Pollution Solution

Program Type: Classroom Program	**_Audience Type:_** Grades 3–8

Description: Students will create model neighborhoods that incorporate green spaces, such as bioswales and parks, to prevent pollution from flowing into a river.

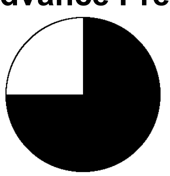
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- Students will use the engineering design process to design a neighborhood with green spaces.
- Students will weigh various factors in planning their neighborhood, including population density, and amount and types of green space.

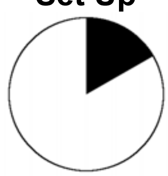
TIME REQUIRED

Advance Prep



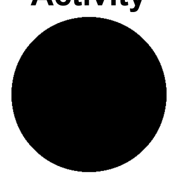
45 minutes

Set Up



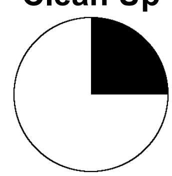
10 minutes

Activity



60 minutes

Clean Up



15 minutes

SITE REQUIREMENTS

- Tables or floor space for each group
- A central testing table, preferably on a surface that can get wet. If a waterproof surface isn't available, consider placing plastic sheeting around the testing table
- Access to water

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large group discussion	10 min
Design, Test, Improve	Group activity	40 min
Wrap-Up	Large group discussion	10 min

SUPPLIES

Permanent Supplies	Amount	Notes
Disposable aluminum cookie sheet	1/group	
Small watering can or similar	1	1qt. size, with sprinkle head
Catchment container	1	Casserole-sized, watertight, rectangular container, wider than the width of the cookie sheet
Reusable metal cookie sheet	1	
Items to prop up testing bed (books, blocks, or boxes)		Must be taller than height of catchment container
Strainer	1	With small holes (sized to strain sequins from water)
Magnets	2	
Large sponges	2/group	Without scrub surface
Plastic mesh pot scourers	3/group	
Craft foam	2-4 sheets/group	Enough to make ~10 houses per group
Masking tape	1 roll/class	
Sticky tack	1 package	*(Optional)*
Brads	5-6 per group	
Sequins	1 small handful/group	A pack with small pouches of different colors is suggested
Graph paper	1–2 sheets/group	With large grid squares
Colored markers	5/group	
Razor knife	1	For use in advance prep
Hot glue gun	1	For use in advance prep
Permanent marker	1	For use in advance prep
Meet an Engineer Video – Emily Harris	1	*(Optional)* Found on USB flash drive provided with manual and website listed in *Advanced Prep*
Computer with Screen	1	*(Optional)* to show *Meet an Engineer* Video
Large measuring cup or pitcher	1	*(Optional)* See Extension
"Pollution Solution Extension" worksheet	1/group	*(Optional)* See Extension
Pencils	1/group	*(Optional)* See Extension

ADVANCE PREPARATION

NOTE: Refer to images in SETUP for context

- Use a razor knife to cut a thin rectangular strip large enough for sequins out of one end of the disposable aluminum cookie sheets leaving the rim intact. This will be the drainage hole.
- Cut the craft foam into rectangles of various sizes to represent houses and apartment buildings. Label with the number of occupants they can hold. Make the area of the rectangle equal to the number of people that can live in that space (e.g., 2 occupants = 1”x2”, 9 occupants = 3”x3”, 24 occupants = 6”x4”). Cut enough rectangles that each group has approximately 10 “buildings” to work with. (As a math extension, you could have students do this).
- Apply a rim of sticky tack or hot glue around the unmarked side of the “buildings” to help them stay put on the cookie sheet.
- Cut the large sponges into rectangles of different sizes: approximately 1.5”x1.5”, 2.5”x2.5” 0.5”x2.5”, and 1”x3”. Cut enough that each group has approximately 5-10 sponge pieces to work with.
- Cut the tie holding the mesh pot scourers together so that they can be unrolled.

