), panty hose should not be below 500 mL mark.
11. Add soil(s) to 2-litre bottle, panty hose should not allow any substances to spill through. (Note: Amount of soil in 2-litre bottle can be determined by mass, volume, or randomly depending on direction of class or emphasis desired.)



2-litre bottle on 1.5-litre bottle
Diagram C

12. Place a small amount of each soil on small white paper plates or newspaper for students to examine.
13. Fill 0.5 mL drinking water bottles with locally available water.
14. The following table (or one similar) can be created on blank paper, in students' journals, or on the blackboard.

Prediction	Outcome

Procedure:

1. ***Motivation:***
   - Present some background information on soil. (See the Introduction of the Soil Chapter of the GLOBE Teacher's Guide; online this can be found at www.globe.gov
   - Ask the groups to determine their individual roles; who will record information, who will keep time, who will pour the water.
   - Explain to the class that students who have been selected to pour the water will pour the contents of his/her drinking water bottle into the pre-cut 2-litre bottle to see what happens. There is something in the 2-litre bottle (potentially soil of some type) and a double-layer of panty hose to act as screening at the bottom of the pre-cut 2-litre bottle.

2. ***Student Inquiry:***
   - Before the students pour the water, have the students (either individual groups or as a class) predict what will happen.
   - If students have trouble coming up with predictions, guide them with such questions as "Which substance will allow the first drop of water through?" or "Which substance will retain the most water?" Have the students indicate within their tables their predictions of how the water will act with the various samples.

3. ***Experimental Design:***
   - Ask the students what additional parameters they might consider when doing this activity. The following questions might be used to lead students to designing their experiments:
     - o Does it matter how fast or slow the water flows through the individual bottles?
     - o What rate should the water be poured into the soil samples?
     - o How can the stopwatch be used in this experiment? What could they time?

- Will the amount of water that flows through the soil samples vary? How can they measure this?
- Ask the students how the water should be poured. Does it matter if water is or is not poured at the same rate? This discussion can lead into the importance of following a measurement protocol – good for schools implementing GLOBE. If students are in disagreement or are not certain if it matters, suggest that a common rate of pouring be established. Once a rate has been established, have the students pour the water (as determined) into the pre-cut 2-litre bottles. The students should pour water so as not to obstruct observation by other students. Table/chair arrangements may need to be slightly modified prior to this activity to allow maximum viewing. Allow the groups time to make observations.

4. ***Recording Observations:***
   - Have students record their observations in the “Outcome” section of the table. Ask if there were any surprises. Explain that unexpected outcomes do not mean incorrect questions or hypotheses. Rather, many scientific discoveries are not expected. Explain that this activity helps to model the properties of different soils – however, these soils have been disturbed. Interaction between soil and water in the natural environment may be different. This could facilitate interest in studying soil.

5. ***Further Investigations:***
   - Ask if there are any questions or further investigations that could come out of this. For example, “Would the same results occur the next day? Why or why not?”
   - Add salt, vinegar, and baking soda to different samples of distilled water, mix. Have students predict and measure the conductivity, pH and/or alkalinity of the water before it is poured and after it has filtered through the soil. Discuss how these characteristics, pH, alkalinity and presence of dissolved salts, affect soil, plants and animals.
   - Discuss soil nutrients that plants use, mainly N, P, and K (Nitrogen, Phosphorous, and Potassium). Using an NPK Kit, measure the amount of N, P, and K in various soils before and after activity. Compare soils and NPK values of the region. How do agriculture specialists address differing amounts of N, P, and K in different soils?
   - Plant the same locally-available seeds in each of the soil types used in this activity. Providing the same amount of water, which soil promotes the best seed germination and plant growth? Discuss how plants around the world have adapted to different soils, differing amounts of water and nutrients.

6. ***Extensions:***

   Ask students the following questions to relate this activity to the ecosystem:
   - How does this activity model the natural environment?
     - How are different environmental concepts represented in this activity?
       - How is precipitation represented? How is soil represented?
   - How might different factors in the soil or water affect plants or animals in the soil?
   - How might plants or animals affect the soil?
   - How might an increase or decrease in temperature or humidity affect the properties of the soil? The water? The plants and animals?
   - Ask students to describe the path of an imaginary drop of water from the bottle to the soil and beyond. How does this drop of water fit into the Hydrologic Cycle?

Optional Infiltration Protocol

Purpose

To determine the rate at which water soaks into the ground as a function of time

Overview

Students place two cans into the soil and add water to them to a depth of at least 5 cm. Students measure and record the time it takes the water level to drop a fixed 2 - 4 cm distance. Students repeat the measurement to determine how easily water moves vertically through the soil.

Student Outcomes

Students will be able to measure water infiltration into soil. Students will understand that the infiltration rate of water into soil changes depending upon the level of soil saturation. Students will understand that water that is not stored in the ground evaporates or becomes runoff and may pool on the surface for a time. Students will be able to determine how flood-prone an area is based on the infiltration rate of the soil.

Science Concepts

Physical Sciences

Objects have observable properties.

Earth and Space Sciences

Earth materials are solid rocks, soil, water, biota, and the gases of the atmosphere.

Soils have properties of color, texture, structure, consistence, density, pH, fertility; they support the growth of many types of plants.

The surface of Earth changes.

Soils consist of minerals (less than 2 mm), organic material, air and water.

Water circulates through soil changing the properties of both the soil and the water.

Scientific Inquiry Abilities

Identify answerable questions.

Design and conduct an investigation.

Use appropriate tools and techniques including mathematics to gather, analyze, and interpret data.

Develop descriptions and explanations, predictions and models using evidence.

Communicate procedures and explanations.

Time

One class period to build and test the double-ring infiltrometer.

45 minutes or one class period for the measurement.

Level

All

Frequency

Three or four times a year at the Soil Moisture Study Site

One time at a Soil Characterization Sample Site

In all cases, three sets of measurements should be taken within a radius of 5 m.

This protocol can be done while samples are collected for the *Gravimetric Soil Moisture Protocol.*

Materials and Tools

Metal ring with a diameter of 10 - 20 cm

Metal ring with a diameter 15 - 25 cm (Coffee cans work!)

Buckets or other containers to transport a total of at least 8 L of water to the site

Ruler

Waterproof marker

Stop watch or watch with a second hand

Block of wood

Hammer

Three soil sample containers suitable for soil moisture measurement

Grass clippers

Funnel

Preparation

Build an infiltrometer.

Prerequisites

None

Optional Infiltration Protocol - Introduction

Infiltration rate is determined by measuring the time it takes for water sitting on a soil to drop a fixed distance. This rate changes with time as the soil pore spaces fill with water. There are three flow rates.

Unsaturated flow is the initial flow rate and is high as the dry soil pore spaces fill with water.

Saturated flow is a steady flow rate that occurs as water moves into the soil at a rate determined by soil texture and structure.

Ponding is the flow rate that occurs when the ground becomes totally saturated and is no longer able to conduct water through its pores.

Teacher Support

Site Selection

Students should select a location within 2 - 5 m of a Soil Moisture Site or a Soil Characterization Site. Students need to be careful that they do not leave a hose running where the water will flow over their soil moisture sampling points.

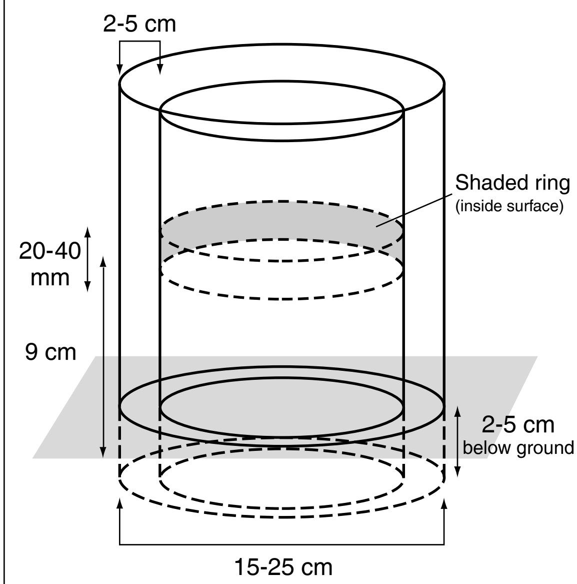
Advance Preparation

Before beginning the infiltration protocol, students need to construct an infiltrometer to measure the infiltration rates of the soil. Students should use the following procedure to construct their infiltrometers.

Construct a Dual Ring Infiltrometer

1. Cut the bottom out of your cans.
2. Use a permanent waterproof marker or paint to partially shade a ban on the inside of the smaller can to use as a timing reference mark. The width of the band should be 20-40 mm and centered roughly 9 cm from the bottom of the can. Many cans have impressed ribs that make good reference marks but it is still necessary to mark them for good visibility.

Figure SOIL-IN-1: Double-ring infiltrometer



3. Measure and record the width of your reference band (in mm).
4. Measure and record the widths of your inner and outer rings (in cm).

Have students practice this protocol, including the timing, at a site where there is easy access to water so that they become comfortable taking the measurements. If students practice in a sandy location, the infiltration time intervals will be short and they will have more opportunities to practice taking measurements in a limited time period.

Managing Materials

Students can use either a stopwatch or a watch with a second hand to time the water flow into the soil. When students use a stopwatch, they should begin timing as water is first poured into the inner ring. They should record the elapsed time as the start time and end time of water moving over a fixed distance.

Infiltration Protocol

Field Guide

Task

To determine the rate at which water soaks into the ground as a function of time

What You Need

- ❑ Infiltrometer (see advanced preparation section)
- ❑ Buckets or other containers to transport a total of at least 8 L of water to the site
- ❑ Ruler
- ❑ Waterproof marker
- ❑ Stop watch or watch with a second hand
- ❑ Block of wood
- ❑ Hammer
- ❑ Three soil sample containers suitable for soil moisture measurement
- ❑ Grass clippers
- ❑ Funnel

In the Field

1. Clip any vegetation (grass) to the ground surface and remove all loose organic cover over an area just larger than your largest can. Try not to disturb the soil.
2. Starting with the smaller can, twist the cans 2 - 5 cm into the soil. A hammer may be used to pound the can into the surface. If you must use a hammer, a block of wood should be used between the hammer and the top of the can to distribute the force of the hammering. Do not hammer so hard that the can crumples.
3. Complete the upper section of the *Soil Infiltration Data Sheet.* If you are using a stop watch, start it.
4. Pour water into both rings. Maintain a level in the outer ring approximately equal to the level in the inner ring. Note that the water level in the outer ring tends to drop more quickly than that of the inner ring. In the inner ring, pour water to just above the upper reference band. **Note**: The outer ring should not be leaking water to the surface around its rim. If it is, start over in another location, push the outer ring deeper into the soil or pack mud around its base.
5. As the water level in the inner ring reaches the upper reference mark, read the stop watch or note the time to the second. This is your start time. Record this time on the *Infiltration Data Sheet*. During the timing interval, keep the water level in the outer ring approximately equal to the level in the inner ring, but be careful not to pour water into the inner ring (using a funnel can help) or to let either ring go dry.
6. As the water level in the inner can reaches the lower reference mark, record the time as your end time.
7. Calculate the time interval by taking the difference between the start and end times. Record this interval on your *Infiltration Data Sheet*.

8. Continue repeating steps 4 - 7 for 45 minutes or until two consecutive interval times are within 10 sec. of one another. Some clays and compacted soils will be impervious to water infiltration and your water level will hardly drop at all within a 45-minute time period. In this case, record the depth of water change, if any, to the nearest mm. Record the time at which you stopped your observations as the end time. Your infiltration measurement will consist of a single interval.
9. Remove the rings. WAIT FIVE MINUTES.
10. Measure the near-surface (0 - 5 cm depth) soil moisture from the spot where you just removed the rings. Follow the *Gravimetric Soil Moisture Protocol*. You only need take one sample.
11. Make two other infiltration measurements within a 5 m diameter area. These measurements can be done at the same time using other groups or over several days (if the near-surface soil water content is not changed by rain). It is not critical that multiple runs have the same number of reading sets, but do not submit runs that are incomplete (e.g. a run that was cut short due to lack of time). If you take more than three sets of measurements, submit your three best sets.

Infiltration Protocol – Looking at the Data

Infiltration rate is determined by dividing the distance that the water level decreases by the time required for this decrease. For GLOBE measurements this is equal to the width of the reference band on the infiltrometer divided by the difference between the start and end times for an interval.

The *Infiltration Data Sheet* can be used to record and help calculate the values needed to plot measurement results. The flow rate for each timing interval is the average value during an interval. The flow rate should be plotted at the *midpoint* of the interval times. Infiltration should decrease with time and it is important to keep track of the *cumulative* time from when water was first poured into the inner ring. The table and graph below demonstrate how to calculate infiltration rates and plot them on a graph.

Figure SOIL-IN-3: Infiltration

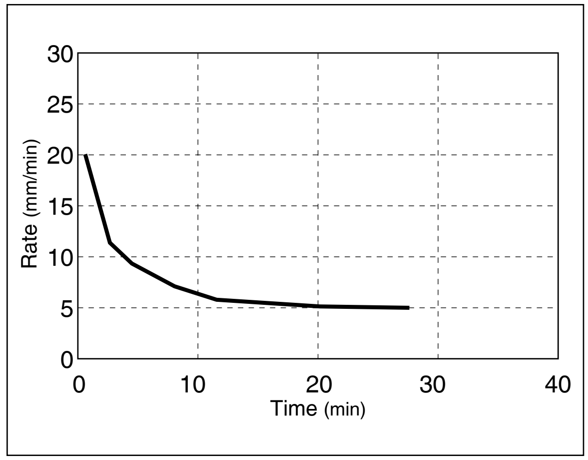


Figure SOIL-IN-2: Infiltration into Jim's Garden

Water Level Change = 20 mm

Time							Flow
Start		End		Interval	Midpoint	Cumulative	Rate
[min]	[sec]	[min]	[sec]	[min]	[min]	[min]	[mm/min]
31	00	32	00	1.00	31.50	0.50	20.0
32	30	34	15	1.75	33.38	2.38	11.43
34	30	36	45	2.25	35.62	4.62	8.89
37	15	40	00	2.75	38.62	7.72	7.27
40	45	44	00	3.25	42.38	11.38	6.15
44	15	47	45	3.50	46.00	15.00	5.71
48	15	52	00	3.75	50.12	19.12	5.33
52	15	56	15	4.00	54.25	23.25	5.00
56	30	00	30	4.00	58.50	27.50	5.00

Soil Investigation
Soil Infiltration Data Sheet

Site Name: ____

Name of Collector/Analyst/Recorder: ______________________________

Sample collection

- date: ___________
- time: _______ (hours and minutes) check one: UT____ Local ____

Distance to Soil Moisture Site _____ m

Sample Set number: ________ Width of your reference band: ______mm

Diameter: Inner Ring: ______ cm Outer Ring: _______ cm

Heights of reference band above ground level: Upper : _____ mm Lower : ______ mm

Directions:

Take 3 sets of infiltration rate measurements within a 5 m diameter area. Use a different data work sheet for each set. Each set consists of multiple timings of the same water level drop or change until the flow rate becomes constant or 45 minutes is up. Record your data below for one set of infiltration measurements you take.

The form below is setup to help you calculate the flow rate.

For data analysis, plot the Flow Rate (F) vs. Midpoint time (D).

Observations:

	A. Start (min) (sec)	B. End (min) (sec)	C. Interval (min) (B-A)	D. Midpoint (min) (A+C/2)	E. Water Level Change (mm)	F. Flow Rate (mm/min) (E/C)
1	___ ___	___ ___	_______	_______	_______	_______
2	___ ___	___ ___	_______	_______	_______	_______
3	___ ___	___ ___	_______	_______	_______	_______
4	___ ___	___ ___	_______	_______	_______	_______
5	___ ___	___ ___	_______	_______	_______	_______
6	___ ___	___ ___	_______	_______	_______	_______
7	___ ___	___ ___	_______	_______	_______	_______
8	___ ___	___ ___	_______	_______	_______	_______
9	___ ___	___ ___	_______	_______	_______	_______

Saturated Soil Water Content below infiltrometer after the experiment:

A. Wet Weight: _____ g B. Dry Weight: _____ g C. Water Weight (A-B): _____ g

D. Container Weight: _____ g E. Dry Soil Weight (B-D): _____ g

F. Soil Water Content (C/E) __________

Daily Metadata/Comments: (optional) ______________________________

____

Investigating Land Cover and Surface Runoff

Purpose
For students to explore the relationship between land cover, surface runoff, and stream discharge by manipulating a computer model.

Overview
In this lesson, students will look at a NetLogo model of surface runoff in a watershed near Chicago, Illinois. They will look at how precipitation becomes surface runoff and then enters streams. Students will learn the concept of stream discharge and be introduced to hydrographs. Students will be able to manipulate land cover in the model to analyze how land cover change can affect surface runoff and streamflow.

Student Outcomes
- Students will understand that water cycles from precipitation to surface runoff to streamflow.
- Students will understand what a streamgage is and that it measures stream discharge.
- Students will understand how a hydrograph displays the discharge of a river over time.
- Students will understand that land cover can have an indirect impact on the rates of stream discharge by affecting surface runoff.

Time
1-2 50-minute class periods

Level
Secondary earth/environmental science (9-12)

Materials and Tools
- Computers with internet access and Microsoft Word or other word processing software — ideally 1 per student
- Netlogo software and runoff model file installed in each computer
- Student Guide
- Printer (so students can print out and turn in copies of the hydrographs the model creates)

Preparation
- Install NetLogo software on each computer.
- Download Runoff model files onto computer and save in a folder that students can access easily. The model files can be found at: http://wd.northwestern.edu/curriculum/curriculum-technology/.
- Select "Download the Runoff model."

