STORMWATER ENGINEERS- South Plant
Fall 2025

Contents

Printing Tip: Print pages 1-14 for most educator uses (skip Appendices for hard copies)

Program Description

In this field program, students actively engage in the engineering design process to tackle stormwater engineering problems. Students will identify stormwater problems in the landscape; research innovative engineered solutions; and test possible solutions using models. This program is designed for classes that are studying erosion, deposition, stormwater, and environmental engineering.

Objectives: Students will leave the program with the capacity to…

- Use and understand the Engineering Design Process
- Identify stormwater problems in their community
- Define a stormwater problem using a model in the lab
- Explain why stormwater runoff is a problem in the urban environment

Outcomes: By the end of the program students will have…

- Explain how an Engineering Design Process can help them develop solutions to problems
- Gather and record data on data tables and maps
- Understand the effects of human decisions on the land, both positive and negative
- Make connections between a stormwater model and stormwater in the real world
- Identify the ways they could positively affect stormwater systems in their own communities

General Schedule

9:00	Educators Arrive and Set up Classroom
10:00	School Arrives - Split into field group, split field groups into engineering teams
10:05	Whole Group instruction in lab
10:35	Field Station 1
11:20	Lunch
12:00	Field Station 2
12:40	Field Station 3
1:15	Conclusion
2:00	Bus departs
2:00	Clean up
2:30	Post Program Debrief Discussion
3:00	Educators Depart

Flow for 2 Field Groups

	First Field Site		**Second Field Site**	**Third Field Site**
GROUP A	Wetland	LUNCH	River	Urban
GROUP B	Urban		Wetland	River

Prep for the Day

Classroom Prep:

- PowerPoint slides displayed on screen
- 6 landform models, each including:
  - Landform model
  - Wash bin
  - 3 collection cups (before, after, and redesign)
  - 1 rain cup set (1 cup with holes, 1 without)
- Clipboards with student's field journal
- Pictures of the development of WaterWorks Garden
- Engineering materials bin for the end of the day
- Visuals: Model, Procedure, Tools

Urban Station Materials:

- 3 "How Water gets dirty" posters
- 3 Pervious pavement models
- 3 filled Nalgene bottles
- Colored pencils: 15 red, 15 green
- Mesh "road"

Prep for each group:

- Backpack with 1st Aid kit
- 3-4 soil cores
- Laminated journal with wet erase marker
- Educator packet of visual aids

River Station Materials:

- 3 soil cores
- Cheesecloth

Wetland Station Materials:

- 2 sponges
- 1 regular Nalgene full of water
- 1 small Nalgene with dirty water
- 3 Soil cores
- Sand/water settling model
- Wetland Plant ID cards (3 sets of four)
- Petri dish

Decisions to make:

- Which order Group A and B will visit field stations
- How will the introduction be split up?
- How will the conclusion be split up?
- Make a plan for resetting models for afternoon
- Who will set up the urban station materials?

Introduction

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Developing and **Using Models** • Planning and **Carrying Out Investigations**	• **Developing Possible Solutions** • **Biogeology** • Earth Materials and Systems	• **Structure and Function**

Learning Target: **I can use the Engineering Design Process to solve a stormwater problem.**

Word Bank: Note word first use will be highlighted in red in curriculum

- Storm- winds, rain, thunder, lighting, or snow.
- Stormwater- water that falls on the ground during a storm.
- Erosion- soil breaking apart because of water or wind.
- Retention pond- human made pond used to hold and clean rainwater.
- Impervious- hard surface water cannot soak into.
- Pervious- allowing water to pass though
- Riparian zone- the area around a river with plants like trees and shrubs. The roots of the plants slow down the stormwater and prevent water pollution. The plants also provide habitat for animals.

Coming off the bus, the class is split into two field groups.

FIELD GROUPS:

1. Introductions of field group members.
2. *Today you will be solving an engineering problem. Engineering is using science and experimenting (trying things out lots of times!) to solve a problem.* Give an example of how you use engineering in your everyday life (a sandcastle built to stop the waves, a Lego spaceship tough enough to not break when dropped, built a fort to hide in, built a snowman etc.)
3. Divide the field group into three "engineering teams" with an adult in charge of each. Highlight the need to pay attention to the adult with their team – they will give instructions throughout the day.
4. The two field groups then meet back up in the lab. Try to have engineering groups sit together. **[Slide 1 on screen]**

IN THE LAB:

