Rain to Drain
Slow the Flow
Rain to Drain—Slow the Flow is a multi-dimensional journey following the movement of stormwater on Earth. The curriculum development was led by Jennifer Fetter, Watershed Youth Development Educator, Penn State Extension, in collaboration with the PA 4-H Youth Development Team, the Penn State Extension Renewable Natural Resources Team, and the Penn State Department of Landscape Architecture.

Special thanks and appreciation go to the following people who served on the development, review, editing, and pilot testing teams. This curriculum guide would not have been possible without them.

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This curriculum guide will lead you through the *Rain to Drain - Slow the Flow* 4-H experiment and additional activities.

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What is 4-H?

4-H is the largest youth development program in the United States. It is run by each state’s land-grant university as part of their Cooperative Extension program, a partnership with the USDA, state, and local governments.

The 4-H mission is to empower youth to reach their full potential, working and learning in partnership with caring adults.

4-H Mission Mandates

The mission of 4-H is to provide meaningful opportunities for youth and adults to work together to create sustainable community change. This is accomplished within three primary content areas, or mission mandates: citizenship, healthy living, and science. The educational foundation of 4-H lies in these three mission mandates.

**Citizenship**

Since its inception, 4-H has placed emphasis on the importance of young people being engaged, well-informed citizens. By connecting to their communities and community leaders, youth understand their role in civic affairs and expand their role in decision-making processes. It’s clear that civic engagement provides the foundation that helps youth understand the “big picture” of life and find purpose and meaning.

**Healthy Living**

Healthy food and nutrition has been addressed by the program since its inception in 1902. Having a long history of promoting healthy living among youth and their families, 4-H has become a national leader in health-related education. The 4-H Healthy Living Mission Mandate engages youth and families through access and opportunities to achieve optimal physical, social, and emotional well-being.

**Science**

The need for science, engineering, and technology education is essential for today’s young people. 4-H programs prepare youth for the challenges of the twenty-first century by engaging them in a process of discovery and exploration.

The activities in the *Rain to Drain—Slow the Flow* curriculum were written to emphasize the use of inquiry and the experiential learning model. The experiential learning model emphasizes the importance of youth being involved in each of the five stages of the model throughout their learning experiences. Youth *experience* the learning activity, *share* their experiences with others, *process* what was important about the experience, *generalize* how their experience relates to everyday experiences, and then *apply* the skills they gained to other parts of their lives. “Do, Reflect, and Apply” are ways to connect life skill development to any subject matter learning experiences.

Water is an incredibly important natural resource. We can’t live without it. We not only need water for our own daily uses, like drinking and washing, we also need water for agriculture, manufacturing, and energy production—and lots of it. Water is found in many places and in many forms on Earth. As a liquid, we can find it in lakes, rivers, and underground aquifers. As a gas, it is drifting through our atmosphere. As a solid, it is frozen in glaciers and on snow-covered mountains.

Not Enough Water

In some parts of the United States water is abundant. It many places, however, water is becoming scarce. Perhaps you have experienced a time when you have had to use less water than normal because your community was experiencing a drought. There are a number of different causes that are contributing to the decrease of water supplies in those communities. No matter what the cause, the result is that water supplies are not able to replenish themselves through rain and snow as fast as people need to use them.

Water found beneath the Earth’s surface, known as groundwater, has been decreasing rapidly in large parts of the United States in recent years. Nearly half of the US population gets its drinking water from groundwater supplies, including almost the entire rural population. Over 50 billion gallons of water used each day for agriculture also comes from groundwater. If groundwater supplies continue to get smaller, the impacts could affect many people.

Photo Credits: “Drinking Water” by Darwin Bell on flickr.com/photos/darwinbell/286131360/ CC BY 2.0.
“Drought 2001” by Kecko on flickr.com/photos/kecko/5704325426 CC BY 2.0.
Too Much Water

Sometimes an abundance of water can also cause problems. Sudden and heavy rains and snow melts can lead to flooding and erosion. When the water makes its way into streams and rivers, sometimes it is too much for the banks to handle. The streams and rivers then overflow into the streets and into homes and businesses and across agricultural lands. Floods can leave a path of destruction in their wake. Over the past 50 years, flooding has accounted for over $97 billion in damages and nearly 4,000 deaths in the United States.

Using Science for Solutions

Understanding the science of how water moves can help us learn how to conserve the water resources that we have. Science can also help to prevent water from being an unnecessarily destructive force. Environmental engineers, landscape architects, and water authority managers, among many other scientists and professionals, are working hard at designing innovative solutions to these problems. They are helping communities find ways to use these solutions to plan current and future development of homes, businesses, and entire neighborhoods.

Your challenge in Rain to Drain—Slow the Flow is to master the science of how water moves and help to design a community where water moves into the ground, becoming a helpful resource instead of becoming a flood.
Let's Get Started: How Water Moves

**Time Needed:** 20 - 25 minutes

**Materials Needed:**
- A baking sheet, plastic tray, or other similar smooth, flat surface with a lip/raised edges all the way around
- A small cup of water
- A ruler
- A damp sponge

**Leader Notes:**
This introductory activity is best done by the youth in a group, but it could be a demonstration led by an adult or teen leader as well.

