Exploring Greenville's Water

An Interdisciplinary Educational Program Designed to Facilitate the Exploration of Water Quality in Greenville, South Carolina

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A Compilation of Interdisciplinary, Place-based Educational Programming Designed to Facilitate the Exploration of Water Quality in Greenville, SC

Water is one of the most essential natural resources that we have. Without water, plants, animals, and people would cease to exist. Water is also everywhere. Through the hydrologic cycle, water travels over and beneath the land, through the soil, through plants and animals, into the air, and back again. There is a finite amount of water on Earth and only a small amount available for human use and consumption. Unfortunately, many of the properties that make water so useful and important have also lead to exploitation and overuse of this resource. Rivers and streams are used as pipelines to flush industrial and municipal waste out to sea. Farmers, mining industries, and manufacturing plants pump huge amounts of water from underground aquifers and reservoirs to use. Development alongside rivers and streams degrade these habitats through alteration of natural flow regimes, erosion and sedimentation, nonpoint source pollution, and more. We know that our water resources need protection and careful management if they are going to be able to continue to sustain our society and environment. Planners, water managers, engineers, politicians, environmental scientists, and more are all working to help reduce our impact on water quality and find ways to clean and protect our water resources. It is essential that students are exposed to water quality issues, as this will continue to be a unifying thread in developing a more sustainable future.

This booklet has been developed by the Livability Educator to provide formal and informal educators with the tools to implement an in-depth exploration of water quality and water issues specific to Greenville, SC. It includes lessons and activities excerpted from the Community Quest and Urban Naturalist programs, background information compiled by the Livability Educator, a list of local organizations that provide water quality education, links to lesson plans and materials from external sources, and more. A program of study that includes an exploration of stormwater runoff and nonpoint source pollution utilizing any of the appropriate lessons and activities within will qualify a school for the City of Greenville's stormwater education credit.

The inclusion of external links in this document is not an endorsement of any organization or product.

Acknowledgments

The development of this document has involved collaboration from a number of individuals including City of Greenville Staff, Planners, Engineers, Educators, Students, and many more. Thanks go out to all of the people who have helped to create, test, and edit the information and activities included in this program.

Specifically, I would like to thank Furman University Intern Emily Hays, Lisa Wells, Environmental Engineer with the City of Greenville, and the Connections Project staff team members Wayne Leftwich and Christa Jordan. Without the hard work and dedication of these individuals, this program would not have been possible.

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Introduction

About Exploring Greenville's Water

This program has been developed as a series of activities and background information related to water quality, the human aspects that contribute to water quality issues, water resource conservation and protection, and the pressures on water resources specific to the urban environment. The majority of the information and activities provided in this program have been excerpted from the Community Quest and Urban Naturalist Programs developed by the Livability Educator for the City of Greenville as part of the Connections for Sustainability project.

An important aspect of this program is the compilation of external resources provided at the end of the document. Water quality is an important universal issue, and as such, many organizations locally and nationally provide educational programming and additional resources devoted to water quality education. Instead of creating entirely new programming, this booklet relies heavily on the resources already available for general education on water quality while focusing on providing place-based information and activities specific to Greenville, SC.

This program can be used as part of an informal or formal education program as a stand-alone program or in coordination with other lesson plans.

Program Objectives

Exploring Greenville's Water is designed to provide formal and informal educators with a variety of information and activities designed to:

- Introduce students to the concept of a water quality as an essential aspect of a healthy natural environment and a healthy society

- Foster a sense of responsibility for the future of our water resources through place-based activities designed to show students how land use and water quality is intricately connected

- Integrate Livability Principles and Sustainability concepts into the formal and informal classroom

- Emphasize the connections between an individual's actions and water quality with a focus on the affects of the urban environment on water quality

- Encourage teamwork, inquiry, observation, and curiosity while forming a connection to the urban environment

- Develop an appreciation for Greenville's water resources

How to use Exploring Greenville's Water

This program was developed to be a program that can span age groups and educational settings. Multiple activities are provided to relate each topic to the learner. Though designed with the formal classroom in mind, the activities and supplemental materials also fit well with afterschool programming, summer, and weekend camps. A wide range of suggested activities, writing prompts, background information, and links to external programming has been compiled in order to make this program flexible and comprehensive.

Program Components:

- Background information - the background information provided in Exploring Greenville's Water is intended to provide the educator with the background information that they need in order to teach the program, including links to extra resources. It is suggested that teachers read the program in full before deciding how they wish to convey the information to their class.
- Word Bank - the word bank list can be used as a vocabulary list, as a word bank for writing prompts, as a research tool, or for reference. Not all of the word bank words can be found in the program, but all are related to the topic. Some are common vocabulary, while others are specific to the fields of science, policy, and management related to water quality.
- Journal Prompts - the journal prompts are meant to be ideas for creative writing exercises that tie into these lessons.
- Student Handouts - where appropriate, student handouts are available for print, or to be saved and provided to the students electronically.
- Activities - rather than providing lesson plans, this program offers suggested activities that relate to the background information provided in each section. Activities are meant to be a starting point, and can be altered by the individual educator however needed to fit their classroom objectives.

*You will notice some repetition in topics, discussion prompts, and word banks between sections. Many water quality topics are interrelated and sections were written so that they could stand alone or be combined. It is up to the individual teacher how much or how little to use from each section.

Photos page 4: Top: *Students analyze the macroinvertebrate assemblage in a water sample taken at Paris Mountain State Park* ***Middle:*** *Greenville's Livability Educator demonstrates how land use impacts water quality using a model watershed for Boys and Girls club students* ***Bottom:*** *Students at A J Whittenberg Elementary School observe aquatic animals from the school's garden pond*

Photos page 5: Top*: Fourth grade students decorate rain barrels as part of a water quality and conservation project* ***Middle:*** *A green team student shares her school's water quality program with a resident at a local community event* ***Bottom****: A community center student shows off the recycled fish suncatcher he made as a reminder of the importance of keeping trash out of rivers and streams*

Greenville Is a Watershed

Word Bank

Aquatic
Aquifer
Contaminant
Development
Effluent
Filtration
Ground water
Hydrology
Impairment
Infiltration
Lake
Natural
Nonpoint Source Pollution
Point Source Pollution
Pollution
Reservoir
Riparian
Sediment
Storm Water Runoff
Topography
Water Body
Water Cycle
Water Table
Watershed

Learning Objectives

Students will

- understand the concept of a watershed
- understand that human activity and development within a watershed affects the quality of water in the water body
- find and research the watershed that their homes and school are located in.

Background Information

A watershed is the entire area of land that drains into a specific body of water. On a topographical map, watersheds can be picked out by finding a high area of land (rise, crest, hill, etc.) that forms a boundary between two bodies of water. Watersheds vary in size and in geography depending on the size of the water body, the topography of the land, and the land use patterns that occur in the watershed as well as surrounding watersheds.

The City of Greenville belongs to the Saluda watershed. All of the precipitation that falls on the City of Greenville eventually flows into the Saluda River. Most of the City is part of the Reedy River watershed. The Reedy River drains into the Saluda River, making the Reedy River a part of the Saluda River's watershed.

The City of Greenville gets its water from three reservoirs, Table Rock, Poinsett, and Lake Keowee. Two water treatment plants treat all of the water that is piped through approximately 2,827 miles of pipeline (2011 Water Quality Report - http://www.greenvillewater.com/waterquality.pdf) to citizens of Greenville every day.

The land around the Table Rock and Poinsett reservoirs is owned by the Greenville Water Company, and through a cooperative agreement with the Nature Conservancy, is in conservation easement. This means that the land around the reservoirs cannot be developed. Lake Keowee is owned by Duke Power, and much of the area around the lake is developed. A 2011 source water assessment conducted by South Carolina Department of Health and Environmental Control (SCDHEC) found 145 possible contamination sources in the 337 square mile watershed surrounding Lake Keowee.

Land use within a watershed affects the water quality of a water body. Water travelling over the land picks up contaminants including soil, litter, and chemicals. Developed land with higher compacted soil or higher percentages of impervious surfaces than undeveloped land will have a higher rate of surface run off, resulting in higher levels of contaminants in the water and lower water quality. Spilled chemicals or breakdown products from industrial sites can leach into the soil and contaminate ground water aquifers which may eventually contaminate surface water bodies.

The City of Greenville gets its water from 2 reservoirs with watersheds that are mostly forested and protected with minimal development and human impact.

As a result, the drinking water that Greenville has is very high in quality and was voted "Best of the Best" tasting water in North America at the American Water Works Association's 2011 conference in Washington, DC.

It is important to remember that Greenville is also part of a watershed, and that the rain water that falls in Greenville makes its way to the Saluda River and eventually, becomes drinking water for people living downstream.

Greenville is a Watershed activities:

Visit a water treatment plant
Contact Greenville Water to visit one of their treatment plants and learn about where we get our drinking water from.

Ask the students to use what they know about the water cycle to ***discuss*** how water moves through their watershed.

Use the Imagine a Watershed ***worksheet*** to trace the movement of water through a watershed as homework or a small group activity.

Once students have completed the first worksheet, either give them the second worksheet in small groups or project it on the board and answer the questions as a class. Or, come back to the Imagine a Watershed Land Use Discussion worksheet after activities from the Land Use or Nonpoint Source Pollution sections as a way to tie the information together.

Greenville is a Watershed Journal Prompts

In your own words, explain the concept of a watershed.

How is a watershed different from a reservoir?

Where do you think the water that you use comes from, and where does the water that goes down your drain go?

Describe the watershed that you live in. Describe the differences between the watershed today and how it may have looked 100 years ago.

Choose a major river in South Carolina (Savannah, Broad, Saluda, Edisto, PeeDee, Santee, Catawba) and research its watershed. Where is it located? What are the major issues that the river faces?

Creating a model watershed can be a time consuming activity. If you don't have the class time to devote to this activity, instead consider inviting a speaker to bring an enviroscape or other model in to speak to your class about watersheds and the impact of land use on the water.
Possible resources:
Environmental Education in South Carolina
Clemson Extension Agency
Greenville County Soil and Water Conservation District

More lesson plans on watersheds are available from PBS: http://www.pbs.org/pov/borders/2004/educators/edu_water1.html

Model a watershed.
Have students create a model watershed in order to visualize how water moves over the land. OR utilize an enviroscape or pre-made model to show how water moves in a watershed. (Model demonstration suggestions available on next page)

*Combine the model demonstration with the information on stormwater runoff and activities on land use to create a multi-lesson unit demonstrating the impact of various land use activities on water quality in a watershed

Follow this link to a full lesson plan on modeling a water shed using cardstock:
http://www.therez.ms/students/documents/watersheds_wetlandsmodel.pdf

WATERSHED DEMONSTRATION: CONNECTING LAND USE AND WATER QUALITY

Teacher's Copy

Materials used for demonstration: (It is most sustainable to use all food products so that at the end of the day, you can compost or dump the waste material down a garbage disposal or outside. Try not to use anything spicy or peppery, as the spices can get into the air when it "rains" and could irritate the lungs.)

- Cocoa powder – soil
- Oregano – organic debris
- Seasoning salt – fertilizer
- Paprika – pesticides
- Soy sauce and water – oil (petroleum based products)
- Cornstarch, water, food coloring – animal waste

Pre-demonstration discussion/lesson options:
- What is land use?
- How do people use the land?
- What do people use to survive, and where do those things come from?
- What is a watershed?
- Landforms and how they are created
- How do people physically alter the land?
- How does water physically alter the land?
- What are nutrients, and where do they come from?
- What are impervious surfaces, and how do they alter the landscape?

The Model Demonstration:
There are many different ways to approach the watershed demonstration. Depending on the focus of your lesson, the age and previous knowledge of your students, and your end goals, you may vary the demonstration accordingly.

An example:
Show the students your model. Ask what they think the model represents or what they see in the model. Define the model as a watershed.

Have students place the model houses and businesses on the watershed in the urban and suburban areas. Ask the students to imagine that they live or work in the model city: Where do they get their water; food; bricks and wood to build their houses; fuel, and the other things that they need to live? As they point out that different products come from farms, mines, forests, factories, or the river, have the students find those locations on the model.

Once you have discussed what people need to survive and where it comes from, start with the cocoa and ask where you might find loose soil. What types of activities cause soil to be loosened or in piles without vegetation on top of it? As the students suggest activities that may contribute to loose soil (construction, logging, forestry, mining), add cocoa powder to the model in the appropriate location. If you know they missed one, prompt them with a question. Continue with each pollutant, and as the students tell you where you might find them, add some to the model.

Once you are finished adding pollutants to the model, make it "rain" and watch as all of the pollutants on land wash into the rivers and streams.

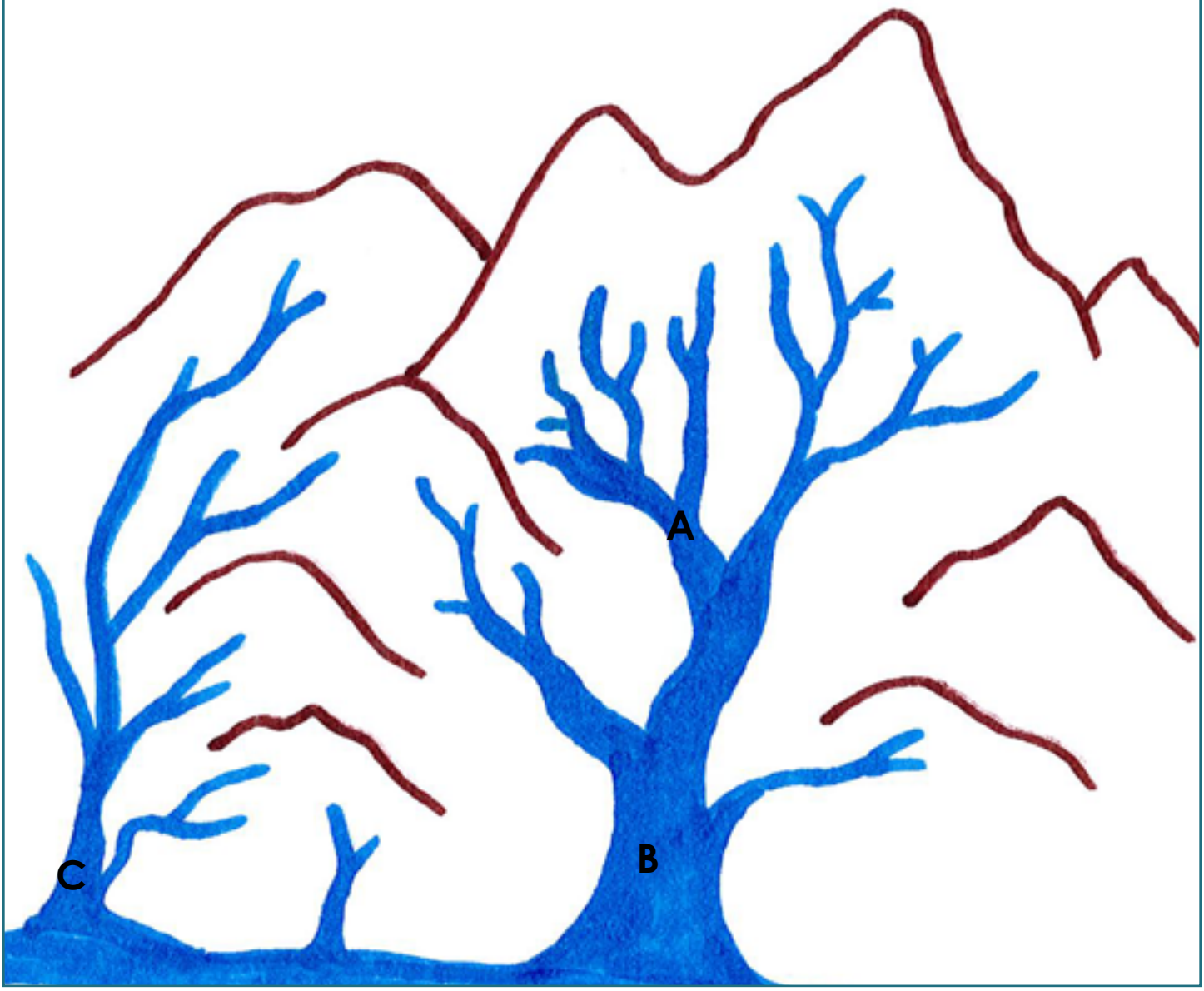
Post-demonstration discussion or writing prompts:

- How accurately do you think the demonstration that you just saw represents what occurs in real life during a rain storm?
    - What do you think was correct or incorrect about the model?
    - Are there any pollutants that you can think of that were not represented on the model?
- What is stormwater runoff?
    - Does this occur in real life?
    - Are there places where we might expect higher levels of stormwater runoff than other places? Where, and why?
- Many of the pollutants that we saw are natural substances (soil, animal waste, organic debris (nutrients)); why do we consider them pollutants?
- What is eutrophication? How does stormwater runoff contribute to eutrophication?
- Some of the processes that we have discussed, such as erosion and eutrophication, are natural processes. Under what circumstances do these natural processes become concerns? Why?
- A well-known adage states "dilution is the solution to pollution." Do you think this holds true? Explain your opinion.
- Which of the pollutants that we discussed concerns you the most? Why?
- What is the difference between point source and nonpoint source pollution? Which of these did we show in the model demonstration?
- Describe the connections between land use and water quality.

Topics for Extension and Research

- Low Impact Development
- Connecting Air to Water: Acid Rain
- Eutrophication
- Wetlands: Benefits of and Threats to
- Urban Alteration: Dams, Baseflow, Canals, Locks – impact
- Waste Water Treatment
- Stream Restoration
- Clean Water Act
- Mitigation
- Point Source Pollution
- Legacy Pollution

IMAGINE A WATERSHED WORKSHEET



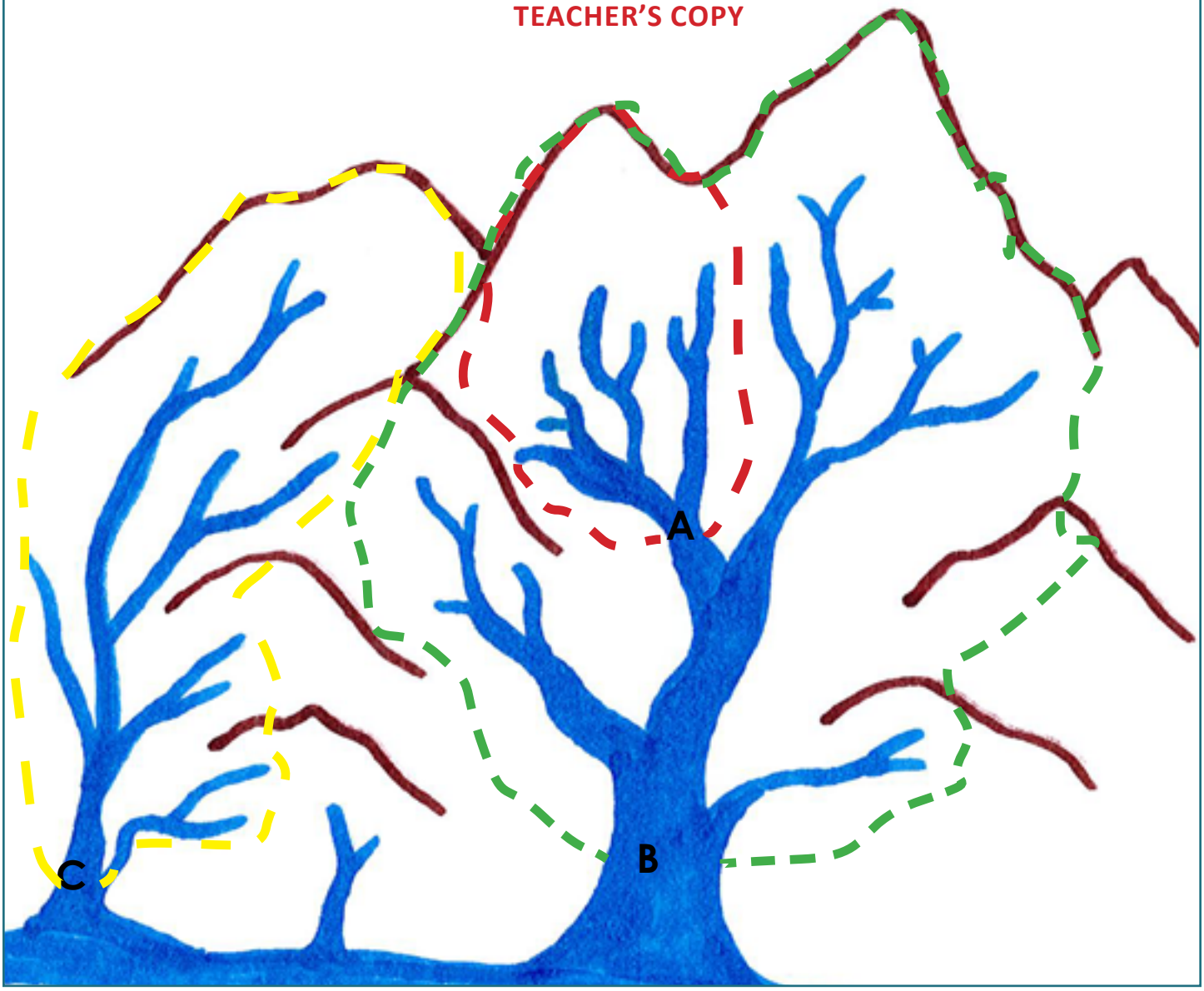
1. Using three different colored pencils, circle the watersheds for the rivers at point A, point B, and Point C on the map.

2. Do any of the watersheds over lap? If so, which ones, and why?

3. Close your eyes and use a fourth colored pencil to place three random dots on the watershed. Draw arrows to trace the path that those three water drops might take to get to the ocean.

IMAGINE A WATERSHED WORKSHEET

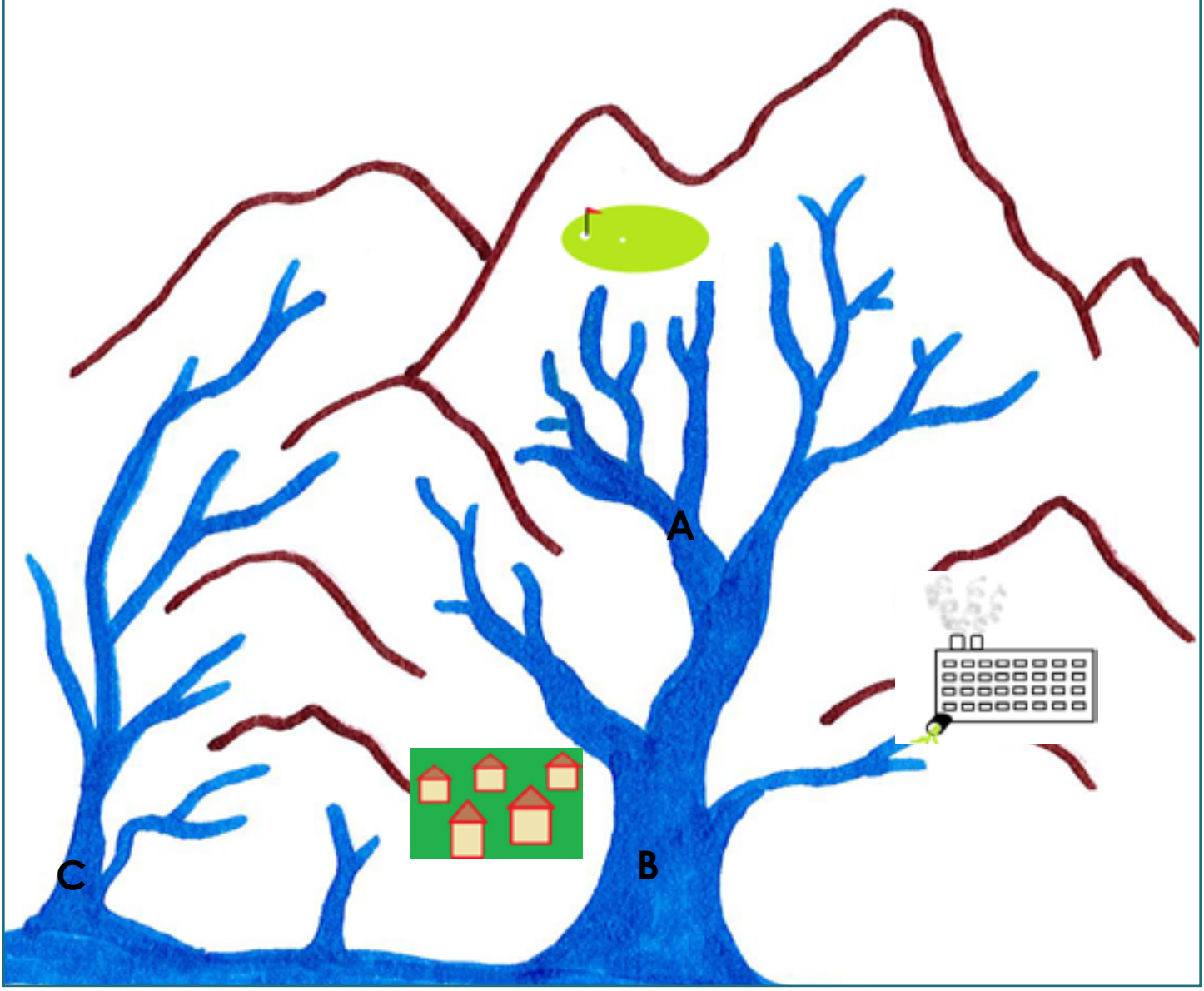
TEACHER'S COPY



1. Using three different colored pencils, circle the watersheds for the rivers at point A, point B, and Point C on the map.
answers are approximate: the important point is that the watershed for each point is all of the land where precipitation on the land would eventually flow to that water body
2. Do any of the watersheds over lap? If so, which ones, and why?
Yes: A and B overlap because the river A is also part of the watershed for the river B.

3. Close your eyes and use a fourth colored pencil to place three random dots on the watershed. Draw arrows to trace the path that those three water drops might take to get to the ocean.
answers will vary

IMAGINE A WATERSHED LAND USE DISCUSSION



Some development has occurred in the watershed. A golfcourse, an industrial factory, and a subdivision have been built. Using your original watershed map and what you have learned about water quality, answer the following questions.

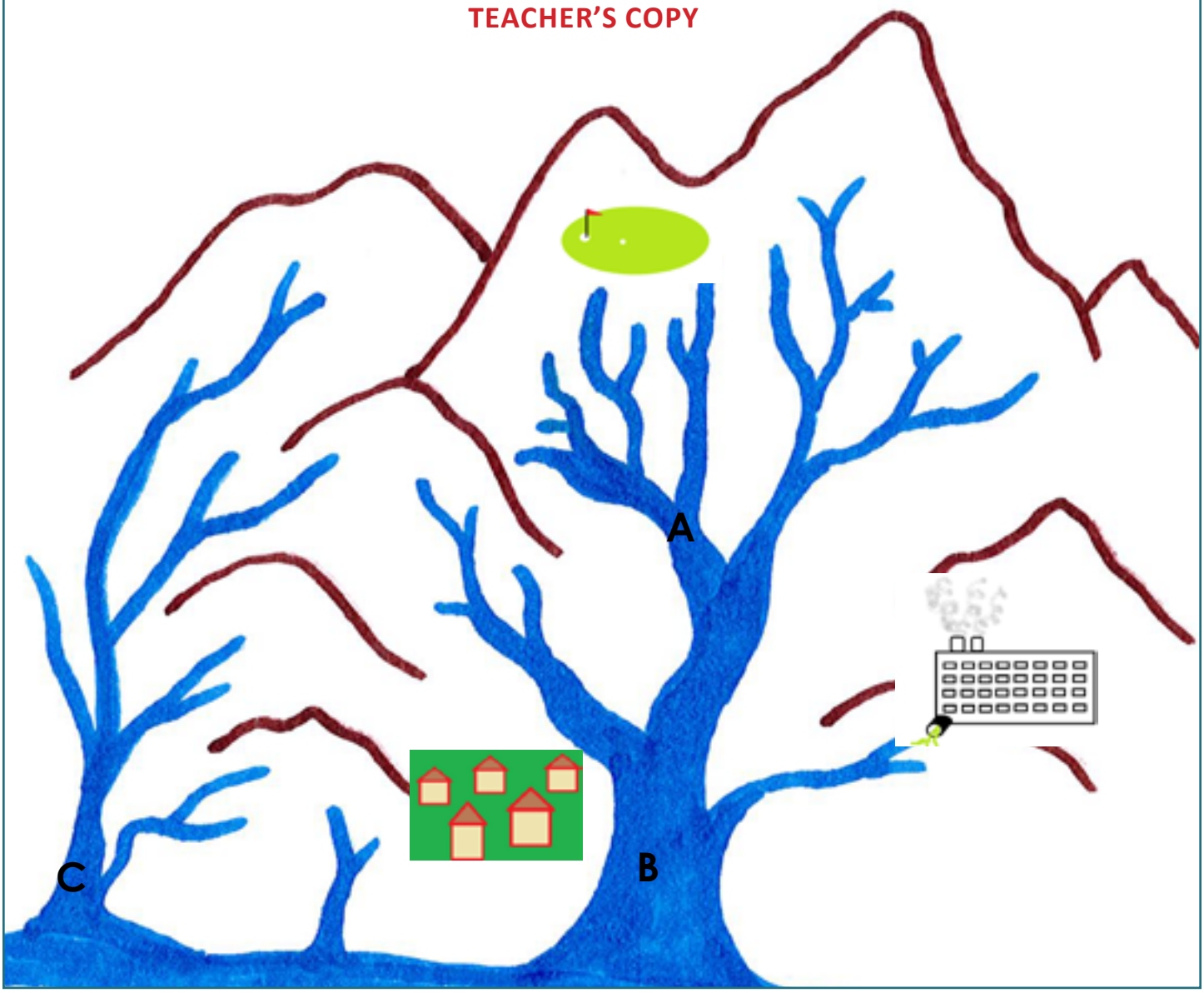
1. How do you think the water quality at point A and B may be affected by the development that has occurred?