- You must unzip the Runoff.zip file before using. Do not remove the "Runoff.nlogo" model from the folder. Important files are also included in the folder and the model will not work without them.
- If you are using a Mac, click "Ok" when you are prompted to unzip the Runoff folder using the Archive Utility. If you are using a PC, you will need to unzip the Runoff folder before NetLogo can access the data files.
- Copy a Student Guide for each student

Prerequisites

- GLOBE Watershed Dynamics Human Impact Activity 1: "Philadelphia Tackles Rainwater Runoff Pollution" podcast
- Activity 2: Building a Watershed Model
- Activity 3: a) Streamflow Lab and/or b) Virtual River
- Activity 4: a) Just Passing Through and/or b) Infiltration Protocol

Background

Students should already know that the boundary of a watershed is defined by high elevations and that water flows from high to low elevations. They should be familiar with the concept of the water cycle.

Teaching Notes

Additional information about the Runoff model can be found on the Information tab in NetLogo. Before the scheduled class, ensure that the model loads properly on all computers and that there is a printer available for students to print out their data.

You may choose to have students work individually or in pairs. Additionally, share with students the kinds of professionals that may use a model like NetLogo: city planners, engineers, real estate developers, etc. This will provide students with a contextual background for this activity.

Students will encounter their first hydrographs in this activity. If you anticipate this will be a challenge to your students you may want to provide additional support for this new type of time-series graph. Students will have more practice reading and interpreting hydrographs in Activity 6.

Extensions

If time allows, instruct students to design their own pattern of land cover in the NetLogo model. Students should then justify their model design and explain how the hydrograph created by the model reflects the different types of land cover present on the map.

Name: ______________________________ Date:__________ Class:______________

Investigating Land Cover and Surface Runoff

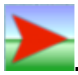
Introduction

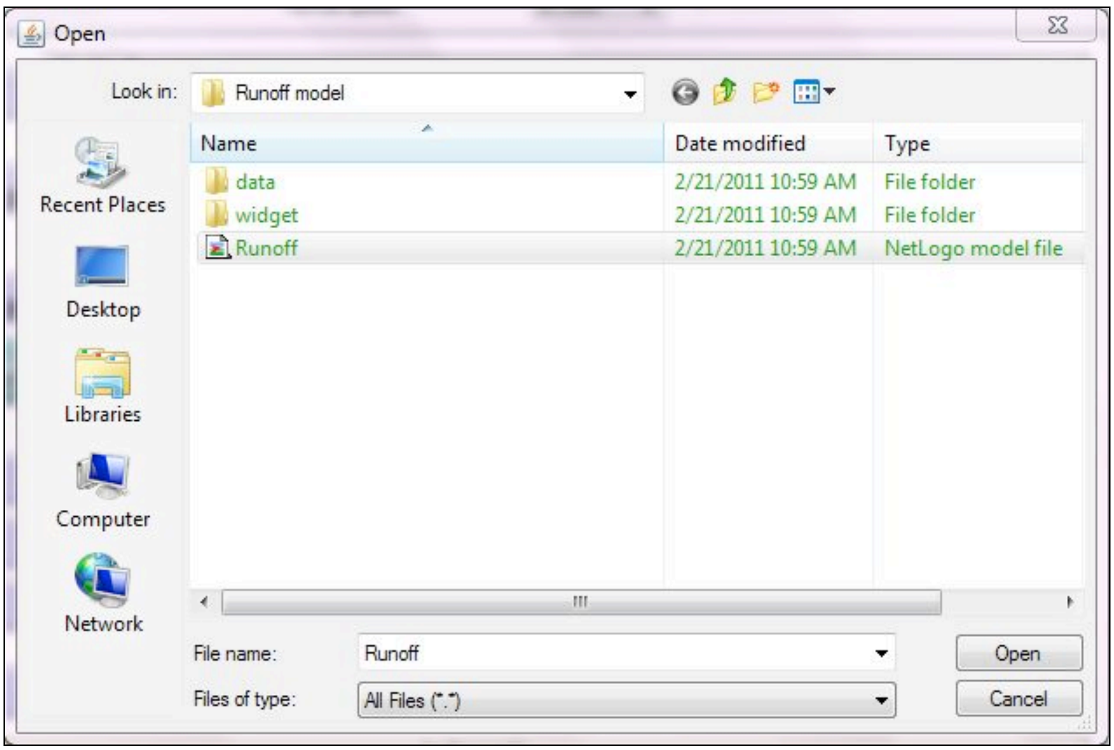
Think about the last time there was a big rainstorm in your town. What happened to all the water that came down? Did it pool on the basketball court, form streams along the side of the roads, or did it soak into the ground right away? After all of the water disappears into the sewer drain or seeps into your backyard, where do you think it goes?

You know already that soil type and elevation can affect the movement of water through a landscape. In this activity, you'll manipulate the NetLogo Runoff model to study how land cover can also affect surface runoff. This model uses data from a watershed near Chicago, Illinois, but the results of your investigation today can be applied to watersheds everywhere. You will see how precipitation becomes surface runoff and then enters streams. Then, you will analyze hydrographs created by the model to explore how land cover can impact stream discharge.

Part 1: Getting Started with the NetLogo Runoff model

You will begin this investigation by using the NetLogo Runoff model to explore how water moves across the ground after it rains.

1. Launch **NetLogo** . Click on the **File** menu, then select **Open.** Your teacher will tell you in which folder the model file is saved. Open this folder and choose the **Runoff** NetLogo model file. Click the **Open** button.

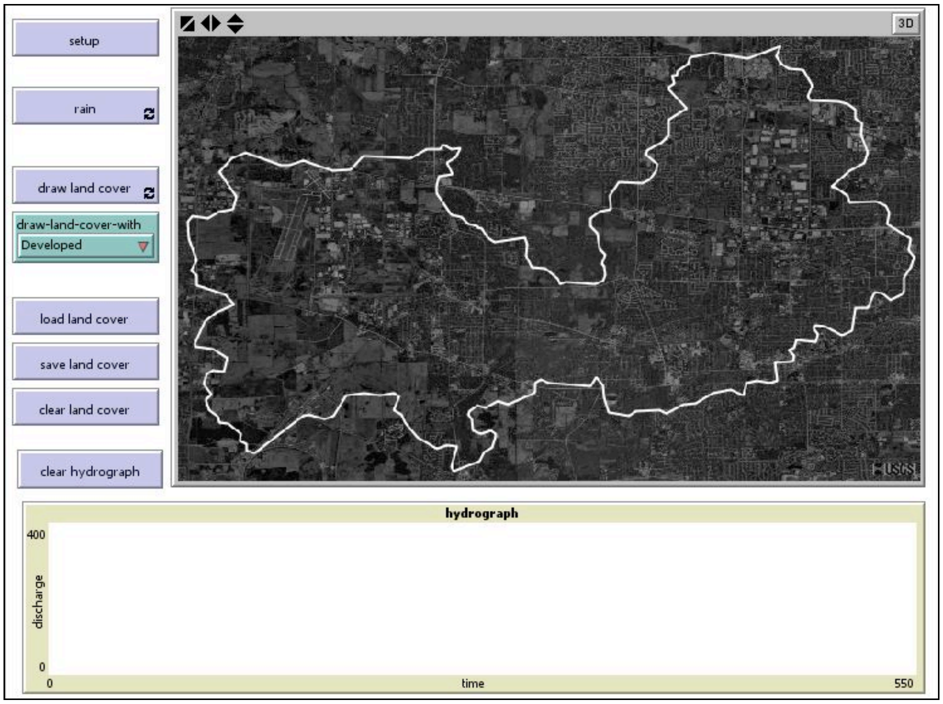


2. When the model loads, you will see a black box in the center of the screen. Click the **setup** 

button in the upper left corner of the screen and a black and white aerial map will appear.

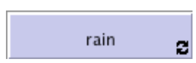
*<u>**NOTE:**</u> The **setup** button will be helpful as you move through the rest of the investigation as it will always reset your model back to zero when clicked.*

When the data loads, your model should look like this:



This model shows an aerial photo of land near Chicago, Illinois. An aerial photo is a picture taken from above, looking down at the ground. The white outline on the photo represents the boundary of the local watershed.

To the left of this aerial map you will notice the **rain** button. This button represents a storm event, and it causes rain to fall evenly over the surface of the land in the watershed.

3. Run the model by clicking the **rain** 

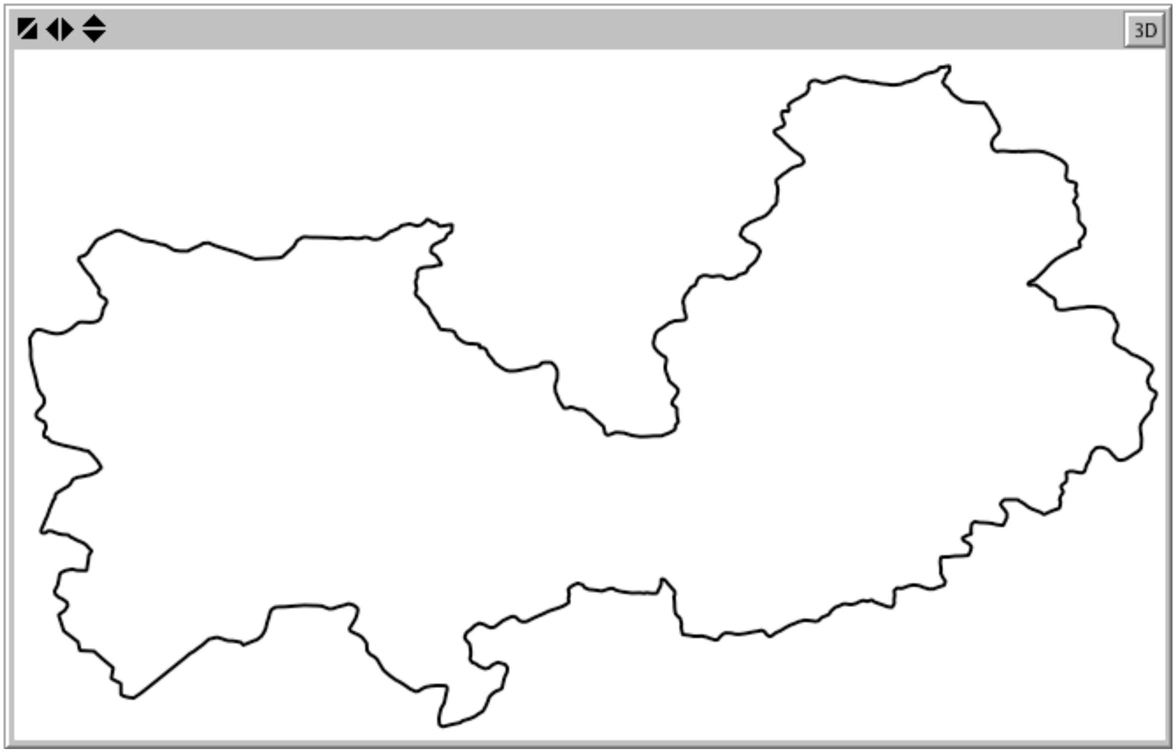
button. Watch how the water moves across the surface of the model. Allow the model to run until of the water drains out of the watershed.

Questions:

Q1. Describe how the water moves across the surface of the model. Does it flow in a straight line or a curve? Does it pool together with other rain?

Q2. Based on what you observed in "Building a Watershed Model," what do you think is determining the direction of the water flow in NetLogo?

Q3. On the blank map below, sketch what you observed in the model. Draw the main river channels that formed.



Below the model there is a **hydrograph**, which shows how much water is flowing past a certain point in the watershed at a time.

The hydrograph in the NetLogo model records how many drops of water flow past a specific location every tick. A tick is a change in time. The water moves once for every tick. In this investigation, your task is to study this hydrograph to determine how water moves over different types of surfaces.

The data in a hydrograph is collected by a *streamgage*. Streamgages are scientific instruments that measure how much water is flowing past a specific location along a river at a certain time.

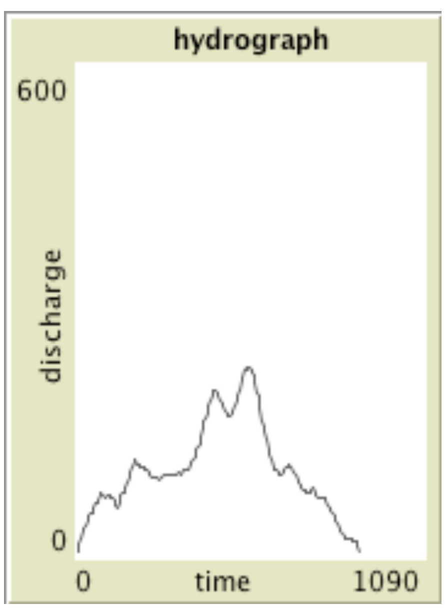
This is a photo of a streamgage at Mulhockaway Creek in New Jersey. In addition to the gage (left) a long ruler is used to measure river height (right).

Photos by Colleen Buzby

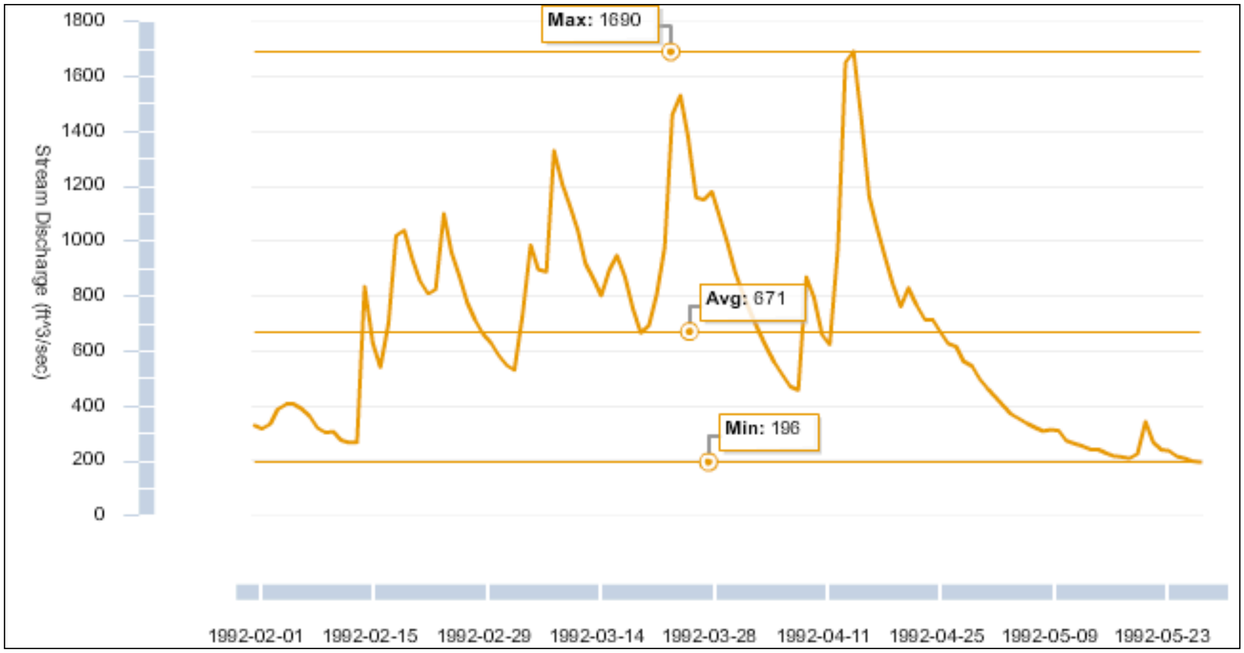
Question:

Q4. Does the streamgage in the photo above look familiar to you? Have you seen streamgages in your area before?

Take a look at the following sample hydrographs. The first hydrograph is similar to the one in your NetLogo model.



This hydrograph shows real data from a streamgage near Chicago, Illinois.



Time series graphs, like these, display change in a variable over time. A hydrograph is used to show **discharge**, the amount of water flowing past a point over time. In the hydrograph created by the NetLogo Runoff model (see previous page) measurements are taken every tick, or every time the water moves within the model. In the hydrograph above, measurements are recorded every day. Time is always on the horizontal axis to show how stream discharge changes over time.

4. Click the **setup** button to reset your model. This will also clear the hydrograph.
5. Click the **rain** button and allow the model to run until all of the water has drained, but this time watch the hydrograph while the model is running.

Questions:

Q5. Based on your observations and the shape of the hydrograph, where do you think the gage is located within the watershed? You can run the model a few times if it will help you.

Q6. Put a star on your drawing on page 62 to show where you think the streamgage is located.

Q7. What is the independent variable? On which axis is it located?

Q8. What is the dependent variable? On which axis is it located?

Q9. Why is knowing how much water is flowing in a stream important for scientists and people like you?

Q10. When there is heavy rainfall, what happens to the amount of discharge?

Q11. Which dates on the Chicago, IL hydrograph indicate the highest discharge? (see page 64)

Q12. What do you think **peak discharge** means?

Q13. What would the hydrograph look like when there is no water in the stream?

Q14. **Baseflow** is the typical amount of water flowing through a stream when there is not a rain event occurring. What is the approximate baseflow for the Chicago, IL hydrograph?

Part 2: Using the model

You are now going to use the NetLogo Runoff model to investigate how land cover can affect stream discharge.

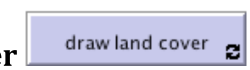
When you have no land cover designated, the model reads the surface as impervious (meaning that water can't infiltrate) and only topography affects the flow of the water. Adding land cover to the model will cause the model to act differently.

In the model, the different land cover classifications cause the rain water to move across the surface at different speeds. The rates are calculated from actual scientific studies of runoff rates. To compare how fast water runs off each type of land cover, you will run the model four times, each time using a different land cover over the entire surface

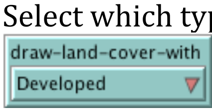
Questions:

Q15. Write a hypothesis about what you expect will happen to the rate of stream discharge when you change the land cover. How will each type of land cover affect stream discharge?

Q16. Will the direction of flow also be affected?

6. To draw land cover onto the model, click the **draw land cover** 

button once. It will turn black.

7. Select which type of land cover you want to draw using the pull-down menu. 

Position your mouse over the aerial photo, hold the mouse button down, and 'paint' the land cover over the entire surface of the model.

8. When you are done editing the land cover, click the **draw land cover** 

button again so it is no longer black.

9. Click the **rain** button to start the model.

10. When the model is finished running click **clear land cover,** then select a different type of land cover and draw it onto the map. DO NOT click **setup**; this will erase your hydrograph.