SET UP

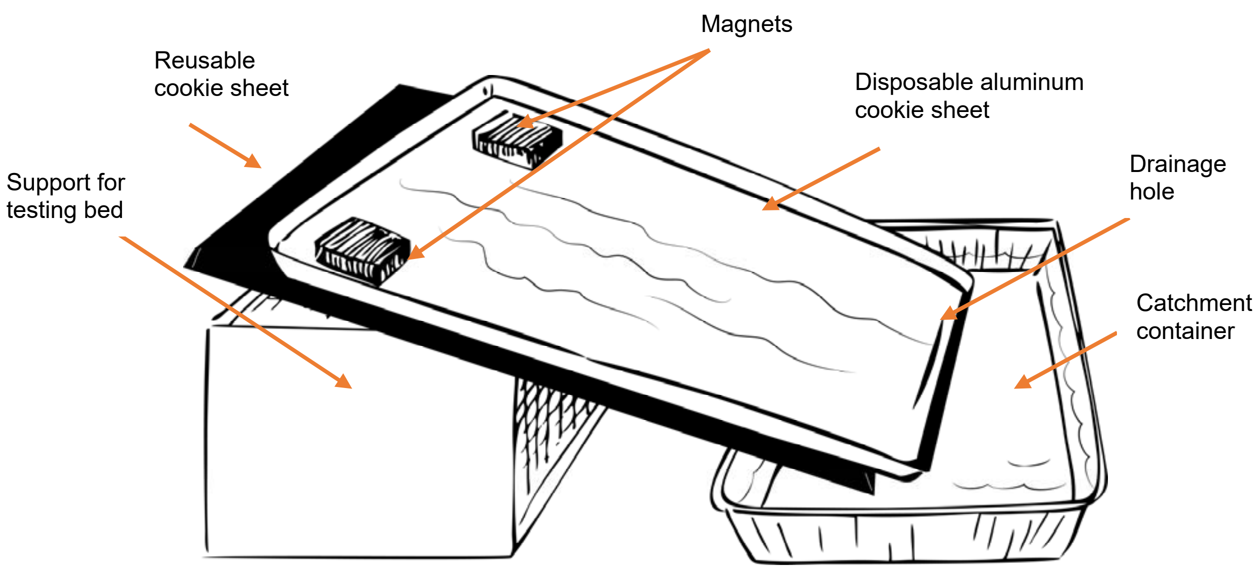


Figure 1: Testing bed apparatus. The upside-down reusable cookie sheet serves as a base for the student models. It is elevated above the catchment container and propped up at an angle using blocks. Two magnets hold the disposable cookie sheet in place on top of it.

- *Prepare the testing bed apparatus.* Turn the reusable cookie sheet upside down. Prop one end up to elevate it above the catchment container. Use tape, if necessary, to secure all the elements. Place the catchment container beneath the edge of the cookie sheet. Place the magnets nearby to hold the student models in place.
- Fill the watering can and have additional water on hand if there is no sink nearby.
- Place the testing bed apparatus in a place where all students will be able to see and use the magnets to secure an empty aluminum cookie sheet, as shown in Figure 1.