1. Lay your baking sheet or tray on a table in front of you. In a moment, you are going to pour your cup of water onto the tray.
2. Before you do that, let’s make a prediction about how the water is going to move on the tray.

Describe what you expect to see on your tray after you pour the water onto it:

3. Now go ahead and pour the water out slowly and close to the tray. Was your prediction accurate?

Describe how the water looks on the tray:

According to **Newton’s First Law of Motion**, “an object at rest will remain at rest and an object in motion will continue moving in a straight line unless compelled to change its state by the action of an external force.”

In this case, the water is the “object” we are observing. By pouring the water out of the cup, we allowed the force of gravity to pull it down to the tray. The tray exerts an equal amount of force in the opposite direction, pushing the water against the force of gravity. These equal, or balanced, forces cause the water to rest in a puddle or droplets on your tray.
How can we get the water to start moving again?

In order to make an object at rest start moving, additional force has to be applied to it. **Forces** generally come in two categories, **push** and **pull**.

4. Can you think of some ways that we could push or pull the water to get it to move on the tray?

<table>
<thead>
<tr>
<th>Describe three ways you could move the water</th>
<th>Is this a push or pull force?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ex. push it with your finger</td>
<td>push</td>
</tr>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
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<td>3</td>
<td></td>
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</tbody>
</table>

5. Try experimenting with one of your three ideas above. Were you able to get the water to move, and did the water move the way you expected it to?

Describe what you observed:

6. Let’s try changing the slope of the tray and see what effect that has on the water. Raise the left edge of your tray off the table, just slightly, until you see the water start to move. (You may have tried this already as your force experiment above; try it again now and have the ruler ready.)

7. Using the ruler, measure how far off the table you had to lift the edge of your tray to get the water to move.

Which direction did the water move? How high was the tray lifted off of the table?

By lifting the edge of the tray, you changed the angle of the tray’s upward “push” force acting on the water. The force of the tray pushing up on the water is called the **normal force**. The **normal force** is a push force exerted perpendicular to any object or surface that another object comes in contact with. When you change the position of a surface, the direction of the normal force changes with it.
Gravity on Earth has an approximate value of 9.81 m/s², which means that the speed of an object falling freely near the Earth's surface will increase by about 9.81 meters (32.2 ft) per second every second.

Does water ever roll uphill without additional forces acting on it?

How can we slow or stop water from flowing downhill?

When more than one force acts on an object, the forces combine to form a net force. The combination of all the forces acting on an object is the net force.

When your tray is on an angle, the push of the normal force of the tray is not as strong as the pull force of gravity because it is now on an angle. They are unbalanced forces, and the resulting net force causes the water to be pulled downhill.

In order to get the net force closer to zero, you would need to add another force. We could try changing the friction. Friction is a force that is created whenever two surfaces move or try to move across each other. Friction always opposes the motion or attempted motion of one surface across another surface. You have been pouring water on a smooth tray, but what if you added a differently textured surface for the water to pass over or through?

8. Lay a damp sponge in the middle of your tray.
9. Tilt your tray to the same height you measured before.
10. Observe the movement of the water on the tray and compare it to water that encounters the sponge.

How did the sponge change the movement of the water downhill?

11. Think of some other surfaces you could place on the tray that might add friction, changing the flow of the water downhill. **Try them out.**

Describe your observations:

*In addition to adding friction, the sponge is also absorbent and actually pulls some of the water up off of the tray.*
Connections to the Environment

Name a hard, smooth surface outside of your home or school that might act like the tray in our experiment:

Think of a time when it was raining and you saw water on that surface. Describe how the water moved on that surface:

Name a surface outside your home or school that might create friction and cause water to move more slowly:

Name a surface outdoors that is absorbent, like the sponge, and able to hold some of the water:

Repeat the last part of the experiment using natural materials you collect from outdoors.

Describe the materials you collected:

Describe how those materials changed the flow of water downhill:

Water is pushed and pulled on Earth constantly as it moves through the water cycle. Two important steps in the water cycle are evaporation and transpiration, known together as evapotranspiration. The sun’s energy, with the aid of plants, draws water molecules up into the atmosphere.

Is evapotranspiration a push force or a pull force?
Now that you understand a little more about how water moves, you can apply that knowledge to the real-life movement of stormwater. **Stormwater** is the water that comes from precipitation events like rain storms or from melting snow and ice. Just like any other water, stormwater moves as a result of the forces that act on it. The force of gravity plays the biggest role in moving stormwater. When stormwater lands on the Earth’s surface, it has to go somewhere. In the *Rain to Drain—Slow the Flow* experiment, you are going to explore where stormwater goes as it moves on Earth. You will also explore how the actions of people can change the way stormwater moves.

There are many parts to the complete water cycle on Earth.