11. Click **rain** to run the model again. Repeat steps 6-10 for all four types of land cover.

12. When you are finished, right-click on your hydrograph and select **Copy Image**. Open a new Word document and paste your hydrograph into it. Write a note next to your hydrograph that explains which line color corresponds to which type of land cover. **Save** this document.

A hydrograph showing high rates of discharge indicates fast runoff, which means that the rain flowed to the streamgage faster.

Questions:

Q17. Complete the data table on page 71. For each type of land cover, describe the features that affect runoff and include details about the hydrograph: height of the peak(s), how much time (in ticks) passed before the all the water drained, the shape of the peaks. Were they spiky, or short and rounded? What do these characteristics tell you about the speed of runoff? Be sure to include the answers to these questions in your table.

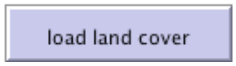
Q18. Which land cover has the fastest runoff? What evidence do you have to support this?

Q19. Which type of land cover has the slowest runoff? What characteristics does this type of land cover have that would slow its rate of runoff?

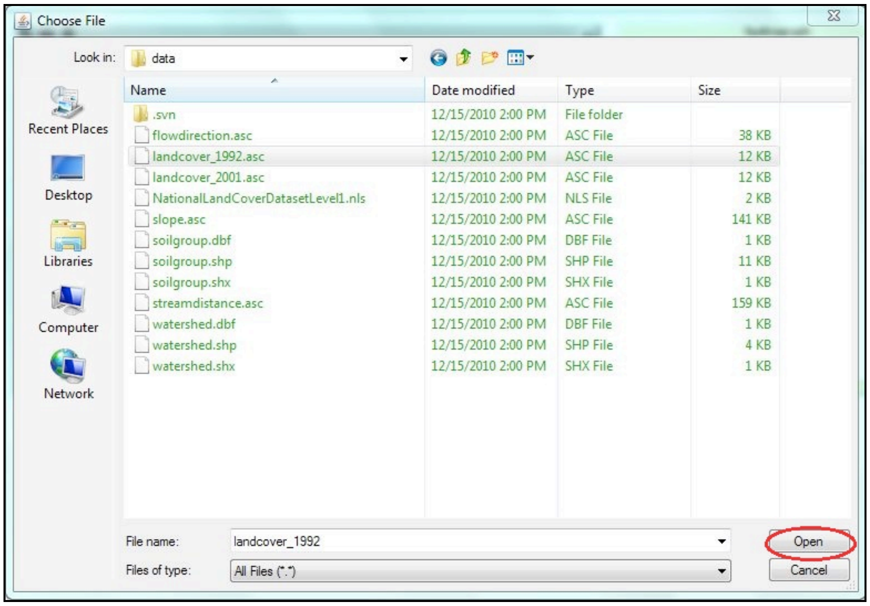
Q20. This model does not incorporate human-made structures, such as sewers, that affect how water moves in developed areas. Yet, it is important to think about how sewers are involved in the water cycle. When rainwater flows into a sewer drain, it does not disappear. Where does it go? Where does it end up?

Part 3: Land Cover Data from 1992 and 2001

Now you will run the model using real land cover data taken ten years apart in this actual watershed in Illinois.

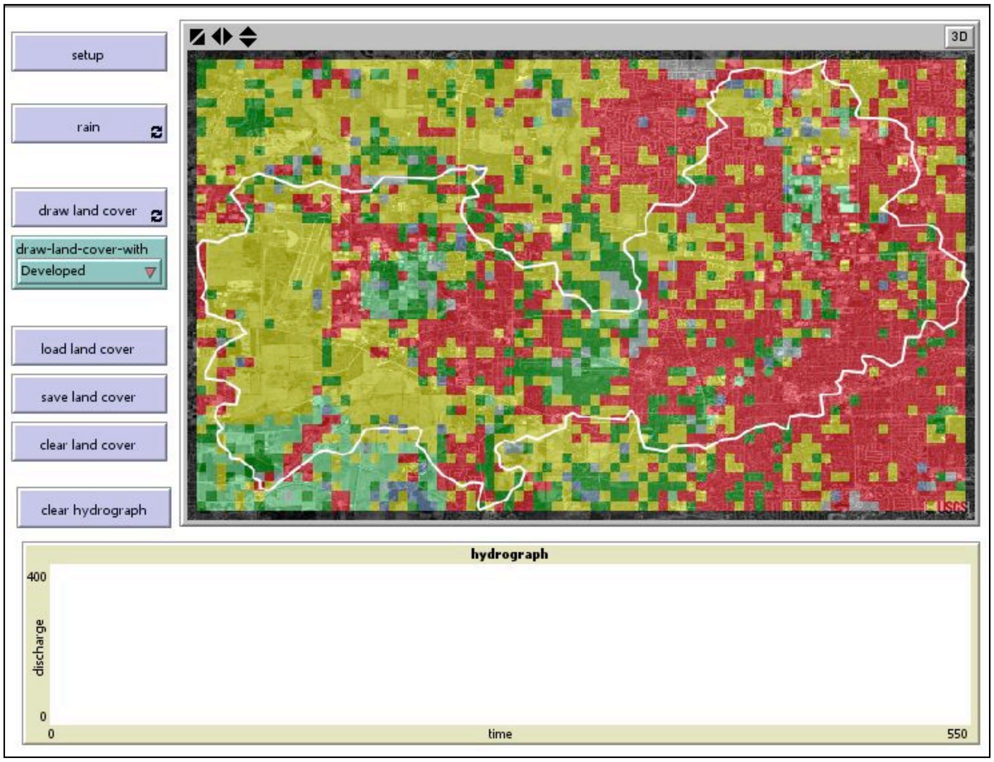
13. Click the **load land cover** 

button. Choose the **data** folder. Choose the file called **landcover1992.asc**. Click **Open**.



This file has the land cover data from 1992.

Your model should look like this:



Q21. Based on the aerial map, estimate the percentage of each category of land cover in 1992. Record your estimates in the data table below.

Land Cover Categories	1992 Land Cover Data	2001 Land Cover Data
Developed	%	%
Agricultural	%	%
Grassland	%	%
Forest	%	%

14. Click **rain** to run the model using the **1992 Land Cover data**.
15. When the model is finished running, right click on the hydrograph produced and select **Copy Image.** Paste this image into the Word document you began in step 13.
16. Repeat step 13, this time selecting the file **landcover2001.asc**. Do not run the model yet.

Questions:

Q22. Complete the data table above for **2001 Land Cover Data**.

Q23. Compare your 1992 and 2001 land cover estimates in the table. Predict how the hydrograph for 2001 land cover will differ from the 1992 land cover hydrograph.

17. Click the **rain** button to run the model using the **2001 Land Cover data**. When the model has finished running, copy and paste the hydrograph into your Word document.

18. **Save** this document, print it out, and attach it to your Student Guide. Make sure to label which line corresponds to which type of land cover in each hydrograph.

Questions:

Q24. How does your prediction in Question 23 compare to the results of this model run?

Q25. How might the change in the land cover affect the watershed and the people who live in it?

Q26. What changes in land cover do you think may have occurred in this watershed from 2001 to today?

Q27. If you could run the model again using current land cover data, what do you think the hydrograph would look like? Think about how this year's hydrograph would be different from the ones created using 1992 and 2001 data.

Land Cover	Map Color	What does this type of land cover look like?	What does the hydrograph look like?	How does this type of land cover affect runoff?
Developed				
Agricultural				
Grassland				
Forest				

Investigating Land Cover and Surface Runoff

Q1. Describe how the water moves across the surface of the model. Does it flow in a straight line or a curve? Does it pool together with other rain?

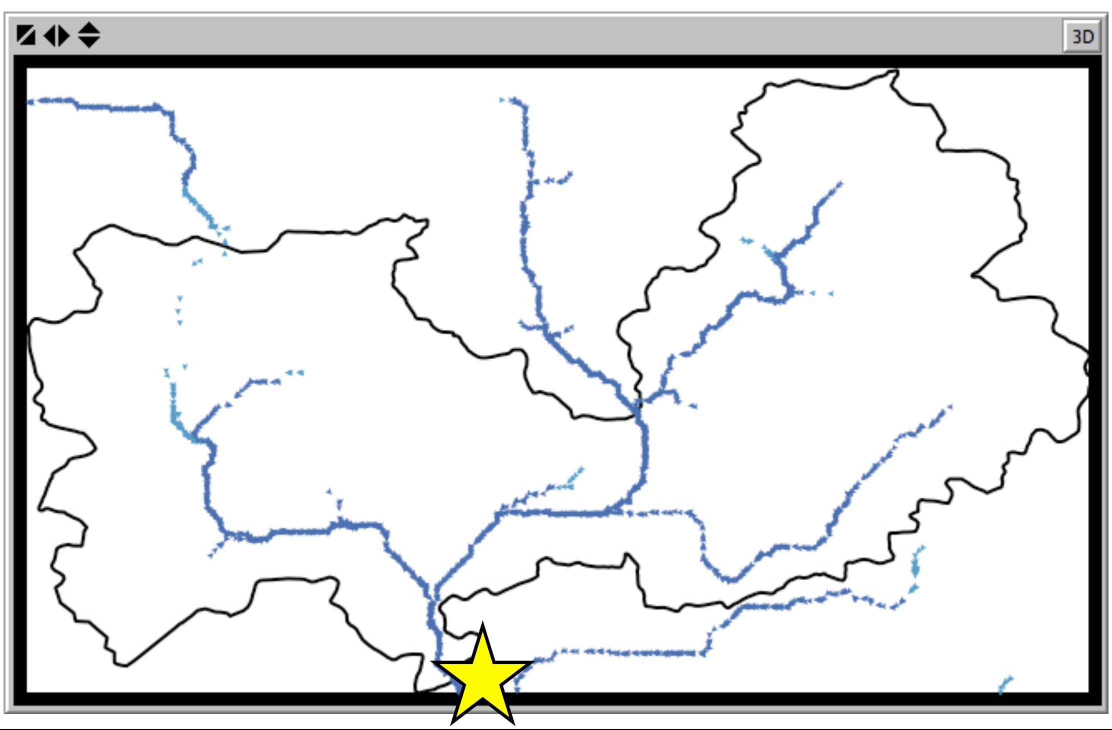
Student answers will vary, but should contain some of these ideas: Water flows from high elevation to low elevation. The water flows together in predictable ways to form streams. The streams come together but do not separate downstream. It the beginning there are a lot of streams, but they flow downhill to a central channel. The water does not stop anywhere on the screen, it flows continuously.

Q2. Based on what you observed in "Building a Watershed Model," what do you think is determining the direction of the water flow in NetLogo?

Elevation. Water flows from high to low elevation.

Q3. On the blank map below, sketch what you observed in the model. Draw the main river channels that formed.

Star is to indicate where students predict the streamgage is. A good approximation should be along the actual river channel, near the bottom of the watershed. The actual gage is at the mouth of the watershed.



Q4. Does the streamgage in the photo above look familiar to you? Have you seen streamgages in your area before?

Student answers will vary.

Q5. Based on your observations and the shape of the hydrograph, where do you think the gage is located within the watershed? You can run the model a few times if it will help you.

Students should put a star near the bottom of the map, where the streams converge just before exiting the watershed. See the map on page 1.

Q6. Put a star on your drawing on page 73 to show where you think the streamgage is located.

Q7. What is the independent variable? On which axis is it located??

The x-axis shows the independent variable. In this case, the independent variable is time. On the NetLogo hydrograph the scale is in ticks, or changes in the model, while in the hydrograph from Chicago, IL, measurements are recorded daily. Students should know that hydrographs always show time along the x-axis.

Q8. What is the dependent variable? On which axis is it located?

The y-axis shows the dependent variable, which in this case is discharge (cfs). On the NetLogo hydrograph discharge is measured in raindrops flowing past a point per tick of the model. While in the second, discharge is recorded in cfs (cubic feet per second).

Q9. Why is knowing how much water is flowing in a stream important for scientists and people like you?

It is important to know how much water is available for human use, or to provide habitats for fish and wildlife. Scientists can assess flood risk based on how much water is in a stream under various conditions. Students may come up with more answers.

Q10. When there is heavy rainfall, what happens to the amount of discharge?

When there is heavy rainfall discharge will rise because more water is entering the stream.

Q11. Which dates on the Chicago, IL hydrograph indicate the highest discharge?

Approximately 4-13-1992, because the graph goes up rapidly indicating a sharp increase in streamflow.

Q12. What do you think **peak discharge** means?

Peak discharge is the highest discharge value on the hydrograph, or the moment when water was flowing the fastest.

Q13. What would the hydrograph look like when there is no water in the stream?

When there is no water in the stream, there is no discharge, so the hydrograph would be flat along the x-axis.

Q14. **Baseflow** is the typical amount of water flowing through a stream when there is not a rain event occurring. What is the approximate baseflow for the Chicago, IL hydrograph? (see page 64)

Approximately 196 cfs because that is the minimum value.

Q15. Write a hypothesis about what you expect will happen to the rate of stream discharge when you change the land cover. How will each type of land cover affect stream discharge?

Student answers will vary, but should include that runoff rates will be slower in undeveloped (forest, grassland) land than developed land.

Q16. Will the direction of flow also be affected?

No. Elevation controls the direction of flow and that is not being changed. Student answers may vary, as this is a prediction.

Q17. Complete the data table on page 71. For each type of land cover, describe the features that affect runoff and include details about the hydrograph: height of the peak(s), how much time (in ticks) passed before the all the water drained, the shape of the peaks. Were they spiky, or short and rounded? What do these characteristics tell you about the speed of runoff?

Q18. Which land cover has the fastest runoff? What evidence do you have to support this?

Developed land has the fastest runoff. The hydrograph is narrowest, indicating that the water moved into the streams and left the watershed fastest.

Q19. Which has the slowest? What characteristics does this type of land cover have that would slow its rate of runoff?

Forest. It has the widest hydrograph.

Q20. This model does not incorporate human-made structures, such as sewers, that affect how water moves in developed areas. Yet, it is important to think about how sewers are involved in the water cycle. When rainwater flows into a sewer drain, it does not disappear. Where does it go? Where does it end up?

Water that flows into storm drains eventually reaches a nearby body of water, such as a bay or a river. How long it takes for the water to travel this distance depends on if it is routed to a wastewater treatment plant or if it travels directly to an outflow. This question is designed to help students realize the function and importance of sewers and stormwater flow to the water cycle.

Q21. Look at the 1992 data and estimate the percentage of each category of land cover in 1992. Fill in your predictions for 1992 in the data table below.

Land Cover Categories	1992 Land Cover Data	2001 Land Cover Data
Developed	30 %	70 %
Agricultural	50 %	10 %
Grassland	10 %	10 %
Forest	10 %	10 %

Q22. Complete the data table for **2001 Land Cover Data**.

See table above.

Q23. Compare your 1992 and 2001 land cover estimates in the table. Predict how the hydrograph for 2001 land cover will differ from the 1992 land cover hydrograph.

Students should predict that the hydrograph will have a higher peak and the water will exit the watershed faster in 2001 because it has more developed land.

Q24. How does your prediction in Question 23 compare to the results of this model run?

Student answers will vary with their predictions.

Q25. How might the change in the land cover affect the watershed and the people who live in it?

As the watershed becomes more developed, the streams are likely to fill with water sooner after a storm. This can make flooding more likely which could be dangerous for the people who live in the watershed, particularly those who live near the river.

Q26. What changes in land cover do you think may have occurred in this watershed from 2001 to today?

Student answers will vary.

Q27. If you could run the model again using current land cover data, what do you think the hydrograph would look like? How would this year's hydrograph be different from the ones created using 1992 and 2001 data?

Student answers will vary, but should include a prediction that the hydrograph will have an even more "spiky" appearance than the hydrographs from 1992 and 2001. If this is not the case, students should provide a logical reasoning for their prediction.

Land Cover	Map Color	What does this type of land cover look like?	What does the hydrograph look like?	How does this type of land cover affect runoff?
Developed	*red*	*Land that has houses, buildings, parking lots, roads covering the ground.*	*The hydrograph peaks sharply and drops back down quickly. This shows that there is one large pulse of runoff into the stream, not a sustained flow.*	*Developed land is made of surfaces that do not absorb water (they are impervious) so the water flows very quickly across them and into the streams. This is the fastest of the 4 classifications.*
Agricultural	*yellow*	*Land that has been converted to farmland for crops or grazing animals.*	*This hydrograph has slightly smaller peaks than the hydrograph for developed land and they are more rounded.*	*Agricultural land has crops or grass for animals to graze on so it slows the rate of runoff. This land is sometimes heavily modified and so water might flow quickly across it, depending on these changes. Water moves slower than developed land, but faster than grassland or forest.*
Grassland	*Light green*	*Prairie grassland or empty fields. Places that are in the natural state but have low-lying vegetation.*	*This hydrograph has smaller peaks than the agricultural hydrograph and they are rounder still. These peaks are bigger than those from the forested hydrograph.*	*Grassland provides resistance for the water and absorption into the soil. When it rains, some of the water sinks into the ground and does not flow to the streams at all because the grass uses it. Also, the grass can slow the rate of overland flow by getting in the way.*
Forest	*Dark green*	*Wooded land that has trees as well as low vegetation.*	*The hydrograph for forested land has the smallest peaks of these land cover types.*	*Trees and shrubs use a lot of the water and the uneven surface of the forest floor provides resistance to flow. Forest has the slowest runoff rates but is only a little slower than grassland.*

Analyzing Hydrographs

Purpose

After an introduction to hydrographs during the NetLogo Activity, students will look more critically at hydrographs. They will examine real hydrographs and explore how local land cover contributes to specific hydrograph shapes.

Overview

In this activity, students will practice interpreting hydrographs. They will look for specific data points and find extreme events. Students will learn that patterns in the hydrograph can indicate certain features about the surrounding landscape. Hydrograph 1 familiarizes students with reading a hydrograph and describing features such as maximum and minimum discharge. They are also introduced to the term 'baseflow.' Hydrograph 2 shows data from the 2008 flood in Cedar Rapids, Iowa. A link to a YouTube video of aerial footage of the city during the flood can be found in the Teaching Notes below. Hydrograph 3 shows data from two rivers: the Des Plaines and the Kankakee. Students are asked to compare hydrographs from these two rivers and provide a logical explanation for the apparent differences based on what they have learned thus far.