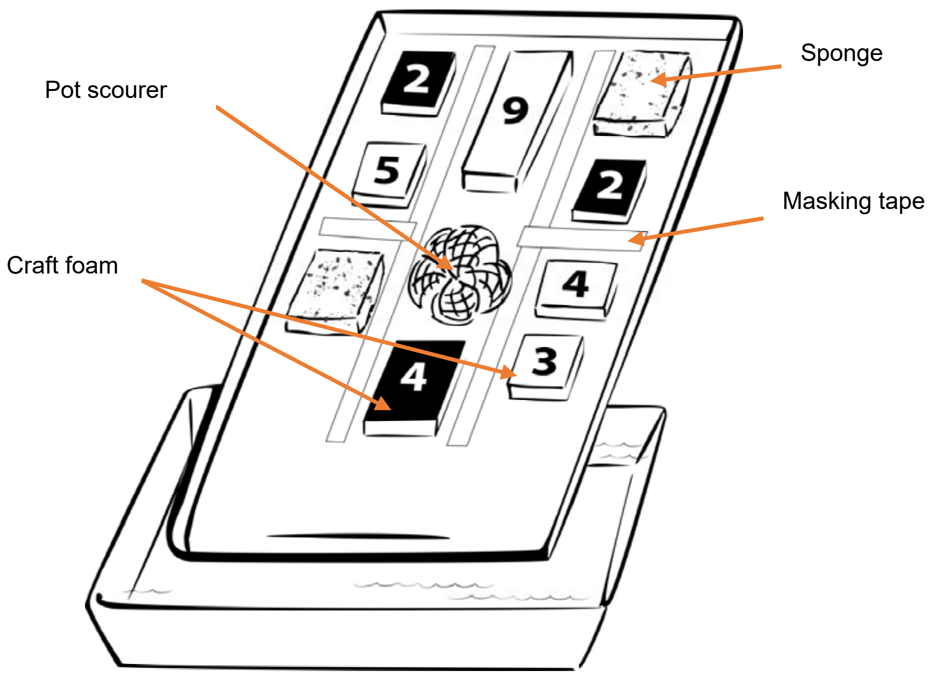


Figure 2: An example of a finished model. The masking tape represents the streets. The building capacity is shown by the numbers on the craft foam pieces. The sponges represent green spaces. The pot scourers, which can be used rolled or unrolled, represent bioswales.

- Prepare the projector and computer to show the *Meet an Engineer Video – Emily Harris* found on the USB flash drive provided with this manual (if applicable), or at https://vimeo.com/254363553/555e253ccd
- If you can't show video to students, watch on your own for reference.

INTRODUCTION

10 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

Do you remember a time when it rained and rained and rained in your neighborhood? Where do you think all that water went?
Into the river, ground, sewer…

When it rains in a forest, or other places with lots of plants, the ground acts like a sponge and most of the water gets absorbed into the soil. Some of that water gets used by plants, and the rest of it flows slowly down through dirt and rock until it reaches a stream. Water that travels this way becomes clean and healthy for the animals, plants, and bugs that live in streams and rivers. You might not think of dirt and plants as things that can make water cleaner, but that's what they do!

What about rain that falls in the city? What happens to the water when it falls on the road or on a roof or in a parking lot?
It flows on top of the street, it doesn't get absorbed, it picks up pollution, then it goes into the sewer.

Water that doesn't get filtered through the ground is called runoff. Cities can have a lot of runoff because pavement and buildings are impervious, which means they don't let water go through. In some cities, too much runoff can cause sewers to overflow into nearby rivers! Cities can also have a lot of pollution in the form of gasoline, motor oil, trash, and pesticides from people's lawns and gardens that can get washed into the river with all the runoff.

What do you think happens to all that pollution?
It gets carried to streams and rivers, it hurts the fish…

If using the optional *Meet an Engineer* video, show it here. Emily Harris is an engineer who works on bioswales and rain gardens. In this 2-minute video, Emily explains her work in Water Resource Engineering.

Draw the students' attention to the testing bed apparatus with an empty cookie sheet.

This cookie sheet is a big impervious surface, like a parking lot. The catchment container below is the stream.

Sprinkle sequins across the sheet.

These sequins represent pollution.

Pour the water evenly across the entire sheet.

What do you observe when we add rain to this area?
It all runs into the stream…

Engineers realized that we could take something that works really well in nature and use the idea to make spaces in cities where plants and soil can filter out pollution naturally. Parks help soak up water, but there are other planted areas that are just for catching and cleaning up runoff. These areas are called bioswales or rain gardens. Water resource engineers design bioswales by choosing the right plants and the right mix of soil and gravel and by placing these components where they can capture the most runoff. Today we are going to be designing a city neighborhood that can filter pollution out before it reaches a stream.