2. Imagine that you are a water manager. What steps might you suggest taking to protect the future water quality in this area?

3. Which of the 3 developments would you be the most concerned about if you live in this watershed, and why?

IMAGINE A WATERSHED LAND USE DISCUSSION

TEACHER'S COPY



Some development has occurred in the watershed. A golfcourse, an industrial factory, and a subdivision have been built. Using your original watershed map and what you have learned about water quality, answer the following questions.

1. How do you think the water quality at point A and B may be affected by the development that has occurred?

Point A: higher nutrient levels due to fertilizer, increased sedimentation from development and higher water temperatures due to clearing leads to lower levels of dissolved oxygen. Point B: increased nutrients and chemicals from subdivision and factory leads to poorer water quality. Point B will also see the same effects as point A.

2. Imagine that you are a water manager. What steps might you suggest taking to protect the future water quality in this area? *Answers will vary. May include:*

Maintain planted buffers, regulate discharge at the factory, put in a stormwater retention pond or rain garden at the golf course and subdivision, educate homeowners about runoff, charge a stormwater fee to all developments and use that for mitigation, etc.

3. Which of the 3 developments would you be the most concerned about if you live in this watershed, and why?

Answers will vary.

Land Use and Water Quality

Learning Objectives

Students will

- understand the general concept of land use and become familiar with some of the most common types with a focus on how land use impacts water quality
- explore the concept of land use in their community and discuss the types of land use that they see on a daily basis
- research an area in the City of Greenville and determine how the land has changed over time and extrapolate ways that land use has impacted water quality

Background Information

Close to 30% of the Earth's surface is land. Many different geologic processes go into creating landforms. The land is constantly changing as a result of these processes. Sometimes land is formed or destroyed quickly through processes like volcanic activity and earthquakes, and sometimes land is created or destroyed over a very long period of time by processes like plate tectonics or weathering.

For millions of years, geologic processes and other natural occurrences such as glacier movement, rain, wind, and the growth and death of plant and animal life were the major driving forces in how the land looked and what it was made up of. Then people came along. Early man probably altered the land little more than other animals, mainly building shelters and gathering food. Approximately ten thousand years ago, with the domestication of the first crop plants, humans began to alter the natural environment more drastically. Today, people are a major driving force in shaping what the land looks like and what it is made up of, and since the land and the water are interconnected, the way that people alter the land has drastic impacts on water bodies.

The sections in this chapter will focus on human interaction with the land, how we change and alter the land, the consequences of poor land use, and some land use issues specific to an urban environment with a focus on ways that land use impacts water quality.

People alter the land around them all of the time in a variety of ways. The way in which people use the land is described by the term *land use.*

Land use as a delineation technique is used in many fields by people like planners, law and policy makers, resource managers, and scientists. In an urban environment, land use is often designated and "zoned."

Land use is an extremely complex issue. The scope of this lesson is to explore some of the most common land uses that might be found in and around Greenville, SC, specifically, agriculture, forestry, developed/urban, mining, and industrial.

Word Bank

Agriculture
Barrier
Brownfield
Clear Cut
Conservation
Cultivate
Desertification
Development
Ecosystem
Environment
Forestry
GIS
Ground Water
Humus
Hydrology
Infiltrate
Introduced Species
Invasive Species
Land Use
Legacy
Mining
Monoculture
Open Space
Plan
Planner
Rural
Silviculture
Soil Profile
Suburban
Top Soil
Topography
Urban
Water Table

Land Use Journal Prompts

List 10 reasons that people need land. To each of those reasons, add one way that this land use might impact water.

Describe a way that people use land, and explain why this land use type is important to society.

List five differences between the way that the land looks in a city and the way that land looks in an undeveloped area. Do you think that these differences have any impact on water? Explain your answer.

Pretend that you are an explorer from a place with no cities and you are visiting the City of Greenville. Write a letter home describing the City. Make sure to use imagery that describes the way the City looks, smells, and sounds. Include the City's water resources in your description.

Agriculture: growing crops or raising livestock for human consumption or use. One of the first ways that people altered the land was through agriculture. Agriculture is the world's oldest industry.

There are two main types of agriculture: growing crops and raising livestock.

Growing Plant Crops

- Land alteration to grow plant crops has a long history. Ancient people purposefully altered the land to grow crops by cutting trees, forming slopes into terraces, diverting streams for irrigation, and through the planting of crops.
- Modern agriculture takes land alteration even further. Conventional agriculture (large farms) clear large areas of land, use machines to aerate and move soil, alter the soil nutrient content through chemical fertilizers, and draw water from rivers, lakes, and underground aquifers for irrigation.

Raising Livestock

- Early farmers that raised animals may have cleared land and built fences.
- Modern livestock operations can have large impacts on the land. Land is still often cleared. The vegetative community of an area may be altered drastically by the grazing of large numbers of animals. Animals also alter the soil through a variety of ways. Some animals aerate the soil and add nutrients while others may compact the soil. Animal operations also require large amounts of water and can have a high impact on the chemical makeup of nearby water bodies through nutrient loading of the water in the form of animal waste being washed into streams, rivers, and ponds.

> The consequences of various types of land use are discussed in more detail in the *considering land use legacy* activity and readings. For this lesson, it is most important that students are introduced to many of the ways that people alter the land.

Forestry: the management of forests for the harvest of forest products as well as conservation of forests as ecosystems.
People use trees and forests for a variety of things. Trees alone provide people with food products in the form of nuts, seeds, fruit, and syrups, as well as other materials including dyes, paper, medicines, and wood.

Forests are complex ecosystems. The management of forests and study of forestry is a complex science. The way a forest is managed depends on what it is being managed for. Some forests are primarily managed for the harvest of trees for lumber or paper while other forests are managed as habitat for wildlife like white-tailed deer, quail, or rabbit. Often, forestry management is complex and takes into account a variety of needs such as harvesting, recreation, aesthetic values, and ecosystem services (water quality, protection or restoration of soil, and air quality).

Plantation forestry – areas are planted with a single species of tree specifically for harvest. In South Carolina, the most common species of tree planted in plantations for harvest is the loblolly pine. These trees are mainly harvested for lumber, pulp, and paper.

- Single age stand – plantations are seeded at the same time, and every tree is the same age.
- Multi age stand – more than two different age classes of trees are grown in an area.
- Clear cut – a large stand of trees or an area of forest is completely cleared. Usually for timber harvest, but clear cuts are also often done prior to new development or agriculture.
- Selective logging practices – there are a variety of techniques for harvesting trees that do not involve clear cutting an area. Sometimes less desirable trees are removed to allow the desired trees to grow, or trees of a certain size or age class may be harvested. Areas managed for selective logging are often managed for other uses such as recreation, ecosystem services, and wildlife conservation. Selective logging practices can be less impactful than clear cutting because they leave much of the forest intact and may take into account the habitat needs of other plants and animals present in the ecosystem.

Mining: the extraction of resources from within the Earth.
Though it is most common to think of a mine as a place where precious metals such as gold and silver are removed from the Earth, many resources are mined including coal, salt, stone, oil, clay, lead, natural gas, copper, and more. Mining provides people with many of the raw materials we use in everyday life. There are two major categories of mining:

- Surface mining - a method of removing earth materials from close to the surface of the land by removing the plants and soil covering the material being mined in strips.
- Subsurface mining – a method of mining that involves drilling into the earth to reach and extract the material.

Mining in South Carolina:
According to SC Department of Health and Environmental Control (DHEC), there are 540 active mine operating permits in South Carolina as of 2012. The South Carolina Mining act, passed in 1974, states that mined lands must be reclaimed into usable land following the mine's decommission. South Carolina has no subsurface mining operations but has a variety of surface mining operations including open pit mines and strip mines. The commodities mined in South Carolina include clay, sand, granite, limestone, shale, vermiculite, peat, gravel, kaolin, and gold.

Online Resources

http://www.dnr.sc.gov/geology/images/Mining-pg.pdf

http://www.scdhec.gov/environment/lwm/html/mining.htm

http://www.scmines.com/education.html (Video on mining in South Carolina)

Water resources are affected by nearby land use in many different ways, including size, shape, and velocity.

Urban development examples
Top: City of Atlanta, GA
Bottom: A silt fence to help control erosion in Greenville, SC

Developed: Cities are defined as areas where development is concentrated. Land that is developed for a city is changed in many ways. Often, the physical structure of the land is altered when it is graded or terraced in order to build buildings. Roads, parking lots, buildings, and other structures are placed on top of the land. Plants are cleared, and other plants are brought in for landscaping purposes, altering the natural community structure of the area. In some urban areas, rivers and streams are canalized, moved, or dammed to harvest water.

Urban areas are important centers of development for people and can include land used for a variety of purposes such as residential, industrial, recreational, and green space.

Industrial: the use of land for manufacturing, factories, power plants, refineries, and other activities that usually require large equipment. Industrial land use can occur in rural or urban areas. Industrial land use often requires a large amount of space dedicated to buildings and heavy machinery. Industry creates most of the materials, technology, and power that people use on a day to day basis.

Other
Conservation: land set aside for the protection of natural areas, communities, and resources.

There are many more categories that land use could be placed into, but these represent some of the most widely used and impactful.

What is Land Use Activities

Brainstorm categories for how people use land.

Before discussing the major types of land use, divide the class into groups and assign or allow the groups to choose a major type of land use. Ask the students to brainstorm in their group to answer the following questions as best they can.

- Why do people use the land this way?
- In using the land for this purpose, is it changed from its natural state?
- How?
- Have you seen this type of land use? If so, describe it.
- Is this type of land use taking place today? In the state of South Carolina? Greenville County? In the City of Greenville?

After the brainstorming session, present each type of land use to the class.

The Land I See

Take a class walk and note the ways that people use the land and note any areas of water you see.

What are the defining features that tell us how people use the land? the water?

Brainstorm what the land and water might look like if there was no city here.

Research an area in the City of Greenville to see how the land has changed over time. Depending on the accessibility of internet access, this could be a small group or a class wide project.

Use the City of Greenville's historic imagery database to see how the land has changed over the last 60 years.
http://gis64.greenvillesc.gov/historicalimagery/

Bring the website up for the class and demonstrate how to use the various tools to search, zoom, move around the map, mark a spot, and change years. Once the class is familiar with the site, either use the worksheet on the next page, or develop your own set of locations and questions for the class to use to explore how Greenville has changed.

As a class, use the website to focus on the Reedy River. How has the river changed over time? How do you think the development of the city has impacted the river?

Read the news, and discuss the ways that the article mentions that Greenville has changed. Discuss why change can be a good thing, and why change can be a negative thing for a city.

Greenville News Article: Though treasures have been lost, downtown finds value in history
http://www.greenvilleonline.com/apps/pbcs.dll/article?AID=2013304280002

*Note that the activities in this section have been excerpted from the Community Quest Program and altered to focus on the connections between land use and water quality

HOW LAND USE CHANGES
USING HISTORIC IMAGERY TO EXPLORE LAND USE PATTERNS OVER TIME

Directions:
Look up the address of your assigned location and go to the City of Greenville's historic imagery database: http://gis64.greenvillesc.gov/historicalimagery/.
Type the address for your location into the search feature.
Use the push pin icon to place a "pin" on the structure that is the focus of your investigation.
Next, use the sliding arrows to view aerial photos from 1955 to the present.

A J Whittenberg Elementary School: 420 Westfield Street 1) After what year was the school built? 2) What do you think this land was used for in 1989? 3) Between which years was Academy Street built? 4) Between which years does it look like the largest change in land use occurred in this area? Explain	**The Wellness Arena: 650 N. Academy** 1) After what year was the Wellness Arena built? 2) What did the land that the Wellness Arena is on now look like in 1955? 3) Between which years does it look like the largest change in land use occurred in this area? 4) Other than the building of the Wellness Arena, how did the land in this location change between 1965 and the present?
Fluor Field: 945 S. Main St 1) After what year was Fluor Field built? 2) What is the name of the road that used to cross the land that Flour Field is now on?	Location of choice Address:_____ 1) Has their been a change in the way the land was used at this location? 2) If so, describe the land use before and after the change.

Describe a way that changing land use over time in the City of Greenville has impacted the Reedy River? How do you feel about this impact?

HOW LAND USE CHANGES
USING HISTORIC IMAGERY TO EXPLORE LAND USE PATTERNS OVER TIME

Directions:
Look up the address of your assigned location and go to the City of Greenville's historic imagery database: http://gis64.greenvillesc.gov/historicalimagery/.
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Use the push pin icon to place a "pin" on the structure that is the focus of your investigation.
Next, use the sliding arrows to view aerial photos from 1955 to the present.

210 S. Main Street (old City Hall)
1) What was this building in the 1920's?

2) After what year was this building demolished?

3) Where is the current City Hall building in relation to the old?

4) How has main street changed since the 60s?

Falls Park: 601 S. Main Street (approximate)
1)What is the name of the road that went through the area that is now Falls Park?

2) After what year was the road from question 1 built, and after what year was it removed?

3) What other observations can you make about the land where Falls Park is now located?

540 Buncombe Street: Heritage Green
1) Describe 3 major changes that occurred in this area of Greenville and list the years in which that change occurred.

Location of choice
Address:_____
1) Has their been a change in the way the land was used at this location?

2) If so, describe the land use before and after the change.

Describe a way that changing land use over time in the City of Greenville has impacted the Reedy River? How do you feel about this impact?

HOW LAND USE CHANGES: TEACHER'S COPY
USING HISTORIC IMAGERY TO EXPLORE LAND USE PATTERNS OVER TIME

Directions:
Look up the address of your assigned location and go to the City of Greenville's historic imagery database: http://gis64.greenvillesc.gov/historicalimagery/.
Type the address for your location into the search feature.
Use the push pin icon to place a "pin" on the structure that is the focus of your investigation.
Next, use the sliding arrows to view aerial photos from 1955 to the present.

A J Whittenberg Elementary School: 420 Westfield Street 1) After what year was the school built? 1997 2) What do you think this land was used for in 1989? Vacant/underutilized: answers may vary 3) Between which years was Academy Street built? 1965 and 1979 (must zoom out some to locate academy street 4) Between which years does it look like the largest change in land use occurred in this area? answers will vary	**The Wellness Arena: 650 N. Academy** 1) After what year was the Wellness Arena built? 1997 2) What did the land that the Wellness Arena is on now look like in 1955? residential neighborhoods. Many small buildings 3) Between which years does it look like the largest change in land use occurred in this area? Answers will vary 4) Other than the building of the Wellness Arena how did the land in this location change between 1965 and the present? Beatie Pl was extended, while other roads were removed. More impermeable surfaces today
Fluor Field: 945 S. Main St. 1) After what year was Fluor Field built? 1997 2) What is the name of the road that used to cross the land that Flour Field is now on? Green Avenue	Location of choice Address:_____ 1) Has their been a change in the way the land was used at this location? 2) If so, describe the land use before and after the change.

Describe a way that changing land use over time in the City of Greenville has impacted the Reedy River? How do you feel about this impact?

HOW LAND USE CHANGES TEACHER'S COPY
USING HISTORIC IMAGERY TO EXPLORE LAND USE PATTERNS OVER TIME

Directions:
Look up the address of your assigned location and go to the City of Greenville's historic imagery database: http://gis64.greenvillesc.gov/historicalimagery/.
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Use the push pin icon to place a "pin" on the structure that is the focus of your investigation.
Next, use the sliding arrows to view aerial photos from 1955 to the present.

210 S. Main Street (old City Hall)
1) What was this building in the 1920's.?
Post office (1920's street map)

2) After what year was this building demolished?
1965

3) Where is the current City Hall building in relation to the old?
On the same block on Main St. (current street view)

4) How has main street changed since the 60s?
The road is now 2 lanes with parking on either side instead of four lanes

Falls Park: 601 S. Main Street (approximate)
1)What is the name of the road that went through the area that is now Falls Park?
Camperdown Way

2) After what year was the road from question 1 built, and after what year was it removed?
1955 and 1997

3) What other observations can you make about the land where Falls Park is now located?

Answers will vary

540 Buncombe Street: Heritage Green
1) Describe 3 major changes that occurred in this area of Greenville and list the years in which that change occurred.

Answers will vary: Major changes include
1955 - 65 - buildings on College Street demolished. Parking lot built on Marshall
1965 - 79 - new buildings built on college st, more parking on Marshal, and new rd: Heritage Green
1997 - 2011: parking lots removed and garage built. Large building (library) constructed. Atwood and Butler streets connected

Location of choice
Address:_____
1) Has their been a change in the way the land was used at this location?

2) If so, describe the land use before and after the change.

Describe a way that changing land use over time in the City of Greenville has impacted the Reedy River? How do you feel about this impact?

Picture the Difference

Greenville's Reedy River is a prime example of the way that development and the changing needs of society alters the land. The river was once utilized to power the textile mills that led to much of Greenville's early development and recognition as the "textile capital of the South." The Reedy River has been bridged, canalized, polluted by industry, and recently, restored and cleaned.

Imagine what the river would look like if Greenville had never been developed?

Use the photograph cards showing various types of land use to promote discussion *(example below)*.

Ask students to note all of the ways they can see that the land has been changed by people. How can they tell? What do they think would the land look like if it was undisturbed by human development? How would water move in this environment? How is water movement different in a natural environment?

Landscape plants planted in specific places rather than natural plants. May absorb water or anchor soil in a different way than native plants

Bridge, road, fence, and other man made structures alter river flow and access to the water. Bridges make crossing water easier

Lawn: short, perfectly green grass is not found in the wild. Cutting this grass may cause fuel to leak into the water

River channel not natural: flow altered by people


THE WESTIN

Considering Land Use Legacy
**adapted from Community Quest*

explore the possible impacts that various types of land use can have on the land, and discuss ways that people can continue to use the land to meet their needs while protecting the environment and human health from negative land use effects

The way that we use land has a huge impact on the natural environment. Different types of land use alter the land in a variety of ways. Most notably, land uses can have long lasting effects on topography, soil composition, hydrology, and the plant and animal communities that inhabit an ecosystem.

Though all of these impacts interact, we will consider each separately for ease of comprehension and focus on hydrology during discussion.

The following informational sheets may be used as critical reading exercises, or for background for your lesson. Each sheet provides background information on a major land use category and then explores some of the ways that type of land use alters the land.

Land Use Legacy Journal Prompts

The term legacy often refers to a gift or characteristic that is left behind once a person has passed away. Why do you think that this section is titled "Land Use Legacy?"

Imagine that it's the year 2150, and there are no longer any people living in Greenville. The City has been empty for 100 years. What do you think the City would look like? Would you be able to tell that a city once stood here, and how? Address the City's water resources in your discussion.

Why is minimizing our impact on the land a goal of sustainable development? Is it possible to develop without impacting the land at all? Explain your answer.

Discuss one way that land use alters the hydrology of an ecosystem. Imagine you are a fish living downstream of this type of land use. How would your environment be altered?

Land Use Legacy: Agriculture

Agriculture: Background

When people use land to grow crops or raise animals for harvest, it is considered an agricultural land use. One of the first ways that people began using the land was for agriculture, and agriculture is considered by many to be the world's oldest industry.

Most modern agricultural systems plant crops in large groups of a single type of plant, called monocultures. Soil is tilled and often planted using large machines. Large machines are also used to harvest crops at the end of the growing season. Crop fields are usually irrigated, meaning that water is brought to the field through a series of pipes and sprayed or dripped onto the crops. These large farm operations, sometimes called agribusinesses, also often use chemical fertilizers to enhance plant growth. Pesticides and herbicides are used to control pests and weeds that may reduce a farmer's yields.

Modern animal operations are often similar to plant operations in that a large number of animals are kept together, machinery is used for much of the care and harvest of the animals or animal products, and chemicals are employed to reduce pests and diseases.

Conventional farm operations using the methods outlined above make up the majority of the agricultural land use in the US, but they are not the only way to grow plants and animals. Many farmers use other methods ranging from multi-crop systems where more than one plant is grown in the same space to small farms using organic methods and free range animal operations.

Agriculture is an extremely important type of land use. Before agriculture, humans were hunters and gatherers that would have to move frequently to find food. Society as we know it would not be able to exist without agriculture. Farmers raise plants and animals that provide us with food, clothing, dyes, medicines, and much more. Yet, agriculture also comes at a price to the land.

Modern agricultural systems modify the topography, soil composition, hydrology, and plant and animal diversity of the land in a variety of ways.

Topography: The Shape of the Land

The topography, or shape of the land, is important for a variety of reasons. The shape of the land can affect which species of animals and plants can live there, how water moves over and through the land, and even the weather. Agriculture alters the shape of the land in many ways.

When farmers clear land for crops, they remove trees and large stones and boulders that were on the land. The space that will be farmed is graded with large machines so that it is as flat as possible. Sometimes if an area is really steep or hilly, that includes building terraces, flat spaces that drop off quickly to another flat space. Terraces look like really large stair cases on the sides of hills. Sometimes stone or packed earth walls are used to hold the soil in place. Imagine how differently water moves over land that is a gently sloping hill compared to land that has been terraced.

Fields used for raising animals may not need to be terraced or tilled, but many animals grazing in one space may compact the soil. Low-lying areas and wetlands also may be filled in order to use those spaces for agriculture.

Areas that were once farmed in the past but have reverted back to forests can often be distinguished from natural areas due to the altered shape of the landscape from terracing, clearing, and compacted soil. Old stone walls, dams, fences, and other structures from farming may also remain part of the landscape long after the farm is gone.

Hydrology: How water moves on and through the land

A natural ecosystem has plants and animals that have adapted to the amount of rainfall that the area receives. Plants grow by absorbing water from the ground, and their roots help increase the infiltration of rainwater into soil. Tree canopies and leaf litter slow rainfall, also increasing the amount of time water has to infiltrate the soil, joining the ground water.

Conventional agricultural systems, on the other hand, compact the soil, making it more difficult for rainwater to infiltrate the soil and increasing surface runoff following a rain event.

In order to grow crops or animals, farmers need water. The water for irrigation or watering animals is often pumped from underground, removing water from underground storage areas called aquifers. Spray irrigation increases evaporation and thus water loss. Sometimes, aquifers receive more water from rainfall, which is known as recharge. If the soil is too compacted or too much water is removed from aquifers, the ground water may dry up, causing destabilization of the ground which can result in sinkholes where the ground itself collapses, and reducing water input to streams.

Some farm operations dam streams or rivers. Dams alter the rate of flow and the composition of the water and create a barrier to movement for aquatic organisms. Finally, the input of animal waste, soil, and chemical pesticides and fertilizers can drastically affect water quality and the ability of aquatic systems to support life.

Soil Composition: The Physical and Chemical makeup of the soil

A natural grassland or forest that has not been farmed has soil that is made up of deep layers of organic matter built up over the course of many years. When plants and animals die and decompose, they become nutrients and organic matter in the soil. The roots of native trees or plants in forests and grasslands hold the soil in place and shade it. When plants die, the organic matter and nutrients that they used to grow go back into the soil to be used again.

When the land is cleared and farmed, at harvest time, organic matter is permanently removed from the soil since the plants are harvested and not allowed to decompose. The soil is also exposed to sunlight which heats the soil, speeding up the decomposition of organic matter, and rainfall, which may wash away some of the soil in a process called erosion. Plowing and tilling also turn and expose soil to light and air which also speeds up decomposition and nutrient loss.

Growing the same plants year after year depletes the soil of certain nutrients and can also encourage the growth of insect pests and pathogens in the soil. Crop rotation systems minimize the risk of disease and some plants, such as beans, fix nitrogen, putting valuable nutrients back into the soil.

Areas that have been farmed for years often have less defined soil layers and less healthy soils than land that has not been farmed. Over time, intensive farming in an area can lead to an overall loss of soil.

In order to combat soil nutrient loss, conventional farming makes use of chemical fertilizers to put nutrients back into the soil. Organic fertilizers and compost soil amendments, the use of winter cover crops to prevent erosion, (as well as shade the soil, and increase organic matter input), no-till agriculture, and rotational grazing are all agricultural practices that help reduce the negative impact of farming on soil composition.

Natural Communities: plant and animal diversity

Many of the ways that agriculture affects the land in turn alter the composition of animal and plant communities. Clearing land for crops or grazing animals removes trees and shrubs and excludes the animals that live in and among them.

Compacted soil is harder for water to infiltrate and harder for plants to grow in, because plant roots may not be able to penetrate compacted soil. So, due to soil compaction, grazing, and altered hydrology, agriculture can change which plants are able to survive in an area.

The loss of soil nutrients due to agriculture also changes which plants are able to grow in the soil.

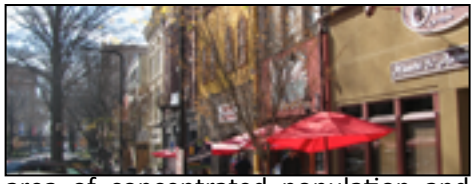
Large monocultures of plants encourage population explosions of insects and other pests that feed on those plants. Plants that grow quickly in high sunlight are often considered weeds in agricultural systems because they compete for water and nutrients with crop plants. Farmers use chemical pesticides and herbicides in order to control pests and weeds. If the pesticides and herbicides aren't specifically formulated to kill just one species, they can kill non-target plants and animals, further altering the species composition of natural communities.

Finally, water runoff from farms carries chemical pesticides, fertilizers, soil, and animal waste into streams. All of these materials cause reduced water quality and alter the species composition of aquatic communities which are the basis for many terrestrial and aquatic food chains.

Land Use Legacy: Urban Development

Urban Development: Background

When people develop a large area of land for commerce, industry, and living, this is considered urban development. Historically, urban areas, also called cities, often grew up around centers of transportation, where people would congregate to trade goods that they could not make or grow themselves. Walls made the city more defensible than the surrounding countryside. Cities eventually became areas where centers of learning, religion, and art where concentrated.



A city can be thought of as an area of concentrated population and development. The buildings within a city are generally taller than buildings in more rural areas in order to fit the activities of more people into less space.

Cities have a wide variety of effects on the natural environment. Since development is concentrated, cities tend to have higher rates of pollution than rural areas. Cities generally have fewer plants and trees and more buildings, roads, parking lots and other structures than rural areas. These alterations in the landscape result in urban areas being warmer than surrounding rural areas, a phenomenon known as the "urban heat island effect." Cities are made up of a network of transportation corridors, buildings, infrastructure, and green space. Each of these has its own purpose and associated environmental effects. Thus, urban development can be thought of as a combination of multiple types of land use with a wide range of possible land use legacies.