Student Outcomes

- Students will understand that hydrographs show change in discharge over time.
- Students will understand that hydrographs have discernable patterns.
- Students will understand that information about land cover can be determined from hydrographs.

Time

One 50-minute class period

Level

Secondary earth/environmental science (9-12)

Materials and Tools

- Student Guide
- Copy of New York Times article: *In Eastern Iowa, The City That 'Would Never Flood' Goes 12 Feet Under.*

Prerequisites

- GLOBE Watershed Dynamics Human Impact Activity 1: "Philadelphia Tackles Rainwater Runoff Pollution" podcast
- Activity 2: Building a Watershed Model
- Activities 3a-b: Streamflow Lab and Virtual River
- Activities 4a-b: Just Passing Through and Infiltration Protocol (optional, but recommended if outdoor space permits)
- Activity 5: NetLogo Runoff model

Background

Students should already know that land cover affects surface runoff and that changes in surface runoff cause changes in stream discharge rates. Students should be familiar with hydrographs and understand that hydrographs show rates of streamflow (in discharge) over time.

Teaching Notes

To avoid students having to read the article during class, you can give the students the article to read for homework the previous night. They can also answer the four questions about the article on page 4 before coming to class. This can lead to a class discussion.

Students can watch a Youtube video, "Aerials of Cedar Rapids Iowa during Flood of 2008," accessible online at: http://www.youtube.com/watch?v=4v4DxnTsucM&feature=related

The New York Times
June 13, 2008

In Eastern Iowa, the City That 'Would Never Flood' Goes 12 Feet Under

By CHRISTOPHER MAAG

http://www.nytimes.com/2008/06/13/us/13flood.html?th&emc=th#

Scott Olson/Getty Images

Volunteers placing sandbags along a road Thursday in Cedar Rapids, Iowa. About 8,000 people had evacuated their homes, and 5,500 were without electricity.

CEDAR RAPIDS, Iowa — They said this city would never flood. They talked about 1993, and 1966 and 1851, years when the Cedar River swelled and hissed but mostly stayed within its banks. They thought they were safe. They were wrong.

Cedar Rapids is experiencing the worst flooding in the city's history. And the water is still rising. By Thursday afternoon, the Cedar River was about 29 feet deep, or 17 feet above flood stage, according to the National Weather Service. The water was expected to rise another three feet by Friday morning, and reach a record crest, 12 feet higher than the previous record, set in 1851.

"Usually if you break a record, you only do it by an inch or two," said Jeff Zogg, a hydrologist for the Weather Service in Davenport, Iowa. "But breaking it by six feet? That's pretty amazing."

The white T-shirt worn by Chuck Johnson, 56, was soaked to the neckline Thursday after he waded through floodwaters to his house to retrieve garbage bags packed with clothes. "We all thought this was a good place to live because it would never flood," Mr. Johnson said.

The pain will not end anytime soon. With heavy thunderstorms rolling in Thursday evening, and more rain predicted for the weekend, flood waters were expected to remain high for at least the next seven or eight days, said Dave Koch, spokesman for the Cedar Rapids Fire Department.

“We’ve got serious problems,” said Justin Shields, a Cedar Rapids City Council member. “And we’ve got a long way to go yet.”

Most of downtown Cedar Rapids was underwater. That includes City Hall, the county courthouse and jail, all of which, in acts of civic hubris, were built on an island in the middle of the river.

“Well, the island is part of the river now,” said Mike Goldberg, the administrative services director for Linn County.

About 8,000 people have evacuated their homes, Mr. Koch said. And 5,500 were without electricity. Those whose power has been lost should expect to go without for a week or more as utility companies struggle to prevent further damage to their critical infrastructure, said Scott Drzycimski, a spokesman for Alliant Energy.

Power failures reduced the local water treatment plant to 25 percent of its capacity. At 6 p.m. Thursday, emergency management officials announced that Cedar Rapids residents were required to reduce their water use to drinking water only until further notice.

“We’ve lost most of the battles at this point,” Mr. Goldberg said. “At this point we’re just waiting for the water to crest so we can get started on recovery efforts.”

Railroad cars filled with rock ballast were parked atop a bridge just south of downtown to try to prevent the river from carrying the span away. By Thursday morning, the bridge lay toppled on its side, white water rushing over its girders. Volunteers and city workers filled sandbags for two days to build up an old levee on the northwest side of the city, Mr. Koch said. They succeeded in raising the height of the wall almost four feet, but on Thursday afternoon it was already two feet underwater.

Michelle Hilton held back tears as she walked from her mother’s house on 19th Avenue Southwest. When she first left the house, at 11 a.m. Thursday, brown water was lapping at the edge of the backyard. By 3:30 p.m., the basement was inundated and the weight of the water had cracked the foundation.

She hoped the water would just stop rising. When told that it would not, she started to cry.

“This is the house I grew up in,” said Ms. Hilton, 46. “I never thought I’d see anything like this. Never. Never.”

When Roger Nielson started packing his belongings into his car on Tuesday, he said, people on his block stood in their yards and laughed at him. As recently as Wednesday, his neighbor was mowing the grass.

When Mr. Nielson left for the last time Thursday, the water on the first floor was almost up to his knees. The river had another 11 feet to rise. “We were the lucky ones,” said Mr. Nielson, 40. “We got out.”

Jim Hovind’s house stood across the street from the Cedar River since 1890. The last time he saw it, water was pouring in the front door. “It got really scary,” said Mr. Hovind, 48. “We were the only ones left in the neighborhood.”

Demenick Ankum drove to his house on 19th Avenue to save anything he could. By the time he finished packing, his car was underwater. He had to pay a neighbor, Louie Brundidge, $10 to rescue him from the house in Mr. Brundidge’s red aluminum boat.

All that Mr. Ankum could carry with him was one blue plastic tub of clothes and a few framed photos of his children. Everything else was gone.

“I never even thought about flood insurance,” said Mr. Ankum, 33. “They said this place would never flood in 500 years.”

Steve Pope/Associated Press

Downtown Cedar Rapids was inundated by the raging Cedar River on Thursday. Heavy rain continued to pound parts of Iowa.

Name: ______________________________ Date: __________ Class: ____________

Analyzing Hydrographs

Red River of the North 1897-1997. Left: A man canoes down a flooded street in Fargo, North Dakota, 1897. Right: The Sorlie Bridge outside of Grand Forks, ND during the 1997 flood. Photos courtesy of the North Dakota Water Science Center

Introduction

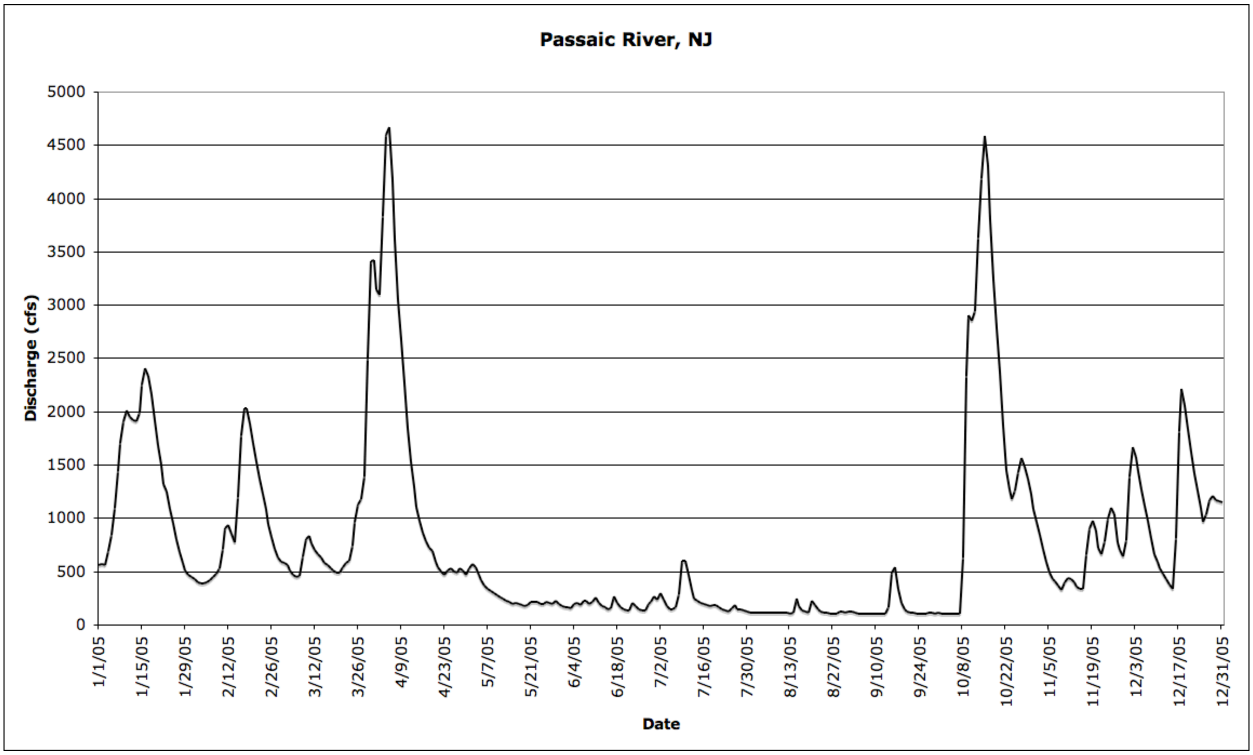
The Red River of the North flows along the border between North Dakota and Minnesota and continues its northerly route all the way to Lake Winnepeg in the Canadian province of Manitoba. In total, this river is 550 miles long- it's the longest northwards-flowing river in the United States. The Red River of the North is prone to flooding. It has reached flood stage more than a dozen times since the USGS first installed streamgages in 1901.

Why does the river flood so often and so dramatically? There are a few explanations: some of them have to do with the shape of the landscape and others are related to weather patterns. This river travels along a very shallow slope in a relatively shallow riverbed, which makes it easy for the water to overflow its banks—there are no steep walls to contain the river when it is running higher than normal. In fact, the region where this river basin lies is actually one of the flattest places in the world. Flooding along this river can happen during spring or summer. Regardless of when it occurs, flooding here is caused by higher-than-normal precipitation and frozen or saturated soil that does not allow rain or snowmelt to infiltrate.

Hydrologists – scientists who study how water flows – use hydrographs to analyze flood events like the ones in the photos above. (Remember, a **hydrograph** is a graph showing changes in the discharge of a river over a period of time.) Hydrographs can give you a lot of information about streamflow, seasonal precipitation patterns, and the frequency of droughts, floods, and other extreme events. Previously in this unit, you created hydrographs from data in your NetLogo Runoff model. In this activity you will practice interpreting hydrographs from four different rivers.

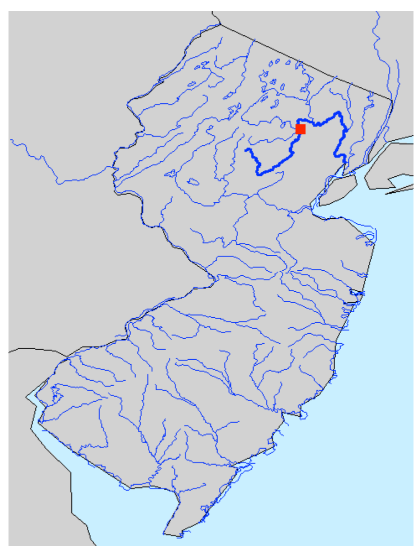
Hydrograph 1: Passaic River, New Jersey

This is a real hydrograph taken from the Passaic River at Pine Brook, New Jersey, for the year 2005.



Below is a picture taken on the Passaic River during the summer of 2005. There is also a map so you can see where the stream gage is located along the river. The dark blue line shows where the Passaic River flows. The red dot is where the stream gage is.

On the river. June 19, 2005.
http://flickr.com/photos/sean808080/20442359
/



Questions:

Q1. Identify the independent and dependent variables and where they can be found on the hydrograph.

Q2. What range of dates does this graph include?

Q3. What unit is used to measure discharge?

Q4. On the graph above, circle all of the peaks where the discharge is greater than 1500 cfs. What do these represent?

Q5. What was the highest discharge in the Passaic River at this gage? When did it occur?

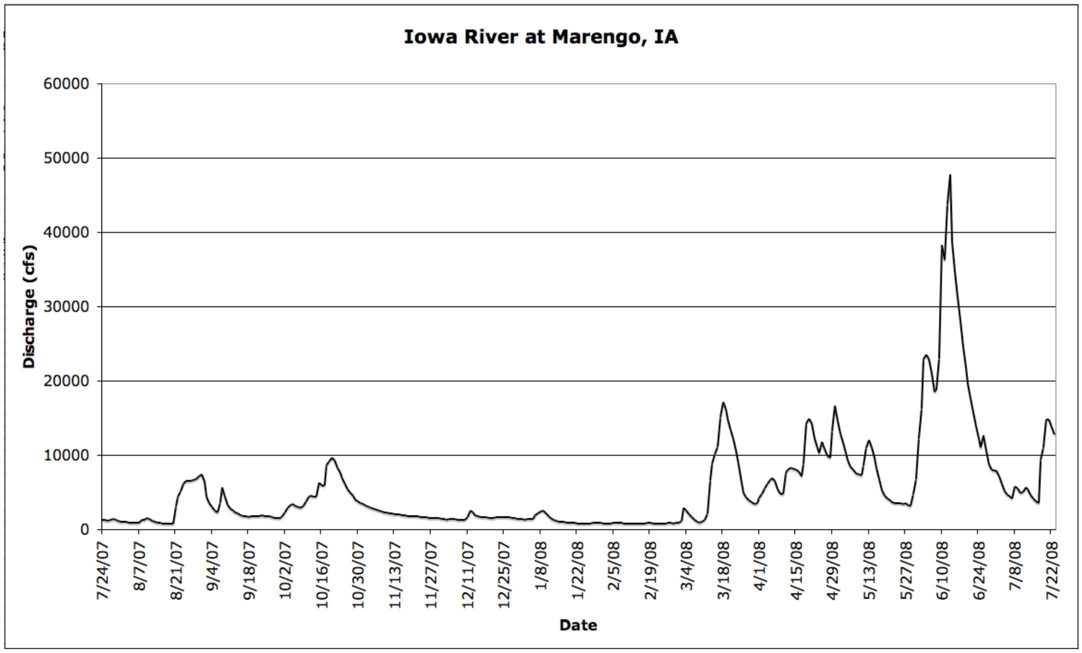
Q6. In what season did the Passaic River have the lowest discharge?

Q7. What direction is the Passaic River flowing? How do you know?

Notice in the hydrograph above that there is no time at which the discharge measurement is 0.0 cfs. Remember that in the hydrograph in the Netlogo model, you did see a discharge measurement of 0.0 cfs. This occurred when all the water left the watershed. Many streams and rivers will continue to have measurable discharge amounts even when there has been no recent precipitation. This is called **baseflow:** basically it is the typical flow of a stream or river not related to a precipitation event.

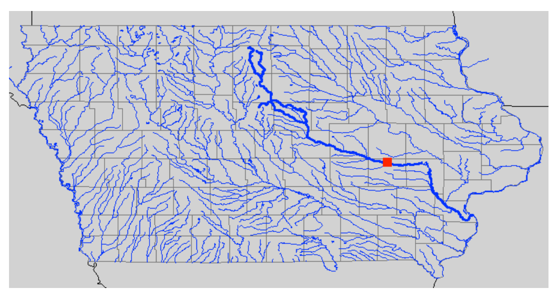
Q8. What do you think the source for baseflow is when there is no recent precipitation?

Hydrograph 2: Iowa River, Iowa



Read the NY Times article about flooding in Cedar Rapids, Iowa: "In Eastern Iowa, the City That 'Would Never Flood' Goes 12 Feet Under"

The article you read is about the Cedar River in Cedar Rapids, Iowa. The Cedar River stream-gage was so flooded that it could not take measurements. The hydrograph above was taken from a stream gage on the Iowa River in Marengo, Iowa. Marengo is only 30 miles southwest of Cedar Rapids.



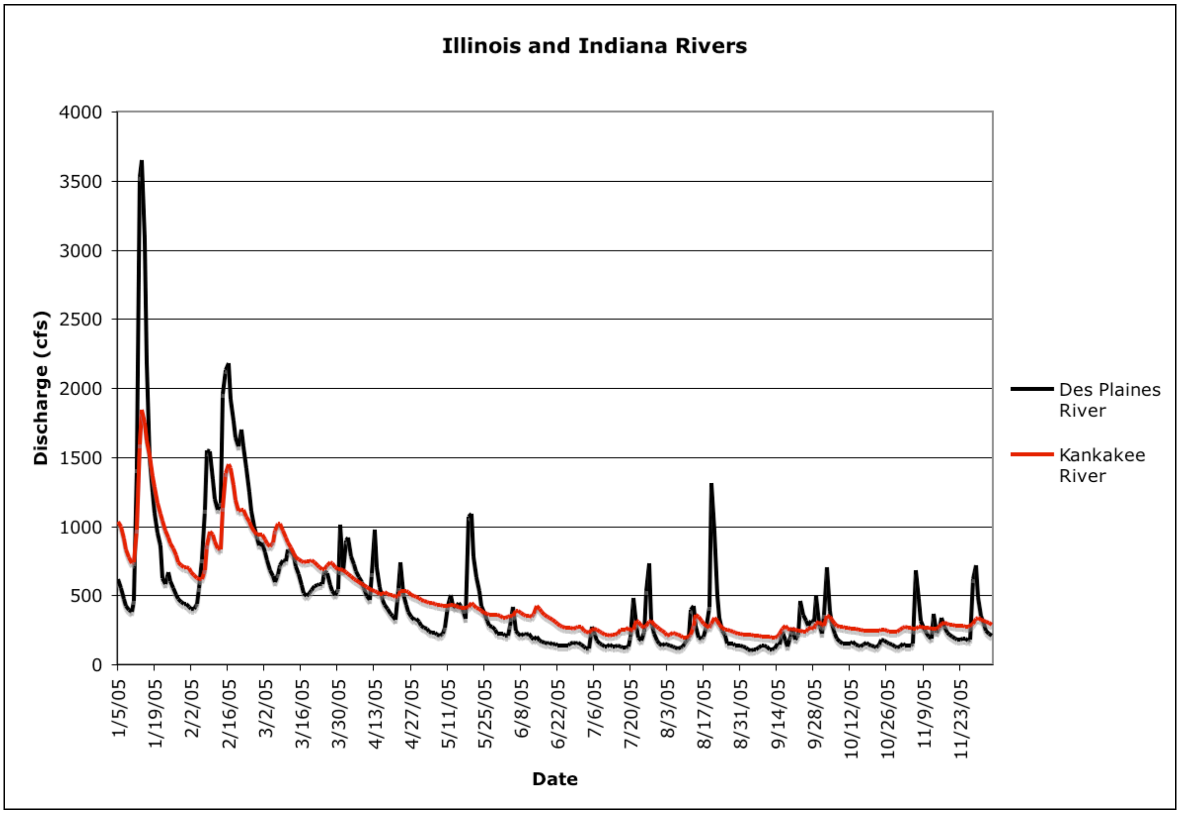
Questions:

Q9. What range of dates does this graph include? When was the news article written?