Your city needs to have all the things that people need to live, like houses *(hold up craft foam houses)* and roads *(hold up masking tape)*, but you will also have parks *(hold up sponges)* and bioswales *(hold up mesh pot scourers)* to work with. Your goal is to stop the pollution from entering the river, and to slow the water down so that more of it soaks into the ground instead of running into the river.

Right now, unfortunately, you are engineers for a city that doesn't know that preventing runoff is important! They want your team of engineers to design a neighborhood for at least 15 people, with roads connecting everything, but they only made room for two parks in the budget! Let's see how environmentally friendly you can make your neighborhood with these limitations!

GROUP ACTIVITY

Design, Test, Improve

40 minutes

Round 1:
Divide students into groups of 3–5 and pass out graph paper and markers. Give the students roughly 5 minutes to plan their neighborhood. Encourage students to draw and label their diagram. Ask questions about how they are choosing to place their two parks.

Pass out an aluminum tray, two feet of masking tape, and two larger pieces of sponge to each group. If you decide to allow the students to use sticky tack to help secure items to the tray, pass out a small piece to each group. Give each group five or six craft foam houses to start with but leave extras in a central location and let students know they are free to get more houses and return ones they don't need.

As students finish, invite them to use the testing bed apparatus:

- **Set up –** Have students place their completed "neighborhood" (on disposable aluminum cookie sheet) on top of testing apparatus. Use magnets to hold in place. (See Figure 1).
- **Add pollution –** Have one student sprinkle sequins along the top of the neighborhood to represent pollution.
- **Add water –** Have another student use the watering can to "rain" down on the neighborhood, aiming most of the water near the top so that runoff flows down the sheet.
- **Observe**
    - Did your bioswales (sponges) trap most of the pollution (sequins)? Or did most of the pollution flow into the river (bottom basin)?
    - Did your bioswales absorb most of the rain, or did most of it run into the river?
    - How could you improve your neighborhood so that less water and pollution make it into the river?
    - **Note: if you wish to answer these questions in a more quantitative way, see Extension.*
- **Reset –** Have students remove remaining sequins off their sheets and squish their sponges so that any absorbed water flows into bottom basin. If bottom basin is starting to get very full (after a few groups), pour the water from the bottom basin back into the watering can, using the strainer to catch the sequins for re-use. (If the mouth of the watering can is small, you may need an intermediate, wide-mouthed container to strain water into before carefully pouring into the watering can).

While students are testing their models, encourage observation of the successful parts as well as brainstorming how they could make their models more effective at trapping the pollution before it runs into the river.

- **Where does the pollution get caught?**
- **Where does pollution get through?**
- **Where does water run off the fastest? How could you absorb some of it?**
- **What would change if you placed your parks somewhere else?**

Round 2:

The city government has seen how much run off there is and how much pollution gets washed into the river when there are only a couple parks in the neighborhood. They've decided to listen to their water resource engineers and let you have as much money for parks and bioswales as you need!

You still need to create roads and housing for at least 15 people, but now you can decide how many parks and bioswales to install and where to place them. Remember, more housing for people is better.

Give students another planning period to draw and label their neighborhood on graph paper. When they are ready, pass out additional sponges and two mesh pot scourers. Include a few brads and explain that they might be useful for holding the bioswales in place.

Circulate among the groups as the students design and build. Many groups will organically come up with the idea to stack housing units to increase population density. They may also layer gardens, housing, and bioswales to create green roofs and other building innovations.

WRAP-UP

10 minutes

When all of the groups are finished designing, have a final showcase to test all of the designs, using the same method as before. Before testing, let each group point out the notable aspects of their designs to the rest of the class. Compare the designs after they all have been tested, emphasizing the unique features and what worked well.