Topography: The Shape of the Land

When people build cities, they alter the shape of the land in many ways. In order to place a building, parking lot, or road on the land, plants are removed from the land, and then the land must be flattened. This is often done with large machines which first move the soil around and then grade and compact it. In order to develop a large section of land, low lying areas and wetlands are often filled in and vegetation and large boulders are removed. Features such as rivers or ravines are sometimes moved, and other times bridged.

Hydrology: How water moves on and through the land

Urban development can have many effects on the hydrology of an area. Often, when cities were built in the past, they were built along bodies of water. Rivers are natural transportation corridors, allowing the movement of people and goods along the river from one place to another. Rivers also provided power for early grist mills and may still provide power in the form of hydroelectricity. Sometimes, people physically alter the shape and placement of rivers by building canals, dredging, or moving the river.

In some urban areas, dams or locks have been built along rivers to either harness electricity or create reservoirs for water storage or recreation. Dams have many effects on the way that water moves and the downstream ecosystem. Dams are physical barriers to movement and may keep animals such as fish from moving upstream to breed. Often, when water is released from the dam, it is a different temperature than water in the river. Temperature can alter the water's ability to support aquatic life. Dams also change the rate of flow in the river downstream of the dam.

The large amount of buildings, parking lots, and roads in urban areas also alters the hydrology of the area. These surfaces, called impermeable surfaces, do not allow water to soak into the soil, but instead funnel water into drains that run directly to rivers and streams. Large amounts of impervious surfaces result in lower base flows for rivers because less water is reaching the ground water table in urban areas. Also, during rain events, there is an increase in the amount of water reaching the river due to surface runoff. That surface runoff is often polluted because it flowed over roads and parking lots, picking up trash and chemicals on the road. High surface runoff may result in flooding and reduced water quality in rivers and streams.

Soil Composition: The Physical and Chemical makeup of the soil

When land is prepared for development, the top layer of soil is often moved and the remaining soil is compacted and graded so that it is flat. Without the protective layer of plant covering that is usually present, soil is vulnerable to wind and rain and erosion is increased. When soil is washed into rivers and streams, it can harm the animals and plants that live in the rivers and streams, and it can also raise the level of the water, leading to flooding.

Soil in developed areas is often compacted. Soil compaction can occur quickly when machinery is driven over an area or over a long period of time by heavy foot traffic. Wet soils are more vulnerable to becoming compacted than dry soils.

Compaction occurs when soil is pressed, removing air pockets. Compaction makes it more difficult for plant roots to become established and for water to infiltrate the soil. Less plant cover and lower rates of water infiltration result in increased erosion, increased storm water runoff ,and lower surface water quality. Soil compaction is very important and necessary for buildings and roads. Without a compacted, stable base, buildings and roads settle and crack over time, which can be dangerous. But, in areas of land left undeveloped, soil compaction can cause many negative environmental impacts.

Natural Communities: plant and animal diversity

Urban development can drastically alter the plant and animal diversity of an area. A common approach to development is to remove all of the plants and animals that were present in an area, build the development, and then strategically landscape the development with new plants.

Many of the plants used in landscaping can become invasive. Invasive species are living organisms that are not native to an area but are brought in from somewhere else, often another country. Once established, invasive species cause environmental or economic harm. Not all landscape plants are invasive, but the ones that are can quickly take over an area, out-competing native plants. Invasive plants can be a concern in the urban environment as well as nearby undeveloped areas that they may spread to.

Whether native plants are removed for development or crowded out by invasive species, plant diversity is often lower in urban areas than in surrounding rural and undeveloped areas. A loss of plant diversity leads to a reduction in animal diversity because animals need plants for food and shelter.

Urban development alters the structure of animal and plant communities in many ways. Urban areas are often noisy, bright and full of traffic and hard surfaces. Some animals, especially nocturnal scavengers like raccoons, and small animals that can move around easily, such as birds, can adapt well to living in an urban environment, while others are unable to survive in urban conditions.

Buildings, factories, roads, bridges, parks and green spaces are all part of the network that makes up urban development, and all of these alter plant and animal diversity in a variety of ways.

Land Use Legacy: Forestry

Forestry: Background

Forests are complex ecosystems that are managed by people for a variety of different reasons. Some of the most common concerns of forest managers include growing trees for harvest, providing wildlife habitat, use of forests for recreation and aesthetic value, and the provision of ecosystem services such as conservation and restoration of soil quality, air quality, and water quality. Because forestry is such a complex issue, we will mainly discuss the management of forests for the harvest of trees and tree products such as paper and timber, but it is important to understand that forests are often managed for a variety of associated products and services.

Trees have been grown and harvested by people for a very long time. Wood has been one of the most common building materials and sources of fuel for as long as human civilization has existed. Today, trees are mainly harvested for use as building materials, paper, and firewood as fuel for cooking and heat.

When a single species of tree is planted for harvest in a large stand, that stand is called a tree plantation. Plantation trees can be planted at the same time so that all of the trees are the same age or planted in series so that there are at least three different ages of trees, but all trees are the same species. Often, trees are harvested from forests that were not planted as plantations but are instead mixed species forests.

There are many different ways of harvesting trees for wood, and each have different consequences. The first method of harvest is clear-cutting. When a forest is clear-cut, all of the trees in an area are removed at one time. As an alternative option to clear-cutting, forests can be harvested through a process called selective logging. When a forest is selectively logged, only a few trees are cut so that there are older trees available to produce seeds, and spaces for young trees to grow. Selective logging is often considered a more environmentally friendly alternative to clear-cutting, but it can be more labor intensive, time consuming, expensive, and yield less of an immediate profit.

Topography: The Shape of the Land

When forests are managed for ecosystem services, recreation, aesthetics, and wildlife habitat, few if any changes occur in the topography of the land. Some movement of soil or gaps in the forest canopy due to tree falls is natural, and forest ecosystems are adapted to dealing with a certain level of disturbance.

Clear-cutting, on the other hand, can have a major effect on the topography of the land. Large machines used for clear cutting create compacted soil in some areas and ruts, gullies, and loosened soil in others.

Trees and shrubs have roots that anchor soil in place and a canopy of branches that slow rainfall. If all of the trees in an area are removed the protective canopy disappears. When rain falls on a bare patch of ground, the speed of the rain hitting the ground is much higher than under a forest canopy. Without the anchoring effect of tree roots, topsoil is much more likely to be washed away by rain.

Clear cut areas are prone to higher levels of erosion and increased frequency of landslides than areas that remain covered with forests. This may result in gullies and exposed areas of bedrock.

Hydrology: How water moves on and through the land

In the presence of sunlight, trees combine water and carbon dioxide to make food. Trees absorb water through their roots and transport it upward to the leaves and branches through the xylem. When sunlight heats the leaves of a tree, some water is lost through small holes in the leaf called stomata. This process is called transpiration. According to the USGS, a large oak tree can transpire 40,000 gallons of water a year.

The absorption and transpiration of water from the soil creates spaces in the soil that do not have water in them. During a rain event, water is more likely to infiltrate the soil to fill the spaces in the soil than to stay on top of the soil. Canopies also slow rainfall, which increases infiltration.

Removing trees, especially through clear-cutting, changes this dynamic. Rainfall hits the ground harder and is less likely to infiltrate the soil. Evapotranspiration rates are much lower, and surface runoff is higher. Combined with compacted soil and increased erosion, the impact of tree removal on water bodies is an increase in surface runoff and a higher probability of flooding. When surface runoff occurs, eroded soil and nutrients will flow over land into water bodies. The lack of trees shading streams increases water temperature. Increased temperature, nutrients, and soil in the water reduce the amount of dissolved oxygen in the water, which in turn reduces water quality and the ability of a water body to support life. Finally, ground water infiltration is lower in areas that have been clear cut, which alters the underground flow of water as well as the above ground flow. Less ground water can cause a reduction in the base flow of rivers and streams.

Soil Composition: The Physical and Chemical makeup of the soil

When trees are removed from an area that was previously forested, the soil is exposed to sunlight and rainwater. The sunlight heats the soil and increases the breakdown of organic matter in the top layers of soil, and the rainwater traveling across the soil increases erosion. Topsoil, the layer of soil that is full of nutrients and organic matter is lost quickly, making the soil less healthy and harder for plants to grow in.

Heavy equipment used to cut and remove trees causes the soil to be compacted. Soil compaction can occur when machinery is driven over an area or over time by heavy foot traffic. Wet soils are more vulnerable to becoming impacted than dry soils. Compaction occurs when soil is pressed, removing air pockets. Compaction makes it more difficult for plant roots to become established and for water to infiltrate the soil. Less plant cover and lower rates of water infiltration result in increased erosion, increased storm water runoff, and lower surface water quality in nearby bodies of water.

The chemical and biological structure of soil is also affected by logging. Trees use nutrients in the soil to grow. When trees are cut down and removed from an area, the nutrients in their tissues are also removed. If a tree falls naturally in a forest, it will decompose, returning nutrients from the tree to the soil which will be used by other plants and animals. Over time, removing trees from a forest will deplete the nutrient content of the soil, making the forest less productive.

Selective logging causes less soil compaction and leaves some trees to shade the soil and continue contributing leaves and branches to the humus layer of the topsoil. Though some biomass is removed from the forest, much is retained, helping to protect the soil while still providing people with timber.

Natural Communities: plant and animal diversity

Forests are complex ecosystems that provide homes for many plants and animals. Altering the structure of a forest by removing trees can have a variety of impacts, both positive and negative.

Some forest species need sunlight in order to grow. Selective logging creates gaps in the forest canopy that can be colonized by species that need more sunlight than is available in mature forests. Like natural tree falls, this may increase species diversity of plants which provide food and shelter for animals, thus increasing the diversity of the animal community.

Clear-cutting, on the other hand, removes all of the vegetation from an area and completely alters the ability of the land to support plants and animals. Plant species that need a lot of sunlight are the only ones that can grow and survive, creating a very different plant community than in a forest with gaps. Over time, the forest may grow back if the topsoil is not all lost to erosion, but it will take much longer than if the area is selectively logged.

When trees are cleared, the animals that depend on them no longer have food and shelter. Some species of animals only make their homes in old hollow trees, or only eat the nuts or berries produced by trees that grow in mature forests. When an area is clear-cut, these species have to find new homes or they won't survive. Because of the interdependency and complex relationships between plants and animals in forest ecosystems, forest managers have a lot to consider when they determine the best way to harvest trees from a forest

Critical Thinking Questions for Land Use Legacy

Agricultural Land Use

1) Choose one of the four topics and summarize how agricultural land use affects either topography, soil composition, hydrology, or natural communities.

2) List three ways that farmers can reduce the impact of agriculture on soil composition. Choose one of the three and explain why you think doing this is beneficial to soil composition and whether or not doing this would impact hydrology in any way?

3) In your opinion, which of the four main ways that agricultural land use affects the land is the biggest concern? Why?

4) You are in a forest that was farmed 200 years ago but is now wooded again. Name three ways that you might be able to tell that the land was once used for farming.

5) How is stream water quality affected by agriculture, and why is water quality important?

6) Choose a negative impact of farming on the land and describe a way that you would minimize that impact.

Urban Development

1) Choose one of the four topics and summarize how urban development affects either topography, soil composition, hydrology, or natural communities.

2) List 4 aspects of urban development that you think are the same in any city.

3) In your opinion, which of the four main ways that urban development affects the land is the biggest concern? Why?

4) What is an invasive plant, and why are invasive plants an environmental concern? Do you think that invasive plants can impact water quality in any way? How?

5) Choose a negative impact of urban development on the land and describe a way that you would minimize that impact.

6) What do you think are the consequences of reduced base flow in urban streams?

Forestry

1) Choose one of the four topics and summarize how forestry affects either topography, soil composition, hydrology, or natural communities.

2) Which has a greater environmental impact; selective logging or clear-cutting? Explain why and how.

3) What is soil compaction, how does it happen, and why is it a concern?

4) List 10 benefits that people receive from forests.

5) Choose a negative impact of forestry on the land and describe a way that you would minimize that impact.

6) What do you think are the consequences of warmer temperatures in forest stream ecosystems following a clear cut forestry operation?

The Urban Water Cycle

Word Bank

Aquatic
Buffer Zone
Condensation
Contaminant
Dissolved Oxygen
Effluent
Evaporation
Green Space
Ground water
Impairment
Infiltration
Pollution
Precipitation
Reservoir
Sediment
Stormwater Runoff
Transpiration
Water Body
Water Cycle
Water Quality
Water table
Watershed
Zoning

Learning Objectives

Students will

- explore the ways in which urban development impacts water quality in urban streams and other surface waters
- understand the water cycle and how the concepts of the water cycle can be applied further to animals, plants, and structures in an urban setting in order to model how water travels through the urban environment

Background Information

The hydrologic cycle, also known as the water cycle, is the process by which water is transferred from oceans to the atmosphere, the land, and finally back to the ocean through evaporation, transpiration, precipitation, and runoff. This lesson modifies the hydrologic cycle to model the movement of water within and through an urban environment.

Greenville's water source is mostly protected, but all water bodies are an important resource, not just our reservoirs.

> Everyone lives downstream. The water that runs over and through the City of Greenville eventually enters the Saluda River and flows to the Atlantic Ocean. People and animals downstream depend on that water.

Less than 1% of the water on Earth is freshwater that is available for human use and consumption.

> Oceans hold approximately 97.2% of the water on Earth, 2.15% is locked in ice caps and glaciers. That leaves less than 1% to make up the water in lakes, streams, rivers, wetlands, and groundwater.

Contamination and destruction of freshwater resources is a very serious problem for both the environment and human health.

> Aquatic freshwater ecosystems are extremely important.

The Urban Water Cycle

The following information can be used independently to foster discussion of the movement of water through an urban environment, or as part of the urban water cycle game.

In order to understand how the urban environment impacts water quality, we will consider a simplified model of the water cycle to study the places that water may travel in the urban environment. You can either play the water cycle game following a discussion about how water moves in the urban

environment, or you can use the game as a starting point and follow with an in depth discussion about how water moves. Though the urban water cycle game does not show every possible path that water can take to cycle through the urban environment, it is a good starting point to begin thought provoking discussion.

Note that the sources and sinks in the urban water cycle game are not equal in volume or in impact.

Urban Water Cycle Model Information

The River –

Water enters rivers

From snow melt in the mountains

From precipitation directly on the rivers

From surface runoff following precipitation events

From drainage pipes

From areas where the ground water discharges into rivers and streams

Water leaves rivers

Is drawn through pipes by people for a variety of reasons

- Drinking water and water used in homes and businesses.
- Irrigation of crops
- Industry – for the creation of goods, cooling of equipment, and other uses

Evaporation

Animals drink directly from the river

Plants alongside the river or aquatic plants in the river may take up water through their root systems

The atmosphere (represented by the cloud)

Water enters the atmosphere

Evaporation from the surface of water bodies

Evaporation through sweat from people and animals

Transpiration from the leaves of plants

Evaporation from puddles and standing water on streets, parking lots, buildings, fountains, and other impermeable surfaces

Water leaves the atmosphere

In the form of precipitation (rain, fog, snow, sleet, hail)

The Urban Water Cycle Journal Prompts

Trace the steps that your water goes through after water the lawn. Does it matter if you spill any water on your driveway? Why or why not?

List 3 differences between the urban environment and the natural environment that affects our water and explain why these differences are important.

Would you rather drink water from a river in the mountains or the City. Explain why.

Research the waste water treatment process at rewaonline.org. Does any part of the process surprise or interest you? Explain.

Is it important that water used in agriculture and manufacturing is clean? Why or why not?

The urban water cycle lesson and activities tie in well with previous lessons, including land use, and Greenville is a watershed. Above, community center students use a model watershed and the urban water cycle game to learn about water and the connections between our water and the way we use land.

The building

Water enters the building

Water is piped into buildings. For the urban water cycle game, water is piped into the building from the river. This is not entirely realistic. In most cities in the U.S., water is treated at water treatment plants (usually different from waste water treatment plants) before being piped to buildings. In Greenville, the drinking water comes from reservoirs, and is treated at a water treatment plant before being piped to residents. In some areas, the water that is piped to buildings comes from underground aquifers, from rivers, or other sources

Water leaves the building

Water is used by people for drinking or cooking

Water is used by people for inside uses such as washing dishes, clothes, or themselves, and it goes down the drain

Any water that goes down the drain in a building in Greenville goes to the wastewater treatment plant

Water that goes down the drain in some rural areas goes to septic tanks

Some water conservation systems, called grey water systems, reuse water that goes down the drain to flush the toilet, water plants, or be filtered for other uses.

Water is flushed down the toilet and goes to the waste water treatment plant

Water is used for outside uses

Watering the lawn or plants

The water would go into the plants or the soil

If sprinklers are used, some water would evaporate and enter the atmosphere

Washing the car, the house, etc.

Water that lands on an impermeable surface such as a driveway would make its way to storm drains and eventually to the river, picking up contaminants along the way

Plant

Water enters the plant

Water is taken up by the plant through the plant's roots

From a source of groundwater

Following a precipitation event

From a river or other water body

Irrigation

Water leaves the plant

The plant takes up some water and assimilates it as part of the plant's tissues

The water would remain inside the plant until the plant dies and then be released into the soil, into a decomposer, or into the atmosphere.
An animal or person may eat the plant and take its water in through ingestion.

The plant transpires extra water through the stomata in its leaves and releases it into the atmosphere

Person

Water enters the person

People drink water from the faucet in buildings

People also ingest water through food

Though the first thing that we often think of are soups or foods that are boiled in water, plants and animals all contain water, and when people ingest them, they are ingesting water

Water leaves the person

People take up some of the water that they drink and eat and assimilate it as part of their tissues.

Like the water inside the plant, the water would remain inside the person until they die and then be released into the soil, into a decomposer, or into the atmosphere.

People use the toilet inside buildings. Once the toilet is flushed, that water goes to the waste water treatment plant.

Some water evaporates from people as sweat and enters the atmosphere.

Road

Water enters the road

Through precipitation directly onto the road

Surface runoff onto roads

From driveways and yards where people water plants or wash cars

From rain events on the land surrounding the roads

Surface runoff is a major contributor to nonpoint source pollution and is considered a major threat to water quality in the U.S. Due to the high percentage of impervious surface and compacted soils and the relatively low rate of vegetation found in urban areas, surface runoff is generally much higher than in rural areas.

The Urban Water Cycle Model information as listed is the reasoning behind the possible pathways that water can take in the urban water cycle game.

This information may be useful to foster discussion following the game. For example, ask the students where their water droplet travelled to from the road, and then discuss whether or not this seems realistic. Many students may not be aware of the fact that stormwater is not treated or filtered and that anything on our road ways goes directly into rivers when it rains.

Download extra copies of the Urban Water Cycle Game Cards from the Connections website.

Water leaves the road

Evaporation into the atmosphere

Storm drains

Many people believe that the water from storm drains is treated before being released into rivers and streams, but that is rarely the case.

Water from roads, along with all of the trash, chemicals, soil, and other contaminants that have been washed into the storm drain, drains directly into rivers and streams.

Waste Water Treatment Plant

Water enters the waste water treatment plant

Any water that is flushed or goes down a drain in any building in the city ends up at the waste water treatment plant

Any plants that are placed in garbage disposals also end up at the waste water treatment plant

Water leaves the waste water treatment plant

Evaporation from settling ponds

Following treatment, most of the water from the waste water treatment plant is returned directly to the river

Urban Water Cycle Activities:

Play the Urban Water Cycle Game

Cut out the water cycle game cards and dice provided. Fold the dice and secure tabs with tape.
Set up:
Create 7 stations, and place a Water Cycle Game card, corresponding die, and a colored marker in the same color at each station.

Explain to the students that they are playing the part of a single water droplet in an urban setting. Provide students with a note card and have them mark each time they go to a station on the card. If they roll the die and it tells them to remain at a station, they should go to the back of the line and mark their card again when they reach the die.

Play for an allotted amount of time or a set number of turns and then follow the game up with a discussion.

Take a **field trip** to the waste water treatment plant to learn more about where water goes when we are finished using it.
http://www.rewaonline.org/tours.php

Brainstorm a list of all of the things that you can think of that people use water for in an urban environment. You may want to challenge the students by saying something like "the last class I taught came up with 20 different things we use water for. Can you think of more than 20?"

Urban water uses guessing game: use either the list that your class created or the list below.
Divide the class into two teams. Introduce the game as charades about water uses in an urban environment. The teams will take turns sending one student up to mime a way that water is used in the urban environment. No speaking is allowed, and a time limit such as 1 minute or 30 seconds should be in place. If the team whose member is presenting can not guess the water use in the allotted time, the other team has a single opportunity to steal their points, but they must make a team decision. The first answer given will be the one that counts.

Some possible water uses for the urban water use guessing game:

Shower	Wash the car
Wash the dog	Clean the dishes
Drinking water	Watering plants
Flushing the toilet	Washing clothes
Brushing teeth	Putting out fires
Decorative fountains	
For pets to drink	Hydroelectric power

Research water quality in your neighborhood:
A water body that is impaired is one that has poor water quality that negatively affects that water body's ability to support life or its use as a recreational or drinking water source.

The following source provides good background information on many different sources for impairment to water bodies.

http://scorecard.goodguide.com/env-releases/def/cwa_cause_class_def.html

Have students research a common impairment, and check scorecard to see if any nearby water bodies are impaired.

Questions for consideration:

1) What are the possible sources of water contamination?

2) What are the possible negative effects the contaminant may have on people or the environment?

3) Can you see the contaminant?

4) What can be done to prevent or clean water that has been contaminated by that substance?

The observe and discuss activity is adapted from the Freshwater Habitats section of the Urban Naturalist Program. For more activities and information related to freshwater habitats, see chapter 6 of the Urban Naturalist Program.

Urban freshwater habitats come in many different shapes and sizes and vary widely in their suitability as habitats for aquatic organisms.

Explore the water treatment process through Greenville Water's virtual tour. A **webquest** is provided on the next page.

http://www.greenvillewater.com/our-water/how-water-works/

Answers to the web quest:

1) thermocline	2) wells
3) *Giardia lamblia*	4) anthracite coal
5) floc	6) fire fighting
7) flushing the toilet	8) 3/4 inch
9) engineering	10) effluent

Observe and discuss the differences between a freshwater habitat that students have observed in an urban environment and that same type of freshwater habitat in a natural environment.

Examples of freshwater habitats in urban areas include decorative ponds, rivers and streams, and bioswales, man-made wetland areas that contain plants and help manage storm water. Urban freshwater habitats and the organisms that live in them face many challenges and are often very different from freshwater habitats in undeveloped areas.

How are the two different, and why? What do those differences mean for the plants and animals that may live in these habitats?

Some ideas for dicussion: water temperature, shade, input of water or debris, depth, type of substrate, openness.

HOW WATER WORKS WEBQUEST

Access Greenville Water's virtual tour of a typical water treatment process. Explore the water treatment process by clicking on the numbers to learn more and fill in the questions below.
http://www.greenvillewater.com/our-water/how-water-works/

1) The temperature gradient that can exist in lakes is called a _____

2) Groundwater sources are generally accessed by _____

3) Conventional water treatment removes harmful bacteria, turbidity, algae and protozoa, such as _____

4) Dual media filters generally have a layer of sand covered by a layer of _____

5) The purpose of a sedimentation basin is to allow _____to settle to the bottom of the tank

6) Water storage facilities are sized and operated to meet consumer demands and provide reserves for _____

7) In North America, a person uses approximately 20 gallons of water a day for _____

8) What is the diameter of the service pipe to an average single family home?

9) The department responsible for the construction and design of the physical aspects of the water system is _____

10) At the waste water treatment plant, the final _____ may be discharged into a river or stream or used for irrigation.

The Urban Water Cycle Game

Directions:
Print out the water cycle dice and cards.
Fold the seven dice into squares, using tape or glue to secure the tabs on the inside of the dice.

Set up 7 stations in the classroom, and place a corresponding card and die at each station. The stations can be randomly placed throughout the room.

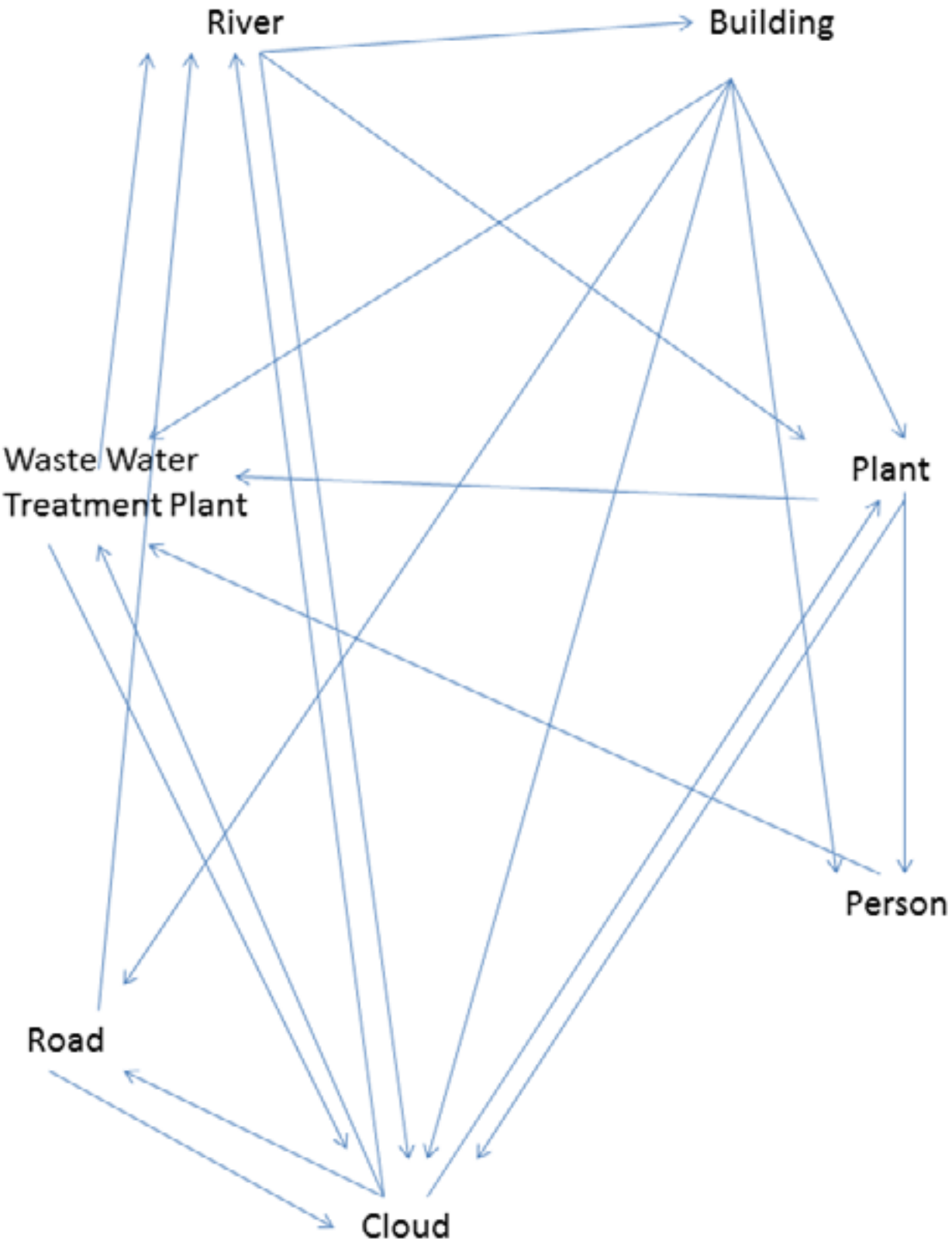
Place a colored pencil, marker, or crayon at each station that corresponds with the color of the station. (or use colored beads and have the students make bracelets as they travel through the urban water cycle)

Explain to students that they will play the part of a water droplet moving through the urban environment. When they reach a station, they should use the colored pen to mark a tally or dot on their paper, roll the die, and follow the instructions on the die to go to their next station.