Look at the water cycle above and consider the forces acting on the water as it moves. Do they appear to be mostly push forces or pull forces?
Pre-Experiment: Preparing Your Community

Time Needed: 20 minutes
Materials Needed:
- A foil cupcake/muffin pan (half-dozen size)
- 6 disposable plastic cups (approx. 9 oz each)
- 3 standard cellulose kitchen sponges
- A roll of clear tape
- A 20-oz plastic soda bottle
- Developed Surface cards (appendix pp. 7-9)
- Green Surface cards (appendix p. 10)
- A tray with a lip around the edge (baking sheet or similar)
- A blue permanent-ink marker
- Water-resistant tape
- Scissors
- Ballpoint pen
- Hammer and a nail

1. Your muffin pan will be the base of a small community model, with five properties or parcels of land and one water body. To prepare it for the activity, poke five holes in the bottom of each muffin cup using a ballpoint pen or nail of similar width. (Four holes surrounding a center hole works best.)

2. Color the inside surfaces of one of the corner muffin cups using the blue permanent-ink marker. This will represent a body of water in your community. It could be a lake, a stream, a river, or a storm drain.

What types of bodies of water do you have in the community where you live?

3. Cut your sponges into five circles that will fit into the bottom of each of the other five muffin cups. These other five muffin cups will represent five parcels of land or properties in your community. The sponges will act as the natural surfaces (soils with plant cover) at each of these five properties.

Leader Notes:
If your time with youth is limited, most of this pre-experiment can be completed in advance. If youth are not part of the pre-experiment set-up, make sure to review what each of the pieces represents and have the youth answer the questions in this section as part of a group discussion.
4. Prepare the Developed Surface cards and Green Surface cards as instructed on the copy pages at the back of this guide.

5. Create a rain maker by cutting the bottom off of a 20-oz plastic soda bottle. Wrap the sharp edge with water-resistant tape for safety. Remove the cap and carefully poke 6 - 10 holes in it using a hammer and a nail. Replace the cap on the bottle.

6. On one of the six plastic cups, color the rim and around the outside (down about an inch from the top) using the blue permanent-ink marker.

Setting up Your Community

1. On the tray, place the muffin pan on top of six cups (all but the rain maker) so that the muffin cups each fit into the top of one of the six plastic cups. Match the blue-colored cup under the blue coloring in the muffin pan.

2. Place a sponge circle in each of five community parcels (the uncolored muffin cups). Make sure your sponges are moist and not dried out. If you aren’t sure, soak them in water and then wring them out to keep them damp but not dripping.

3. Gently lift the cup that is farthest from the blue cup (the opposite corner), and place the roll of tape underneath it. This will create a hill in your community, with the waterbody at the bottom of the hill.
Your Community, In a Natural State

This is a map of your community model in its natural state. No homes or businesses have been built here yet, and the five parcels of land are in the most natural condition they can be, which is represented by the sponges.

What was the natural environment like in the community where you live before people moved in and altered it? Was it forests, prairies, grasslands, something else? (You could discuss this question with someone who might know the answer.)
Make it Rain in Your Natural Community

1. Measure 8 oz of water in your measuring cup. We will use 8 oz of water every time we make it rain in our community, so this will be a **controlled variable** in our experiment. Controlled variables stay the same throughout an experiment.

2. Hold your rain maker bottle over your community model (8 - 10 inches above) and pour in the water from your measuring cup. *(You can move your rain maker over the model if you want, but the idea is for the rain to fall on your entire community model, but not outside the borders.)*

3. Observe where the rain water ended up after the storm in your community by looking in the cups under the model.

Measuring the Results

1. Carefully slide the blue cup out from under the muffin pan and use the measuring cup to measure how many ounces of water were captured there.

   This represents the amount of the stormwater that rained directly in the body of water (lake, river, etc.) and also the stormwater that drained from your community into that body of water. When stormwater moves across the land and directly into a nearby body of water, we refer to it as **runoff**.

   Record this runoff volume in the table.

2. The water in the other five cups, along with the water soaked up by the sponges, represents stormwater that **infiltrated** into the soil to become groundwater.

   To measure the groundwater, first squeeze each sponge into the empty measuring cup. Now lift the muffin pan off of the other five cups, and empty each of the five cups into the measuring cup as well.

   Record the infiltration volume in the table.
Using the table, calculate what percentage of the stormwater became runoff, the percentage that infiltrated, and the percentage of stormwater we lost during our experiment.

<table>
<thead>
<tr>
<th>Community—Natural</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff into the local body of water (blue cup)</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Infiltration into groundwater (all other cups and sponges)</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

What percentage of stormwater did you lose during your experiment? __________%

(Lost stormwater should be 25% or less of the total stormwater; if it’s greater than that, you may want to repeat this part of the experiment while being more careful to direct your rain onto the community model. Small amounts of lost water could represent water that evaporated or that was used by plants and animals in the community.)

NOTES:
Your Community, In a Developed State

Set up your community as follows:

1. Dry off your tray and reset your community model on top of the six cups as before. Match the blue-colored cup under the blue-colored well and replace the sponge under the opposite corner cup to create your hill.

2. Place a sponge circle in each of five properties (the uncolored wells). Make sure your sponges are moist but squeezed out.

3. Cover each of the properties, but not the waterbody, with a laminated *Developed Surface* card. The cards should overlap and extend beyond the edge of the community model.