Which features of the models were most effective at catching pollution? Did it matter where you placed them?

Which features of the models were most effective at preventing runoff? Did it matter where you placed them?

Why do you think it would be important to include more bioswales and green spaces in our cities?

CLEAN UP

10 minutes

- Students squeeze out their sponges and pot scourers and place them somewhere to dry.
- Students throw away the masking tape from their trays and return craft foam houses and brads to the box.

- Rinse off the trays over the sifter to capture any stray sequins. Stack trays to dry.
- Pour the catchment container through the sifter and disassemble the testing bed.

EXTENSION

As an optional extension, have students quantify the amount of runoff and pollution that flows into the river, using the “Pollution Solution” Worksheet.

Use the procedure outlined above for testing student’s models, with the following changes:

- Start with the bottom basin (the “river”) empty of sequins. (This means emptying and straining the basin after each group).
- Have students measure a designated number of sequins to sprinkle on the sheet; either count them out, or use a relatively precise measuring tool, like a tablespoon.
- Have students measure a designated amount of water to rain down on the sheet; use a large measuring cup or a pitcher with gradation marks.
- After testing, have students measure the pollution in the river by counting the number of sequins in the bottom basin. Record results on the “Pollution Solution” worksheet.
- Lastly, have students determine how much runoff was absorbed by the sponges. To do this, first empty the basin. Then, have students wring out their sponges over the empty basin. Then, carefully pour that water back into the measuring cup. Record results on the “Pollution Solution” worksheet, using whatever units (mL, oz, cups, etc.) are on your measuring device. Remember, the more water that is absorbed by the sponges, the better!
- Clean trays and reset as usual.

BACKGROUND INFORMATION

Urban runoff is water that puddles and flows on streets, parking lots, and other impermeable, urban surfaces. It is a major source of flooding and water pollution. When rain falls on impermeable surfaces, it pools and flows, rather than absorbing into the ground. The result is flooding. What's more, as the water flows downhill, it picks up trash, oil, and other contaminants. This pollution eventually makes it into streams, rivers, and groundwater.

City planners and landscape engineers design ways to reduce flooding and water pollution associated with urban runoff.

Bioswales, or rain gardens, are permeable basins that collect water, allowing it to slowly soak into the ground. Layers of vegetation, soil, and sand filter out trash and contaminants. Bioswales are better for the environment and more cost-effective than traditional storm drains, which transport runoff to a central sewer system.

Bioswales are easy to find if you know what to look for. They can be found as road medians, ditches, and green islands in parking lots. Increasingly more of them are being installed around new urban constructions, schools, and municipal buildings.

The plants in bioswales are typically native plants chosen for their strong root systems and ability to do well in wet and dry conditions. They might not be the prettiest plants, but they have a job to do! There also might be a drainage grate for overflow control visible or a gravely area at the lowest point of the bioswale. Larger rain gardens can include shrubs and trees and can serve as little parks!

Other innovations to manage runoff include green roofs, permeable pavement, and rain barrels.