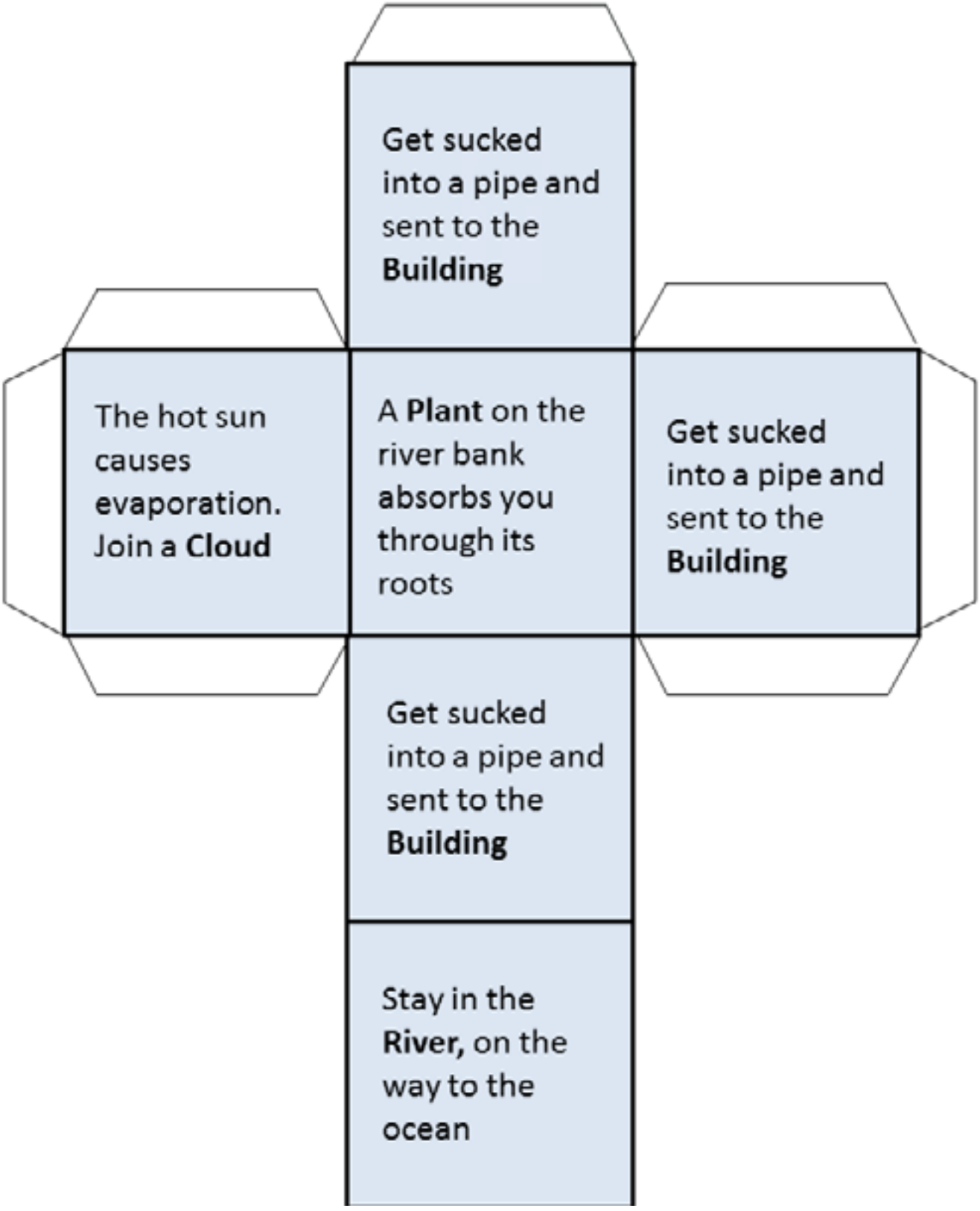
If told to remain at a station, they should go to the back of the line, mark their paper a second time with the same color, and roll again.

Play the game for an alloted amount of time and then call the students back for discusssion.

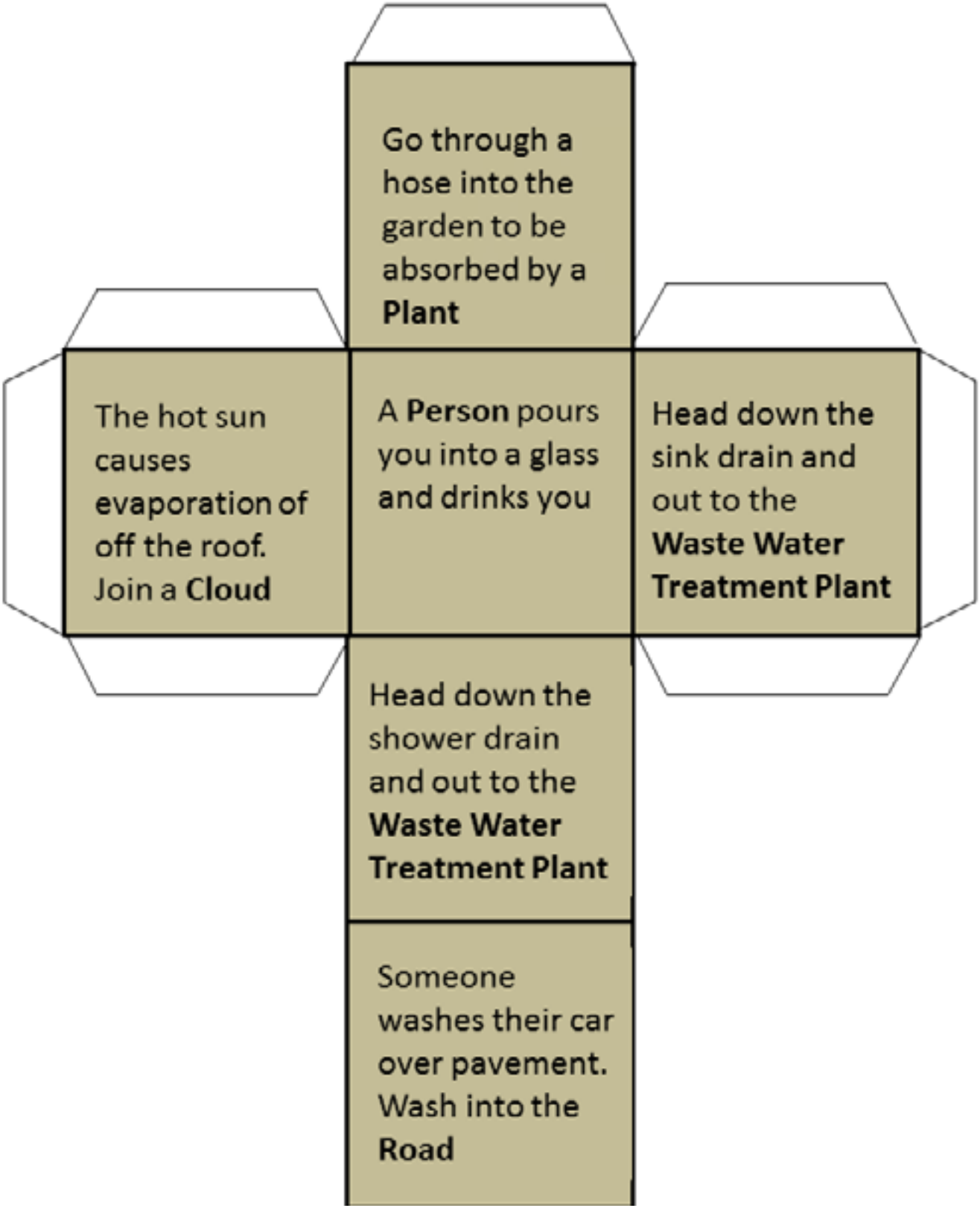
Diagram of possible paths for a water droplet in the Urban Water Cycle Game



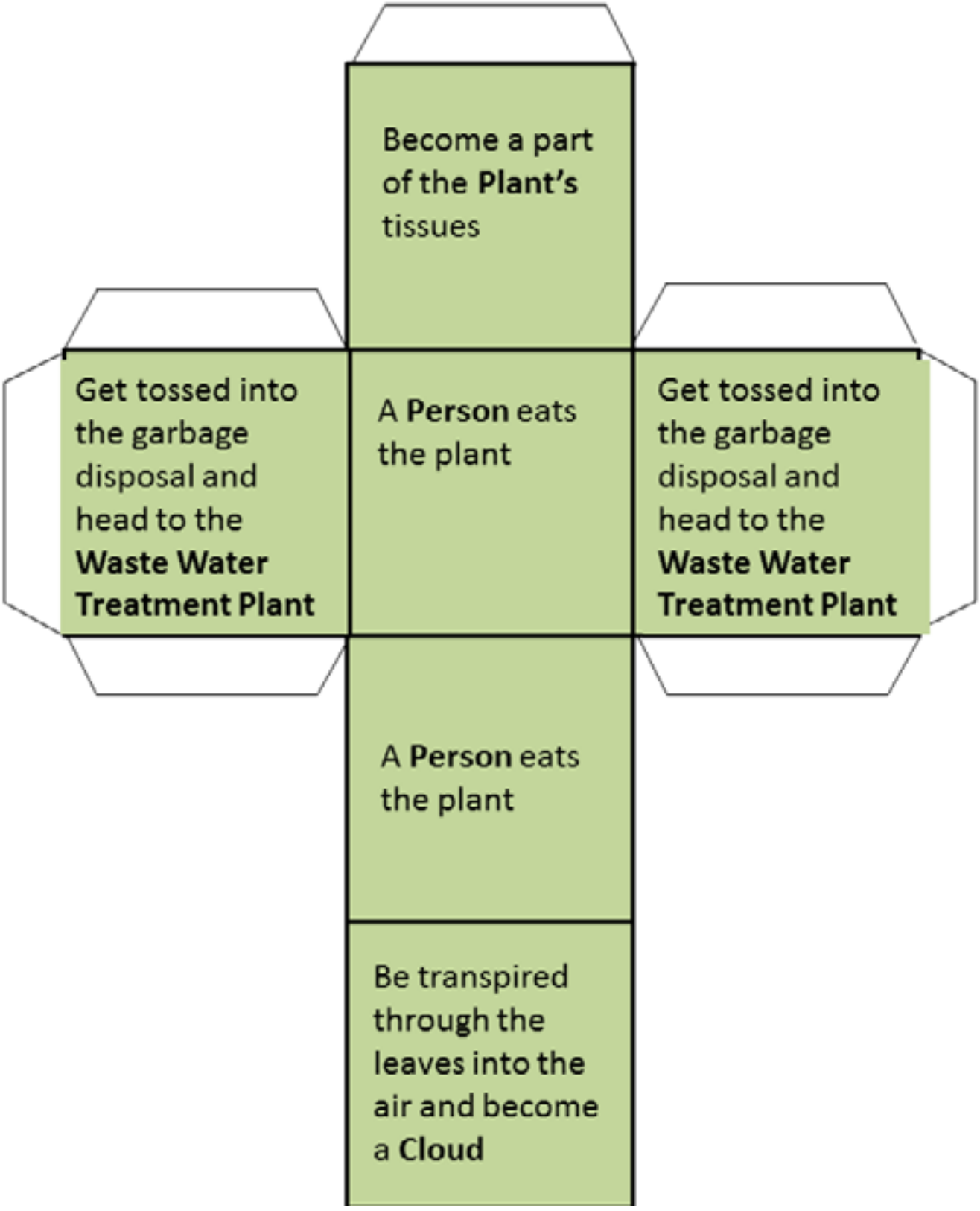
RIVER


Get sucked into a pipe and sent to the **Building**
The hot sun causes evaporation. Join a **Cloud**
A **Plant** on the river bank absorbs you through its roots
Get sucked into a pipe and sent to the **Building**
Get sucked into a pipe and sent to the **Building**
Stay in the **River,** on the way to the ocean

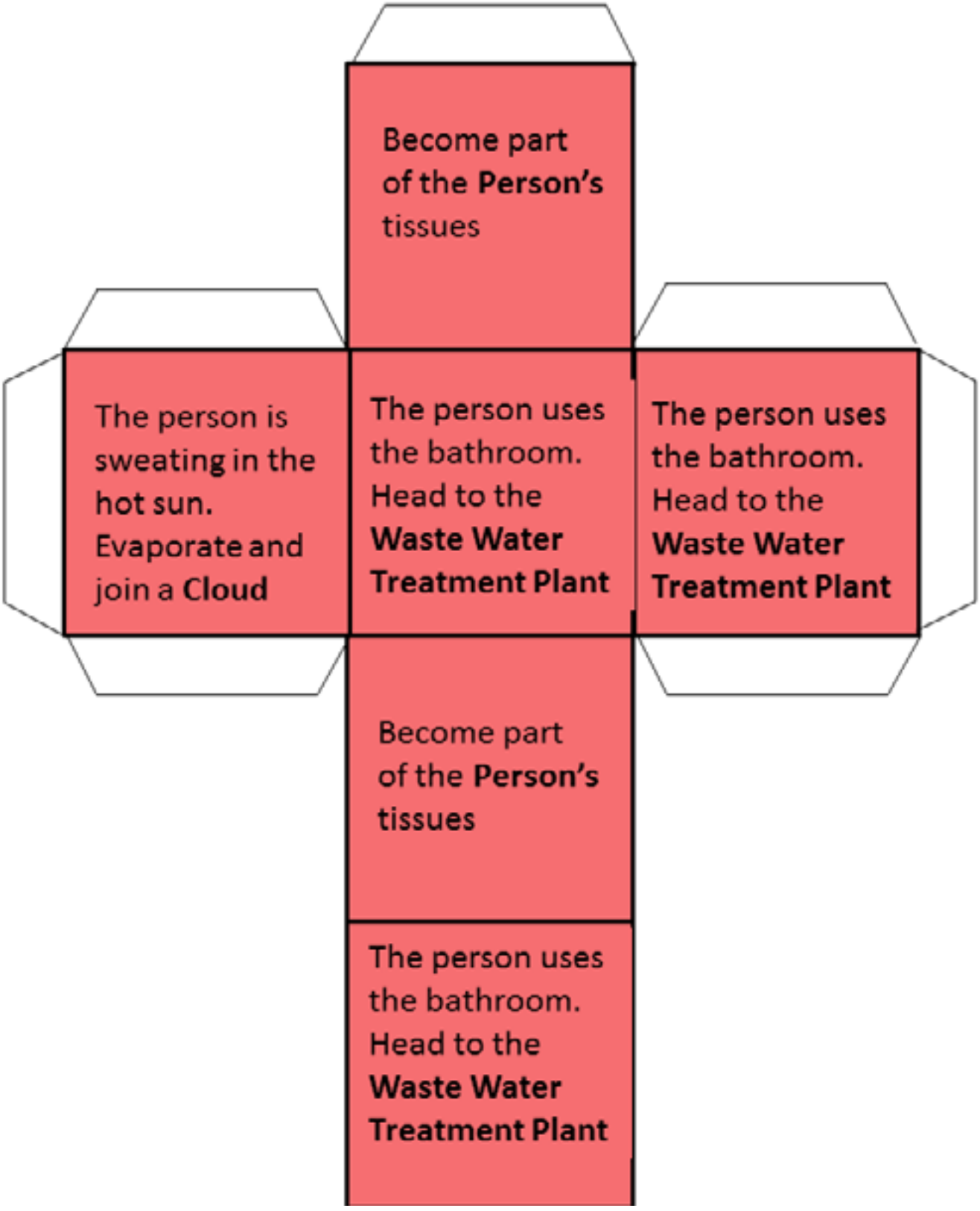
BUILDING


Go through a hose into the garden to be absorbed by a **Plant**
The hot sun causes evaporation of off the roof. Join a **Cloud**
A **Person** pours you into a glass and drinks you
Head down the sink drain and out to the **Waste Water Treatment Plant**
Head down the shower drain and out to the **Waste Water Treatment Plant**
Someone washes their car over pavement. Wash into the **Road**

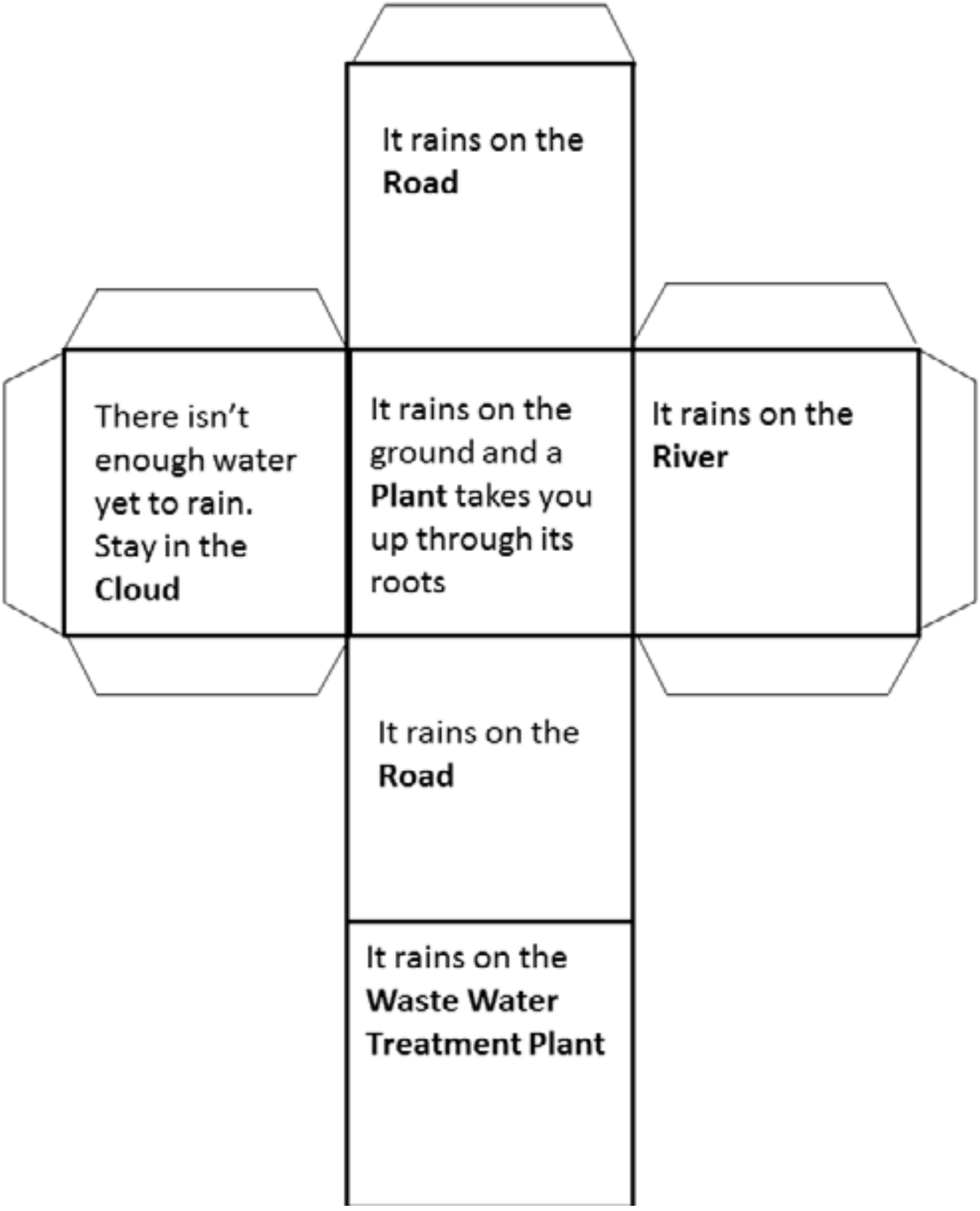
PLANT


Become a part of the **Plant's** tissues
Get tossed into the garbage disposal and head to the **Waste Water Treatment Plant**
A **Person** eats the plant
Get tossed into the garbage disposal and head to the **Waste Water Treatment Plant**
A **Person** eats the plant
Be transpired through the leaves into the air and become a **Cloud**

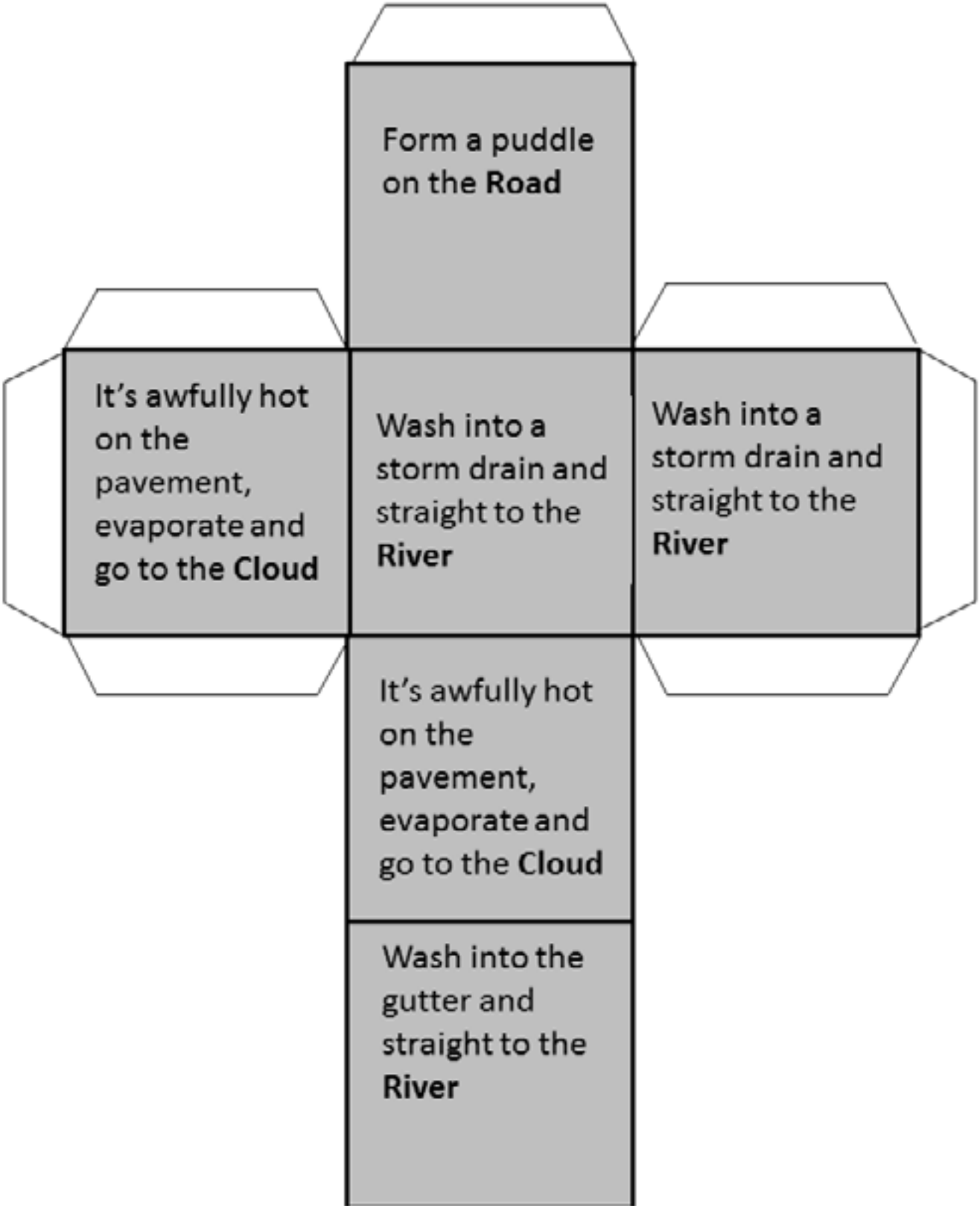
PERSON


Become part of the **Person's** tissues
The person is sweating in the **hot sun.** Evaporate and join a **Cloud**
The person uses the bathroom. Head to the **Waste Water Treatment Plant**
The person uses the bathroom. Head to the **Waste Water Treatment Plant**
Become part of the **Person's tissues**
The person uses the bathroom. Head to the **Waste Water Treatment Plant**

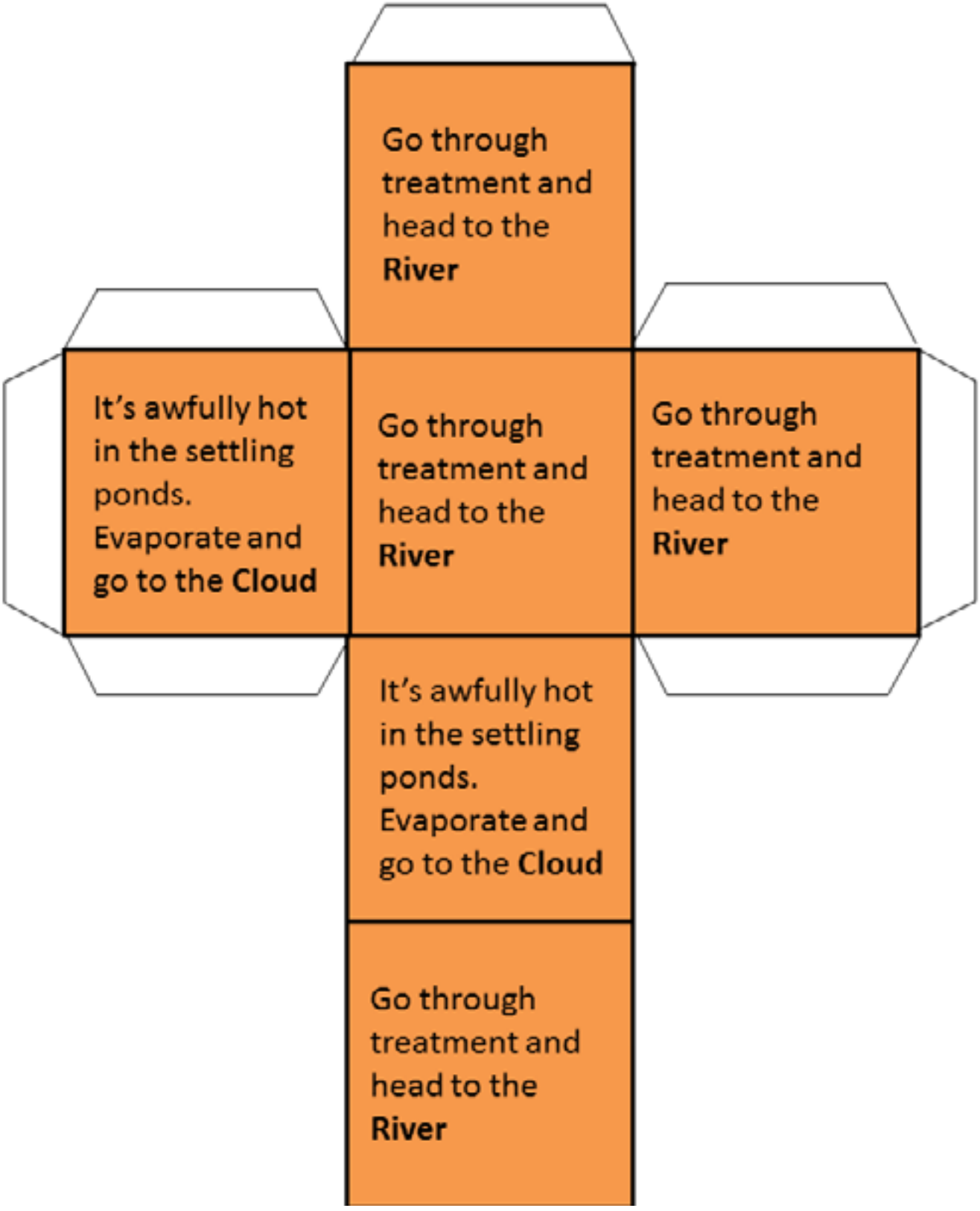
CLOUD


It rains on the **Road**
There isn't enough water yet to rain. Stay in the **Cloud**
It rains on the ground and a **Plant** takes you up through its roots
It rains on the **River**
It rains on the **Road**
It rains on the **Waste Water Treatment Plant**

ROAD


Form a puddle on the **Road**
It's awfully hot on the pavement, evaporate and go to the **Cloud**
Wash into a storm drain and straight to the **River**
Wash into a storm drain and straight to the **River**
It's awfully hot on the pavement, evaporate and go to the **Cloud**
Wash into the gutter and straight to the **River**

WASTE WATER TREATMENT PLANT



River

Person

Waste Water Treatment Plant

Building

Plant

Road

Cloud

Urban Surfaces
Permeable vs. Impermeable

Learning Objectives

Students will

- learn the difference between permeable and impermeable surfaces
- discuss ways that buildings, roads, and other impermeable surfaces impact the environment with a focus on water quality
- analyze the percent impermeable surface area of Greenville, SC through GIS mapping technology

Background Information

Urban areas are generally highly developed and populated by humans compared to other types of land use. One major way that people alter the land in urban areas is through the creation of buildings, roads, sidewalks, parking lots, and other covered surfaces. Surfaces that do not allow water to penetrate to reach the soil are called impermeable surfaces.