5. **[Slide 2]** *What is this building? Why is it loud?* Explain Wastewater treatment briefly - *dirty water from inside buildings and houses comes here to be cleaned* (yellow boxes).
6. Go over logistics - Where are the bathrooms?
7. What are the teacher's expectations today*? This is just like your classroom today. We have expectations just like your teachers do, even when we're outside today.* [One person talks at a time, listen and follow teacher instructions, raise your hands to share]
8. Journals- *Please put your name and your engineering team name on your journal as these are yours for the day. Make sure to take these journals seriously today as you will be turning them into your teacher at the end of the day.*
9. **[Slide 3]** Students volunteer to read aloud the learning target for the day. ***"I can use the engineering design process to solve a stormwater runoff problem."*** [Click to underline]
10. **[Slide 4]**. Go over the definitions of "Engineer" and "Stormwater". **Check for understanding**: *What do engineers do?* [Solve problems]
    - *Let's talk more about stormwater… When a big storm occurs, the water must go somewhere.*
11. **[Slide 5]** ***Rain can also cause problems –what problems can you think of related to rainwater that occur in your neighborhood when there's a big storm?***
    - Students turn and talk at tables – then take a few whole-group share-outs
    - Record responses on the board. Possible responses: trees fall over, floods, too much water for plants, clogged drains (leaves), pollution, dirty water, chemicals.
12. Point to **Engineering Design Process Poster.** *Engineers use an **engineering design process** to solve* problems. Have students read three steps chorally (all together). *They also use certain practices as they go through the process* [point out the **Science and Engineering Practices** cards]. *Today, we will some of these practices and the engineering design process as we work to solve our stormwater problem.*

Write ahead of time on the board:

Learning Target: I can use the engineering design process to solve a stormwater runoff problem.

Stormwater Model Investigation Roles & Procedure:

Make sure all group members are ready

Role	Job
Cloud	1. **Hold cloud** cup over road
Rain-maker	2. On "Go", **pour all the water** into cloud cup
Drain Manager	3. Help **clean the drain** and keep it clear
Sample Collector	4. **Catch** stormwater runoff in **sample cup** 5. On "Stop": **pull sample cup** away from drain

Additional jobs:

- Observer
- Notetaker
- Timekeeper

Educator Note: Check for understanding (CFU): CFUs are an engagement strategy that can come in many forms. When giving instruction, include quick ways to check that students are following along and understand concepts and procedures.

Stormwater Runoff Model

1. **PRACTICE HIGHLIGHT***: First, we will **develop and use a model** for an experiment. As engineers, the model will help us examine a problem created by stormwater. At the end of the day, our model will help us test out solutions.*
   a. *Hold up a "fist to five". Do you know what we mean when we say "model" in science?* [Encourage all to participate by holding up their fingers 1-5, 1=new to me, 5=I know the word]
   b. *Has your class ever used a model in the classroom?*
2. Pass out 1 "Stormwater Runoff Model" visual to each table. **[Slide 6]** *Scientists and engineers use models to help show how something works.* Explain each part of the model:
   (One educator explains/holds up each part, while the other educator clicks/ shows the parts of the model slide.)
   a. *The dirt and gravel are a **model** of land in the community*
   b. *The foil **models** sidewalks/ roads that do not absorb water.* CFU: *Is it really a road?* [No! It's a model of a road]
   c. *The water we will add* (hold up cup) *is a **model** of rainwater from a big storm.*
   d. *This cup with the holes at the bottom is a **model** of cloud where the rain will fall from.*
   e. *The water that flows out the other end comes out these drainage holes* (point)*. This **models** a storm drain. From here, water flows to streams, rivers, and lakes, in areas where people, plants, and animals live.*
   f. **[Slide 7]** *Give me a thumbs up if you know what each part of our model represents. Any questions about this?*
3. **PRACTICE HIGHLIGHT***: In your groups you will **carry out an investigation** to help us define our stormwater problem.*
4. **[Slide 8] Explain procedure and jobs**. One educator models/ explains, the other clicks/ points. *These are the jobs for our experiment. You will do these jobs more than once, so if you don't have the job you want this morning, you'll have another chance in the afternoon.*
   a. *The first job is the cloud.* CFU: *What's the job?* [Cloud]. Click. *The Cloud holds the cloud cup over the road.* CFU: *Where do you hold the cloud?* [Over the road]
   b. Repeat for Rainmaker, Drain Manager, and Sample Collector – ask "*What's the job?*" and quick CFUs for each.
   c. Optional: *There will also be a:* _____ (add Observer, Notetaker, Timekeeper depending on need/ group sizes)
5. Explain the Journal questions on page 5. Once everyone is clear on procedure, jobs and journal questions send engineering teams to their stations.
6. Run initial test - Set timer to 15 seconds and help students follow procedure.
   - Have teams bring their sample cup back to tables and fill out journals.
7. **PRACTICE HIGHLIGHT: Define the problem:** *Which problems that we wrote earlier appeared in your model?*
   a. *Which ones didn't?* (Erase or cross out any problems that weren't represented in the model.)
      - Guide students to narrow down to**: (1) too much water** (flooding) and **(2) dirty water** (stuff in the water)
8. **[Slide 9]** Click. *Engineers use something called **criteria** to help define the problem they are trying to solve*.
   CFU: *What do they use?* [Criteria]. TPR: Make a check mark with finger. Go over definition on slide.
   a. *What are the criteria for success today? What should our sample cup look like in the afternoon if we were successful at solving these two problems?* Write the following two criteria on the board:
      i. (1) too much water → **less water**
      ii. (2) Dirty water → **cleaner/ clearer water**
   b. Click. *Engineers also have to work with something called constraints.* CFU: *What's the word?* [Constraints]. TPR: Make an X with your arms. Click. *Constraints are limits or restrictions to a design. For engineers, this usually includes materials, time, and cost, because we do not have unlimited amounts of time or money. Today our constraints will have to do with time and materials.*
9. *At the end of the day today, we will come back to these models to try out solutions to our problem. But first, we need to research the possible solutions.*