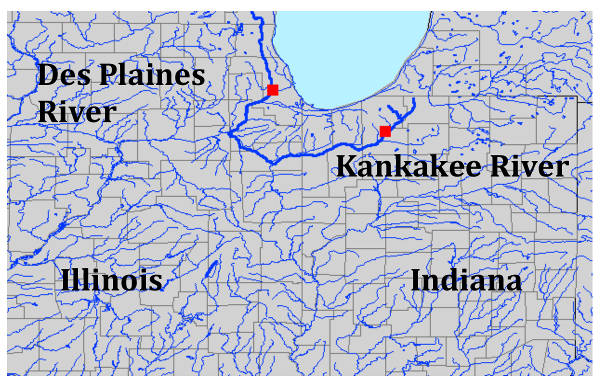
Q10. How much higher is this flood level than the previous record level? What year did the previous record occur? Find the date the article was written about the flood. What part of the hydrograph corresponds to this date?

Hydrograph 3: Des Plaines River, Illinois, and Kankakee River, Indiana

This hydrograph shows two different gages on rivers near one another in Illinois and Indiana. The black line shows the Des Plaines River, while the red line shows the Kankakee River. The two rivers are about the same size and near one another geographically, but have very different responses to storms.



The map on the right shows where the gages are in relation to one another. The streams meet in Illinois and eventually flow together into the Mississippi River.



Q11. Complete these predictions:

The land cover around the Des Plaines River is ____________________ and I know this from the hydrograph because:

____.

The land cover around the Kankakee River is ________________________ and I know this from the hydrograph because: ____.

These pictures are of the Des Plaines River (left) and the Kankakee River (right).

	
Kappel, Michael. Joliet Des Plaines River 3. June 1, 2008. http://flickr.com/photos/m-i-k-e/2542497603/	Kankakee Carl. Kankakee River Scene 012. May 17, 2008. http://flickr.com/photos/carlclub/2500238548/

Questions:

Q12. How are the Des Plaines River and Kankakee River hydrographs similar? For example: Do they show the same storm events on the same dates?

Q13. Give the dates of the 2 largest storms.

Q14. Describe differences between the two hydrographs. Be specific.

Q15. Why do you think the Kankakee River has a much smoother graph? Explain.

Q16. What do the peaks on the hydrograph tell you about the speed of surface runoff flowing into a stream? What is happening to the water when the hydrograph shows a straight line?

Q17. Based on what you saw in the NetLogo Runoff model, can you make any predictions about what might be different between the land cover in these 2 areas?

Analyzing Hydrographs

Hydrograph 1: Passaic River, New Jersey

Q1. Identify the independent and dependent variables and where they can be found on the hydrograph.

Date, a measure of time, is the independent variable and it is located on the x-axis. Discharge, in cfs, is the dependent variable and it is measured on the y-axis.

Q2. What range of dates does this graph include?

January 1, 2005 – December 31, 2005

Q3. What unit is used to measure discharge?

cfs or cubic feet per second

Q4. On the graph above, circle all of the peaks where the discharge is greater than 1500 cfs. What do these represent?

These represent major rain/storm events. Students should have six circles on their graphs.

Q5. What was the highest discharge in the Passaic River at this gage? When did it occur?

4670 cfs on April 5, 2005. Students should come up with a value between 4500-5000 cfs around April 5, 2005.

Q6. In what season did the Passaic River have the lowest discharge?

Summer had the lowest mean-average discharge rates, but the discharge stayed low through the beginning of fall.

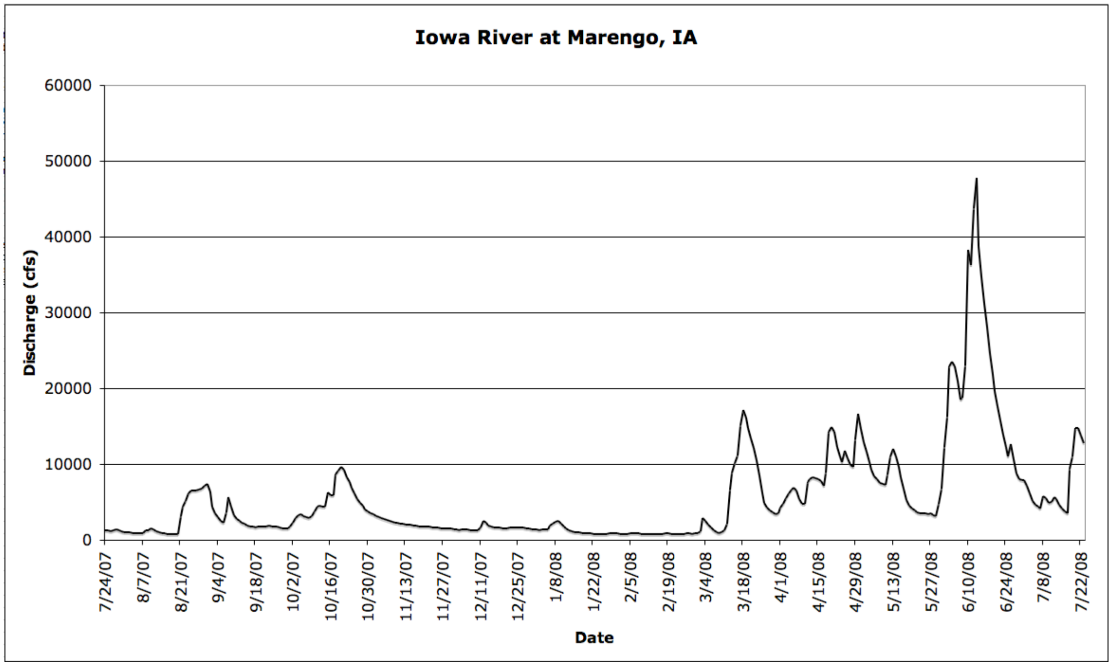
Q7. What direction is the Passaic River flowing? How do you know?

It is flowing to the east. All water flows towards the oceans (sea level). You can see this on the map.

Q8. What do you think the source for baseflow is when there is no recent precipitation?

Student answers will vary. Rivers upstream in the watershed may flow into this stream, snow may melt into the river, and groundwater may contribute to this river when there has been no recent precipitation.

Hydrograph 2: Iowa River, Iowa



Q9. What range of dates does this graph include? When was the news article written?

The graph range is July 24, 2007 – July 24, 2008, the axis ends at July 22, 2008, which would also be a reasonable answer.
The news article is from June 13, 2008.

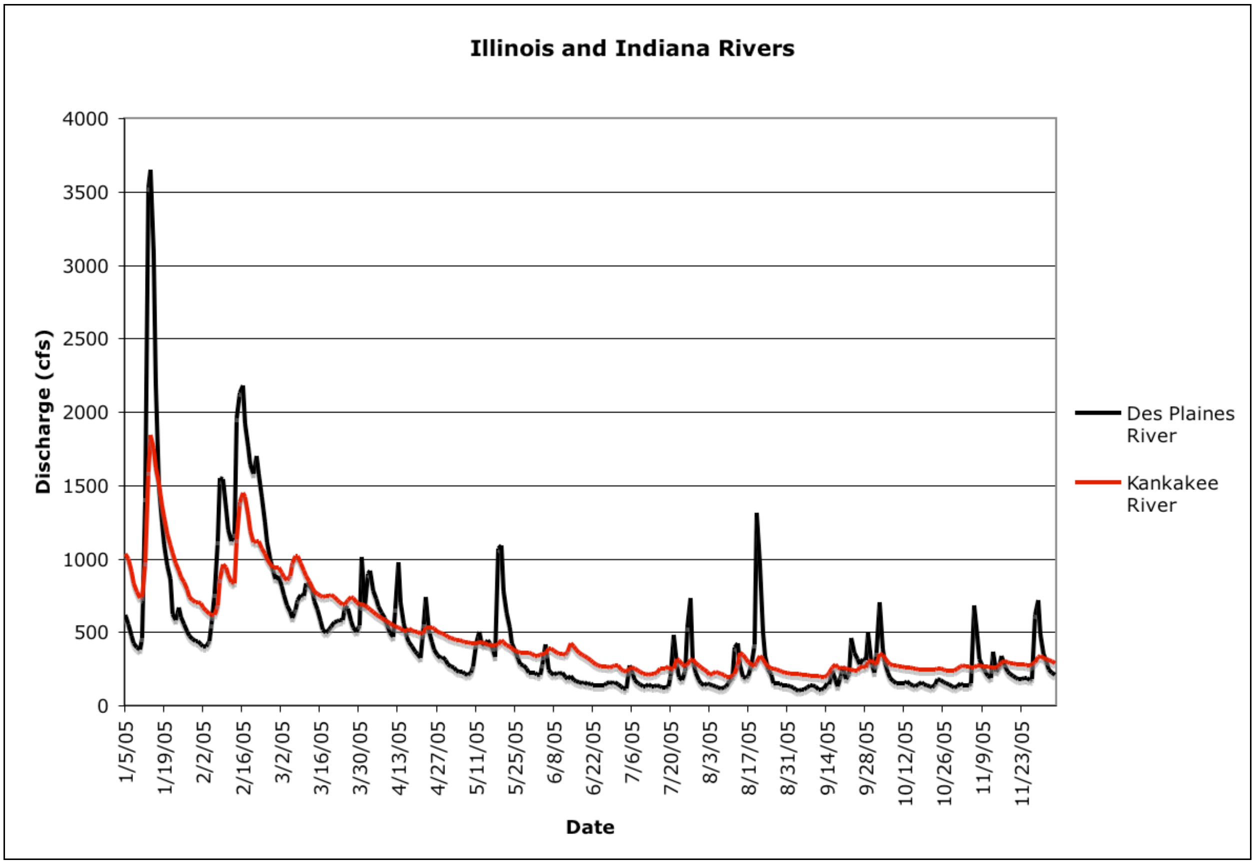
Q10. How much higher is this flood level than the previous record level? What year did the previous record occur? Find the date the article was written about the flood. What part of the hydrograph corresponds to this date?

The river peaked 12 feet higher than the previous record, which was set in 1851. The highest value on the graph (peak discharge) occurred around the same date as the article.

NOTE: This article uses "feet above flood stage" as their unit of measure. Flood stage is a river height (or depth) when there is enough water to overflow the banks of the river. When measuring streams this way, it is sometimes referred to as gage height. These *measurements are another way to measure the volume of water in a river and are closely related to discharge.*

Hydrograph 3: Des Plaines River, Illinois, and Kankakee River, Indiana

This hydrograph shows two different gages on rivers near one another in Illinois and Indiana. The black line shows the Des Plaines River, while the red line shows the Kankakee River. The two rivers are about the same size and near one another geographically, but have very different responses to storms.



Q11. Complete these predictions:
The land cover around the Des Plaines River is *developed* and I know this from the hydrograph because *the graph is not smooth and very spiky*

The land cover around the Kankakee River is *agricultural* and I know this from the hydrograph because *the graph is much smoother and does not have extreme spikes like the Des Plaines.*

Q12. How are the Des Plaines River and Kankakee River hydrographs similar? For example: Do they show the same storm events on the same dates?

The two hydrographs show similar mean-average discharge rates and often have peaks on the same dates.

Q13. Give the dates of the 2 largest storms.

Around 1/15/05 and 2/16/05

Q14. Describe differences between the two hydrographs. Be specific.

The Des Plaines shows spikier peaks and has a greater range from baseflow to peak discharge. The Kankakee has wider peaks, indicating a gradual rise and fall in discharge.

Q15. Why do you think the Kankakee River has a much smoother graph? Explain.

The Kankakee River has a much smoother graph because the land around it is not developed. Water is absorbed into the substrate more and does not runoff quickly into the river which would produce a much spikier graph.

Q16. What do the peaks on the hydrograph tell you about the speed of surface runoff flowing into a stream? What is happening to the water when the hydrograph shows a straight line?

When the hydrograph shows a straight line, the streamgage is recording a constant rate of flow in the stream or river.

Q17. Based on what you saw in the Netlogo Runoff model, can you make any predictions about what might be different about land cover in the 2 areas?

The Des Plaines River likely has more developed land around it than the Kankakee River.

How Does Land Cover Change Affect Stream Discharge?
A FieldScope Investigation

Purpose
For students to explore the relationship between land cover and stream discharge in a watershed of their choice by manipulating FieldScope, an online GIS tool.

Overview
Students will begin by reading a supplementary online article about Urban Sprawl and listening to a podcast about USGS streamgages. They will collect stream discharge data from USGS streamgages in 1992 and then how land cover changed between 1992 and 2001. They will use this data to hypothesize how stream discharge will have changed between 1992 and 2001. Students will then use FieldScope to collect USGS streamgage data from 2001 and compare their results to their hypothesis. They will conclude the activity by reading information on climate change in their region and predict how it is likely to affect stream discharge in the future.

Student Outcomes
- Identify what types of land cover encompass the selected watershed
- Use a GIS tool, FieldScope, to determine changes in land cover and compare to changes in stream discharge
- Analyze hydrographs for patterns.
- Make predictions about how streamflow may change with further land cover modifications.
- Understand that environmental research may have confounding variables and some may not be addressed in this investigation.

Time
3 50-minute class periods

Level
Secondary earth/environmental science (9-12)

Materials and Tools
- Computers with internet access to: http://wd2.fieldscope.us/ (1 computer for each student recommended)

Preparation

- Schedule time in the computer lab; the entire FieldScope activity is available online. No Student Guides are necessary.
- Create student logins for each student in the teacher dashboard.

Background

Students should be familiar with the concept of surface runoff and how it is affected by land cover. Students should also understand the concept of stream discharge and how to measure stream velocity.

Prerequisites

- GLOBE Watershed Dynamics Human Impact Activity 1: "Philadelphia Tackles Rainwater Runoff Pollution" podcast
- Activity 2: Building a Watershed Model

Teaching Notes

The FieldScope investigation may be used as the culminating activity for Module 2 of Watershed Dynamics or it may be completed in sections as students progress through Module 2.

Selecting good study sites: Teachers should work with students at the beginning of the investigation to help them identify what makes a good area of interest. This could be encouraging them to read articles about sprawl, thinking about places they have heard of or visited, or using their own watershed to promote a sense of place.

Throughout the Lab Journal there are questions marked with ***stars*** that indicate they are synthesis questions. These questions are important places for students to summarize their knowledge and may be used in class discussions after the investigation is completed.

In particular, students should recognize at the end that this investigation is a research project in which some variables are not directly addressed. They should identify ways in which this investigation simplifies certain parts of the water cycle and not discount their importance.

The article "Urban Sprawl" (Activity 7a) may be used as an introduction to this investigation. Reading comprehension questions have been embedded in the text. See the related Teacher Overview document for the answer key.

Troubleshooting FieldScope: If you are experiencing difficulties using FieldScope, consult 'FieldScope Troubleshooting Guide.docx.'

FieldScope Dashboard Guide

Please note: The Dashboard and LabJournal Library are under active development, and this guide reflects their current state. Over the coming months, functionality may be added or removed and the layout may change. If you see any bugs, or have any suggestions for improvement, please contact us at osep@northwestern.edu. Thank you for your patience.

Go to: http://www.fieldscope.org/labjournal/login

Enter your username and password provided at the Professional Development

For future reference, record your…

Username: ______________________________

Password: ______________________________

Click the Log In button.

You will now be at: http://www.fieldscope.org/labjournal/dashboard/

Your username is in the top right of the screen next to the Logout option. There are three areas of interest in the main page.

The **Students** area is where you can get a quick look at all student progress and where you can click on each student to see their Lab Journal Responses. You will see more of this after you add students.

Groups allow you to group your students/users in multiple ways. You can create groups by class, by reading level, by differentiation strategy, or any other way you choose to organize your students. One student can be in multiple groups. This will allow you to organize your students by a variety of strategies.

The section titled "**Lab Journals**" allows you to browse, create, and edit Lab Journals. You have one lab journal available currently. You can view this Lab Journal, but do not edit it.