![Community Model Diagram]

*This is a map of your community model in its developed state. Homes or businesses have been built on each of the five parcels of land. The cards represent familiar surfaces you would find outdoors in your own community including streets, sidewalks, parking lots, rooftops, and concrete.*

What kinds of developed surfaces are found in the community where you live? What do you see outside that wasn’t there before people developed your community?

Make it Rain in Your Developed Community

1. Measure 8 oz of water in your measuring cup and then pour it in your rain maker bottle while holding it over your community (8 - 10 inches above). Move the rain bottle around to rain on the whole community.

2. Observe where the rain water ended up after the storm in your developed community and then measure the runoff water and infiltration water as you did before.
Using the table, calculate what percentage of the stormwater became runoff, the percentage that infiltrated, and the percentage of stormwater we lost during our experiment.

<table>
<thead>
<tr>
<th>Community—Developed</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff into the local body of water (blue cup)</td>
<td>8</td>
<td></td>
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<tr>
<td>Infiltration into groundwater (all other cups and sponges)</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
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<td></td>
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</tbody>
</table>

What percentage of stormwater did you lose during your experiment? _________%

(Lost stormwater should be 25% or less of the total stormwater; if it’s greater than that, you may want to repeat this part of the experiment while being more careful to direct your rain onto the community model. Small amounts of lost water could represent water that evaporated or that was used by plants and animals in the community.)

NOTES:
Compare Your Natural Community to Your Developed Community

In which community, natural or developed, did more water infiltrate into the groundwater?

In which community, natural or developed, did more water run off into the local body of water?

Describe how adding parking lots, rooftops, and other similar surfaces could increase the chances of a flood during a storm:

If a community depends on groundwater to provide the drinking water for the people who live and work there, how might adding parking lots, buildings, and other similar surfaces impact the drinking water supply over time?

What are some ways to reduce the chances of flooding in your developed community?
Using your model community, you discovered the different ways that stormwater can move when it falls on the land. In natural environments, the majority of stormwater soaks into the ground through infiltration. Only a small portion of stormwater flows across the surface as runoff, into the nearest body of water. High levels of infiltration and minimal runoff are both healthy qualities for the environment. They reduce incidents of flooding, help maintain the groundwater supply, and decrease water pollution.

In the communities where we live, however, much of the Earth’s natural surfaces are covered by impervious surfaces. Impervious surfaces are surfaces that water cannot pass through readily. Examples of impervious surfaces include asphalt, concrete, and rooftops—surfaces we saw in the developed community model in this experiment. As the Earth’s natural surfaces are covered with impervious surfaces during development, the amount of runoff and infiltration changes.

As the amount of impervious surface increases, does runoff increase or decrease?
Exploring Green Infrastructure

Take a look at the photos provided on the *Green Infrastructure* copy pages in this book. These are photos of various types of “green” development practices. These development practices help reduce the amount of stormwater that runs off into local water bodies. They also help increase the amount of stormwater that is able to infiltrate into the ground and replenish groundwater supplies. All of these practices are collectively referred to as **green infrastructure**.

Below is a list of impervious surfaces found in a developed community. Choose a green infrastructure practice from those that are pictured that could improve or replace each one:

- **Pavement Driveway:** ________________________________
- **Metal Rooftop:** ________________________________
- **Concrete Sidewalks:** ________________________________
- **Asphalt Parking Lot:** ________________________________
- **Concrete Town Square:** ________________________________

There are many more examples of green infrastructure practices; there may even be some in your own community that you could visit and explore.
Your Community, Improved With a Green Practice

Thinking about the examples of green infrastructure you just saw in the photos, let’s redevelop your community and try to improve the stormwater situation.

Set up your community as follows:

1. Assemble your model community like before, with the tray placed over the six cups and a sponge in each of the five “properties.”

2. This time, you have several green infrastructure practices to use in your community that could replace or improve the surfaces represented on the development cards from the last steps of this experiment. Choose one of the green practices listed below to place over one of the five properties in your model.
   a. Pervious pavers and stone pathways can replace concrete sidewalks or help to move water into proper drainage areas. (Add a handful of stones over one of the properties, covering the sponge.)
   b. Green rooftops can replace traditional rooftops. (Place damp felt on top of the rooftop card, and place that over one of the properties.)
   c. Permeable pavement can be used to replace some streets and alleys. (Place the plastic canvas over one of the properties.)
   d. Bioswales and curb cuts can be added to parking lots to allow water to drain into natural areas. (Place the parking card with the bioswale cutout over one of the properties)
   e. Rain gardens can be added near homes and businesses to capture water running off of their impervious surfaces. (Place the concrete card with the rain garden cutout over one of the properties.)
   f. Preserved open space and natural areas can be planned into a community instead of developing all of the land. (Leave one of the properties uncovered.)

Which of these practices is familiar to you or similar to something you have seen in the community where you live?

3. Cover the remainder of your properties with the Developed Surface cards from the previous steps of the experiment. Remember to leave the body of water uncovered.
This is a map of your community model in an improved state. There are still homes and businesses built on each of the five parcels of land, but one property has converted a traditional, impervious surface to a green infrastructure surface.