It is important to note that the terms pervious and impervious are often used interchangeably with the terms permeable and impermeable when discussing water infiltration into the ground. The main difference in the terms being that pervious and impervious are used most often by regulatory organizations and refer specifically to surface materials while permeable and impermeable are scientific terms that can also be used for other substances. For example, a membrane may be permeable or impermeable to air.

Impermeable surfaces affect the urban environment in a variety of ways.

- The dark color of roads, parking lots, and roofs absorbs heat, contributing to the urban heat island effect.

  An urban heat island is a developed area that is hotter than the surrounding rural area. According to the US EPA, a city of 1 million people can be 1-5 degrees F hotter during the day and up to 22 degrees F hotter at night. This may not seem like much, but a few degrees can have a big impact on energy costs, increase air pollution, and even lead to increased mortality rates.

- Impermeable surfaces do not allow water to infiltrate into the soil leading to

  An increase in the volume and speed of storm water runoff; water washing over the surface of the ground during and following precipitation events

  Decrease in water quality of rivers, streams, ponds, and lakes due to pollutants such as litter, oil, gasoline, soap, pet waste, fertilizers, and sediment washed into water bodies by storm water runoff.

Word Bank

Aquifer
Barrier
Base Flow
Bioswale
Development
Dilution
Erosion
Flood
Ground Water
Hydrology
Impact
Impermeable
Impervious
Infiltrate
Permeable
Pervious
Remediation
Stormwater Runoff
Topography
Urban Heat Island
Water Quality
Water Table
Zoning

Urban Surfaces Journal Prompts

Close your eyes and imagine that you are standing outside in the city. Then, imagine you are outside in the country. How is the ground different? Why?

What does permeate mean, and how does that term relate to the way that we use the land?

If cities are warmer than the surrounding countryside, how might that affect plants and animals that live there? What about urban water bodies?

Research the term "Low Impact Development." Why are impermeable surfaces an important part of this concept?

How do impermeable surfaces contribute to lower base flow of urban rivers and why is this a concern for people?

Slower recharge of underground aquifers and less flow of ground water. Since water cannot seep into the ground, water that is removed from aquifers through wells and pumps for irrigation is not replaced. This leads to less ground water. A loss of ground water can lead to other problems such as the formation of sinkholes or the infiltration of salt water into fresh water aquifers.

Lower base flow of urban streams and rivers due to lower levels of ground water. Lower base flows mean lower water levels in general which can contribute to lower levels of Dissolved Oxygen and thus lower water quality.

Lower base flow also reduces the dilution power of water bodies, altering the ability of rivers and streams to disperse permitted effluents, leading to a higher probability of negative impacts.

Increased probability of flooding and economic and environmental damage associated with floods.

Increase in the temperature of water bodies due to stormwater absorbing heat from dark road surfaces prior to washing into streams and rivers.

Decrease in the level of Dissolved Oxygen that water can hold due to increased temperature. Dissolved Oxygen is essential for aquatic life to survive.

Urban Surfaces Activities:

Research the Urban Heat Island Effect using the Environmental Protection Agency's (EPA) website. Assign each student one of the following pages and ask them to read the page and then choose two important facts about heat islands to present to the class.

http://www.epa.gov/hiri/about/index.htm

http://www.epa.gov/hiri/mitigation/trees.htm

http://www.epa.gov/hiri/mitigation/greenroofs.htm

http://www.epa.gov/hiri/mitigation/pavements.htm

Impermeable surface survey

Demonstrate for the class:
Go to the City of Greenville's Historical Imagery Database.
http://gis64.greenvillesc.gov/historicalimagery/

Using only the most current aerial photos, zoom all the way in to the image somewhere within the city limits of Greenville. You may use the search address tool, represented by the binoculars icon at the top of the screen to find specific addresses, or choose at random.

(Google Earth or another mapping tool would also work for this exercise.)

Estimate the percent of the land covered by impermeable surfaces. Remind the students that buildings, roads, parking lots, and sidewalks are all examples of impermeable surfaces.
Estimate the percent of the land covered by permeable surfaces.
Estimate the percent of the land covered by water.

Either provide the class with the impermeable surface survey worksheet, or write the questions you will be using up on the board.

Depending on the age of your students, the EPA website may be a challenge to read. An option would be to turn this into a deductive reasoning activity to define unknown words.

Students use the City of Greenville's Historical Imagery Database to perform the impermeable surfaces survey following a lesson on land use and its impacts on water quality

IMPERMEABLE SURFACES SURVEY
WORKSHEET

Directions:
Go to the City of Greenville's Historical Imagery Database.
http://gis64.greenvillesc.gov/historicalimagery/
Choose a point on the map and zoom in completely. Close out the address search window. Fill out the questions below for 5 different places in the City.

Using the scale bar at the bottom left corner of the screen, estimate the area of land shown in the picture. (This # should be the same for each measurement)

_____

Estimate the percent of the photo covered by impermeable surfaces.

1) _____ 2) _____ 3) _____ 4) _____ 5) _____

Estimate the percent of the photo covered by permeable surfaces.

1) _____ 2) _____ 3) _____ 4) _____ 5) _____

Use the whole class' results to answer the following questions.

1) What is the average estimated % area covered by impermeable surfaces.

2) Do you think that this number is higher or lower than it would be outside of the City limits?

Why?

3) Name some of the surfaces that you saw in the pictures that are impermeable.

4) Name some of the surfaces that you saw that were permeable.

5) What are some of the negative consequences of a high percent of impermeable surface areas in the City?

6) What do you think could be done to reduce the percentage of impermeable surface in the City while still making it possible for people to live and work here comfortably?

Permeable VS. Impermeable Surfaces Experiment

Depending on the age of your students and the amount of class time that you have to dedicate to this experiment, you may want to perform it as a demonstration, or assign each group one or two earth materials to test.

Students will be creating their own experiment to test the permeability of the earth materials and how the speed of water (equivalent to speed of rain) effects the permeability. The final questions may be used as class discussion, or as journal prompts.

You may want to perform the set up for each group prior to the start of the experiment.

You will need:
Clear plastic bottles
Cheese cloth
Tape
Scissors
Earth materials (sand, gravel or rocks, soil)
Stop watch or clock
Modeling clay (make sure students fully cover the soil with the clay)
A metal pie tin
Basin

Make sure that students know to get a new layer of dry soil to use as a base for each of the earth materials that they are testing.

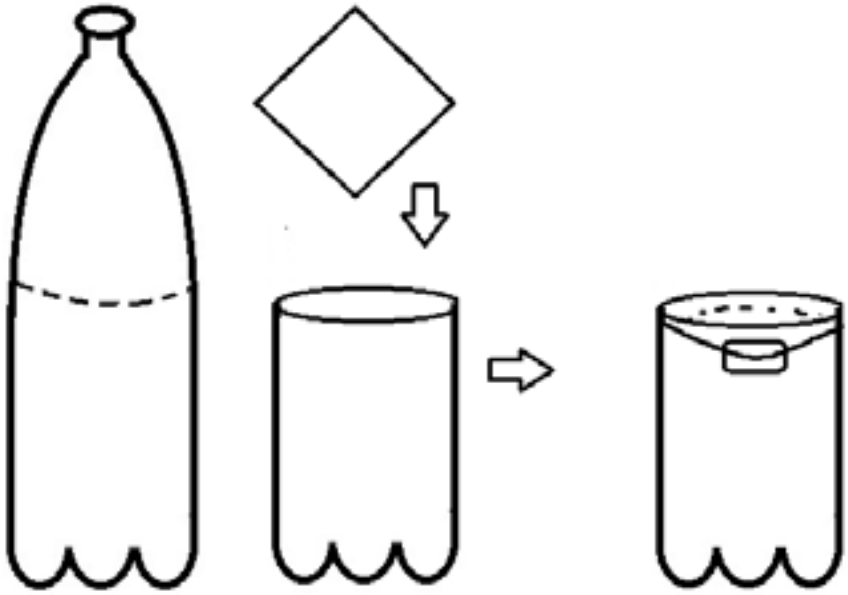
*The metal pie tin is for you to demonstrate the permeability of surfaces such as roofs and roads that are not permeable at all. Place the tin upside down over the bottle while the bottle is in the basin. Ask the students to predict what will happen when it "rains" on a roof or road. Pour the water over the pie tin.

Ask the students what they think this means in an urban environment? Where does all of the water from roofs, roads, parking lots, and other impermeable surfaces go?

PERMEABLE SURFACES
EXPERIMENT

Set up

1. Cut the top off of the plastic bottle, and punch a hole in the bottom of the bottle, near the top.
2. Using a graduated cylinder, pour 50 mL of water into the plastic bottle. Use a permanent marker to mark the level of the water on the bottle.
3. Repeat step 2, marking every 50 mL until you have reached the top.
4. Place the cloth over the top of the plastic bottle. Press the cloth down so that it is at least one inch below the top of the bottle.
5. Tape the overlapping cloth to the outside of the bottle.
6. Place the bottle in the plastic basin.



Observe and Predict

1. Measure out 500 mL of water into a pitcher, and pour the water over the cloth into the bottle.
a) What happens?

b) How much time does it take for all of the water to drain into the bottle?

c) Does the speed that you pour the water make a difference?

2. Touch each of the earth materials that you will test.

a) Which of the earth materials do you think will be the most permeable? Which will be the least?

b) Do you think the speed that you pour the water into the bottle will affect the permeability of the earth materials? How?

3) Generate a hypothesis

Design your experiment and Test your hypothesis

Control
1) Place a layer of soil in the bottle so that the cloth is covered.
2) Slowly pour 500 mL of water over the soil.
3) Use the stopwatch to record when the water in the bottle reaches each mark on the bottle.

Once you have the data from your control, you may test your hypothesis. Record your data below. (Depending on your hypothesis, you may not need to use every column)

Volume	Slow: soil	Fast: soil	Slow: sand	Fast: sand	Slow: rock	Fast: rock	Slow: clay	Fast: clay
50								
100								
150								
200								
250								
300								
350								
400								
450								
500								

Draw Conclusions: (answer these questions on a separate sheet of paper)
1) Which of the materials that you tested was the most permeable?

2) Which of the materials that you tested was the least permeable?

3) Did the speed that you poured the water make any difference in permeability?

4) Was your hypothesis correct?

5) What do your results suggest about permeable and impermeable materials in the real world? Based on your experiment, would you expect soil infiltration rates to vary based on the amount or speed of rainfall?

Word Bank

Aquatic
Aquifer
Clean Water Act
Climate
Contaminant
Discharge
Dissolved Oxygen
Ecosystem
Effluent
Filtration
Ground water
Hydrology
Impairment
Impervious
Infiltration
Natural
Nonpoint Source Pollution
Pervious
Point Source Pollution
Pollution
Reservoir
Resource
Sediment
Storm Water Runoff
Water Body
Water Cycle
Water Quality
Water Table
Watershed
Wetland

Water Quality and Conservation

Learning Objectives

Students will

- research a water quality issue
- brainstorm ways that they can conserve and protect water quality in an urban environment
- perform a water conservation audit of their own habits

Background Information

The Clean Water Act, CWA, is the set of laws and regulations put into place by the federal government in 1972 that regulates the discharge of pollutants into water bodies and sets standards for water quality in U.S. surface waters. It is illegal to discharge any pollutant from a point source into a water body in the U.S. without a permit.

Point source discharge occurs when a pipe, ditch, or other man-made system allows any substance to drain directly into a water body. Nonpoint source pollution is any pollution that enters a water body through any other method, such as through storm water runoff from agricultural fields or urban streets. Prior to the CWA, point source pollution was a major concern in the U.S., as many industries pumped pollutants directly into water bodies. Though point source pollution still occurs, nonpoint source pollution is a larger concern today, partially because it is very difficult to track and regulate.

Due to the relatively rainy climate in the Southeast, water is often not seen as a limited resource, but conservation and protection of water quality is a very real concern. Human activities have a huge impact on water quality and quantity available for use by people as well as natural systems.

Water quality

Water quality refers to the suitability of water for a specific use based on physical, chemical, and biological characteristics. Often, when discussing water quality, human health is a major concern, but the ability of a water body to support life is also an important measure. Water that is contaminated in some way is considered to be poor in quality. When contamination occurs on the scale of a body of water (stream, river, lake, etc.) that water body is said to be "impaired."

It is important to note that a contaminant does not have to be a chemical pollutant in order to cause impairment of a water body. Soil from erosion and hot water from impervious surfaces can both cause poor water quality, making it difficult for a water body to sustain aquatic life.

As has been discussed in previous lessons, storm water runoff is a major contributor to poor water quality in the US. When water flows over urban surfaces, it picks up soil, trash, oil from vehicles, chemicals and pesticides from urban lawns, pet waste, and more and sweeps it into storm drains which flow directly to the river.

Water conservation – the amount of water we use is important
Water everywhere is connected through the water cycle. Water flows. The water that you use will eventually end up in the ocean, but if we use too much water, we can disrupt downstream processes. Aquatic organisms need certain levels of water in streams and rivers in order to survive. Without the right amount of water coming in from upstream, swamps, marshes, and other wetlands can dry up. Many ocean animals use estuaries and marshes as nurseries, and without enough water, these animals won't be able to reproduce. Using too much water could have far reaching consequences.

There are many ways that we can conserve and protect water quality. One is through regulation. Laws and regulations such as the Clean Water Act are important in that they set standards for behavior and consequences for breaking the law. Yet, laws can only do so much. Day to day behavior of individual citizens can have a large effect on water quality.

Water Quality and Conservation Activities:

Brainstorming: impairment source and human behavior

List an impairment, and then ask the students to brainstorm where that impairment may originate on land, what human behaviors could cause it, and finally, what could be done to help reduce that type of pollution.

EXAMPLE:
Impairment - high levels of nutrients
Source - animal waste, fertilizer, sewage leaks
Human behaviors that might lead to excessive nutrient levels in water - allowing pet waste to remain on the ground near rivers, placing excessive fertilizer on lawns near water, putting fertilizer out right before it rains, leaking septic systems
Ways to reduce the problem - pick up or bury pet waste so that it doesn't wash into rivers; only use the amount of fertilizer you need, and make sure you check the weather before applying fertilizer and don't apply it right before a rain event.

Some examples of impairments to list:
Plastic trash
Sediment
Pesticides
Toxic Chemicals
Oil
Nutrients
Debris

Water Quality and Conservation Journal Prompts

Why do you think it is important to conserve and protect water resources?

Describe the difference between conservation and protection.

What are two things that you or your family does that wastes water at home? How can you change those habits to keep from wasting water?

Describe the connections between water resource protection and land use.

Use the information that you have learned to write a letter about the importance of water conservation and/or protection to a community leader. Make your letter as specific as possible.

During what activity did you use the most water?

Do you feel like you wasted water? Why or why not?

How do you think you could alter your activities to use less water?

Were you surprised by how much water you used in a day?

Perform a Water use Audit

*Individual water use audit worksheet available on the next page.

As a class, list the ways that you use water throughout the day. Remind the students that drinking water is necessary and one of the reasons that we are doing this audit is to conserve and protect water for drinking, so drinking water is exempt from the water use audit.

Brainstorm ways that water is wasted in everyday use, and then brainstorm solutions for each waste. After brainstorming multiple solutions for each waste, vote as a class to find the "best" solution.

EXAMPLE:

Water Use	How water is wasted	Possible Solutions
Washing hands	while waiting for water to warm up, some goes down the drain	install a tankless water heater wash hands with cold water collect water as it is heating up and use it to water plants
Washing hands	while soaping hands, extra water runs down the drain	don't use soap turn the water off while soaping hands

**note that not all solutions to conserving water when washing hands are feasible. While not using soap to wash your hands may save water, it isn't good for personal health. Water conservation must strike a balance where water is still used when needed yet saved when possible.*

Provide students with copies of the water use audit to perform at home, preferably on a weekend. Once the audits have been performed, have a class discussion about home water use. Use the questions shown left as a starting point for discussion. Compile the data taken by the class to extrapolate water use to your community.

Home Water Use Audit

Instructions: Place a bowl beneath the faucet in your sink. Turn the water on the way you normally would to wash your hands or brush your teeth and leave it on for 5 seconds. Measure the amount of water in the bowl. Use the water for watering plants, pets, or drinking and repeat until you have 3 sets of measurements. Find the average amount of water that you use in 5 seconds. Divide by 5 in order to find the amount of water that you use every second. Repeat for your shower. Fill in the data table provided with your measurements.

Use a stop watch or clock to time your water use and fill in the data table provided. Ask your parents for help answering the rest of the water audit questions.

Bathroom Sink

Trial 1: 5 seconds running = _____
Trial 2: 5 seconds running = _____
Trial 3: 5 seconds running = _____

Average vol in 5sec = _____
Volume/sec =

Use 1:_____ sec
Use 2:_____ sec
Use 3:_____ sec
Use 4:_____ sec
Use 5:_____ sec
Use 6:_____ sec
Use 7:_____ sec
Use 8:_____ sec
Use 9:_____ sec

if you need more space, continue on a separate sheet of paper

Shower/Bath

Trial 1: 5 seconds running = _____
Trial 2: 5 seconds running = _____
Trial 3: 5 seconds running = _____

Average vol in 5sec = _____
Volume/sec =

Time in shower = _____ sec OR
Time water runs to fill bath= _____ sec

Questions:

How many sinks are in your home?

How many people live in your home?

How many toilets are in your home?

Do you have a dishwasher?
Is it an ENERGY STAR dishwasher?
How many times a week does your family run the dishwasher?
Do you pre-rinse your dishes?

Do you have a washing machine?
Is it an ENERGY STAR washing machine?
How many times a week does your family run the washing machine?

How many times did you flush the toilet in a day?
Do you have an irrigation system for your lawn?

List any other ways that you use water, other than drinking/cooking:

Class Home Water Audit Data Collection

Have each student total the amount of time that they ran the water in their bathroom in a day and compile those numbers in a table on the board, or in a separate document. Add a tally of all of the answers collected from the home water audit.

Use the data collected to do some math, either as a group or individually. Some ideas for water audit math are below:

A (# of students in class) = _____

Find the average volume of water/second for the class's bathroom sink (Class total/A) = _____

Find the total volume of water used from the bathroom sink (Class total time in seconds x ave volume/sec) = _____

Find the average volume of water used from the bathroom sink by one person in a day (class total vol/A) = _____

Extrapolate the volume of water used from the bathroom sink by a person in a day to the entire population of Greenville County, then the population of South Carolina (use the data on the useful water facts and figures data sheet).

Extrapolate the volume of water used from the bathroom sink for one person in one week, all of Greenville County in a week, and all of South Carolina in a week.

Find the total amount of water used in the class' washing machines in one week. Divide that amount by the number of students in the class for an average amount of water used in washing machines per person. Repeat for dishwashers.

Find the average # of flushes per person each day, and the average volume of toilet water used daily.

Add all of the averages per person together and extrapolate to Greenville County and South Carolina to see how much water we use in a day.

Discuss the results of the water audit as a class.

Make sure to remind your class that the results that you have didn't take into account every water use in their homes.

Ask students to brainstorm ways that they could conserve water while still using what they need.

Common ideas may include (but are not limited to):

turn the water off while brushing your teeth

scrape food off plates instead of pre-rinsing

only wash a full load of clothes

take shorter showers

water plants with a drip irrigation hose instead of a spray irrigation that loses water to evaporation

Extend the Class Water Audit:

If you would like to put your water conservation knowledge to the test, repeat the class home water audit and ask the students to put all of their water saving tips to use.

Have students spend a second weekend tracking their water use time, but with all of their water conservation habits in place.

Compile the new data and see how much water they saved.

If every person in Greenville County or South Carolina did the same simple water conservation steps, how much water would they save in a day, a week, or a year?

Rain barrels make a great class or group project to encourage water conservation and draw connections between storm water runoff, land use, and water quality.
For more information, check out Clemson University's rainwater harvesting guide.

Useful facts and figures: Water Audit Data

2010 population Greenville Co	451, 222
2010 population South Carolina	4,625,364
Ave water used per load ENERGY STAR dishwasher	5 gal
Ave water used per load non ENERGY STAR dishwasher	6 gal
Ave water used per load ENERGY STAR washing machine	15 gal
Ave water used per load non ENERGY STAR washing machine	23 gal
Ave water used per flush in a standard toilet	3.5 gal
Amount of water in an Olympic sized swimming	2,500,000 L
1 Gallon	3.78514 L
16 Cup	1 gal

The TUNZA magazine is unique because many of the articles are written by young people. You could start a class publication as part of Community Quest. Students could research different topics of interest to their community, relate them to what they have learned in class, and put the articles together as a magazine for their friends or family.

Read and discuss pages 16 and 17 of the TUNZA, UNEP magazine for youth. The article explains some ancient and innovative methods for harvesting water in dry climates. Ask the students to imagine that they needed water but were unable to find a water source. How would they go about harvesting and collecting water?

http://www.unep.org/pdf/Tunza/TunzaV4N1-DesertsDrylands.pdf

Test out your knowledge
Let students play the EPA's WaterSense game.
http://www.epa.gov/watersense/kids/games.html

Learn about mercury and pcb contamination and fish consumption advisories in South Carolina by visisting the SCDHEC website:
http://www.scdhec.gov/environment/water/fish/map.htm

Are there any consumption advisories near you?

Perform an Experiment:

http://water.epa.gov/learn/kids/drinkingwater/upload/2005_03_10_kids_activity_grades_4-8_plantsinwaterfiltration.pdf

Use the experiment above to show how plants can help filter pollutants from the soil.

To further illustrate the filtration properties of plants, double the number of cups that you use, and for each "pollutant" that is poured into a plant, also pour the same pollutant into a cup with just soil and rocks.

Make an aquatic animal sun catcher as a reminder of the importance of conserving and protecting water resources.

Materials:
Plastic 2 Liter bottles (clean, with labels removed)
Scissors
Permanent markers
Tape
Drawing or picture of a fish or aquatic animal

1. Cut the top and bottom off of the 2 Liter bottle and cut 2 slits straight down the sides of the bottle. You should now have 2 curved pieces of plastic.
2. Tape the picture of a fish or other aquatic animal to the desk and tape the piece of plastic over the top.
3. Use the permanent markers to color in and trace the picture.
4. Remove the tape from the plastic and use the scissors to cut out the animal.

If you would like, punch holes in the sun catchers and let the students hang them. They can be sent home or used to decorate the classroom as reminders to conserve water.

Recycle the leftover plastic bottle pieces.

Recycled fish suncatchers make a fun and simple project to remind students that we aren't the only ones who need clean water.

Download and ***read*** the children's story and coloring book "The Great Pond Clean-Up" from the Connections for Sustainability website http://connections.greenvillesc.gov/forms/EdMaterials/wqcolorbookweb.pdf

If you have older students, use this book as an example and then ask them to ***create their own fiction story*** with a science background about an aspect of water quality to share with an elementary school class.

Read the short essay, "Water through the ages" as a class, in small groups, or individually.

You may utilize the discussion questions provided or create your own.

Water through the ages

By Emily Hays, Furman University

Let's flash back to the year 1854. In a London neighborhood, 127 people living on Broad Street died within three days of each other. Almost every family in the neighborhood experienced the death of at least one family member. People started packing up and moving out for fear of catching the disease. After a single month had passed, the death toll reached 500 people. Something was very wrong; a cholera outbreak had occurred. Cholera is an intestinal disease that can cause death within a few hours of symptoms, such as vomiting and diarrhea. The problem was that no one knew where cholera came from, and many believed that it was spread through "bad air."

A British doctor, John Snow, did not think cholera was spread through the air, so he started investigating the situation. He made a map of the city including the city water pumps, and homes of those who died. He noticed that people that lived close to the Broad Street water pump were dying in greater numbers than those living elsewhere in the city. He contacted local officials, had the Broad Street water pump handle removed, and the outbreak stopped. Doctor Snow had discovered that water was the connection. It turned out that raw sewage, or human waste, was dumped into the Thames River in London, just above the location where the Broad Street pump drew in its water. People had noticed that their water smelled bad and looked cloudy, but they drank it anyway. Today, John Snow is famous for his discovery about the spread of cholera, and the importance of having clean drinking water.

All throughout history, people and ecosystems have depended on water for life. Cities and towns develop near water sources, because we all need fresh water. Rivers, lakes, and oceans are used for transportation, which is important for trade between countries. People catch fish and find other food in water. When European cities developed, water was a crucial source of power and energy, fueling industry. By building dams and canals, people are able to direct water flow in such a way that it helps get jobs done. Water was, and still is, crucial to jobs, transportation, food supply, and health.

John Snow showed us that water impacts our health. The people in London lived in very crowded, dirty conditions, which also helped diseases like cholera spread quickly. The English did not know that their water needed

to be taken care of, and it made them sick. The ancient Romans, on the other hand, were famous for their clean city and water. They constructed tall downward sloping tunnels, called aqueducts, to bring water from the mountains into the city. The water from the mountains was coming from a clean and protected source. They even had separate areas to put human waste and bath houses, unlike London. Romans were ahead of their time; no one had ever done that before.

Greenville has worked to protect our water, and as a result, we have one of the most protected and cleanest sources of drinking water around! Just like the Romans had aqueducts bringing their water into the city, Greenville pipes its drinking water in from reservoirs surrounded by forests located in the mountains. The drinking water here is some of the best in the country, and that is good for both the people and the environment. No matter the time period, and no matter if you are coming from London, Rome, or Greenville, water has always been extremely important. Water impacts our health, and our environment, helps us grow food, and even provides us with sources of transportation and relaxation. As we have seen, when people do not take care of their water source, it can negatively impact their health. A healthy community is dependent on healthy, clean water.

DISCUSSION QUESTIONS FOR "WATER THROUGH THE AGES"

Who is John Snow, and how has his discovery influenced our present day society?

What are some of the different ways people have depended on water in history, and how do we depend on water today?

Describe some of the things that can happen if a community's water source becomes contaminated?

What are some things that you can do to help protect Greenville's water supply?

We know how important our water supply is, but chemicals, waste, trash, and other contaminants are still dumped into water sources every day. How does that make you feel? Do you think that we protect our water sources enough? If not, what would you do differently if you were in charge of protecting our water resources?

Nonpoint Source Pollution and Water Quality

Word Bank

Abiotic
Aquifer
Bacteria
Biodiversity
Bioswale
Chemical
Clean Water Act
Concentration
Contaminant
Data
Discharge
Dissolved Oxygen
Ecosystem
Effluent
Food Chain
Impairment
Impervious
Infiltration
Nonpoint Source Pollution
Nutrient
Persistent Organic Pollutant
Pervious
pH
Point Source Pollution
Pollution
Riparian Buffer
Sediment
Storm Water Runoff
Turbidity
Water Quality
Weathering
Wetland

Learning Objectives

Students will

- understand the difference between point and nonpoint source pollution
- explore the importance of the urban landscape when discussing nonpoint source pollution
- analyze water quality data from SCDHEC
- become more familiar with the main pollutants of concern in Greenville, SC, including where they come from and what problems they cause
- brainstorm ways to reduce nonpoint source pollution

Background Information

Water quality can be defined as the suitability of water for a particular use. The parameters that scientists and water managers use to define water quality vary based on that water's intended use. For example, the quality of water intended for drinking will be measured by different parameters than water used for swimming. Water quality and water quantity are linked. The same amount of pollutant will have a greater effect in a small pond than it will in a large river. This is one reason that understanding the rate of flow in rivers and streams is important for scientists and water managers.

Water quality can be determined utilizing a variety of methods that measure physical, chemical, and biological characteristics of the water or water body. Some of the most common parameters measured when determining water quality include (but are not limited to):

Dissolved Oxygen (DO)

http://water.usgs.gov/edu/dissolvedoxygen.html

Macroinvertebrate Assemblages

http://water.epa.gov/type/rsl/monitoring/vms40.cfm

E. Coli

http://water.epa.gov/type/rsl/monitoring/vms511.cfm

Turbidity

http://water.usgs.gov/edu/turbidity.html

pH

http://water.usgs.gov/edu/phdiagram.html

What is Nonpoint Source Pollution?