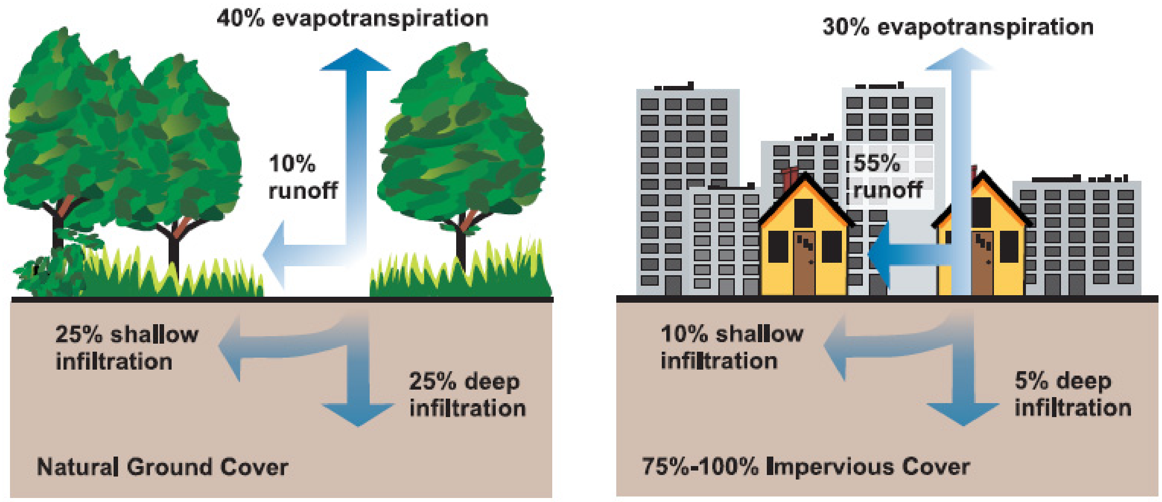


Figure 3: Spaces with permeable surfaces—like parks, rain gardens, and bioswales—generate less runoff than urban areas with primarily impermeable surfaces. (Image from EPA, courtesy of Wikimedia Commons).

Figure 4: A small bioswale in an urban area. The pavement dips slightly down towards the curb, causing water to flow into the planted area, where it slowly filters back into the ground. (Image from Greg Raisman, Flickr).

GLOSSARY

Bioswale	A rain garden that uses plants and soil to clean runoff from a road, construction site, or other urban or agricultural land that might contain pollutants.
Runoff	Precipitation that flows across the surface of the land that ultimately reaches streams. Since it doesn't flow through the ground, it can carry pollution or other types of particles into the water.
Non-point-source pollution	Non-point-source pollution comes from many sources, not just one place like a factory. It can happen when runoff from rain or snow carries pollution into streams. In agricultural land, pesticides and fertilizers get washed away; in cities, the pollutants are often gasoline, motor oil, and trash.
Impervious	An impervious surface is one that cannot effectively absorb or infiltrate rainfall. These surfaces include driveways, roads, parking lots, rooftops, and sidewalks. When natural landscapes are intact, rainfall is absorbed into the soil and vegetation.

NEXT GENERATION SCIENCE STANDARDS

	Practices
✓	Asking questions and defining problems
✓	Developing and using models
	Planning and carrying out investigations
	Analyzing and interpreting data
	Using mathematics and computational thinking
✓	Constructing explanations and designing solutions
	Engaging in argument from evidence
✓	Obtaining, evaluating, and communicating information

	Crosscutting Concepts
	Patterns
✓	Cause and effect
	Scale, proportion, and quantity
✓	Systems and system models
	Energy and matter
✓	Structure and function
	Stability and change

	Disciplinary Core Idea	3	4	5	MS
	Physical Science				
PS1	Matter and Its Interaction	n/a	n/a		
PS2	Motion and Stability: Forces and Interactions		n/a		
PS3	Energy	n/a			
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	
	Life Science				
LS1	From molecules to organisms: Structures and processes				
LS2	Ecosystems: Interactions, Energy, and Dynamics		n/a		
LS3	Heredity: Inheritance and Variation of Traits		n/a	n/a	
LS4	Biological Evolution: Unity and Diversity		n/a	n/a	
	Earth & Space Science				
ESS1	Earth's Place in the Universe	n/a			
ESS2	Earth's Systems				
ESS3	Earth and Human Activity			✓	
	Engineering, Technology, and Applications of Science				
ETS1	Engineering Design	✓	✓	✓	✓

DCI Grade Band Endpoints

3-5 ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (By the end of Grade 5)

3-5 ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (By the end of Grade 5)
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (By the end of Grade 5)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (By the end of Grade 5)

3-5 ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (By the end of Grade 5)