Make it Rain in Your Improved Community

1. Measure 8 oz of water in your measuring cup and then pour it in your rain maker cup while holding it over your community (8 - 10 inches above).

2. Observe where the rain water ended up after the storm in your improved community and then measure the runoff water and infiltration water as you did before.

Which green infrastructure practice did you use?

What types of forces are changing the way stormwater moves across the green infrastructure practice that you chose?
Using the table, calculate what percentage of the stormwater became runoff, the percentage that infiltrated, and the percentage of stormwater we lost during our experiment.

<table>
<thead>
<tr>
<th>Community—Improved</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
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<tbody>
<tr>
<td>Runoff into the local body of water (blue cup)</td>
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<td>Infiltration into groundwater (all other cups and sponges)</td>
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What percentage of stormwater did you lose during your experiment? __________%

*(Lost stormwater should be 25% or less of the total stormwater; if it’s greater than that, you may want to repeat this part of the experiment while being more careful to direct your rain onto the community model. Small amounts of lost water could represent water that evaporated or that was used by plants and animals in the community.)*

**NOTES:**
Your Community, Designed Green by You

1. Set up your community one more time.

2. This time make it as green as possible, but also a place people can live and work. It is up to you to decide what surfaces you want to use in this stage of the experiment. You can use a mixture of any of the green infrastructure surfaces listed previously or the developed surfaces.

   Remember, you are developing a community for people to live and work in, so it can’t be all preserved open space and natural areas; limit that to one property if you choose to use it.

3. Record your community’s surfaces in this diagram:

   ![Diagram of community surfaces]

   This is a map of your experimental green community model. The community has been developed to live in, but designed by you to be as green as possible.

   Predict what percent of water will run off in the local water body in your green community: _______%

   Predict what percent of water will infiltrate into the groundwater in your green community: _______%

Make it Rain in Your Green Community

1. Measure 8 oz of water in your measuring cup and then pour it in your rain maker cup while holding it over your community (8 - 10 inches above).

2. Observe where the rain water ended up after the storm in your improved community and then measure the runoff water and infiltration water as you did before.
Using the table, calculate what percentage of the stormwater became runoff, the percentage that infiltrated, and the percentage of stormwater we lost during our experiment.

<table>
<thead>
<tr>
<th>Community—Green</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
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<td>Infiltration into groundwater (all other cups and sponges)</td>
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<td>8</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

What percentage of stormwater did you lose during your experiment? __________%  

(Lost stormwater should be 25% or less of the total stormwater; if it’s greater than that, you may want to repeat this part of the experiment while being more careful to direct your rain onto the community model. Small amounts of lost water could represent water that evaporated or that was used by plants and animals in the community.)

NOTES:

Leader Notes:  
A consolidated data sheet can be found on appendix pp 11 - 12. You may find it helpful for youth to record all of their data in one place, especially if you are not giving the participants each their own copy of this book.
Compare Your Green Community Results to Your Predictions

Was your prediction about the amount of runoff water too high, too low, or just about right?

Was your prediction about the amount of groundwater infiltration too high, too low, or just about right?

Were you able to improve the stormwater situation in your community?

Describe how you might change your design in the future to improve the outcome:

What factors might prevent a community from using green infrastructure practices?

What other materials could you use to simulate green infrastructure surfaces in your model? Can you collect some ideas from the outdoors?
Want to repeat your experiment with different green community designs? Here are some extra notes pages for you to track your results:

**Community—Green**  
(2)  

<table>
<thead>
<tr>
<th>Runoff into the local body of water (blue cup)</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Infiltration into groundwater (all other cups and sponges)</td>
<td></td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

What percentage of stormwater did you lose during your experiment? __________%  

**NOTES:**
Want to repeat your experiment with different green community designs? Here are some extra notes pages for you to track your results:

<table>
<thead>
<tr>
<th>Community—Green (3)</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff into the local body of water (blue cup)</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Infiltration into groundwater (all other cups and sponges)</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

What percentage of stormwater did you lose during your experiment? __________%

NOTES:

Leader Notes:
Ideas for additional experiments include changing the elevation/slope of the model, observing the effect of impervious surfaces near and far away from the body of water, or changing the rainfall amount.
Want to learn more about stormwater and green infrastructure? Consider the following activities to extend your *Rain to Drain—Slow the Flow* experience.

**How Stormwater Causes Pollution**

Stormwater is the major force that carries non-point source pollution into our waterways. Do a little research to find out more about non-point source pollution and then try this adaptation to the experiment.

1. Set up your community model using the *Developed Surface* cards.

2. Sprinkle the surfaces with dry drink mix powder to represent non-point source pollution on the ground.

3. Make it rain and watch what happens to the non-point source pollution.

4. Record your observation about how impervious surfaces affect the movement of pollution into the water body.

5. Try the experiment again using green practices. Do the sponges, representing natural soils and surfaces, help to filter the pollution out of the stormwater?

6. With an adult helper, head outside with a broom and dustpan. Try sweeping up a small section of driveway, sidewalk, or patio nearby (you may want to wear a respirator mask for this activity). What kinds of debris and potential pollution did you find there?
Using GIS to Map Your Property and Create a Real Green Plan
You can calculate the amount of stormwater that runs off of your home or school property and design a green plan using GIS technology.