A pollutant can be described as any substance that is potentially harmful and out of place. Many of the substances that can become pollutants are natural substances. Many pollutants; including sediment, nutrients, and even metals; are beneficial or necessary to life, but when these substances are present in a place where they are not naturally occurring or in too high of a concentration, they can be harmful. Regulatory organizations use the term Pollutant of Concern (POC) when discussing a specific problem pollutant they are concerned with.

Nonpoint source pollution (http://oceanservice.noaa.gov/education/tutorial_pollution/04nonpointsource.html) is defined as pollution that comes from diffuse sources.

Examples of nonpoint source pollution water pollution include the runoff from agricultural fields and stormwater runoff from urban areas. http://water.usgs.gov/edu/runoff.html

Point source pollution comes from a distinct point. Examples of point source pollution include wastewater treatment plants and industrial discharge. Point source water pollution usually comes from a pipe, though many municipalities (including Greenville) have stormwater sewers that drain directly into rivers, but since the water in them runs off of roads, buildings, parking lots, and sidewalks, the impact is still considered nonpoint source pollution.

Nonpoint source pollution is the most impactful source of water pollution in the United States today.

Where is nonpoint source pollution coming from?

Urban Runoff: urban areas are a significant contributor to nonpoint source pollution because of -

Impervious surfaces – a high percent of impervious or impermeable surface area in developed locations leads to less infiltration of rainwater into the ground and higher amounts of runoff than in natural areas

Studies have shown that natural ground cover has approximately 50% infiltration, 10% runoff, and 40% evapotranspiration rate, while high density (urban: 75-100% impervious surface) developed areas have 15% infiltration, 55% runoff, and 30% evapotranspiration rates http://www.cep.unep.org/pubs/Techreports/tr32en/fig2.gif

(Arnold, C.L. and Gibbons, C.J., 1996, Impervious surface coverage: American Planning Association Journal, v. 62, no. 2, p. 243-258.)

Compacted soil – even in unpaved areas, often the bare ground in cities is compacted due to high traffic of people, animals, and vehicles (not just cars: lawn mowers, golf carts, recreational vehicles, etc.). Compacted soils do not absorb water well and can contribute to higher rates of runoff in developed areas

The presence of pollutants in urban areas is often higher than in less developed areas. Some examples include:

- Soils and earth materials displaced during construction
- Metals from industrial activity and from automobiles
- Chemicals from industrial activity, from the breakdown of trash, from pesticides and herbicides, and more
- Trash/litter or debris from human activity
- Oil from vehicles

Nonpoint Source Pollution and Water Quality Journal Prompts

Compare and contrast point and nonpoint source pollution.

Why is bacteria considered a pollutant of concern, and how does stormwater runoff contribute to bacterial pollution?

What is the connection between urban development and nonpoint source pollution?

Describe a type of nonpoint source pollution that you have seen. What could be done to reduce the impact of that problem?

Retention ponds, bioswales, and permeable surfaces like gravel all provide spaces for increased infiltration of water into the soil in the urban environment, reducing the effects of nonpoint source pollution on water bodies.

- Nutrients from pet waste
- Metals, chemicals, and more from brownfield properties

Suburban Runoff

Similar to urban sources, suburban areas are characterized by increased amounts of impervious surface and compacted soils. Common nonpoint source water pollutants in suburban areas include oils and gasoline from vehicles, pesticides, soils and earth materials (sediment) from construction, and nutrients from pet waste and fertilizers.

Agricultural Runoff

Though fewer impervious surfaces exist in agricultural areas than in urban and suburban areas, the soils are often compacted, contributing to higher rates of surface runoff than in natural areas.

The potential pollutants in an agricultural setting include

- Nutrients in the form of synthetic and natural fertilizers added to fields.
- Nutrient and pathogens from animal waste
- Chemicals including pesticides and oil from farm machinery
- Sediment from fields
- Organic debris left over from harvest or animal feeding operations

**Note that these are not the only sources of nonpoint source pollution, but are some of the most concern for Greenville County. For example, in another place, runoff from a mine or leakage from boats may be a major concern.*

Pollutants of concern

Nutrients

Nutrient pollution is a major concern in U.S. water bodies. The two nutrients that contribute the majority of this type of pollution are Nitrogen (N) http://water.usgs.gov/edu/nitrogen.html and Phosphorous (P) http://water.usgs.gov/edu/phosphorus.html. N and P come from many sources including:

- Fertilizers from lawns, gardens, golf courses, parks, and agricultural operations
- P from soaps (banned in 1992)
- Pet waste
- Organic debris and sediment
- Animal agricultural operations (overflow from detention ponds and runoff from fields)
- Acid rain (N) from the burning of fossil fuels http://water.usgs.gov/edu/acidrain.html

- Sewage (septic tank failure, overflow, etc.) is another source of nutrient pollution, but may be considered point source

Nutrient pollution contributes to a variety of problems, many of them associated with eutrophication, a boom in primary productivity followed by an increase in bacterial growth and loss of dissolved oxygen. These problems include:

- Loss of dissolved Oxygen
- Fish kills
- Toxic algal blooms
- Degradation of coral reefs
- Loss of biodiversity
- Loss of sea grass beds
- Loss of aquatic animal breeding habitat

Bacteria http://water.usgs.gov/edu/bacteria.html

Bacteria are single-celled organisms that perform a variety of functions. (http://www.biology4kids.com/files/micro_bacteria.html) The majority of bacteria are beneficial or benign, but some can cause illness and disease. These harmful bacteria are of concern for water quality and can be introduced into water bodies from a variety of nonpoint sources (mostly through fecal matter)including:

- Pet waste
- Animal agricultural operations
- Runoff from agricultural fields where manure is used as fertilizer
- Improperly functioning septic systems
- Wildlife

  Especially in urban areas, geese, ducks, and other birds may gather on manicured lawns in parks where people feed them and become an important contributor to nonpoint source pollution. Wildlife is less of a concern in natural areas because of the natural systems that are intact in these areas.

Harmful bacteria in the water can lead to:

- The spread of disease to aquatic animals, terrestrial animals, and people
- Fish kills
- Loss of recreational use of water bodies due to health concerns and the loss of revenue ($) from recreation
- Loss of biodiversity
- Lowered DO levels

Hand feeding birds can contribute to non-point source pollution.

Chemicals

There are many different chemicals – some are synthetic, others are organic. Just because a chemical is organic doesn't mean it won't be harmful (ie. Nicotine). Chemicals come from many different sources including:

- Pesticides
- Industry and Manufacturing
- Legacy chemicals from contaminated soils and sites
- (brownfield properties)
- Breakdown products of litter such as plastic, cigarettes, etc.
- Soaps from washing cars
- Pharmaceuticals
- Illegal dumping of oil, paint, etc.
- Some of the major chemical pollutants we deal with include POPs (PAHs, PCBs, etc.) Persistent Organic Pollutants

POPs take a long time to break down leading to long term effects. We still find DDT and its break down products in samples many years after its use in the US was banned.

Chemicals lead to a wide variety of environmental and health issues such as

- Some chemicals act as endocrine disruptors which cause reproductive issues such as hermaphroditic frogs, male fish with eggs, tumors, deformed fetuses, and more.
- Illness
- Death
- Loss of biodiversity
- Extinction of species
- Higher prices of cleaning and purifying water for human consumption and use

Scientific studies of water leaving treatment facilities have shown varying success removing chemicals

Sediment

Sediment includes particulate organic and inorganic matter.

- Erosion
- Mines
- Logging
- Agriculture
- Construction

Sediment can be contaminated from past industry or mining with chemicals and metals and can include organic debris which contain nutrients. So, in addition to the problems associated with sediment pollution, erosion can also cause problems associated with metal, chemical, and nutrient pollution.

Sediment

The major issues associated with sediment pollution include:

- An increase in turbidity which leads to loss of sunlight infiltration into the water column. Over time, this can cause the death of aquatic plants through lack of sunlight and inability to perform photosynthesis. This can lead to eutrophication and fish kills due to lack of DO in the water.
- A build-up of sediment over time can reduce habitat variability, filling in pools and changing the flow of the river. Habitat loss can lead to reduced species diversity.
- Alteration of water flow

It is important to note that these are not the only ways that pollutants cause harm to people or ecosystems. Also, many of the impacts discussed have far reaching consequences. For example, fish kills may lead to the collapse of a fishery industry or a lack of food for animals further up the food chain, which could result in localized extinctions beyond the animals directly harmed by the pollutants. Furthermore, due to the diffuse nature of nonpoint source pollution, many different pollutants may be impacting water quality at the same time.

Nonpoint source pollution comes from many different sources and impacts ecosystems, animals, and people in many different ways. There are many varying approaches to reducing and controlling nonpoint source pollution, and in order to be effective, individual watersheds must be evaluated to determine the major pollutants of concern and a plan that often includes multiple management strategies should be crafted to fit the individual watershed. Some of the options for controlling and reducing nonpoint source pollution include:

Land management

Regulation of the release of atmospheric pollutants

Proper application of fertilizers (amount and time)

Treatment of agricultural wastes as point source pollutants

Litter control

Reduction of impervious surface area

Maintain and create planted riparian buffer zones

Utilize wetlands and retention ponds to treat runoff

Education and outreach programs

Water conservation

Collection and disposal of pet wastes

Rain barrels, cisterns, and rain gardens – collection of water to prevent runoff

Fines and education to prevent illegal dumping

*especially to storm drains

Properly utilize silt fences and other techniques to prevent erosion http://water.usgs.gov/edu/sedfences.html

Reduce use of fossil fuels, oils, pesticides, and other chemicals

Nonpoint source pollution control measures are widely variable. Some include: Top - Properly utilizing silt fences to reduce erosion. Middle: Educational signage in public parks. Bottom: Planted bioswales for stormwater management

The model watershed can be used for multiple topics and activities found in this program. Students may even want to use it to create a PSA about a single pollutant or issue of concern as a service learning project.

Nonpoint Source Pollution and Water Quality Activities:

Use the background information in this section in combination with the ***watershed modeling activity*** "connecting land use and water quality" from the Greenville is a Watershed section to emphasize the importance of nonpoint source pollution.

Ask students to ***download and read*** *Streets in the City: It's a hard (surface) life* from the EPA http://water.epa.gov/polwaste/nps/upload/streams_city_article-2.pdf

Questions for comprehension and/or discussion:
1) What are the main points of the article?
2) There is a listing of careers on the bottom right corner of the second page of this article. What do these professions have to do with streams in the city?
3) Analyze the title of this article. Is it a good title? Why or why not?
4) Describe 2 ways that streams in the city are different from streams in the forest.

*Expand by assigning students the "shower sleuthing"activity on the second page bottom left of this article. Or take the class out to map stormwater runoff following a rainstorm at your school.

Risk assessment: Go on a "discovering nonpoint source pollution" class walk around your school to try and spot places where nonpoint source pollution may be taking place. Also note any management practices that are in place to reduce nonpoint source pollution.

*examples may include trash in or near storm drains, oil slicks or spills on parking lots, loose soil, pet waste, pesticides or fertilizers applied to lawns
*management practices may include native tree plantings, mulch, rain gardens, silt fences, retention ponds, poop scoop stations, stencils of "do not dump" on storm drains, rain barrels, and more

After returning to the classroom, discuss your findings.
Are there any major nonpoint source pollution issues near your school?
What could you do about them?

Provide 1 or more of the Sustainability Spotlight articles on the next three pages to your students to **read and discuss**.

Use the ***Interpreting Water Quality Data worksheets*** provided as homework or class work.

If you would like to perform more in-depth analysis of water quality data, you can download SCDHEC's data from 1999-present from the EPA's STORENET database. Instructions on how to download the data are available here: https://www.scdhec.gov/environment/water/docs/storettxt.pdf

*Expand your class risk assessment to a larger area or into an environmental action project. Students may wish to "adopt a pollutant" and create an educational campaign or service project to reduce that pollutant's impact on local water bodies.

Recycled CD artwork with a water quality conservation and protection theme

Don't Feed The Geese!

Sustainability Spotlight Article Excerpt From Connections For Sustainability Newsletter Issue 4: April 2012
By Jaclin DuRant - Livability Educator

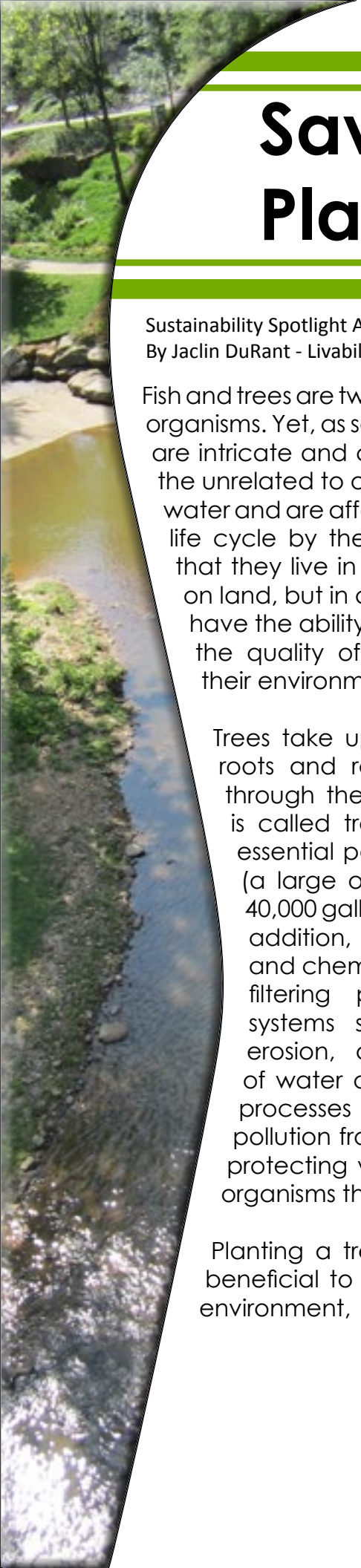
Canada Geese are without a doubt, beautiful birds, and they are a federally protected species under the Migratory Bird Treaty Act. Yet, studies suggest that large populations of Canada Geese contribute to water pollution problems, specifically, through the introduction of pathogens and bacteria by the washing of fecal matter (AKA Goose Poo) into water bodies by storm water run off.

Luckily, there are quite a few ways to deal with Goose induced pollution without harming the birds. Geese like well manicured, open banks. So, planting shrubs and allowing native grasses to grow by the water is an aesthetically pleasing way to reduce population presence.

Also, hand feeding encourages Geese to stay in one place and acclimatizes them to the presence of humans. So, the next time you're out and about, remember to help reduce water pollution and don't feed the Geese!

Signs like this one are reminders that birds, even in urban parks, are wild animals and are perfectly capable of finding their own meals.

connections
FOR SUSTAINABILITY



Save a Fish Plant a Tree

Sustainability Spotlight Article Excerpt From Connections For Sustainability Newsletter Issue 3: March 2012
By Jaclin DuRant - Livability Educator

Fish and trees are two seemingly unrelated organisms. Yet, as so often in nature, there are intricate and complex ties that bind the unrelated to one another. Fish live in water and are affected throughout their life cycle by the quality of the water that they live in while trees mostly live on land, but in a variety of ways, trees have the ability to affect and protect the quality of the water bodies in their environment.

Trees take up water through their roots and release it into the air through their leaves. This process is called transpiration and is an essential part of the water cycle (a large oak tree can transpire 40,000 gallons of water a year). In addition, trees absorb nutrients and chemicals present in water, filtering pollutants out. Root systems stabilize soil, prevent erosion, and slow the runoff of water over land. All of these processes help to reduce water pollution from storm water runoff, protecting water bodies and the organisms that live in them.

Planting a tree anywhere can be beneficial to both people and the environment, but trees alongside streams, rivers, and other water bodies are especially important and function as "riparian buffers." Riparian buffers are vegetated strips alongside water bodies that protect water quality and aquatic life by slowing and filtering storm water runoff.

Trees also provide shade for water bodies which can be essential to aquatic life forms during summer months. Dissolved oxygen content in water decreases as temperatures increase, and dissolved oxygen is essential for fish and other aquatic organisms to survive. So if you're looking for an easy, fun, and aesthetically pleasing way to help protect the environment, planting a tree is a great way to help protect water quality and our fishy friends.

connections
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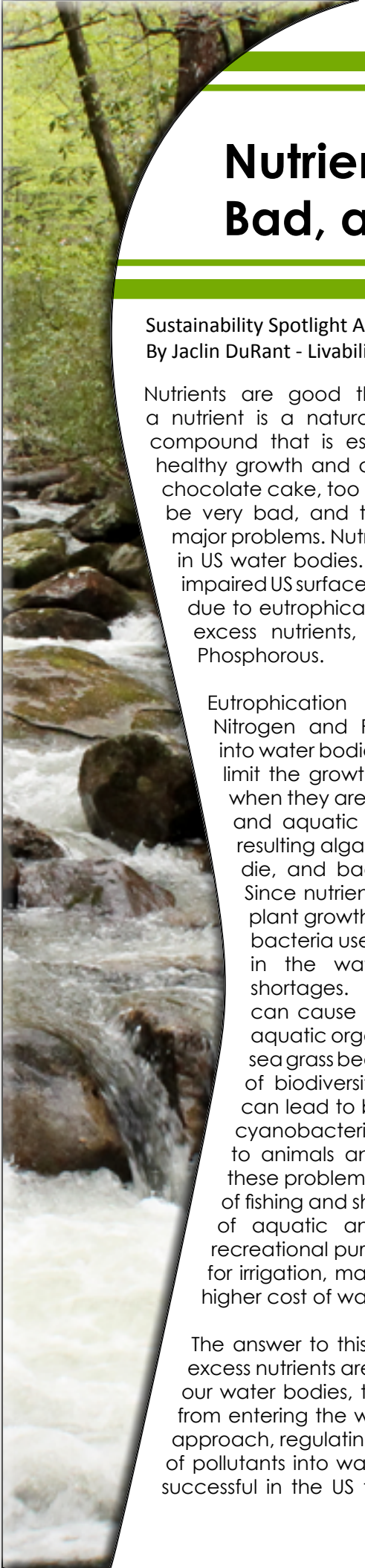


Nutrients in the Water: The Good, the Bad, and What we can do about it

Sustainability Spotlight Article Excerpt From Connections For Sustainability Newsletter Issue 22: January 2014
By Jaclin DuRant - Livability Educator

Nutrients are good things. By very definition, a nutrient is a naturally occurring element or compound that is essential for an organism's healthy growth and development. Yet, just like chocolate cake, too much of a good thing can be very bad, and too many nutrients cause major problems. Nutrients are a major pollutant in US water bodies. In fact, more than half of impaired US surface water bodies are impaired due to eutrophication, a process caused by excess nutrients, especially Nitrogen and Phosphorous.

Eutrophication occurs when excess Nitrogen and Phosphorous are washed into water bodies. These nutrients normally limit the growth of aquatic plant life, so when they are available in excess, algae and aquatic weeds grow quickly. The resulting algal blooms and excess plants die, and bacteria break them down. Since nutrients lead to an explosion of plant growth, the resulting explosion of bacteria uses up the dissolved Oxygen in the water, leading to Oxygen shortages. Oxygen shortages in turn can cause fish kills, loss of habitat for aquatic organisms, the degradation of sea grass beds and coral reeds, and loss of biodiversity. Also, nutrient pollution can lead to blooms of toxic algae and cyanobacteria which can be harmful to animals and people. If unchecked, these problems may lead to the collapse of fishing and shellfish industries, extinction of aquatic animals, loss of water for recreational purposes, lack of clean water for irrigation, manufacturing, and drinking, higher cost of water processing, and more.

The answer to this problem seems simple. If excess nutrients are causing such problems in our water bodies, then we should stop them from entering the water in the first place. This approach, regulating and controlling the input of pollutants into water bodies, has been very successful in the US to reduce water pollution from industry. But, nutrients enter the water mostly as nonpoint source pollution, meaning that the come from many diffuse sources, making it very difficult to regulate their input. Nutrients come from agricultural operations as runoff from over fertilized fields or animal waste; from atmospheric sources due to the burning of fossil fuels and in acid rain; from cities in the form of stormwater runoff carrying pet waste, fertilizers, soaps, and more into rivers and streams; from construction sites, logging operations, and old mines as part of sediment erosion and organic debris.

Nutrient pollution is a serious problem in the US, and as we continue to develop and grow, it is extremely important that we take as many steps as we can to reduce nutrient inputs into our water bodies. Since it is so difficult to control and regulate nonpoint source pollution, it is up to each of us to be aware and control our nutrient pollution. If every pet owner picked up and buried their pet waste away from water and every home owner and farmer reduced the amount of fertilizer they used; if every time you wash your car you make sure it's over grass or in a car wash; if every business and home installed rain barrels or cisterns to collect rain water and reduce storm water runoff; if every construction utilized properly installed silt fences and left planted buffer areas around streams to capture and absorb stormwater; we wouldn't solve the problem, but we could make a big step in the right direction.

connections
FOR SUSTAINABILITY

INTERPRETING WATER QUALITY DATA

The state agency in South Carolina that is responsible for monitoring water quality is the South Carolina Department of Health and Environmental Control (SCDHEC). SCDHEC scientists routinely and randomly sample and analyze surface waters in South Carolina in order to determine water quality. The purpose of this monitoring is to understand the water quality of the waters in our state, to determine if water bodies meet water quality standards, which water bodies and watersheds may need additional attention, and to help set permitting limits for effluent discharge in accordance with the goals of the Clean Water Act.

Results from the 2002-2006 water quality monitoring program found that all six of the stations evaluated on the Reedy River were impaired for either aquatic life or recreation purposes. The water quality indicators of concern include macroinvertebrate density and fecal coliform bacteria counts. Over the course of the study, 2 sites did show improvement (indicators Cu and fecal coliform counts) while 2 sites showed degradation. Overall, the Reedy River was classified as poor for aquatic life and poor for recreation.

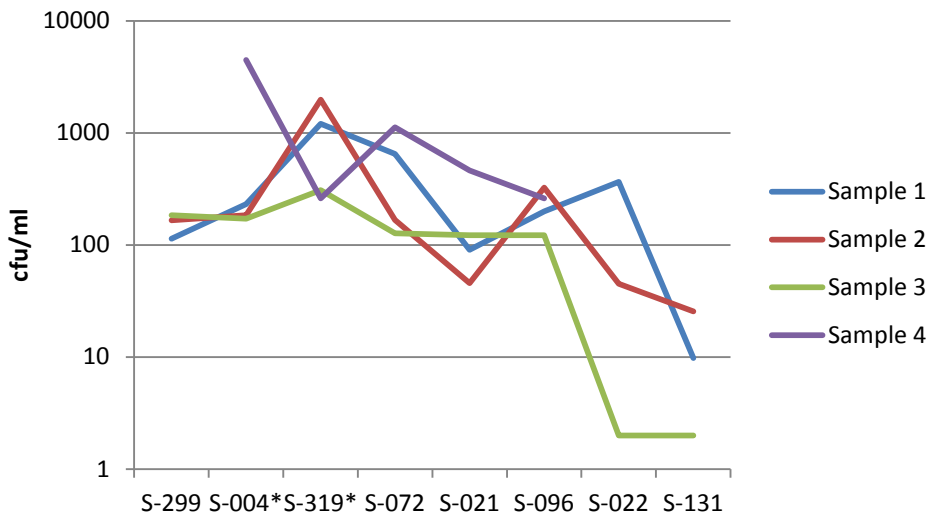
South Carolina water quality standards state that for freshwater, E. coli counts should not "exceed a geometric mean of 126/100ml, based on at least four samples collected from a given sampling site over a 30 day period, nor shall a single sample maximum exceed 349/100ml"
*Since we do not have enough data to determine a geometric mean, we will use the regular mean for our analysis.

Station ID	Sample 1	Sample 2	Sample 3	Sample 4
S-299	114	166.4	185	n/a
S-004*	231	185	171.2	4479.6
S-319*	1203.3	1986.3	308.4	260.4
S-072	650.5	167.5	127.4	1119.9
S-021	90.9	45.7	122.3	461.1
S-096	198.9	325.5	122.3	260.3
S-022	365.4	45.2	2	n/a
S-131	9.8	25.6	2	n/a

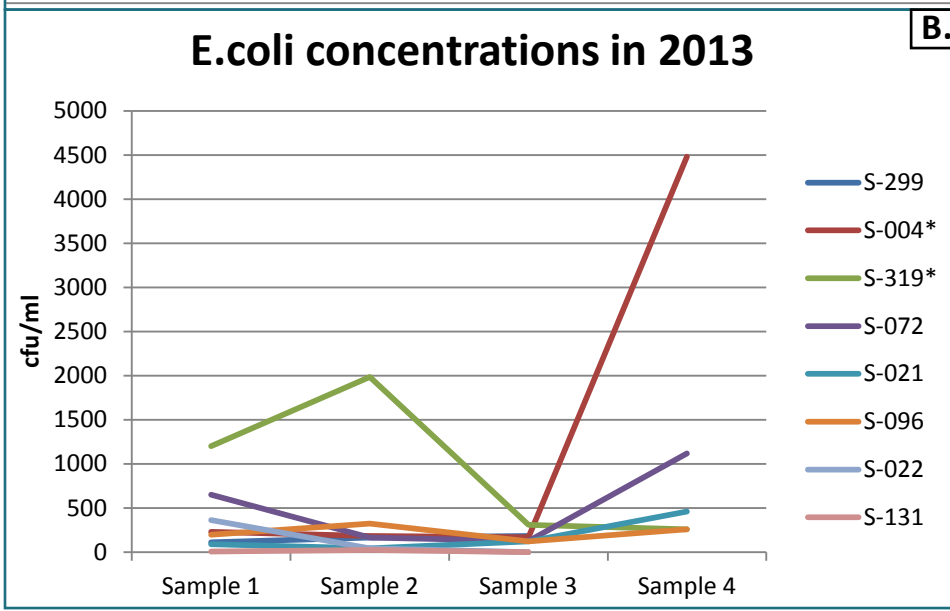
Table 1: E. coli concentrations measured in cfu/100ml at 8 sampling stations along the Reedy River and into Lake Greenwood in 2013
**Four samples were randomly chosen from samples taken in February, April, June, and August at these locations to match the data sets from other sampling locations.*

1)Find the mean E. coli concentration for each station
2)Did any stations exceed the standard of 126cfu/100ml for the mean? If so, which ones?
3)What other determinations can you make from this data?
4)Create a hypothesis related to water quality based on this data and explain how you developed your hypothesis.

A.



B.



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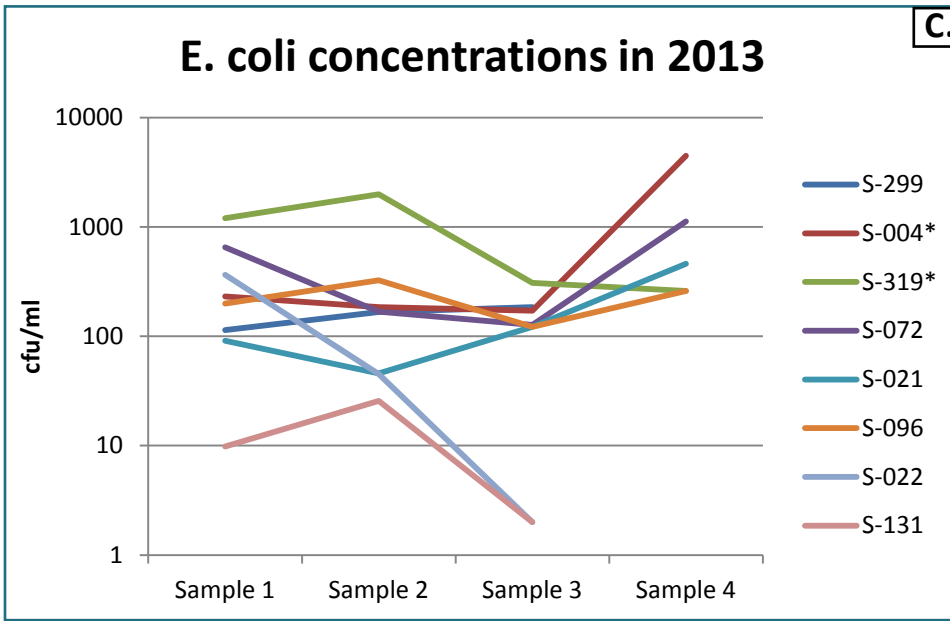

Each station was sampled 4 times during the 2013 calendar year. Timing of samples varied some, but most sites were sampled in February, April, June, and August. Sites S-004 and S-319 were sampled every week as part of a statewide monitoring program for E. coli, so in order to match the rest of the data set, 1 sample from each of the target months was chosen randomly to be used for this data set.