MS ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (By the end of Grade 8)

MS ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (By the end of Grade 8)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (By the end of Grade 8)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (By the end of Grade 8)
- Models of all kinds are important for testing solutions. (By the end of Grade 8)

MS ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (By the end of Grade 8)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (By the end of Grade 8)

3-5 ESS3.C: Human Impacts on Earth Systems

- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. For example, they are treating sewage, reducing the amounts of materials they use, and regulating sources of pollution such as emissions from factories and power plants or the runoff from agricultural activities. (By the end of Grade 5)

Performance Expectations

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
5-ESS3-1	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Pollution Solution

Appendix

Name ___________________________

Pollution Solution

Keep pollution and runoff out of the river!

Instructions: Each time you test your model neighborhood, measure how much pollution and runoff flows into the river. Can you use bioswales and greenspaces to absorb more runoff and trap pollution? Don't forget to include housing for at least 15 people.

	How many people can live in your neighborhood?	How much pollution flowed into the river? *Count number of sequins*	How much water did your sponges absorb? *Measure amount of water*
Trial #1			
Trial #2			
Trial #3			
Trial #4			

Were you able to improve your design?

What techniques worked best for keeping pollution and runoff out of the river?

Nombre ___________________________

Pollution Solution
(Solución a la contaminación)

¡Ayuda a que la contaminación y los vertidos no lleguen al río!

Instrucciones: Cada vez que pruebes tu prototipo de barrio, mide cuánta contaminación y exceso de lluvia llega al río. ¿Puedes utilizar bio-filtración y espacios verdes para absorber más exceso de lluvia y atrapar la contaminación? No olvides incluir viviendas para por lo menos 15 personas.

	¿Cuántas personas pueden vivir en este vecindario?	¿Cuánta contaminación llegó al río? *Cuenta el número de lentejuelas*	¿Cuánto exceso de agua está en las esponjas? *Mide la cantidad de agua*
Prueba #1			
Prueba #2			
Prueba #3			
Prueba #4			

¿Pudiste mejorar tu diseño?

¿Qué métodos funcionaron mejor para mantener la contaminación y los vertidos de agua lluvia fuera del río?

FACILITATION GUIDE

Pollution Solution

Description: Students will create model neighborhoods that incorporate green spaces, such as bioswales and parks, to prevent pollution from flowing into a river.

Promoting collaboration and organization

- Optional: Assign individual roles for students in collaborative groups. Possible roles can include group leader, recorder, materials manager, timekeeper, and ambassador (shares ideas with other groups). Index cards with the role descriptions can be given to each group prior to the activity, and students can switch roles with each iteration.
- Encourage groups to draw and label their design on paper before starting to build. However, their design on paper will naturally change during construction of the model.
- Have students take charge of clean up between test runs as much as possible to speed up the testing process.

Encouraging iteration

- *Round 1 (limited supplies):* "Does it matter where you put your two parks?"
- "Is there housing for 35 or more people?" "Are there roads connecting all the buildings?"
- *Round 2 (unlimited supplies)*: "How are you going to make room for both people and parks or bioswales?"
- "Do you think there will be any difference between the effectiveness of the parks and the bioswales? Would you put them in different places?"
- How could you fit more housing?

Helping those who are stuck

- Encourage students to go look at what their classmates are doing.
- If a group is having a hard time drawing, let them go look at the materials for a little while to get ideas.
- If a group is building too hastily or not working toward the same goal during construction, encourage them to go back to their drawing to solidify a plan.
- To encourage students towards green roofs and other innovative structures, show images of green roofs, green walls, etc.

Real-world applications

- Bioswales are increasingly common, especially in places that get a lot of precipitation. They are better for the environment and more cost effective than traditional storm sewer systems.
- Bioswales, or rain gardens, are easy to find if you know what to look for. They can be found as road medians, ditches, and green islands in parking lots. Look for them around schools and other public buildings, too.