1. Visit this website: http://www.stormwaterguide.org/
2. Enter your home or school address and an areal photo of your property will be provided.
3. Carefully follow the instructions on how to draw your property boundaries and outline the green and natural surfaces on your property.
4. Next, mark any places where you’ve noticed stormwater moving across the ground, causing temporary ponds or streams when it rains.
5. Finally, add some green infrastructure practices to your property and create a plan to improve stormwater movement at your home or school.

![Screen shot of a green plan creation process using GIS technology.](image-url)
Explore Real-Life Green Infrastructure Solutions

It’s likely that someone in your community is already implementing some of the stormwater solutions that you learned about in the *Rain to Drain—Slow the Flow* experiment. Take a field trip to visit them, or explore online.

1. Contact your local government, extension office, or soil and water conservation district to find out if they are aware of any green infrastructure practices being implemented in your community.

2. Take a field trip to visit sites that you identify, and ask to speak to the property owner or someone who can tell you more about why the practices were installed at that site.

3. Find out if the practices are working the way they were meant to.

   If there are no green infrastructure practices that you can find in your community, if you are unable to take a field trip, or to explore more amazing green infrastructure being used in communities across the United States.


5. Watch the entire movie at this website, or explore individual stories from communities near you.

6. Consider using the tools and resources on this website to prepare a presentation about stormwater and green infrastructure for your community.
Take Action—Be a Stormwater Hero
You can make a difference in your community! Consider developing a plan and installing a green infrastructure practice at home or at your school.

1. Talk to your family or school administrators about how stormwater moves on your home or school property, and the issues it might be causing.

2. Work together to develop a plan to reduce stormwater runoff or increase infiltration at a site on your property. You may want to contact your county extension office, soil and water conservation district, or local watershed association for assistance.

3. Organize a volunteer work day to get the job done. Your friends and family could help you install a rain garden, rain barrels, pervious pavers, natural space, a native meadow, or another green practice.

4. If you can’t arrange to install a practice on your own property, you might be able to find a similar community event that you can volunteer at. Check online for tree plantings, Earth Day volunteer opportunities, or even clean-up events in your area.
Career Exploration

There are many careers that you can consider if you are interested in a future working with the movement of stormwater and green infrastructure.

- **Botanist**: Scientist who studies plant life and organisms. A botanist’s work might include looking at how plant life can help to benefit the environment.

- **Construction Laborers and Managers**: Laborers perform work in nearly every facet of construction including developing highways, erecting buildings, and heavy equipment operating. All of these skills are needed to develop green infrastructure.

- **Ecologist**: A scientist that finds ways to use natural resources efficiently and manage them responsibly, and studies the environment in general. There are lots of special types of ecologists.
  - **Wetland Ecologist**: An ecologist that assesses the health of wetlands and determines how human activities, as well as nature, influence a wetland’s physical conditions.
  - **Restoration Ecologist**: An ecologist that assists in ecosystem restoration and management projects. Projects may include environmental mitigation, lake and pond shoreline restoration, wetland restoration, stream stabilization, and general native landscaping.

- **Engineer**: Engineers work in a variety of fields to analyze, develop, and evaluate large-scale, complex systems. They improve and maintain current systems and create brand new projects. Engineers will design and draft blueprints, visit systems in the field, and manage projects. There are lots of different types of engineers.
  - **Civil Engineer**: Engineers that specialize in road, bridge, buildings, and water supply system design and construction. They supervise and direct construction teams and work with other engineers.
  - **Environmental Engineer**: Engineers that use science and engineering principles to protect and improve the environment. The quality of air, water, and soil is their primary focus.

- **Environmental Educator**: Educators that teach youth and adults how to learn about and investigate the environment and make informed decisions on how to care for it.

- **Horticulturist**: Horticulturist positions involve using a combination of plant knowledge and physical labor to establish and maintain outdoor properties. Horticulturists work on farms and as managers of nurseries and greenhouses, master gardeners, and groundskeepers.
- **Hydrologist**: Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society. They may be concerned with finding water supplies for cities or irrigated farms, or controlling river flooding or soil erosion.

- **Land Developer**: Developers acquire property and oversee construction of residential, commercial and industrial structures. They work with local governments to ensure land is developed in compliance with zoning ordinances and regulations.

- **Landscape Architect**: Landscape architects plan and design land areas for parks, recreational facilities, private homes, campuses, and other open spaces. They create plans and designs, prepare models and cost estimates, and do research, including developing plans that incorporate green infrastructure.

- **Municipal or Local Government Employees**: Local government service is related to building and improving communities. These jobs include public works staff, who build and rebuild the physical infrastructure, as well as city and county planners, who help envision and shape future city growth, including using green infrastructure.

- **Nursery and Greenhouse Production**: Nurseries and greenhouses are business that grow and produce plants. Employees propagate new plants, prune and control weeds, control pests, and may specialize in certain types of plants like annuals or trees.

- **Outreach Coordinator**: Outreach includes developing, organizing, and implementing various community and marketing programs that will create resident awareness, interest, and participation in environmental projects such as using green practices.