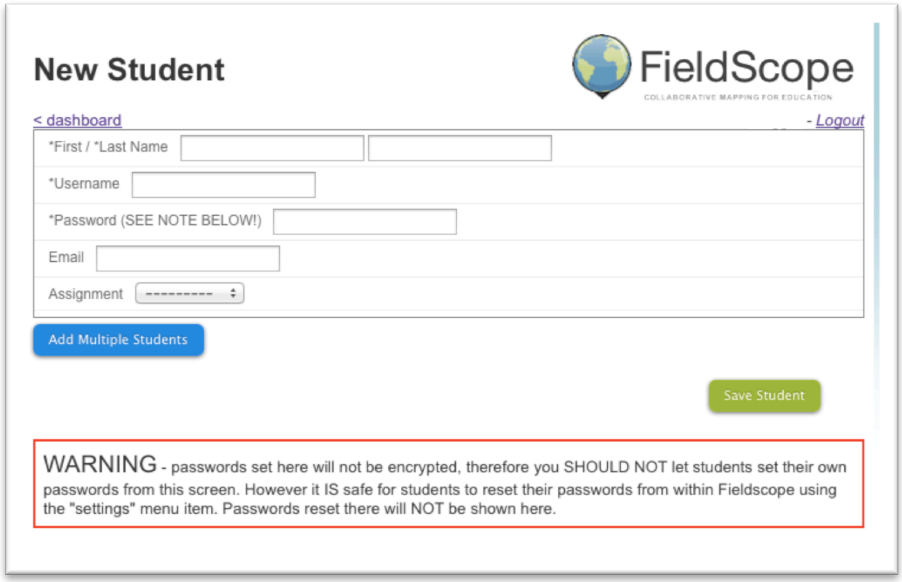
Use this guide to learn how to:

- Create Student Accounts and Groups
- Subscribe to a Lab Journal from the Library
- Create your own Lab Journal
- Review Student Work

If you need to create additional teacher accounts, fill out the Teacher Account request form at: http://www.fieldscope.org/labjournal/teacher/new. You will receive an email with a confirmation link; follow the directions in the email and you should be all set.

Create Student Accounts

Clicking the blue plus sign next to "Students" will take you to this page. You may enter multiple students at once on this page with the button "Add Multiple Students."



Enter a username and a password for the student.

You do not need to record student usernames and passwords as you create them. Once you are done creating students, use the blue "Print Passwords" button on the main Dashboard page to print out a list of student usernames and passwords formatted for cut-out strips.

You may also add the student's email address and assign them to a specific Lab Journal using this form. Note that you will need to subscribe to a Lab Journal (see p. 97) before you can assign it to your students.

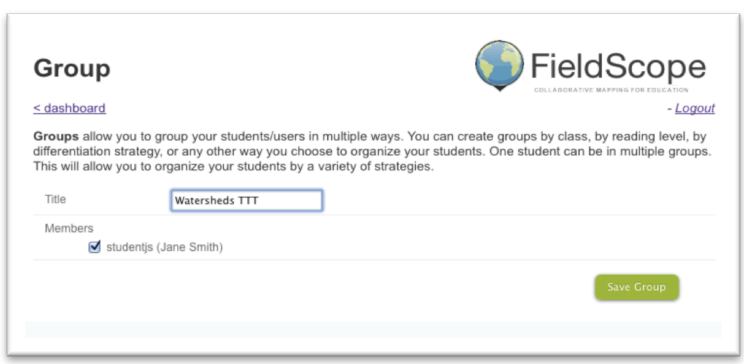
NOTE: Students will only be able to change the passwords if you enter an e-mail address.

When you have made your changes, click Save Student.

Repeat these steps until you have created student accounts for your entire class.

Create Groups

Select the blue plus sign next to "Groups."



On the next page, enter the name of the group where prompted.

Use the checkboxes next to your students' names to assign students to the new group. One student may be assigned to multiple groups.

When you are done, click "Save Group."

NOTE: you cannot add more than one group without returning to the dashboard first.

Repeat this process until you have created all the groups you want. To add students to a group at a later date, select the edit link next to the name of the group on the Dashboard homepage. On the Group page, use the checkboxes to assign specific students.

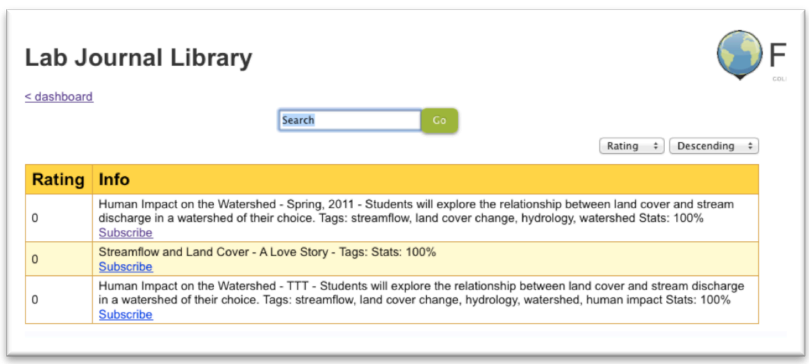
Click "Save Group" when you are done.

Subscribe to an existing Lab Journal

When you first make your teacher account, no Lab Journals will appear in your Dashboard. You must first subscribe to one in the Library or create your own.

To subscribe to an existing Lab Journal, select the "Library" button in this window.

Use the Search window to find a Lab Journal on a specific topic, or browse through the list that appears here. You can see titles and a brief description of each investigation, as well as a list of relevant subject tags.



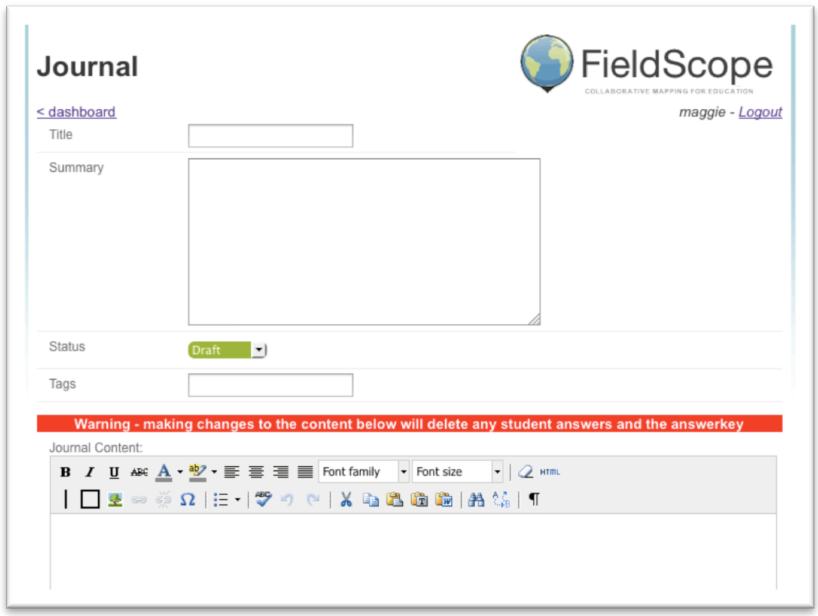
To sort the Lab Journals by popularity, use the white "Rating" button on the right-hand side of the page. You may choose to sort by descending or ascending rating.

Use the "Subscribe" button to store a copy of a particular Lab Journal in your Dashboard.

You will not be able to edit a Lab Journal you did not author; however, you may copy the contents into the editor (see next page), modify it, and save it with a new title.

Create a new Lab Journal

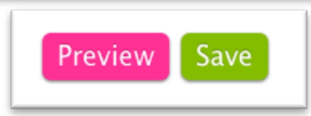
On the main page of the Dashboard, select the blue plus sign next to "Lab Journals." This will take you to a content editor like the one below.



Give your new Journal a title and provide a short summary of its objectives. Leave the status as "Draft" until it is completed and you are ready for it to be public.

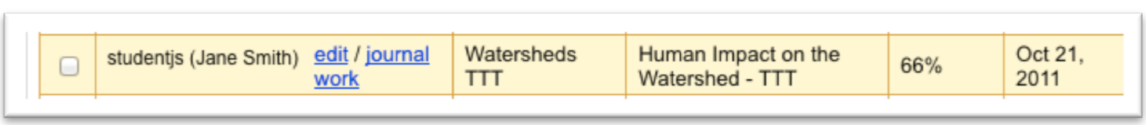
Save your draft often. You may preview what your Lab Journal will look like in FieldScope using the pink button at the bottom of the window.

NOTE: You may assign a Journal to your students while it is still in "Draft" format; however, you will not be able to make changes to the body of the Journal once it has been assigned to students. Doing so will erase any completed student work and the answer key if you have created one.



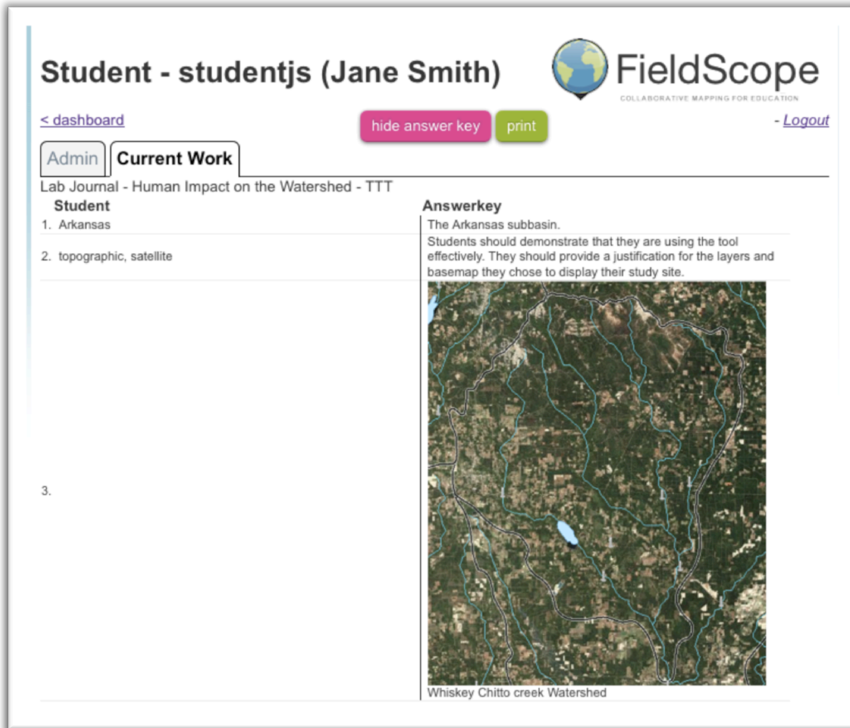
Review Student Work

After you have assigned the Lab Journal to your class, you will be able to track student progress and view student responses. In the example below you can see how progress will be reported. Studentjs (Jane Smith) has progressed 66% of the way through the lab journal, meaning she has posted an answer to 66% of the questions asked. You will see "N/A" as the status for students who have not yet answered any questions.



You can also look at individual students' answers to see how well they are grasping the material during the investigation and to review student work at the end of the assignment.

Click on "journal work" after the student's username to review their work.



In the **Current Work** section, you will see all student answers, including the screenshots and pictures they have posted with associated captions. If you do not want to see the answer key alongside student responses, use the pink "hide answer key" button at the top of the page.

Use this page for grading online or print it out. Alternatively, you can have students submit a pdf copy of their entire lab journal, which they have the option to generate in FieldScope interface at the end of their investigation.

Use the **Admin** tab to edit student information or change the lab journal to which they are assigned.

Streamgages: The Silent Superhero

Transcript:

http://www.usgs.gov/corecast/details.asp?ep=106

Jennifer LaVista: Whether you drink water from your tap, use electricity, or canoe down your local river, chances are you benefit from US Geological Survey's streamgages. So, what is a streamgage and what does it do for you? I met with the experts to find out more.

Matthew Larson: A streamgage is a very simple mechanical device that measures how much water is flowing in a river.

Thomas Graziano: The streamgage data are utilized in real time by the National Weather Service to issue timely and accurate river forecasts and warnings necessary to assure and promote public safety nationwide.

Joseph Hoffman: We turn on our taps and we don't recognize where that water comes from. Few people realize who their water supplier is, much less that they have relied upon a streamgage to make sure that that water gets to the customer.

Sue Lowry: They're used to turning on their tap and having water come out without really understanding just how intricate and involved it is to make sure that that tap doesn't ever run dry for them.

Joseph Hoffman: The Potomac River in the background is shared by Maryland along with Virginia and West Virginia and the District of Columbia. So, they periodically have disputes that come about. And having gage information helps to resolve some of those discussions. In the western states, where it's sometimes much drier than it is in the East, they utilize gages to divide that water up amongst the states.

Sue Lowry: The USGS is critical because they're seen as an impartial third party. Of course, neither states can trust the other one to necessarily collect data that wouldn't in some way help their position.

Joseph Hoffman: The drinking water providers need to know how much flow there is to base their treatment. They need to know what the loading is, how much is coming in, what kind of pollutants are there that they have to address.

Sue Lowry: Water needs for fisheries and ecological purposes are also critical. The least terns and the piping plover, those are both endangered species that are throughout our area. They need bare sandbars for their nesting. And so, again, the agencies like the Corps of Engineers needs streamflow information so that those nesting habitats will be available and hopefully these birds then will be able to recover.

Thomas Graziano: Streamflow information is critical in situations of drought or low flow, as well as in situations of high flow or flooding. With climate change, with increasing population resulting in increasing stresses on our limited water supply in this country, water information is becoming all the more important to what we do and to decision makers nationwide.

Joseph Hoffman: Streamgage information is utilized by engineering firms, consultants, by the federal governments, the state governments, as they design projects such as this bridge that we have in the background. The river has gotten up to just over 41 feet back in 1936 with a flood they had. So, when this bridge was built, they have to make sure that that bridge is high enough.

Gretchen Ellsworth: Rowers, like any paddle sports, anybody who's using the river, we need to know what the river is doing. There are very serious consequences we're taking when rowing boats out into water that's too rough or too fast.

Joseph Hoffman: Into the next decade, I see the continuing need for streamgages. I don't think we can cut back on them. In fact, we'd probably want to see more of them. We've got big infrastructure problems in the US. Bridges, highways, all need to be replaced or repaired. And we've got to utilize gage information in order to effectively design those replacements or those repairs.

Sue Lowry: I think there's a real misconception out there that once you've had a gage in place for maybe 10 or 15 years that you have all the information that you need, when in fact, we really need these gages to be in place for, in some cases, 100 years because there's so much seasonal variability in how water can come off. We might have a really dry June. We might have a wet July. No two years are exactly the same. So, unless you have the full range of precipitation covered by these gages, you don't have the confidence that you really know and can project what kind of water may be coming.

Matthew Larson: Water is probably the most important commodity for the nation. It's one that's underappreciated but it's essential for life, as we know. None of us can get by within a day or two without drinking it. And so, knowing how much water is available in our rivers and our streams is critical for the national health. And using our streamgages, we can monitor that flow in rivers and know how much water is available. It's critically important as we go into the future and an uncertain climate, as climate change affects the availability of water in rivers and streams around the country.

Jennifer LaVista: To learn more about the USGS streamgaging program, visit water.usgs.gov/nsip. That stands for the National Streamflow Information Program. CoreCast is a product of the US Geological Survey, Department of the Interior. I am Jennifer LaVista.

Fieldscope Investigation – Answer Key

Many of the responses provided below are based on a sample investigation and they are specific to a watershed in Louisiana. These responses are marked in "quotation marks." However, they contain all of the information your students should include when they complete the FieldScope investigation on their own. Important information in these answers is <u>underlined</u>.

<u>Part 2: Choosing your study site</u>

Q1: In what subbasin is the border between Oklahoma and Kansas located?

The Arkansas subbasin.

Q2: Which layers did you use to find your watershed? Which basemap? What information did they provide and why was it useful?

Students should demonstrate that they are using the tool effectively. They should provide a justification for the layers and basemap they chose to display their study site.

Q3: Drag and drop the screenshot of your watershed into the space below

Q4: Where is your study site?

"Along the Whiskey Chitto Creek and Calcasieu River north of Kinder, Louisiana."

Q5: What is the name of the subbasin where your study site is located?

"Whiskey Chitto subbasin"

Q6: What is the name of the largest stream or river in that watershed?

"Whiskey Chitto Creek and Bundick Creek are approximately the same size. They are the two largest rivers in the subbasin."

Q7: For each of the different types of land cover in your watershed, provide the percent change from 1992-2001. Make sure to include whether the change was an increase or a decrease.

"Developed land: +4.81%; Agricultural land: -9.21%; Grassland: +6.96%; Forested: -16.1%. Positive changes indicate an increase in that type of land cover, negative changes indicate a decrease."

Part 3: Streamgages: The Silent Superhero

Q8: What is a streamgage?

A streamgage is an instrument that records information about a stream such as flow rate, temperature, and water chemistry. Streamgages are an example of remote sensors.

Q9: List four reasons why streamgages are important.

Possible answers include:

- *To deliver accurate river forecasts and warnings to the public*
- *To provide unbiased information on rivers to help solve disputes at the county or state level about water rights and allocation*
- *Water treatment facilities use streamgage information to determine how much water will be arriving and how polluted it is so they can address this contamination safely and effectively.*
- *Agencies like the Corps of Engineers use streamgage information to monitor wildlife habitats, such as those of least terns and piping plovers, to make sure the conditions are right for these birds to nest and reproduce.*
- *Streamgage information is utilized during the design of bridges, roadways, etc. so that they are built with consideration for peak flow and past flooding events.*
- *Rowers and other people who use the river for watersports follow streamgage information so they know how safe the river is at a given time.*

Q10: In the space below, record the name of your selected streamgage.

"Calcasieu River near Kinder, LA."

NOTE: This streamgage is just beyond the boundary of the watershed in this example, *but that is acceptable because it will primarily reflect only the land cover changes upstream in the Whiskey Chitto watershed. A streamgage close to the mouth of the watershed and on the main river channel is a good choice.*

Q11: ****Describe your study site. In which direction is the river flowing, and what major body of water does it flow into? (Look upstream and downstream.) Describe the size and shape of the watershed and list any interesting features of the site. Explain why you chose to study this watershed.****

"There are several creeks in this subbasin which all feed into the Whiskey Chitto Creek. The Whiskey Chitto Creek <u>flows south into the Calcasieu River</u> <u>near Kinder, LA</u>. My <u>streamgage is located on the Calcasieu River</u> near Kinder, LA which is just south of the Whiskey Chitto subbasin boundary. I <u>chose this streamgage because</u> even though it actually lies just outside the Whiskey Chitto watershed boundaries, it will record stream discharge rates that reflect land cover over the entire subbasin. The Whiskey Chitto <u>subbasin is irregularly shaped</u>, somewhat round. It is 29 miles wide, from west to east, and 34 miles from north to south. <u>About one-quarter of this watershed is designated as the Kisatchie National Forest</u>. <u>I chose this area to study because</u> it is where my mom grew up. My grandparents still live there are we go to visit every summer."