The graphs A. B. and C. are three different graphic representations of the data in table 1.

Use the data table, and the background information provided as well as your own previous knowledge of the topic to answer the following questions:

1)What are the dependent and independent variables being analyzed?

2) What does "Sample n" really mean?

3) Are all of these graphical representations of the data valid? Why or why not?

4) Which of the 3 graphs do you think shows the data in the most useful way?

5) Using these graphs, draw a conclusion about E. coli concentrations in 2013.

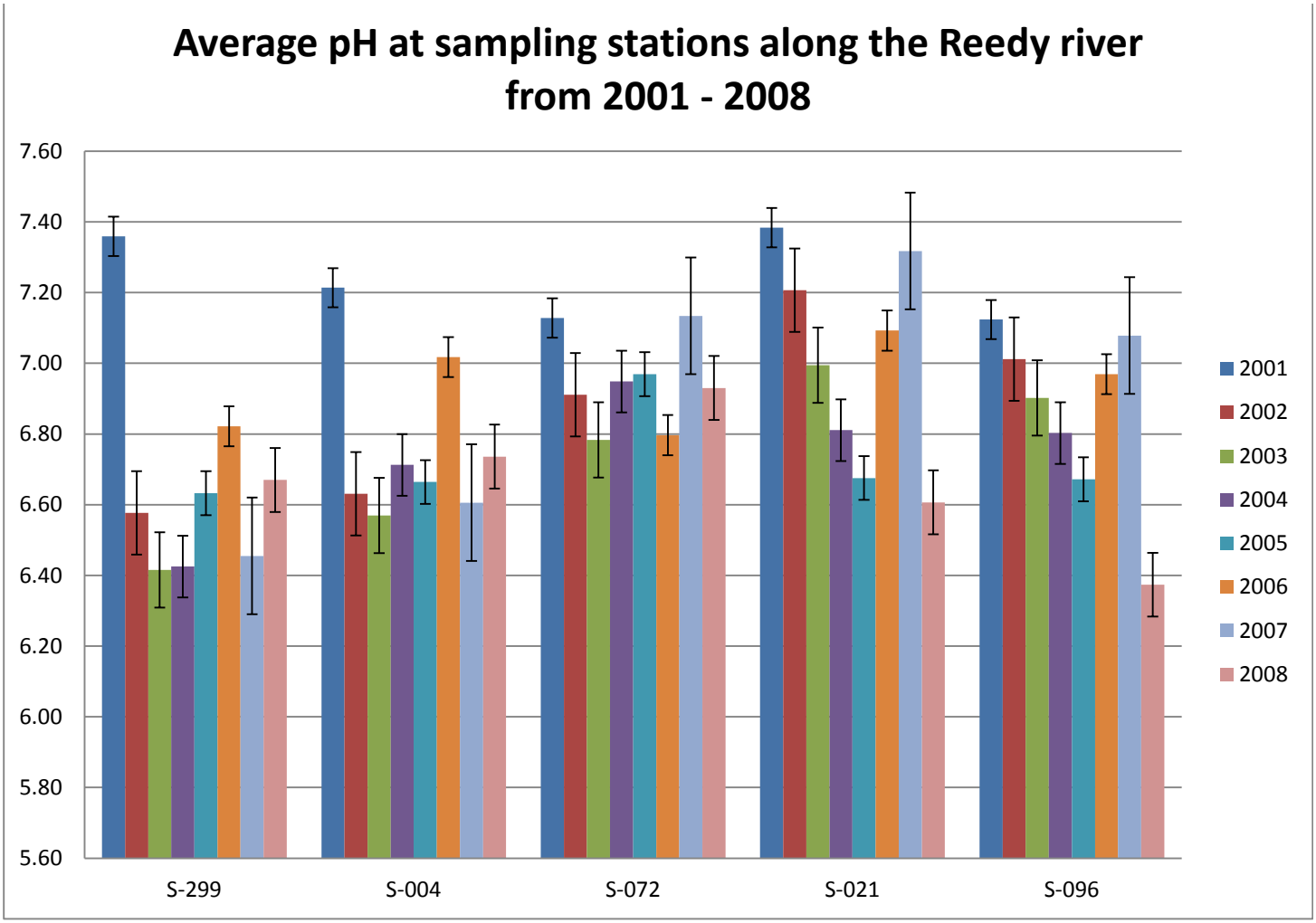

Figure 1: Average pH values of surface water sampling at 5 sampling stations along the Reedy River from 2001 through 2008.

Background information:
Read the USGS Science School article pH -Water Properties
https://water.usgs.gov/edu/ph.html
Read pages 2 and 3 of "Understanding your Watershed: pH" by N. Mesner and J. Geiger
http://extension.usu.edu/files/publications/publication/nr_wq_2005-19.pdf

In South Carolina, the water quality standard of pH for freshwater is 6.5-8

After reading the background information above, answer the following questions:

1) Where there any years where the average pH of a sampling station fell outside of the pH limits for water quality in South Carolina? If so, which years and which stations?

2) Using the information above, develop a hypothesis related to pH for the Reedy River.

3) What other data would you need to collect in order to test your hypothesis?

4) Do you think that pH should be a major concern when considering watershed management plans for the Reedy River Basin?

INTERPRETING WATER QUALITY DATA
TEACHER'S COPY

The Interpreting water quality data worksheets can be stand alone single sheets or used as a group.

The state agency in South Carolina that is responsible for monitoring water quality is the South Carolina Department of Health and Environmental Control (SCDHEC). SCDHEC scientists routinely and randomly sample and analyze surface waters in South Carolina in order the determine water quality. The purpose of this monitoring is to understand the water quality of the waters in our state, to determine if water bodies meet water quality standards, which water bodies and watersheds may need additional attention, and to help set permitting limits for effluent discharge in accordance with the goals of the Clean Water Act.

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South Carolina Department of Health and Environmental Control. 2011. Watershed Water Quality Assessment: Saluda River Basin.Technical Report No.9C21-11. Bureau of Water, Columbia, S.C.
https://www.scdhec.gov/environment/water/shed/docs/Saluda.pdf
Background information on E. coli http://www.epa.gov/region9/water/tribal/training/pdf/Ecoli.pdf

South Carolina water quality standards http://www.scdhec.gov/environment/water/wq_standard.htm state that for freshwater, E. coli counts should not "exceed a geometric mean of 126/100ml, based on at least four samples collected from a given sampling site over a 30 day period, nor shall a single sample maximum exceed 349/100ml"
*Since we do not have enough data to determine a geometric mean, we will use the regular mean for our analysis. See http://www.usawaterquality.org/volunteer/ecoli/June2008Manual/Chpt7_ecoli.pdf for more information about analyzing E. coli data

Station ID	Sample 1	Sample 2	Sample 3	Sample 4
S-299	114	166.4	185	n/a
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Table 1: E. coli concentrations measured in cfu/100ml at 8 sampling stations along the Reedy River and into Lake Greenwood in 2013
**Four samples were randomly chosen from samples taken in February, April, June, and August at these locations to match the data sets from other sampling locations.*

1)Find the mean E. coli concentration for each station
S-299: 155.13, S-004:1266.70, S-319: 939.60, S-072: 516.33, S-021: 180.00, S-096: 226.75
S-022: 137.53, S-131: 12.47

*The newly adopted standards for E. coli monitoring are based on a geometric mean of at least 4 samples taken within 30 days of each other. We do not have this data to analyze, but you could discuss how to find the geometric mean

$$GM=(1s \times 2s \times 3s \times ns)^{1/N}$$

and why the geometric mean might be used in this type of analysis. Also consider performing your own E. coli analysis of a local water body.

2)Did any stations exceed the standard of 126cfu/100ml for the mean? If so, which ones?
Yes. All of the stations except for 131 exceeded the standard

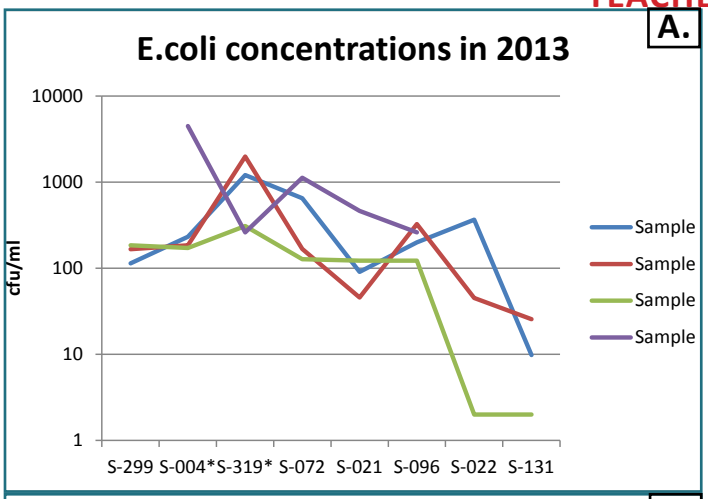
3)What other determinations can you make from this data?
Answers will vary. Some may include: 65% of the samples taken exceed the water quality standard for South Carolina freshwaters. Only 1 site did not exceed the standards at any time. Sampling station S-319 (Reedy River at Rivers St in Downtown Greenville) shows highly elevated levels of E. coli throughout the year. Station S-004 had the highest reading recorded. This reading may be an outlier since all of the other samples at this station were significantly lower (though still not in compliance).
Personal determination: swimming in the Reedy River may be hazardous to your health

4)Create a hypothesis related to water quality based on this data and explain how you developed your hypothesis.
Answers will vary but should be backed up by the data.

INTERPRETING WATER QUALITY DATA

TEACHER'S COPY

A.



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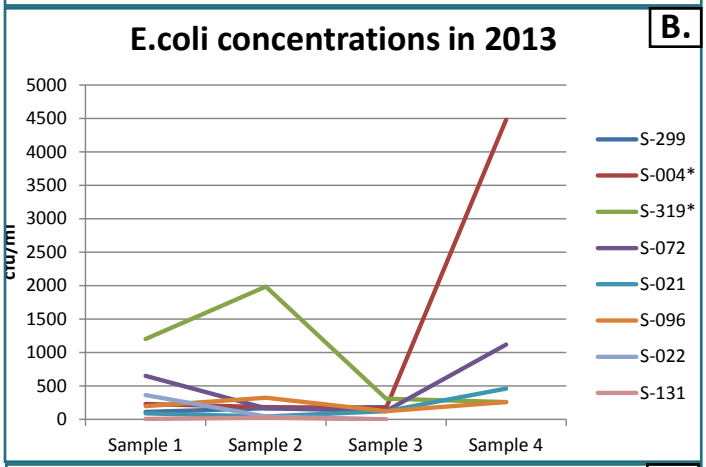
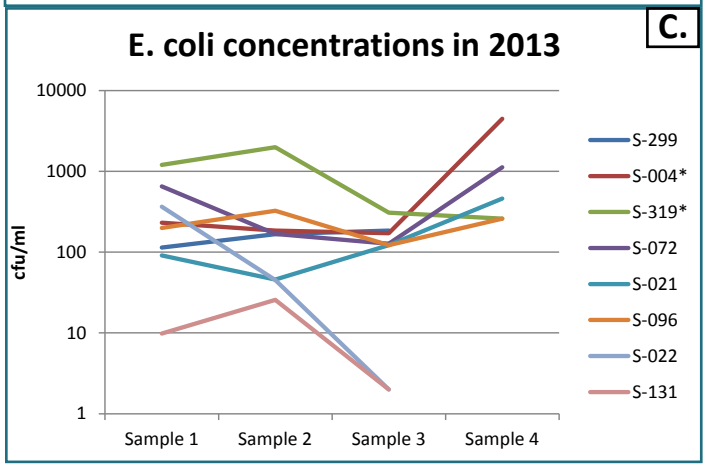


C.



Each station was sampled 4 times during the 2013 calendar year. Timing of samples varied some, but most sites were sampled in February, April, June, and August. Sites S-004 and S-319 were sampled every week as part of a statewide monitoring program for E. coli, so in order to match the rest of the data set, 1 sample from each of the target months was chosen randomly to be used for this data set.

The graphs A. B. and C. are three different graphic representations of the data in table 1.

Use the data table, and the background information provided as well as your own previous knowledge of the topic to answer the following questions:

1)What are the dependent and independent variables being analyzed?
Dependent variable = E. coli concentration
Independent variables = site location and sample #

2) What does "Sample n" really mean?
Month of the year the sample was taken

3) Are all of these graphical representations of the data valid? Why or why not?
Yes, all of the graphs are valid since the x axis either represents a continuum in time or space (sampling points move from upstream to downstream)

4) Which of the 3 graphs do you think shows the data in the most useful way?
Answers will vary. The logarithmic transformation allows for lesser variation to be noted.

5) Using these graphs, draw a conclusion about E. coli concentrations in 2013.
Answers will vary. Some possible answers include: In June, E. coli concentrations tended to drop as you move downstream. E. coli concentrations at sampling station S-131 are generally lower than at any other sampling station. E. coli concentrations at sampling stations S-319 were higher than any other station except for samples taken in August. The highest concentration of E. coli sampled was at station S-004 in August. All of the stations that had samples taken in August showed a spike in E. coli concentrations except for S-319.

TEACHER'S COPY

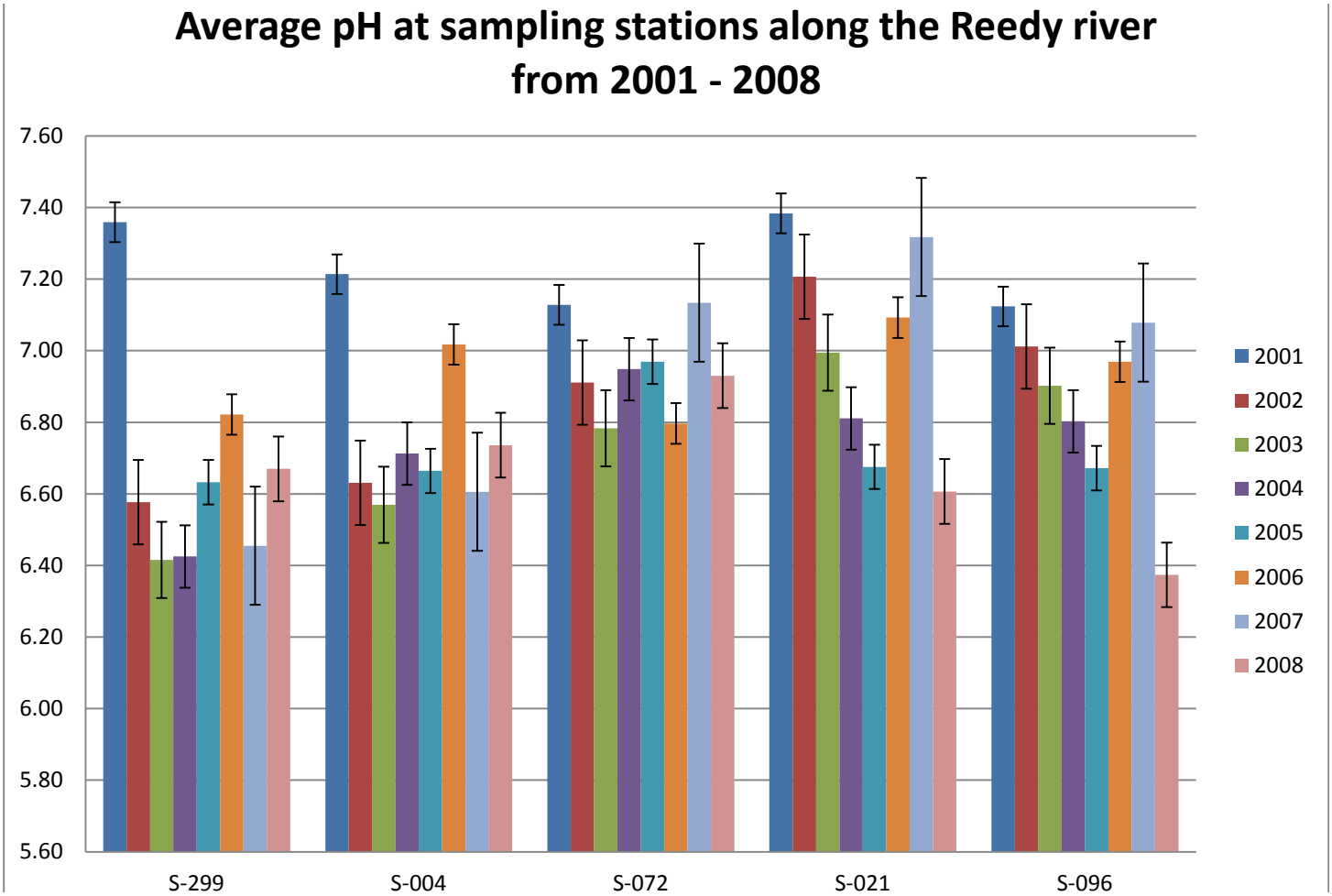


Figure 1: Average pH values of surface water sampling at 5 sampling stations along the Reedy River from 2001 through 2008.

Background information:
Read the USGS Science School article pH -Water Properties
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Read pages 2 and 3 of "Understanding your Watershed: pH" by N. Mesner and J. Geiger
http://extension.usu.edu/files/publications/publication/nr_wq_2005-19.pdf

In South Carolina, the water quality standard of pH for freshwater is 6.5-8

After reading the background information above, answer the following questions:

1) Where there any years where the average pH of a sampling station fell outside of the pH limits for water quality in South Carolina? If so, which years and which stations?
If utilizing the error bars, then only station S-096 in 2008
2) Using the information above, develop a hypothesis related to pH for the Reedy River.
Answers will vary
3) What other data would you need to collect in order to test your hypothesis?
Answers will vary: may include rainfall data, land use patterns, location information, etc.
4) Do you think that pH should be a major concern when considering watershed management plans for the Reedy River Basin? No: data shows that the Reedy is mostly in compliance for water quality standards for pH, but it should continue to be monitored. Data for S-299 shows multiple years were average pH was close to non-compliance, and the error bars suggest that some individual readings were below the standard.

Macroinvertebrate Bioassessment

Word Bank

Adaptation
Aquatic
Benthic
Bioassessment
Biodiversity
Biotic
Dissolved Oxygen
D-net
Ecosystem
Ecotone
EPT
Freshwater
Habitat
Indicator Species
Macroinvertebrate
Microhabitat
Photosynthesis
Pool
Riffle
Riparian
River
Run
Sensitive Species
Solute
Species
Velocity
Water Quality
Wetland

Learning Objectives:

Students will

- learn that macroinvertebrates are small animals without internal skeletons that can be seen without a microscope
- understantd aquatic macroinvertebrates have varying degrees of sensitivity to Dissolved Oxygen. This sensitivity allows scientists and lay people to use the presence and/or absence of different groups of aquatic macroinvertebrates as an indication of the relative health of cold water streams.
- participate in a field expedition to perform a macroinvertebrate bioassessment.

Background Information

Stream health is extremely important for both people and the environment. Healthy streams provide a home for a wide variety of organisms.

Most municipalities get their drinking water from streams, lakes, or rivers.

Healthy streams contain a variety of microhabitats that are home to the juvenile stages of insects, fish, and other animals that are the basis of many terrestrial food chains.

Streams and rivers transport water and anything in the water downstream. We all live downstream from someone and someone else always lives downstream from us. It is important to know the quality of water that we are using and be aware of ways that we affect water quality in order to protect stream health and our natural resources.

Why Bioassessment?

It is common for people to wonder why they should study stream macroinvertebrates, rather than just take a water sample. The answer is simple: Water moves.

Since water is always moving, a water sample only gives a momentary snapshot of stream health. If a water body is being polluted, especially by non-point source pollutants, a water sample will only show contamination if you happen to take it at the right time, immediately following the introduction of the pollutant.

Stream macroinvertebrates live in the water, and many have relatively long life cycles (a year or longer), so the absence of a diverse and healthy macroinvertebrate community in a stream can indicate that there is a problem with the water quality even if pollutants are not present in the water at the time of the sampling.

Macroinvertebrates vary in sensitivity to a variety of physical and biological parameters of their environment; most importantly, dissolved oxygen, but also temperature, sedimentation, nutrients and chemical and organic pollutants.

Macroinvertebrates are indicators of stream health, meaning that the presence or absence of sensitive species can be used to determine general health of a stream. It is still important to take physical and chemical data (such as pH, dissolved oxygen, chemical analysis, temperature, etc.) in order to know what is affecting the macroinvertebrate community.

- The diversity and abundance of macroinvertebrates in a stream will tell a scientist if the stream is being impacted by a pollutant.
- The chemical and physical data allows a scientist to understand more about what pollutants are present, where they may be coming from, and more.

Detailed information and protocol for Rapid Bioassessments developed by the US EPA is available on the EPA website: http://water.epa.gov/scitech/monitoring/rsl/bioassessment/download.cfm

Full data sheets for EPA bioassessments are also available: http://water.epa.gov/scitech/monitoring/rsl/bioassessment/upload/2001_03_08_monitoring_rbp_app_a.pdf

For the purpose of this program, you will be performing a simplified bioassessment and discussing the importance of stream health. Students should come away with the understanding that there is a wide variety of small animals living in streams that you rarely see, and that these animals' presence or absence can help determine whether or not a stream is healthy. If you have time and older students, this lesson could be expanded to perform a more in-depth stream health analysis or compare the biological communities in multiple streams or the biological community in the same stream at different places (such as upstream and downstream from a development or discharge point).

Important Terminology

Macroinvertebrate: invertebrates (animals without a back bone) large enough to be seen without the need for a microscope. Macroinvertebrates typically found in streams include aquatic worms, snails, clams, crayfish, aquatic insects, and immature stages of insects (larvae and nymphs). The most common macroinvertebrates found in streams are usually insect larvae and nymphs.

Benthic: the ecological zone that includes the sediment layer at the base of the stream. Often the term "Benthic Macroinvertebrates" or BMI is used as an acronym for the assemblage of stream macroinvertebrates that live on or close to the bottom of the stream

D-Net: a macroinvertebrate sampling device. A d-net is an aquatic net with the opening in the shape of a "D." The flat side is placed on the stream bottom while sediment upstream of the net is disturbed with the intention of capturing macroinvertebrates as they float downstream.

Macroinvertebrate Bioassessment Journal Prompts

Describe the physical attributes of a stream that you have visited.

What is a microhabitat and why are these important when considering stream health?

Research one of the macroinvertebrates that you have found and list it's characteristics, habitat requirements, and any other important information.

Describe what "indicator species" means and why some macroinvertebrates are considered indicator species.

Draw and diagram a stream.

If a bioassessment has shown that the water quality in an area is poor, what are the next steps that you would perform?

A single stream will have many different microhabitats. When sampling, make sure to visit multiple types of microhabitats, since different animals can be found in each.

EPT: the three orders of insects whose aquatic larval stages are most sensitive to dissolved oxygen concentrations in the water are the EPT: Ephemeroptera, mayflies; Plecoptera, stoneflies; and Tricoptera, Caddisflies. The richness, ratio, and other statistics involving these three orders of organisms is often used as a measurement of stream health.

Dissolved Oxygen (DO): the concentration of oxygen dissolved in water is referred to as D.O. Oxygen gets into the water through aeration, the movement of water through air, diffusion from the surrounding air, and photosynthesis by aquatic plants. Oxygen is used up through respiration.

Dissolved oxygen is necessary for aquatic life. The presence of sensitive macroinvertebrates (such as EPT taxa) in a stream is an indicator of a high level of dissolved oxygen and thus a healthy stream.

Most pollutants negatively affect the level of dissolved oxygen in the water. For example, excessive sediment in the water blocks light, causing aquatic plants and algae to not be able to perform photosynthesis. The lack of photosynthesis means that oxygen is not being put into the water as a photosynthesis by-product. In addition to this, without photosynthesis, eventually the plants will die. Bacteria then decompose the plants, using up more oxygen in the process, and the DO concentration drops more. Too much sediment in the stream for a long time, and the DO will drop so low that fish and other animals will die.

Sections of a stream

A stream or river is not a continuous habitat, but rather can be considered in sections based on the physical, chemical, and biological parameters found in a particular area. The variations between these microhabitats allow different aquatic organisms to survive in different places within the stream.

Riffles: This microhabitat is characterized by shallow and fast moving water. The substrate is usually coarse stones and gravel with areas where the substrate breaks the surface of the water.

Runs: This microhabitat is deeper than a riffle with fast to moderate speed water where no substrate breaks the surface of the water. Average depth measurements should be taken in runs.

Pools: Pool microhabitats are the deepest with a finer sediment bottom of sand and silt and slower moving water. Pools are bowl like depressions in the bottom of the channel.

How to perform a stream health analysis:

If you have very young students, or if you are sampling in a stream that you know will be contaminated, you may want to have an adult do the actual stream sampling and set up clear plastic containers of varying size containing stream water along with pipets, spoons, and forceps for sorting on the bank for the students to do the macroinvertebrate identification. Make sure that everyone is wearing shoes that can get muddy and wet.

Choose your stream ahead of time in order to make sure that it is accessible and safe, and contact property owners in order to make sure that you are

allowed access to the stream at your chosen site. When checking out the stream, remember to look around the banks for poison ivy, yellowjackets, and other potential hazards that you need to be aware of. Small streams with gently sloping banks are recommended when performing bioassessments with younger students.

Before going to a stream, make sure that everything you will be using is clean and dry (make sure that sampling equipment is washed between sites. The last thing you want to do is introduce a foreign animal, plant, or toxin into a stream). Emphasize to students that you must be careful to *disturb the stream habitat as little as possible when sampling.*

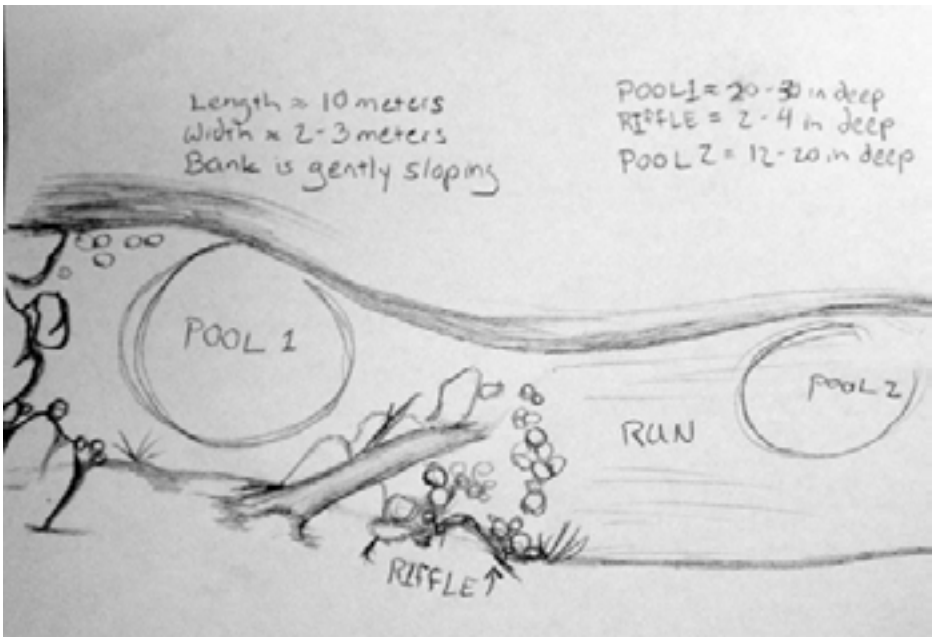
Once you are in the field:

Look at the stream: take note of the physical characteristics of the stream, stream bed, and habitats within the stream.

Collect data: have students draw a picture of the section of stream that you are sampling and label different microhabitats. Collect some physical data.

i. Depth
ii. Width
iii. Length
iv. Description of smell
v. Description of banks
vi. Presence or absence of vegetation

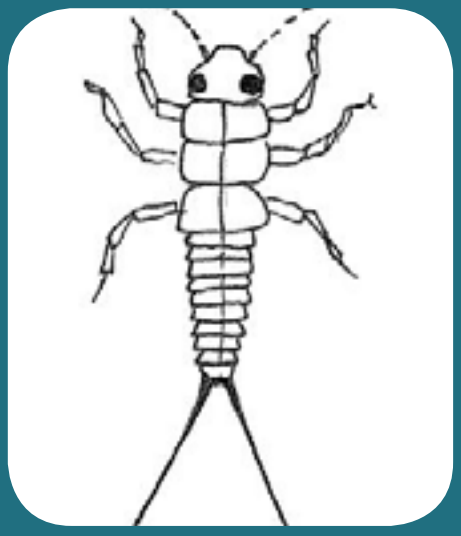
Example:



If you have the capability, have the students **collect data about the water in the stream.** An extended project for older students would be to use this data and the macroinvertebrate data to compare two streams.