- **Soil Scientist**: Scientists that explore and seek to understand the Earth’s land and water resources. They identify, interpret, and manage soils for agriculture, forestry, rangeland, ecosystems, urban uses, and more in an environmentally responsible way.

- **Urban Forester**: Foresters that care for urban forest ecosystems within cities and developed areas for the benefit of residents of the area and the natural environment. Urban foresters are often called on to help residents with tree care and tree problems such as proper planting, pruning and maintenance techniques, as well as helping residents select the proper tree species.

- **Water and Wastewater Treatment Operators**: Water and wastewater treatment plant and system operators manage a system of machines, often through the use of control boards, to transfer or treat drinking water or wastewater for communities and industries.
Glossary

- **Controlled variable**: in an experiment, something that is constant and unchanged
- **Evapotranspiration**: the process by which water is transferred from the land into the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants
- **Force**: something that causes a change in the motion of an object
- **Friction**: the force exerted by a surface as an object moves across it or makes an effort to move across it
- **GIS technology**: A geographic information system, or GIS, is a computerized data management system used to capture, store, manage, retrieve, analyze, and display spatial information. Data captured and used in a GIS commonly are represented as maps.
- **Gravity**: the force with which the Earth, moon, or other massively large object attracts another object toward itself. All objects on Earth experience a force of gravity that is directed "downward" toward the center of the Earth.
- **Gray infrastructure**: refers to traditional practices for stormwater management and wastewater treatment, such as pipes and sewers
- **Green infrastructure**: an approach to water management in developed areas that protects, restores, or mimics the natural water cycle (see a list of examples on the next page)
- **Groundwater**: the water found underground in the cracks and spaces in soil, sand, and rock; the source of drinking water for many communities
- **Groundwater recharge**: the inflow of water to the groundwater system from the surface
- **Impervious surface**: constructed surfaces such as buildings, roads, parking lots, brick, asphalt, concrete, and human-made compacted soil that do not allow water to be absorbed
- **Infiltrate**: when a liquid permeates something by filtration
- **Net force**: the overall force acting on an object, or the sum of all forces acting on the object
- **Non-point source pollution**: pollution from dispersed sources like agricultural activities, urban runoff, and atmospheric deposition
- **Normal force**: the support force exerted upon an object that is in contact with another stable object; for example, if a book is resting upon a surface, then the surface is exerting an upward force upon the book in order to support the weight of the book
- **Outfall**: the discharge point of a waste stream, like a drain or sewer, into a body of water like a river, stream, or lake
- **Pervious**: a substance allowing water to pass through; permeable
- **Runoff**: the draining away of water, and the substances carried in it, from the surface of an area of land, a building, or structure, etc.
- **Soil compaction**: when soil has been compressed by foot traffic or by vehicles or equipment driven over it, decreasing the pore spaces and reducing the perviousness of the soil
- **Stormwater**: water that originates during precipitation events and snow/ice melt
- **Stream base flow**: the sustained flow (amount of water) in a stream that comes from groundwater discharge or seepage
- **Watershed**: an area of land that all drains to the same body of water
Glossary—Green Infrastructure Practices

- **Bioswales**: vegetated, stone, or mulched channels that provide treatment and retention as they move stormwater from one place to another
- **Created or constructed wetland**: an artificial wetland created as a new or restored habitat for native and migratory wildlife, for anthropogenic discharge such as wastewater, stormwater runoff, or sewage treatment, or other ecological disturbances
- **Curb cuts**: a break in a curb allowing water to be directed away from roadways and parking lots
- **Green roofs**: roofs that are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water
- **Gutter or downspout disconnection**: refers to the rerouting of rooftop drainage pipes to drain rainwater to rain barrels, cisterns, or permeable areas instead of the storm sewer
- **Permeable pavement**: paved surfaces that infiltrate, treat, and/or store rainwater where it falls; may be constructed from pervious concrete, porous asphalt, permeable interlocking pavers, and several other materials
- **Planter boxes**: urban rain gardens with vertical walls and open or closed bottoms that collect and absorb runoff from sidewalks, parking lots, and streets
- **Rain barrel**: a rain water harvesting system, typically connected to a gutter or downspout, that slows and reduces runoff as well as provides a source of water for gardening, car washing, etc.
- **Rain garden**: shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets
- **Riparian buffer**: a vegetated area near a stream, usually forested, that helps shade and partially protect a stream from the impact of adjacent land uses
- **Street trees**: trees planted in cities and other urban settings that reduce and slow stormwater by intercepting precipitation in their leaves and branches
- **Treatment wetland**: engineered systems, designed and constructed to utilize the natural functions of wetland vegetation, soils, and their microbial populations to treat contaminants in surface water, groundwater, or waste streams
The following is a list of Middle School Level performance expectations from the Next Generation Science Standards (NGSS)*, which are addressed by Rain to Drain – Slow the Flow. For other grade levels, you can explore the NGSS Disciplinary Core Ideas to find appropriate performance expectations. The Cross-Cutting Concepts and Science & Engineering Practices addressed in this curriculum are also listed.

These lists are not meant to be all-inclusive, but rather a guide to incorporating Rain to Drain – Slow the Flow into a course framework.