<u>Part 4: Designing your Investigation</u>

Q12: In the space below, write your hypothesis about the relationship between land cover and stream discharge.

"As land cover in this subbasin becomes more developed and forested land decreases, surface runoff rates after storm events will increase."

NOTE: A hypothesis should be testable and specific, even if at the end it could not be supported by the data.

Q13: Think about the kinds of information you will need to help you investigate your hypothesis. What will be the most important variables to consider? Why?

"Changes in land cover types will be important to consider in this investigation, as well as changes in recorded streamflow between the two study years. These are the two most important factors because they are both included in my hypothesis."

Q14: Write a step-by-step procedure that will guide you as you collect the information you need to investigate your hypothesis. Make sure to incorporate the tools and data listed above AND the variables you identified in the previous question.

> *"First I will need to use FieldScope to collect USGS stream discharge data from my streamgage for 1992 and 2001. Then, I will collect National Land Cover Data for the same two years and look for changes. It will be important to look at how land cover changed, and see if those changes could explain the stream discharge data I collected."*

Part 5: Collecting Stream Discharge Data -1992

Q15: Why should you collect twelve months of data? (Why not longer or shorter?)

> *It is important to collect a longer period of data to make sure the data are not heavily influenced by one period of rain or a season of drought. A whole year of data would most likely include a range of seasons – both dry and wet – that would be an accurate representation of the regional conditions. On the other hand, collecting too much data can be a burden because it provides too much information and might make it difficult to see patterns and draw conclusions.*

Q16: Why do you think you should choose a major river? Why would choosing a small stream possibly give you poor data?

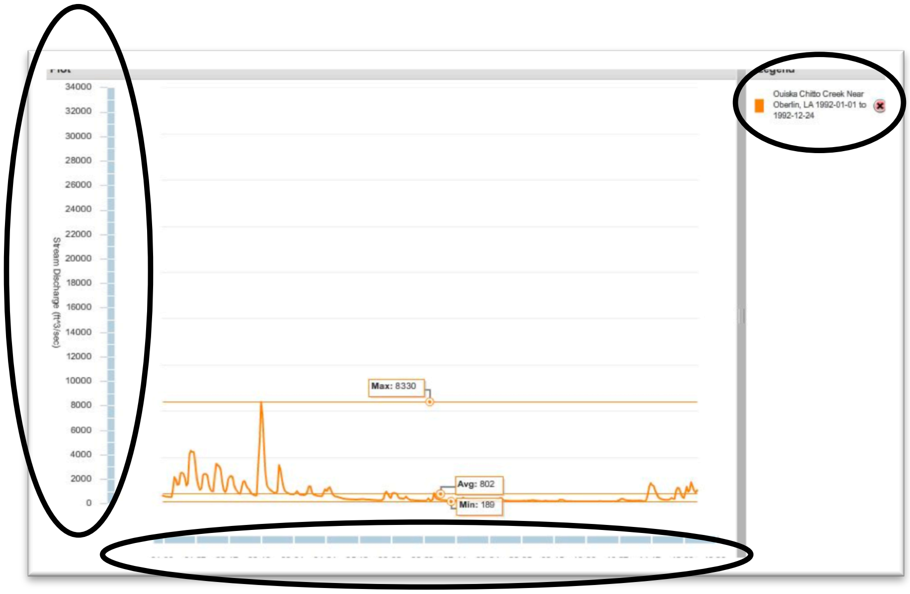
> *A small stream may not drain enough water from the watershed to accurately reflect land cover changes.*

Q17: Why is it important to avoid rivers or streams that have dams? Why might this make your hydrograph difficult to read correctly?

> *Dams interrupt regular streamflow and can also be used to manipulate streamflow to a desired rate. This means that the stream discharge rates of rivers with dams will not necessarily reflect recent precipitation and surface runoff*

Q18: Use the TAKE SCREENSHOT function to save an image of your hydrograph with the axes and legend. Make sure to give it a descriptive name, including the dates and year. Drag and drop your hydrograph into the space below.

> *Student hydrographs should include all of the components in the image that follows and have a title such as, "Hydrograph from Ouiska Chitto Creek streamgage near Oberlin, LA:1-1-1992 to 12-31-1992."*



Q19: Describe the major features of your hydrograph. How large are the peaks and when did they occur? What is the baseflow?

> *"This hydrograph shows several small peaks in stream discharge during the year. These peaks range from 1000 cfs to 4500 cfs and they are concentrated during January –March. There is only one spike in discharge, about 8500 cfs, and it occurs in early March. The baseflow of this stream very low- it looks like it almost dries up between storm events."*

Q20: What kinds of events might have caused spikes in the hydrograph?

> *"I think that these peaks were caused by precipitation in the form of rain, since this watershed is in the southern U.S. in a region that doesn't see snow very often."*

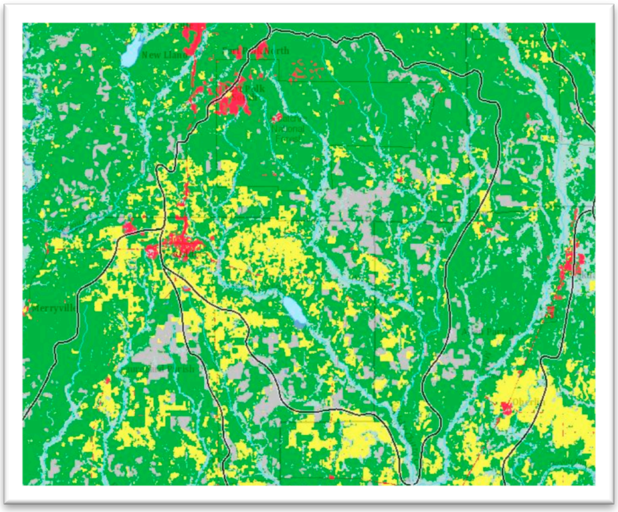
Q21: Think about typical weather patterns in your hometown. Does your hydrograph reflect the same patterns? If not, propose an explanation.

> *Student answers will vary considerably here. They may have chosen their hometown for their study site or they may have chosen another site in a very different climate zone.*

Part 6: Investigating Land Cover from 1992 to 2001

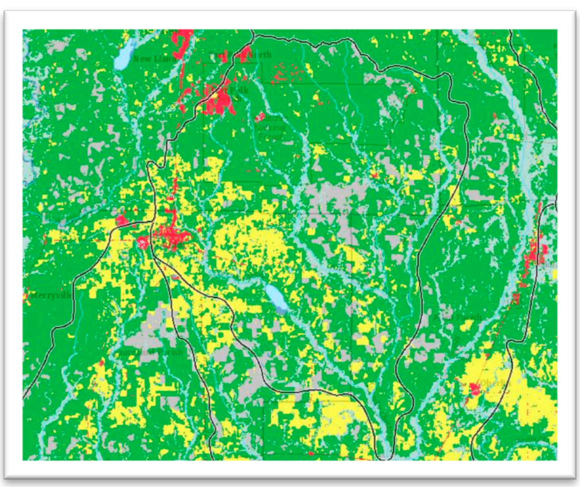
Q22: Take a screenshot of the 1992 land cover map and save it with a descriptive name. Drag and drop it into the space provided.

Student maps should show the entire watershed boundary and have a descriptive title such as, "1992 Land Cover map for Whiskey Chitto subbasin near Kinder, Louisiana."



Q23: Take a screenshot of the 2001 land cover map. Drag and drop this map into the space below.

Student maps should show the entire watershed boundary and have a descriptive title such as, "2001 Land Cover map for Whiskey Chitto subbasin near Kinder, Louisiana."



Q24: Using the legend to help you, list the three most common types of land cover found in your region in 2001. Provide the color associated with the land cover.

> *"Forest (in dark green) is the most common land cover in this subbasin. There is also a lot of agricultural land (yellow) and many wetlands (gray). There are four areas of developed land scattered around the boundary of the watershed."*

Q25: As you compare the two years, what color(s) do you see more of on your map in 2001 compared to 1992? What color(s) do you see less of?

> *"There is a lot less yellow and dark green, and more brown instead. The red areas have also increased in size. Green is still the dominant color on the map."*

Q26: What trends in land cover change do you observe from 1992 to 2001? For example, has developed land been converted to agricultural land? Explain what you see when you slide the bar.

> *"There was a lot of shrubland in this subbasin in 2001, which is significant because there was no visible shrubland on the map in 1992. There is still a lot of forested land, but the agricultural land is much less than it was in 1992. In addition, all of the towns along the boundary of the watershed have increased in size, which means more of land is developed."*

Q27: Are land cover changes uniform throughout your watershed, or are they concentrated in certain areas?

> *"The increase in developed land cover is happening only where it was already established in 1992. Most of the shrubland that appeared during this time period was in the southwest part of the watershed."*

Q28: Whether you live in a large city, a suburb, or a small town, there's a good chance that the way your hometown looks today is different from how it looked the year you were born. What land cover changes have you noticed in your lifetime? Are these changes similar to or different from the changes in your study site?

> *Student answers will vary considerably. They should note if any of the following have been built in their lifetime: new housing subdivisions, parks, malls, office buildings, parking garages, etc. They should also include whether the trends they notice in their hometown are similar to the ones they are learning about in their study site.*

Part 7: Predicting Stream Discharge

Q29: In the NetLogo Runoff model, you looked at four different types of land cover. In the space below, describe how each of them (developed, agricultural, grassland, forest) affects stream discharge. *(If you did not use the NetLogo Runoff model, leave this question blank.)*

> *NOTE: Students do not need to complete answers as detailed as the ones provided below.*
>
> *Developed land: Developed land is made of surfaces that do not absorb water (they are impervious) so the water flows very quickly across them and into the streams. This causes the hydrograph to peak early, which means a fast increase in stream discharge. This is the fastest of the 4 classifications.*
>
> *Agricultural land: Agricultural land has crops or grass for animals to graze on so it slows the rate of runoff. This land is sometimes heavily modified and so water might flow quickly across it, depending on these changes. Water moves slower than developed land, but faster than grassland or forest. Runoff from agricultural land will cause spikes in stream discharge but they will be smaller than those in developed areas.*
>
> *Grassland: Grassland provides resistance for the water and absorption into the soil. When it rains, some of the water sinks into the ground and does not flow to the streams at all because the grass uses it. Also, the grass can slow the rate of overland flow by getting in the way. Because the rate of runoff is slower, stream discharge does not show sharp peaks—the runoff takes a longer time to reach the stream.*
>
> *Forest land: Forest causes the lowest peak in the hydrograph because trees and shrubs use a lot of the water and the uneven surface of the forest floor provides resistance to flow. Forest has the slowest runoff rates but is only a little slower than grassland.*

Q30: What other kinds of land cover are present in your watershed? How will they influence stream discharge?

> *"There are a lot of wetlands in this subbasin, and they increased in prevalence by almost 3% between 1992 and 2001. Wetlands are well adapted to handle pulses of additional water, so I think that they moderate runoff during storm events. The amount of barren land decreased during this time period, and I predict that will slow surface runoff because surface resistance will have increased, as well as the presence of plants that can take up water from the soil."*

Q31: Describe the path water takes when it lands on grass, soil, or farmland- in other words, a surface it can soak into. How is this different from what happens when rain lands on a sidewalk or street?

When rain or snowmelt seeps into the ground, it can travel vertically into an aquifer or it can travel more horizontally- though still downhill- towards the nearest body of water. This movement is not in the form of runoff because it is sub-surface. However, it will eventually be contributed to a river or lake via groundwater seepage. This process takes much longer than surface runoff and so it does not show up as sharp peaks on a hydrograph. Instead, this would look like a rounded peak on a hydrograph. This is very different from surface runoff, where the precipitation or snow melt travels directly to the nearest body of water (storm drain, river, lake) in one pulse, taking with it all of the chemicals that it picks up from sidewalks and streets along the way.

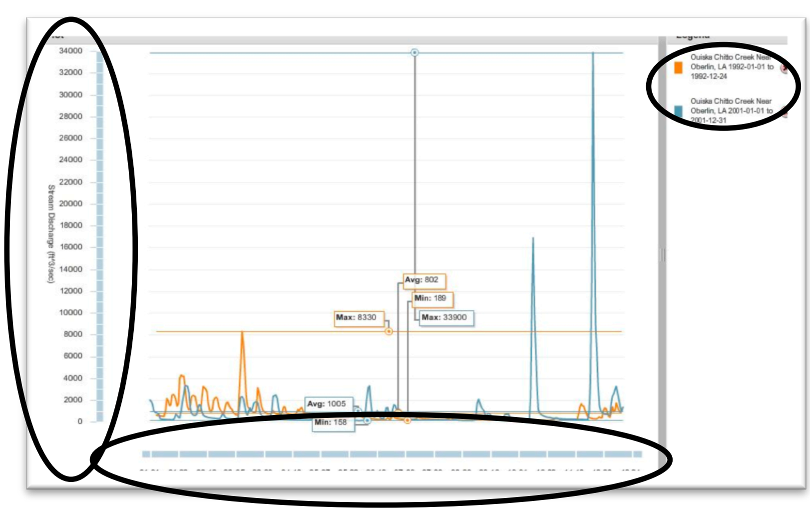
Q32: Consider the changes in land cover that have taken place between 1992 and 2001 in your watershed. Predict how you think these changes will affect 2001 stream discharge rates within your watershed. Explain your reasoning.

"I think that the discharge rates will be spikier in the 2001 data than they were in the 1992 data because the land cover changes that have occurred (such as loss of forest) favor increased runoff rates."

Part 8: Collecting Stream Discharge Data - 2001

Q33. Use the TAKE SCREENSHOT button to save a copy of your hydrograph with the axes and legend. Make sure to save it with a descriptive name that includes the years, then drag and drop it into the box below.

"Ouiska Chitto Creek stream discharge data 1992 and 2001"



Q34: Describe the major features of your 2001 hydrograph. How large are the peaks and when did they occur? What is the baseflow?

> *"This hydrograph shows 12 spikes in stream discharge during the year. Between January and September, the peaks are small and they range in size from 2000 cfs to 4000 cfs. From October to December, there are two, much larger peaks that show discharges of 17000 cfs and 34000 cfs, respectively. The baseflow of this stream very low- it looks like it almost dries up between storm events."*

Part 9: Analyzing Your Data

Q35: ****Describe how the National Land Cover Data were collected.****

> *The National Land Cover Data are compiled from satellite imagery and coded to show certain categories of land cover. This is an example of remote sensing.*

Q36: Describe how the USGS stream discharge data were collected.

> *USGS stream discharge data is remotely collected by a network of streamgages on rivers and streams across the U.S. The data is then sent to USGS field offices, where it is analyzed and added to existing streamgage data.*

Q37: Can you tell from your data the months when storms were most frequent?

> *"It looks like the most precipitation occurs between October and March in this watershed. The streamgage recorded very low discharge rates during the summer months and there are very few peaks between April and September."*

Q38: Recall the podcast "Streamgages: The Silent Superhero," in which scientist Sue Lowry mentioned how variable streamgage data can be. Is a 12-month set of data enough data to use for this investigation? Is it too much? Why?

> *Twelve months is good amount of data to start this investigation with, because it shows how stream discharge rates change during different parts of the year. It would be helpful, though, to look at more than 12 months because then it would be easier to see if 1992 and 2001 were typical years in terms of runoff rates. It could also be helpful to look at the data in smaller increments to compare seasonal trends.*

Q39: ****Compare the hydrographs from 1992 and 2001. What are the major differences between them? Are there any similarities? Use appropriate scientific vocabulary.*****

> *"There were more peaks in 1992 than 2001 but they were of a smaller magnitude. While there were <u>fewer peaks in stream discharge in 2001</u> they were consistently*

greater in magnitude, particularly in the winter months. During the summer the baseflow rates were very similar between the two years."

Part 10: Conclusions

Q40: ****Re-state your hypothesis (Question 12). Do your data support or contradict your hypothesis? Explain using specific examples from the data.****

"My hypothesis stated: 'As land cover in this subbasin becomes more developed and forested land decreases, surface runoff rates will increase.' My hypothesis was partially supported by the data. Land cover change in my watershed did not change solely from forested to developed. There was a big loss in forested land, but also in agricultural land. The biggest increases were in shrubland and grassland; developed land increased only a little bit. In 2001 there were larger spikes in stream discharge during the early spring and winter months than there were in 1992 and those could be caused by increased runoff over shrubland compared to forest and/or agricultural land. However, those peaks could also be due to more rainfall. The shape of the peaks during January – March is similar between 1992 and 2001, which indicates that the runoff rates may not have changed all that much in this watershed during that time period. It would be helpful to have more years of data post-2001 to see if changes in surface runoff are actually occurring."

Q41: State your conclusion about the relationship between land cover and stream discharge in your study site.

"In the Ouiska Chitto subbasin, land cover changed considerably between 1992 and 2001 but it is difficult to determine specifically how this change has impacted surface runoff given the limited data comparison."

Q42: ***Consider the additional variables you listed in Question 13 and others you have thought of along the way. How could they be influencing the patterns you see in your hydrographs? Which of the differences between your two hydrographs could be due to land cover and which could be due to other variables?****

"In question 13 I identified only land cover change and streamflow rates as the variables I would need to consider in this investigation, but I think that precipitation (namely, rainfall) is affecting the hydrographs from my streamgage. I can't tell from the hydrographs alone if the differences in peak size are due to land cover changes or rainfall variability, or both."

Q43: ****Consider everything you have learned about watershed dynamics. Do you think your conclusion about your study site will be the same for other watersheds? Make a general statement about the relationship between land cover and stream discharge that can be applied to any watershed.****

> *"My conclusions in question 41 do not apply to all other watersheds. Land cover change does impact surface runoff, but the extent of the impact is heavily influenced by the kinds of changes that have occurred/are occurring in a certain watershed."*

"Urban Sprawl" – from City Sidewalks.net

Purpose
This article describes the origins and environmental impacts of urban sprawl.