Simple items like bowls and plastic spoons are perfect for sorting macroinvertebrates.

The first A J Whittenberg Urban Naturalist Class on a field trip to Wild Cat Wayside to study a cold water stream.



Line drawing of a Stonefly found at Paris Mountain State Park.

Urban Naturalists collect and identify macroinvertebrates

- Temperature
- pH
- Dissolved oxygen content
- Velocity (meter stick, ping-pong ball, and a stop watch: Have one person hold the meter stick while another holds the ball and stop watch. Place the ball on the surface of the water at the upstream end of the meter stick and start the time as soon as you let the ball go. Stop when the ball reaches the end of the meter stick. Make sure someone is ready to catch the ping-pong ball. Measure 3 times and average for velocity.)

Extension: Have the students make a hypothesis about the velocity of different areas of the stream. Discuss why we measure multiple times and use the average to report our measurements.

Collect Macroinvertebrate Samples

Divide the students into groups. Each group will be responsible for counting and identifying the macroinvertebrates in a sample. If you have limited time for this lesson, only sample riffle habitats, since these are the places where many macroinvertebrates are most likely to be found. Begin downstream and work your way upstream for each sample. That way you are sampling undisturbed areas each time.

Using a "D-net," the net holder will place the flat portion of the net directly onto the bottom of the stream with the net opening facing upstream. Wiggle the net until the flat end is flush with the stream and water is flowing through the net.

Determine the sample area: Each sample should be the width of the net and a predetermined length (1M is a good standard) or length of time (2 minutes).

The sampler should pick up any large rocks in the sample area and check for macroinvertebrates clinging to the rocks (snails, water pennies, caddisflies). These rocks can be placed directly into a sampling container (clear or white bucket or Tupperware container)

Once large rocks have been checked, the sampler will stand upstream of the D-net and disturb the bottom of the stream using their feet to stir up debris and sediment. The sampling portion should be timed for 2 minutes or measured for 1 meter. The sampler will make their way upstream, disturbing the bottom as they go, and the D- Net should be moved to stay close to the area that is being disturbed. At the end of 2 minutes or 1 meter, the net holder will lift the net from the stream and deposit the contents in a sampling container.

Place about 1-4 inches of stream water in a sampling container. Carefully turn the net inside out over the container. Using a spray bottle filled with stream water, a pipet, spoon, or forceps, examine the net for any stray macroinvertebrates and deposit them into the sampling container.

Stream Macroinvertebrate Bioassessment Data Sheet

Date:
Time:
Name:

Stream Name and Location:

Weather:

Physical Characteristics of the Stream:

Place an X next to each category of macroinvertebrates that you find

Highly Sensitive	Sensitive	Tolerant
___ Caddisflies ___ Mayflies ___ Stoneflies ___ Riffle beetles ___ Water pennies ___ Gilled snails	___ Dobsonflies ___ Alderflies ___ Fishflies ___ Crayfish ___ Crane flies ___ Scuds ___ Dragonflies ___ Clams ___ Damselflies ___ Sowbugs ___ Net spinning caddisflies	___Aquatic worms ___ Blackflies ___ Midges ___ Leeches ___ Lunged snails
___ Total # of x's	___ Total # of x's	___ Total # of x's
Total x3 = _____	Total x2 = _____	Total x1= _____

Add the three numbers together. Total Index Value = _____

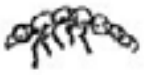
Water Quality (circle the correct answer)

Excellent (more than 22) Good (17-22) Fair (11-16) Poor (less than 11)

Aquatic Macroinvertebrates
Dichotomous Key

1

A. The organism has segmented legs
.....BOX 2

B. The organism does NOT have segmented legs .....BOX 13

2

A. The organism has **6** segmented legs
.....BOX 3

B. The organism has more than 6 segmented legs .....BOX 12

3

A. Body is longer than it is wide (elongate)
.....BOX 4

B. Body oval or rounded .....WATER PENNY

4

A. The organism has **2 or 3** tails or filaments
.....BOX 5

B. The organism has no tail or a single filament.....BOX 7

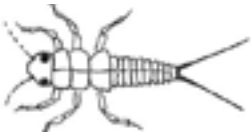
5

A. 2 or 3 hairlike tails (most often 3) and has gills along the side of the abdomen.
.....MAYFLY NYMPH

B. 2 or 3 hairlike tails with NO gills along the side of the abdomen.....BOX 6

6

A. 2 or 3 hairlike tails (most often 2),2 claws at the end of each leg, and NO gills alongside abdomen .....STONEFLY NYMPH



B. 3 broad leaf like tails and NO gills along the side of the abdomen
.....DAMSELFLY NYMPH

7

A. Hardened abdomen (covered by plates or hard) .....BOX 8

B. Soft flexible abdomen.....BOX 9

*This key will help to identify most but not all of the macroinvertebrates found in cold water streams in the upstate of South Carolina.

8

A. Wide abdomen, large eyes, and no tail .....DRAGONFLY NYMPH

B. Entire body hardened and stiff.....BEETLE LARVA

9

A. Fleshy extensions or thin filaments extending from **sides** of abdomen.....BOX 10

B. No filaments extending from sides of abdomen.....BOX 11

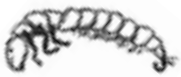
10

A. Fluffy or branched gill tufts under abdomen, large mouthparts short forked tail with hooks .....DOBSONFLY LARVA (HELLGRAMMITES)

B. No gill tufts **under** abdomen, thin filaments extending from sides of abdomen, one tail .....BOX 11

11

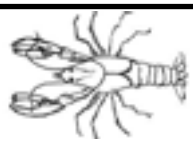
A. 2 small hooks on forked back end. Abdomen may have gills .....CADDISFLY LARVA



B. Abdomen that ends in a long tail or filament .....ALDERFLY LARVA

12

A. 10 segmented legs, large claws, body is lobster like .....CRAYFISH



B. Body shrimp-like, no claws .....SCUD (or Freshwater shrimp)

13

A. Fleshy body with no shell .....BOX 14

B. Fleshy body with a shell.....BOX 15

14

A. Fleshy caterpillar like body with fleshy finger-like extensions from one end .....CRANE FLY LARVA

B. Fleshy caterpillar like body that tapers to points on both ends .....FLY LARVA (horse and deer flies)

15

A. Has a single spiral shell.....BOX 16

B. 2 shells that open on a hinge .....FRESHWATER CLAM

16

A. When point of shell is up and opening is facing you, opening of shell is on right .....GILLED SNAIL

B. When point of shell is up and opening is facing you, opening of shell is on left .....LUNGED SNAIL

Macroinvertebrates found at Paris Mountain State Park
Top: Stonefly Nymph
Middle 1: Caddisfly Larvae
Middle 2: Caddifly Larvae in its case
Bottom: Dragonfly Nymph

Macroinvertebrate Bioassessment Activities:

Perform a macroinvertebrate bioassessment of a stream.

*To find the most macroinvertebrates, choose a cold water stream that is protected and in a natural area. Many South Carolina state parks have programs that include macroinvertebrate bioassessments and have trained personnel and the tools and materials that are needed in order to collect, observe, and identify macroinvertebrates. Contact a ranger to arrange a field trip. Paris Mountain State Park and Jones Gap State Park are good options.

If you don't have the ability to set up a field trip with a park, you still need to make sure that you have permission to sample in whatever stream you are using. Check with the property owner to make sure they will allow you to sample on their land.

Follow the procedures in the background information of this section, and use the macroinvertebrate bioassessment data sheet (modified from the Save our streams protocol) and the macroinvertebrate key (modified from the SC Master Naturalist macroinvertebrate key) to identify the animals that you find.

Using pipets, spoons, or forceps, the students should carefully go through the samples and place macroinvertebrates into petri dishes with water from the stream. Remind the students to take their time, be gentle, and look for movement.

Students will then use the keys provided to identify the macroinvertebrates. Each group should have a data sheet that they can use to record the number and type of macroinvertebrates that they found.

Other keys for macroinvertebrate identification are available online:

For practice using an online dichotomous key to identify macroinvertebrates: http://people.virginia.edu/~sos-iwla/Stream-Study/Key/MacroKeyIntro.HTML

For a "tree" style macroinvertebrate key that can be printed and used in the field (if you will be performing this analysis multiple times, laminate or protect with a sheet cover so that you can reuse the key): http://www.stroudcenter.org/education/MacroKey_Complete.pdf

http://www.dep.wv.gov/WWE/getinvolved/sos/Documents/Benthic/WVSOS_MacroIDGuide.pdf

When you are finished sampling, gently return the macroinvertebrates to the stream.

After performing the bioassessment and studying the stream, tally the students' results (or have each group tally separately and compare) to ***determine the relative health of the stream.***

Discuss your results. Some discussion prompts may include:

- In what category does the water quality in the stream fall?
- Is that what you would expect to find in this stream, and why or why not?
- Are there any land use impacts upstream of your sampling location (development, farms, logging, etc.), and how would you expect types of land use to impact the health of the stream?
- Did anyone find any organisms in the tolerant category? What do you think that means? (if only tolerant organisms are present, the water quality can be considered poor, but if a wide variety of organisms are present and some are tolerant, it doesn't mean that the water quality is poor)

The same Caddisfly larvae in it's case shown on page 102 in a plastic teaspoon

**Most macroinvertebrates are very small. Students should take their time while sorting and watch for movement in their sample. Remind them that these animals are well adapted to blend in to their environment and not to be discouraged if they don't see a lot of animals right away*

Urban Naturalists use keys to identify macroinvertebrates

Urban Naturalists use nets to catch animals in a freshwater stream at Paris Mountain State Park

Urban Naturalists observe a crayfish that they caught while sampling a stream

Compare and contrast the macroinvertebrate community in a natural and an urban stream.

Repeat the procedure for macroinvertebrate bioassessment at an urban stream and have students compare their results.

*Urban streams may be polluted enough to cause human health impacts, so especially with younger students, the instructor should do the actual sampling, and everyone should wear gloves and wash their hands well after working with organisms from an urban stream.

Greenville County Organizations that Provide

Organization	Contact	Website	Topic(s) Covered
Greenville Soil and Water Conservation District	Lynn Pilewski lpilewski@ greenvillecounty.org	Yuckyducky.com Poopfairy.info	Stormwater Nutrient pollution (poop fairy) Pollutants Point and Nonpoint Source Pollution Conservation Connecting students to the land
Greenville Water	Tours: K.C. Price kcprice@greenvillewater.com 864 241-7833 Classroom: Dennis Porter dporter@greenvillewater.com	Greenvillewater.com	Water Treatment Water Quality Water Resources Water Conservation
Lake Conestee	Gina Varat Gina@lakeconesteenaturepark.com	Lakeconesteenaturepark.com	Rivers and Beavers Reedy River Watershed Stormwater Runoff Greenville History Legacy pollution Adaptation Wetlands Keystone Species
Paris Mountain State Park	Cathy Taylor ctaylor@scprt.com 864.244.5565	http://southcarolinaparks.com/parismountain/introduction.aspx	Water Quality Biotic and Abiotic Factors Aquatic Macroinvertebrates Life Cycles of Aquatic Organisms Forest Ecology Landuse and water connections
Renewable Water Resources	Ashley Rhinehart ashleyr@re-wa.org 864 299-4000 ext 283	Rewaonline.org Befreshwaterfriendly.org	Wastewater Treatment Process ReWa (careers) Water Resource Conservation Nonpoint Source Pollution
Roper Mountain Science Center	864 355-8967	www.ropermountain.org	Human Impact on Oceans Land Use and Streams Watersheds Aquatic Organisms

Educational Programming Related to Water Quality

Type of Program	Location	Age Range	Cost	Standards
School Assembly (mascot visit) Classroom Presentation	Your school	Pre-K – adult	Free in Greenville County	In Progress
Facility Tours Classroom Presentation	L.B. Stovall Water Treatment Plant Your School	Tours: middle school-adult Classroom: all ages	Free	No
Field Study	Lake Conestee Nature Park	4th grade	$5 per student. Need based discounts available	Yes
Field Study	Paris Mountain State Park	2nd grade 5th grade	$40 per 20 students	Yes
Tours of Wastewater Treatment Facilities Classroom Demonstrations	Any of 8 Renewable Water Resources facilities (see website) Your School	Tours: middle school-adult Classroom: all ages	Free	Yes
Field Study Laboratory Studies	Roper Mountain Science Center	5th grade – High School	Free in Greenville County	Yes

More Lesson Plans and Educational Resources

City of Greenville

The City of Greenville's Environmental Engineering Division provides brochures, materials, and resources to schools and teachers within the city on stormwater, water quality, water resource protection, and more.

http://www.greenvillesc.gov/PublicWorks/EnvironmentalEngineering.aspx

Download the Exploring Greenville's Water Educational program free:
http://connections.greenvillesc.gov/EdMaterials.aspx

Curricula

Project WET

General water education
K-Middle

Website and activities for students:
http://www.discoverwater.org/

Lesson plans and resources for teachers
http://www.projectwet.org/

Carolina Clear

Lesson Plans and Interactive Whiteboard activities
Watershed, Stormwater, Pollution
Middle School

http://www.clemson.edu/public/carolinaclear/education/

The Water Source Books: EPA

Lessons and activities related to water and water quality developed by the EPA
Broken into grade levels K-2, 3-5, 6-8, and 9-12

http://water.epa.gov/learn/kids/drinkingwater/wsb_index.cfm

Lesson Plans

Who Polluted the River?
Source: Des Moines Water Works
Activity and reading: where pollution comes from
Elementary

http://www.dmww.com/upl/documents/education/education-resources/water-activities/who-polluted-the-river.pdf

Build Your Own Aquifer
Source: Louisiana Department of Environmental Quality
Groundwater contamination demonstration

http://www.deq.louisiana.gov/portal/Default.aspx?tabid=1966

Exploring the Environment: Water Quality
Source: Wheeling Jesuit University/NASA supported Classroom of the Future
Exploring water quality using problem based learning in a fictional watershed
High School

http://www.cotf.edu/ete/modules/waterq3/WQmain.html

Water Quality Degradation in the Oceans
Source: National Geographic
*Connecting water quality to real environmental issue*s
High School

http://education.nationalgeographic.com/education/activity/water-quality-degradation-in-the-ocean/?ar_a=1

The Water Cycle and Forestry
North Carolina State University

http://www.nc-climate.ncsu.edu/edu/k12/

Games

Classroom Games and Activities
Source: Athens-Clarke County Government
water jeopardy, water conservation card games, and more

https://athensclarkecounty.com/3927/Water-Education-Programs-Activities

Online Game - Water Life
Source: NOAA
Estuaries, water pollution, aquatic food chains

http://games.noaa.gov/oscar/foreducators.html

Urban Water Cycle
Source: Minnesota Department of Health
Short video followed by information and games:
Runoff, Wastewater Treatment, Ground Water, Water Conservation

http://www.health.state.mn.us/water/urbancycle/n

Discover Water
Source: Project Wet
K-Middle
Website, activities, games, badges, and self tests for students

http://www.discoverwater.org/

Videos

"After the Storm"
EPA and The Weather Channel
Video exploring pollution from stormwater runoff
21:48

http://water.epa.gov/action/weatherchannel/index.cfm

"Poisoned Waters"
PBS
Runoff and water pollution
DVD - 120:00

http://www.pbs.org/wgbh/pages/frontline/poisonedwaters/

Fifteen to the River: Explaining Stormwater Runoff
Source: West Michigan Environmental Action Council
1:49
Short cartoon explaining stormwater runoff

https://www.youtube.com/watch?v=GrBEEjijxaY

Glossary

A

Abiotic
Not living

Adaptation
A physical, behavioral, or morphological trait that allows an organism to survive in its environment.
The adjustment of an organism over time in such a manner that it becomes more suited to its environment.

Agriculture
The cultivation and management of land for production.

Amphibian
A vertebrate animal that is ectothermic, has porous skin, and lives some part of its life cycle in water. Most amphibians go through metamorphosis. Due to their porous skin, they are highly sensitive to pollutants and are considered indicator species.

Aquatic
Relating to or living in or on water.

Aquifer
A porous and permeable underground layer of material in which water freely moves and can be extracted from.

B

Bacteria
Single celled prokaryotic micro organisms

Barrier
An object or item that keeps things separated from one another.

Base Flow
The level of water in a moving water body such as a river or stream that is made up of the discharge into the stream from natural sources including ground water. The flow of a river when not impacted by a rain event.

Benthic
The lowest layer of an aquatic habitat, namely of an ocean or lake, includes the sediment and sub-surface and all of the organisms that live there.

Bioassessment
A scientific study using biological organisms to determine the relative health of an ecosystem.

Biodiversity
The amount of different species of plants and animals in a particular ecosystem, including genetic diversity within a species.

Biotic
Living

Bioswale
Vegetated landscape features consisting of swales and slow drainage courses designed to help filter and remove pollution from surface runoff water.

Brownfield
An underutilized or abandoned property where redevelopment is hampered by environmental contamination or the possibility of the property being contaminated by a hazardous pollutant, usually due to past land use as industrial or commercial facilities. Cleaning up and reinvesting in brownfield properties promotes economic development, protects the environment from further contamination, reduces blight and takes development pressure off greenfields.

Buffer Zone
A neutral area designed to mitigate conflict. In the context of planning, a buffer zone helps mitigate frictions between commercial-residential district boundaries.

C

Clean Water Act
A set of Federal legislation regulations and amendments passed in 1972 that allows the US Environmental Protection Agency to regulate the discharge of pollutants into US water bodies.

Clear Cut
The forestry practice of clearing all trees in a stand, leaving it empty.

Climate
Description of the characteristic weather conditions in particular geographic areas, usually based on average temperature and rainfall.

Concentration
An amount: measured by percent volume of one substance inside another substance

Condensation
The act of a gas becoming a liquid

Community
All populations inhabiting an area at a specific time. For people, community is a social science construct about the relationships that people may form and can include individuals joined by shared interests, geographic residence, history, or ethnicity.

Conservation
The protection and management of resources or property to ensure longevity and preservation.

Construction
The act or process of creating structures on a property; subject to design standards of the district.

Contaminant
A material or substance (physical, biological, or chemical) that is out of place and may cause harm or damage.

Contamination
The existence of undesirable materials in the wrong place, making an area unfit for its intended use.

Cultivate
Grow or raise, usually used to denote the growing and raising of crops for human consumption or use.

D

D-net
An aquatic net opening in the shape of a "D" used to collect macroinvertebrates. The flat side is placed on the stream bottom while sediment is moved around upstream.

Data
Individual bits of information used to represent ideas, theories, conclusions, or objects.

Desertification
The degradation of soil and vegetated areas due to human activity resulting in poor soil and lack of vegetation including expansion of arid environments.

Development
Human induced change of a land area intended to bring about growth. Includes construction of new buildings, zoning, building relocation, improving real estate, paving, excavating, etc.

Dilution
The act of reducing the concentration of a solute in a solvent. Usually by adding more of the solvent to the solution.

Discharge
Release.

Dissolved Oxygen
The amount of oxygen gas dissolved in water; a measurement of water quality.

Diversity
Variety, not being the same; being composed of many different elements.

E

Ecosystem
All living and nonliving components of a community interacting to form an ecological system. Examples include deserts, grasslands, tundra, marshes, lakes, and tropical rain forests.

Ecotone
A habitat that is a transitional zone between two distinctly different ecosystems that contain organisms found in the bordering areas as well as organisms distinct to the ecotone. Many wetlands are ecotones between many aquatic habitats and terrestrial habitats.

Effluent
The output of a process; example: water from a waste water treatment plant.

Emission
The release of chemicals, particulates, or pollutants into the air.

Environment
All factors living and non living that affect an individual throughout the individual's lifecycle.

EPT
Three insect orders whose larval stages are most sensitive to dissolved oxygen levels and stream health that are used in some bioassessments as indicators of stream health. E = Ephemeroptera (Mayflies) P= Plecoptera (Stoneflies) T= Trichoptera (Caddisflies)

Erosion
The movement of soil particles or sediments by wind or water.

Evaporation
The process of a liquid becoming a gas.

F

Filtration
The process or act of separating something. Usually the process or act of separating solids out of a liquid, and allowing the liquid to pass through.

Flood
A large amount of water overflowing its natural boundaries and covering an area that is usually dry land.

Food Chain
A series of organisms, each dependent on the species below it as a source of food.

Forestry
The management of forests; includes developing, cultivating, growing, harvesting, transporting, and selling trees for commercial use and management of forest ecosystems for wildlife habitat, recreation, conservation, and other uses.

Freshwater
Water that has a very low concentration of dissolved salts. The initial source of most freshwater on Earth is precipitation.

G

GIS
Geographic Information System (GIS)
A spatial computer system capable of storing, visualizing, analyzing, retrieving, and transferring geographic data of an area.

Green Space
Undeveloped areas of a city that are specifically set aside for recreation, aesthetic relief, or wildlife conservation.

Ground Water
Water accumulated underneath earth's surface, filling all pores and spaces in rock or soil. It serves as a reservoir for springs and wells and is replenished by surface water.

H

Habitat
The physical environment an organism, species, or population naturally dwells.

Humus
The dark brown, nutrient rich topsoil of a soil sample; organic matter that has reached a point of stability in which all organic matter (such as dead leaves and wood) has decomposed.

Hydrology
The movement of water through and over the land. Includes evaporation, precipitation, absorption, above and below ground flow, recharge, discharge, and other parts of the hydrologic cycle.

I-K

Impact
An effect

Impairment
A loss in function or diminishment of value.

Impermeable
An impenetrable surface, where substances cannot pass through or seep into.

Impervious
See impermeable

Indicator Species
A species that is a sign of the relative health or state of an ecosystem, either through the presence, absence, or well-being of the species in a particular habitat. Scientists use indicator species as guides for determining areas and issues that need further study.

Infiltration
The downward movement of water as it permeates the ground and moves into the subsoil.

Introduced species
Species living in an area outside of its natural geographic range; they are either intentionally or unintentionally brought in to a new environment.

Invasive species
Any exotic (non-native) plant, animal, or pathogen that can out-compete native species and causes environmental, economic, or human damage in a new environment.

L

Lake
A large body of water surrounded by land.

Land Use
The way individuals use the land. In planning, land use is often designated and zoned.

Legacy
Something that is left behind once a person, animal, or thing is gone.

M

Macroinvertebrate
Invertebrates (animals without a back bone) large enough to be seen without the need for a microscope. Aquatic macroinvertebrates are an important part of many water quality monitoring programs due to their sensitivity to toxins and Dissolved Oxygen levels.

Microhabitat
A small, specialized habitat that varies from the surrounding habitat.

Mining
Material extraction from the land.

Monoculture
Typically used to describe crops on farmland, referring to agricultural systems where the majority of the crop is of the same species, resulting in low crop diversity.

N

Native
Belonging to or coming from a particular place, innate.

Natural
Something existing or occurring apart from human intervention or activity.

Nonpoint Source Pollution
Pollution that comes from a diffused source, such as sediment runoff, fertilizer, and pesticides and that are influenced by the topography of the land.

Nutrient
A naturally occuring chemical substance that plants or animals utilize as a function of their growth and survival.

O

Open Space
A land area set aside by zoning that is to remain undeveloped. Open spaces are areas then used for recreation or resource protection and also provides visual relief to developed areas.

P-Q

pH
A measure of the acidity or alkalinity of a solution on a 14 point scale.

Permeable
Can be passed through. Most often used in relation to water.

Persistent Organic Pollutant (POP)
A toxic chemical substance that is resistant to breakdown or degradation and persist in the environment for a long time. Many POPs bioaccumulate through the food chain leading to higher level predators having high levels of toxins in their tissues.

Pervious
See Permeable

Photosynthesis
The chemical process all green plants undergo to make their own food. Energy from the sun, carbon dioxide, and water create glucose for the plant, and oxygen is released as a by-product.

Plan
A proposal or diagram that maps out a course of action intended to lead to a future goal.

Planner
A job in which people help develop a broad vision for a community and what it can be by identifying values and creating development goals and then implementing a strategy to achieve those goals; a branch of urban planning.

Point-Source Pollution
Specific sources of pollution that are easily identifiable, such as a smoke-stack or factory drain.

Pollution
Contamination of air, water, or soil by undesirable materials. Can be physical, chemical, or biological. Not all pollutants are innately harmful, but when taken out of natural context or in high quantities, they can become pollutants.

Pool
A microhabitat in a stream or river that is deep with a fine sediment bottom of sand and silt and slow moving water. Pools are bowl like depressions in the bottom of the channel.

Population
A group of individuals sharing genetic information of the same species that occupy a habitat at a given time.

Precipitation
Water that falls to the ground (rain, snow, sleet, or hail).

R

Remediation
The clean-up of a polluted area to an uncontaminated state.

Reservoir
A natural or artificial basin used for the storage, regulation, and control of water.

Resource
A source of supply one can draw from for support. Examples include: wood as a resource from trees, money, etc.

Riffle
A stream or river microhabitat that is characterized by shallow and fast moving water. The substrate is usually coarse stones and gravel with areas where the substrate breaks the surface of the water.

Riparian
Of or relating to the banks of a body of water (most often a river or stream).

Riparian Buffer
A vegetated space alongside rivers or water sources that reduce the impact of storm water runoff by keeping the water shaded, stabilizing the bank, protecting water quality, and providing a wildlife habitat.

Run
A stream or river microhabitat with fast to moderate speed water where no substrate breaks the surface of the water.

Rural
Land areas that are less-developed, consisting mainly of open spaces and areas used for farming, forestry, and resource extraction.

S

Sediment
Soil matter, such as sand, silt, clay, and minerals, that has been or is being moved by wind or water.

Sensitive Species
Any plant or animal classified as having the potential to become endangered in the near future due to living in a particular environment or being sensitive to change.

Silviculture
The growing of trees for agricultural purposes.

Soil Profile
A vertical section of soil that shows the horizons, or layers of material beneath the surface of the land.

Species
All organisms that share a genetic heritage and can reproduce viable offspring.

Solute
The substance that is dissolved in a solvent in any given solution.

Storm Water Runoff
Surplus water runoff resulting from rainfall that does not seep into the earth. Impermeable surfaces in cities and the compaction of soil contribute to large amounts of stormwater runoff.

Suburban
Usually residential development that occurs just outside of a city; characterized by the need for personal automobiles as a major form of transportation and lower population density than a city.

T

Top Soil
The surface layer of soil, rich in organic matter and humus.

Topography
A representation of earth's physical land surface showing elevation, position, and slope.

Transpiration
The process of water being taken up by plant roots and transported to the leaves where it is released into the air as water vapor (evaporated) from small pores in the underside of the leaves.

Turbidity
The cloudiness of water.

U

Urban
Of or pertaining to a developed area or city.

Urban Heat Island
An area of human development that is warmer than the surrounding undeveloped area.

V

Velocity
The rate of how fast and how far an object travels during a specific length of time.

Vernal Pool
A seasonal, temporary wetland.

W-Y

Water Body
An area of water accumulation. (river, stream, lake, pond, wetland, ocean, marsh, swamp, etc.)

Water Cycle
The processes that water follows when it changes form and moves across the earth. Usually includes evaporation, transpiration, condensation, and precipitation.

Water Quality
The physical, biological, and chemical characteristics of water that determine the suitability of water for any intended use.

Water Table
The upper surface of the ground that is completely saturated with water.

Watershed
Total land area surrounding a particular body of water that all water drains into; watersheds vary in size and in geography depending on the size of the water body, the topography of the land, and the land use patterns that occur in the watershed as well as surrounding watersheds.

Weathering
The act of changing in appearance or texture (or wearing down) over time due to exposure to constant atmospheric conditions.

Wetland
A habitat where the soil is saturated at least some part of the year.

Z

Zoning
The classification of land types designating what type of land use should be placed where in a geographic area, usually based on population density. Zoning's original purpose was to protect people and their environment by insuring that land use types are evenly distributed throughout an area and that some land use types are separated from others.