**PHYSICAL SCIENCE**

**MS.FORCES AND INTERACTIONS**

**MS-PS2-2.** Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object.

**PS2.A: Forces and Motion**

**LIFE SCIENCE**

**MS.INTERDEPENDENT RELATIONSHIPS IN ECOSYSTEMS**

**MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

**LS2.C: Ecosystem Dynamics, Functioning, and Resilience**

**LS4.D: Biodiversity and Humans**

**ETS1.B: Developing Possible Solutions**

**EARTH AND SPACE SCIENCE**

**MS.EARTH'S SYSTEMS**

**MS-ESS2-4.** Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

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

**ESS3.A: Natural Resources**

**MS.HUMAN IMPACTS**

**MS-ESS3-2.** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

**MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

**ESS3.C: Human Impacts on Earth Systems**

*Disciplinary Core Ideas listed in blue*
Crosscutting Concepts

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-4)

Stability and Change
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)
- Small changes in one part of a system might cause large changes in another part. (MS-LS2-5)

Patterns
- Graphs, charts, and images can be used to identify patterns in data. (MS-ESS3-2)

Influence of Science, Engineering, and Technology on Society and the Natural World
- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-LS2-5), (MS-ESS3-2)
- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-4)

Science Addresses Questions About the Natural and Material World
- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS2-5), (MS-ESS3-4)

Science and Engineering Practices

Planning and Carrying Out Investigations
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS2-2)

Engaging in Argument from Evidence
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-LS2-5)
- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-ESS3-4)

Developing and Using Models
- Develop a model to describe unobservable mechanisms. (MS-ESS2-4)

Analyzing and Interpreting Data
- Analyze and interpret data to determine similarities and differences in findings. (MS-ESS3-2)

Scientific Knowledge is Based on Empirical Evidence
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2)

Pervious Pavers and Stone Pathways

Stones or bricks that are arranged to allow water to flow through into the ground below, or to channel and move water while minimizing erosion.

How to simulate this practice using your model
Green Rooftops

A roof that is planted with vegetation.
Permeable Pavement

Concrete or asphalt pavement that has been engineered to be porous. It allows water to flow through the hard surface and into the ground.

How to simulate this practice using your model
Bioswales and Curb Cuts

Curb cuts are spaces built into curbing to direct water into a bioswale or a vegetated area that can hold and absorb water from a parking lot or roadway.
Rain Gardens

A bowl-shaped garden that is designed to capture, hold, and infiltrate stormwater.

How to simulate this practice using your model
Preserved Open Space and Natural Areas

Areas that have been left undeveloped where trees and plants can grow. Parks are a good example.
Developed Surface Card Copy Pages

Instructions
1. Print these pages singed-sided on card stock (65 lb or higher so that they stay flat and don’t curl).
2. Cut the individual cards out so that you have 5 total 4x4-inch cards.
3. Laminate the cards so that each card has a lip of lamination around the edge (you want the cards to hold up after getting wet repeatedly).
Developed Surface Card Copy Pages

Instructions
1. Print these pages single-sided on card stock (65 lb or higher so that they stay flat and don’t curl).
2. Cut the individual cards out so that you have 5 total 4x4-inch cards.
3. Laminate the cards so that each card has a lip of lamination around the edge (you want the cards to hold up after getting wet repeatedly).
Instructions

1. Print these pages singed-sided on card stock (65 lb or higher so that they stay flat and don’t curl).
2. Cut the individual cards out so that you have 5 total 4x4-inch cards.
3. Laminate the cards so that each card has a lip of lamination around the edge (you want the cards to hold up after getting wet repeatedly).
Instructions
1. Print these pages singed-sided on card stock (65 lb or higher so that they stay flat and don’t curl).
2. Cut the individual cards out so that you have 2 total 4x4-inch cards.
3. Use a pen knife or similar to cut out the marked areas from the card centers.
4. Laminate the cards so that each card has a lip of lamination around the edge.
5. Use a pen knife to cut out the laminated area in the holes created during step 3. Leave a lip of lamination by not cutting right up to the edge of the card.
<table>
<thead>
<tr>
<th>Community—Natural</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff into the local body of water</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltrated into groundwater</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

What percentage of stormwater did we lose during our experiment? __________% 

<table>
<thead>
<tr>
<th>Community—Developed</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

What percentage of stormwater did we lose during our experiment? __________% 

Which green practice did you use? __________________________________________

<table>
<thead>
<tr>
<th>Community—Improved</th>
<th>Total Volume Collected (ounces)</th>
<th>Total Volume of the Storm (ounces)</th>
<th>Percentage of Stormwater Collected</th>
</tr>
</thead>
<tbody>
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<td>Runoff into the local body of water</td>
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<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

What percentage of stormwater did we lose during our experiment? __________%
Record your green community’s surfaces in this diagram:

Predict what percent of water will runoff into the local water body. _________ %

Predict what percent of water will infiltrate into the groundwater. _________ %

<table>
<thead>
<tr>
<th>Community—Green</th>
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<td>8</td>
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</table>

What percentage of stormwater was lost in the experiment this time? _________ %