Overview
Students will read the article titled, "Urban Sprawl" from CitySidewalks.net. This article explains how urban sprawl first began after World War II as people moved from city centers to surrounding lands. It also details the environmental costs of urban sprawl, such as pollution, fragmentation of wildlife habitat, and disruption of the natural water cycle via increased surface runoff.

Student Outcomes
- Students will understand the causes and consequences of urban sprawl.

Time
Less than one 50-minute class period

Level
Secondary earth/environmental science (9-12)

Materials and Tools
Copies of article with questions – 1 per student

Preparation
Copy article and reading questions for each student

Prerequisites
N/A

Background
Students should have a grade 9-10 reading level.

Answer Key

Q1. In your own words, write a definition of the term "urban sprawl." What are some common characteristics?

Student answers should contain some of the following characteristics:

- *Widespread, low-density development not typically on a grid or planned with space efficiency in mind*
- *Strip malls, large office buildings*
- *Housing subdivisions with homes of a specific price range on wide, new roads*
- *Residents dependent on cars for transportation instead of walking or public transit*

Q2. Name three causes of urban sprawl.

Student answers should include 3 of the following:

- *The GI Bill after World War 2*
- *Increased road building*
- *Increased automobile manufacturing*
- *Inexpensive land, and federal subsidies for commercial development and highway construction*
- *Ineffective or nonexistent land use planning*

Q3. Describe four ways that urban sprawl negatively impacts the environment.

- *Habitat fragmentation due to construction of subdivisions, commercial developments, roads*
- *Damage to or loss of wetlands*
- *Air pollution from cars*
- *Water pollution from surface runoff over highways and parking lots that picks up contaminants and deposits them in local waterways*
- *Increased competition for resources among surviving wildlife as habitat and other resources are diminished or lost entirely*

Name ______________________________ Date __________ Class ______________

“Urban Sprawl”
– from City Sidewalks.net

The following article can be found online at: http://www.citysidewalks.net/faq.htm.

Urban sprawl is difficult to define but people usually know it when they see it.

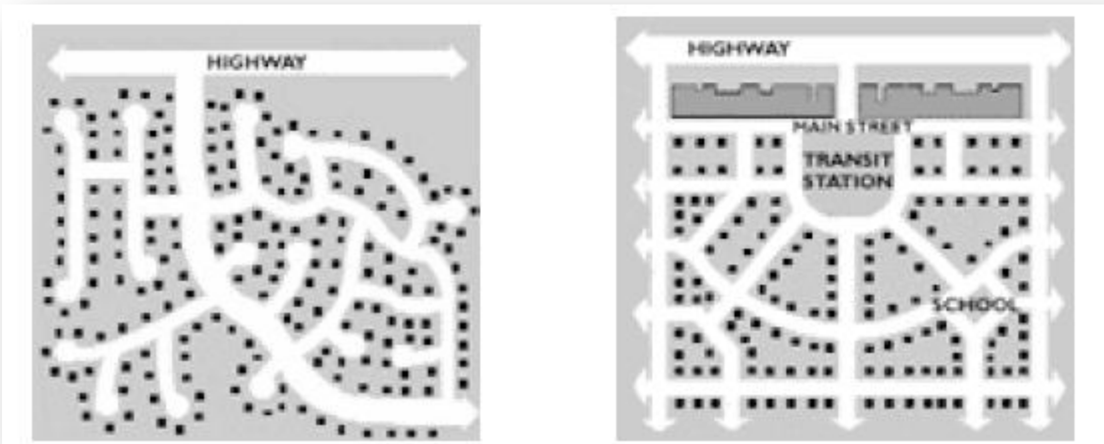
Urban sprawl, also known as suburban sprawl, is the spreading of a city and its suburbs over rural land at the fringe of an urban area. Residents of sprawling neighborhoods tend to live in single-family homes and commute by automobile to work. Low population density is an indicator of sprawl. Urban planners emphasize the qualitative aspects of sprawl such as the lack of transportation options and pedestrian friendly neighborhoods. Conservationists tend to focus on the actual amount of land that has been urbanized by sprawl.

From Wikipedia, the free encyclopedia

It all began during the post-war prosperity of the 1950's and 60's, when housing developments popped up across the landscape like mushrooms after a rain. A half-century later, we now understand that many environmental problems accompany the outward spread of cities: fragmenting and destroying wildlife habitat, for example, and discharging polluted runoff water into streams and lakes.

Know sprawl when you see it! Maybe you've noticed your community is getting a little bigger. Road construction seems to be everywhere and traffic is more heavy than it used to be; new strip malls and “big box” stores are popping up; and land on the outskirts of your town is being cleared for new housing subdivisions. Your community could be experiencing urban sprawl, an issue that has affected cities and towns across the country.

Urban sprawl can be generally defined as wide-spread, low-density development that consists primarily of strip commercial developments, such as malls and large office buildings, and housing subdivisions connected by new, wide roads and boulevards. The subdivisions are set apart from other development and built within a specific price range, and people are dependant on their cars to get them from one place to another. With sprawl, fewer people occupy more land and as the people spread out, so do the buildings, roads and houses. Urban sprawl is difficult to define but people usually know it when they see it. The following maps describe what an urban sprawl suburb might look like (left) compared to the land use plan of a town that avoids sprawl (right).



Graphics: Urban sprawl layout (left) compared to an anti-sprawl urban design (right). Maps by Gail Dennis, Michigan Land Use Institute. Source: "The Next American Metropolis," by Peter Calthorpe.

What are the causes of urban sprawl?
After World War II, people started moving from the cities into the countryside. The GI Bill, road building projects, and increased car manufacturing all contributed greatly to this shift, and living in "suburbia" signified a better quality of life. Land was cheap and there was plenty of it, and government incentives and subsidies helped families realize their dream. Today, subsidies from the federal and state governments, such as for highway construction and commercial development, continue to promote sprawl and its effects.

The lack of effective land use planning allowed this move to the countryside to occur virtually uncontrolled. All Great Lakes states allow local governments to create comprehensive plans to guide growth and to create local laws (called zoning ordinances) to decide what types of development can happen where. However, none of the Great Lakes states actually require local land use planning.

In all of the Great Lakes states, land use planning happens at the smallest level of government (e.g., town, township, city), so the state has very little say in how land gets developed, except when it involves spending state tax dollars, such as for major highway projects. When local land use plans are developed, often they are inconsistent with the zoning ordinances and do not consider the impacts on surrounding areas and nearby communities. In practice, zoning ordinances and building codes, not land use plans, govern most land development decisions. The problem with this is that zoning tells "where" and "what type" of development can take place, but it does not consider questions of "how" and "when" development should take place. Most zoning ordinances separate different types of land uses, establish minimum distances between houses, minimum setbacks from roads, minimum parking space requirements, minimum road widths, and so on so that the only type of development that can occur is sprawl. In this way, the lack of land use planning and the reliance on zoning ordinances has promoted sprawl.evelopment that can occur is sprawl. In this way, the lack of land use planning and the reliance on zoning ordinances has promoted sprawl.

"Sprawl" is the increased use of urbanized land by fewer people than in the past. Traditional cities were compact and efficient, but over the past 30-50 years, the density of land used per person has declined drastically. Although the U.S. population grew by 17 percent from 1982 to 1997, urbanized land increased by 47 percent during the same 15 year period. The developed acreage per person has nearly doubled in the past 20 years, and housing lots larger than 10 acres have accounted for 55 percent of land developed since 1994, according to the American Farmland Trust. Between 1950 and 2002, the number of acres of farmland in Wisconsin dropped by 32.6%, from 23.6 million acres down to 15.9 million.

With little or no land use planning to protect greenfields, farm fields and rural countrysides and ecologically important habitats such as wetlands have been carved up. More roads were needed to connect the new development to downtown, which invited more development on the outskirts and the cycle continues today. As more people and businesses move out to former greenfields, fewer taxpayers are supporting older towns and cities, leaving them to deteriorate.

Question:

Q1. In your own words, write a definition of the term "urban sprawl." What are some common characteristics?

Q2. Name three causes of urban sprawl.

What are the effects of urban sprawl?

According to a 1998 Sierra Club report, cities in six of the Great Lakes states account for six of the top 20 sprawl threatened cities (over one million residents) in the United States: Cincinnati, Minneapolis-St. Paul, Chicago, Detroit, Cleveland and Pittsburgh. In Chicago, for example, the population increased only 9% from 1990 to 1996, but land area development has increased more than 40% in that same time period. In Michigan, over 100,000 acres of farmland are lost to urban sprawl every year. And the amount of time Cincinnati drivers were stuck in traffic jams increased 200% from 1982 to 1994.

Sprawl can damage ecological systems and their natural functions, such as wildlife habitats and wetlands. Housing subdivisions, commercial developments, and the roads that connect them all divide a landscape, which results in habitat fragmentation. This fragmentation forces wildlife to either find another place to live or compete with each for a smaller amount of land. Urban sprawl is also threatening wetlands, an important key to healthy ecosystems. In addition to being home to a number of critical wildlife and plant species, wetlands improve water quality by filtering out sediments and other pollutants, protect the shorelines of rivers and lakes from erosion, and help control and reduce flooding. However, since 1800, over two-thirds of Great Lakes wetlands have been lost or severely damaged, and land development continues to destroy wetlands today.

Pollution is also a cost of urban sprawl. Most sprawling towns are built for cars and force us to drive more frequently and for longer periods of time. And increased use of cars leads to more air and noise pollution as well traffic jams. As for water pollution, lands covered with highways, buildings, and parking lots increases runoff, polluting our streams, lakes, and watersheds. As a result, our access to clean and safe drinking water becomes threatened, and our aquatic plant and animal life suffer.

Question:

Q3. Describe four ways that urban sprawl negatively impacts the environment.

Watershed Dynamics Extension Activities

Purpose
For students to demonstrate understanding of how land cover affects streamflow.

Overview
This activity provides two options for students to apply their new knowledge about the relationship between land use and streamflow.

Option 1: They will be given two hydrographs and asked to explain why they look the way they do. Both are taken from the same stream gage, but in different years. They will need to create a story about the area to explain how the land cover has changed. They will include key terms that are essential to explain the hydrographs.

Option 2: They will be given a scenario of a small town that is about to change. It is mainly surrounded by forests and will be developed in the following years. Students need to create two hydrographs (one before the change and one after it has been developed) and explain why they look the way they do, including key terms they have learned during the Human Impact module.

In addition, students can also research different methods that will decrease future runoff when this area becomes developed. This can include new technologies and/or various landscape designs.

Student Outcomes
- Students will demonstrate that they understand how land cover affects streamflow.
- Students will show that they understand key terms.
- Students will demonstrate that they understand hydrographs.

Time
- 1-2 50 minute class periods

Level
Secondary earth/environmental science (9-12)

Materials and Tools
- Student copies
- Rubric

Rubric for Extension Option 1						
Categories	0 pts	1 pt	2 pts.	3 pts.	4 pts.	Total
Explanation	No Explanation	Brief explanation, included 3 key terms or less	Mostly explained, may have included 3-5 key words, not fully correct	Full explanation, mostly correct, includes all 5 key terms	Full and correct explanation, including all 5 key terms	
Creativity/ Length	No Story	The story is less than half a page long and shows little evidence of creativity	Story is about a page long and contains a few creative details and/or descriptions	Story is one to two pages in length and contains a few creative details and/or descriptions	Story is about 2 pages and contains many creative details and/or descriptions	
					Total Points	

Rubric for Extension Option 2

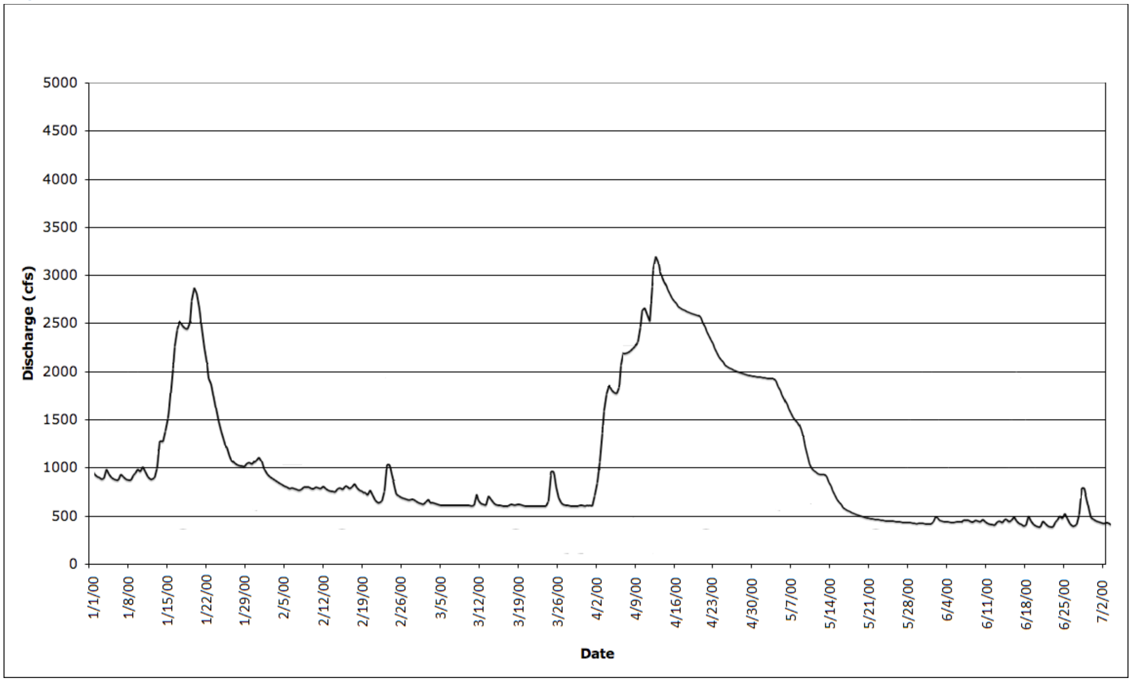
Categories	0 pts	1 pt	2 pts.	3 pts.	4 pts.	Total
Graphs	No Graphs	Have one or two graphs, not labeled, incorrect represent-ation	Have both graphs, partially labeled and somewhat correct represent-ation	Have two graphs, all or mostly labeled, mostly correct represent-ation	Two graphs, very well labeled, both show correct representations of land cover and discharge	
Explanation	No Explanation	Brief explanation, included 3 key terms or less	Mostly explained, may have included 3-5 key words, not fully correct	Full explanation, mostly correct, includes all 5 key terms	Full and correct explanation, including all 5 key terms	
					Total Points	

What is going on with the water?

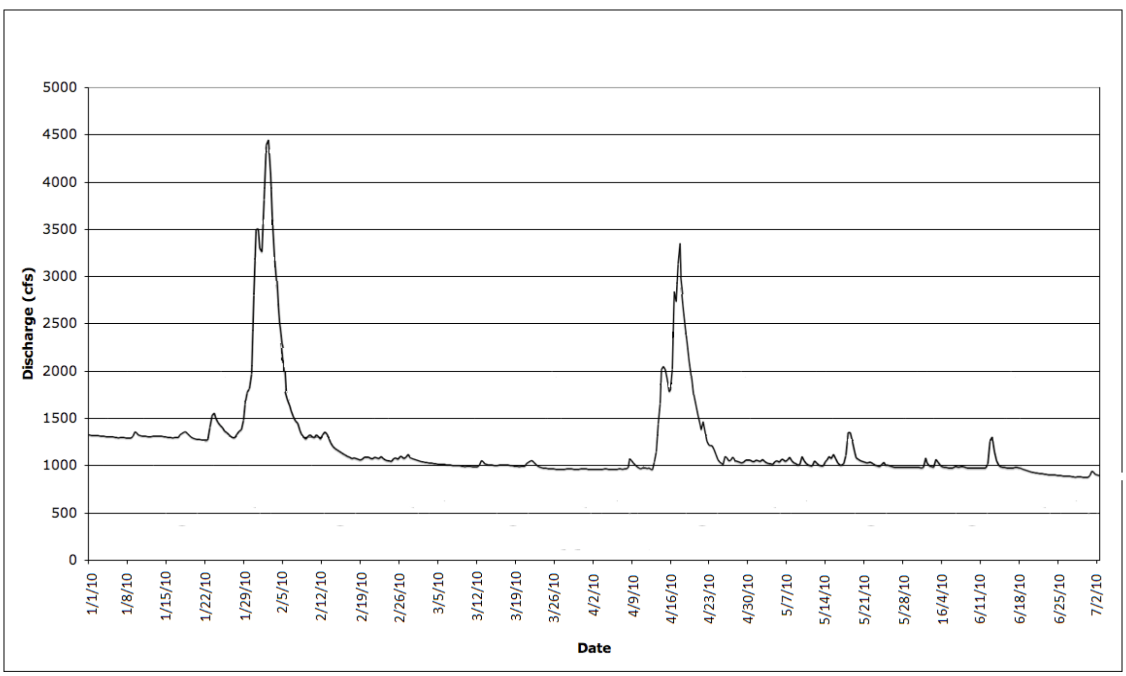
Introduction

Take a close look at the hydrographs on the following page. They show data collected from the same streamgage but in two different years. Your job is to create a story that explains the differences between them by describing what happened to the area surrounding the stream between the times the data were collected. Make sure to use key terms you have learned in this unit, including: **runoff, infiltration, baseflow, discharge, and peak discharge.**

Hydrograph 1



Hydrograph 2



What will happen to the flow?

You live in a very small town that is mostly surrounded by forest. Recently, a large company bought a sizable plot of land to build new headquarters within town limits. This is exactly what your small town needs to get the economy going! It will create lots of jobs and more people will move into the town, which means that more stores will spring up to support this larger population. Unfortunately, this also means that a good amount of forested land that is within town limits will be developed for more housing, stores, and parking lots.

You have been hired by the town as a consultant to show how this development will impact the local watershed. You have access to a local streamgage that you will be able to use to measure streamflow. To demonstrate the expected impact of this development, you will need to create two hydrographs to show to town officials. The first hydrograph should show streamflow patterns based on current land cover; the other should show what you predict streamflow will look like once the land development is complete. You must explain why the hydrographs look the way they do and include key terms including: **runoff, infiltration, baseflow, discharge, and peak discharge.**