Introduction to the Day's field work

1. **[Slide 10]** ***Engineers use the Engineering Design Process to solve problems.*** *Today we'll be using the same process that scientists and engineers use every day to research stormwater solutions here at South Plant.*
    a. *Problem - we already did that*
    b. *Test – we did our first test, redesign will happen after our investigation*
    c. *Solution - we are going to investigate that out in the field next*
2. *You and your group will go to three different filed stations – you will go to one before lunch, and two after lunch. At each station, you will investigate a solution and learn about tools you can add to your team's model.*
    a. Group A lines up first – good time for bathrooms, then circle up **across road** for a trail safety talk.
    b. Group B stay in classroom while Group A transitions. Explain that you will be starting at the Urban station.
        - Circle up inside classroom – do a short game or movement break - Options:
            - **Wastewater or Stormwater Movement** – go through a list of pollutants – if it is most found in wastewater, students squat, if it is most found in stormwater, students jump (Examples: Human poop, Dog poop, Car soap, Food scraps, Flushable wipes, Fertilizers, etc.)
            - **Four Categories**: Explain that there are trash, organics, germs, and chemicals in wastewater, play "four corners", but instead of numbers 1-4, each corner is a category
            - **Dealer's choice** - If you have a good quick game or activity, feel free to try it out here!

IN FIELD GROUPS

3. [Group A – walk to WaterWorks sign, Group B circle up near parking lot] *The outside area we will be exploring today used to be a big dirt patch.* Show South Plant construction picture. *During big rainstorms, rain would pick up dirt and carry it directly into the river next to it, called the Black River.*
4. *When engineers redesigned this area, their goal was to reduce excessive runoff, erosion, and try to stop pollutants from getting to our waterways. The engineers used a variety of different approaches to reduce the amount of water and the dirtiness of the water.* Show pictures of once the WaterWorks garden was added. *What do you notice?*
5. *We are going to explore this engineered site to help us* ***research possible solutions*** *for the problems in our models. At each stop, we will* ***carry out investigations****. At the end of the day we will meet back with the other group. Each engineering team will develop a solution to add to their model and test with the same procedure we just used.*

Wetland Station

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Developing and **Using Models** • Planning and **Carrying Out Investigations**	• **Developing Possible Solutions** • **Biogeology** • Earth Materials and Systems	• **Structure and Function**

Big ideas at the Wetland:

- ✓ *The Wetland in WaterWorks Garden* ***collects all the stormwater from impervious surfaces*** *at the wastewater treatment plant, also 80 acres.*
- ✓ ***Wetlands are like big sponges****; they slow the water down and hold it in place so it can soak in slowly through the ground. This keeps water from moving quickly into streams, which then results in less erosion and less flooding.*
- ✓ *Water in wetlands is still,* ***provides habitat*** *for plants and animals that need still and shallow water.*
- ✓ ***Humans can create wetlands*** *or similar water-storing areas by building* ***rain gardens, restoring natural wetland areas, and creating ponds*** *with wetland edges.*

Teaching Considerations at the Wetland

Trail etiquette – share the trail, stay to the right, stay with the group, stay on trail (frequently dog poop on trail edge)

Dogs and walkers are frequent, remind students to step to edge of trail and not pet dogs as they walk by.

EXPLORE AND OBSERVE

1. Gather the students in a semi-circle and pull out the picture of the wetland during construction.
    a. *This area used to be a large grassy field. There are two solutions here that help clean and slow down water.* ***Retention ponds*** *and* ***wetlands****.*
    b. *Big machines were used carve out retention ponds. Special soil and wetland plants were installed to create the wetland, and the water from the storm drains on the facility were re-routed to flow through the ponds.*
    c. *It was a lot of work to build these ponds and wetlands. Let's think… Why would the engineers spend the time and effort to change the landscape?* [Don't take answers, just pose as question to consider]
2. Explain the ponds - *When the water goes down storm drains onsite, it comes first to this pond. Why would the water sitting in a pond help clean it?* (pair and share)
    a. Hold up the settling model and start shaking it. *Inside my model I have sand and water, the sand represents pollution from the stormwater. What happens when I let the water sit?*
        i. Stop shaking the model and have students share out observations.
    b. *We are using time and gravity to clean the dirty stormwater. In this pond, the water sits, and the pollution sinks to the bottom. Where is the clean water?* […] *It's on the top layer. How do you think the water leaves the pond?* Stop and have students look at the pond and make guesses.
    c. *When the pond gets full enough, the clean water spills into the tubes on top. Then the water flows to the next pond. There are many ponds for the water to move through, getting cleaner at every step.*
3. Explore the **wetlands –** *In a minute, your team will explore this area, and make observations to help us understand what a wetland is and why engineers designed this.*
    ➢ Have students turn their journal to page 3.
    a. *We are going to search this area for special wetland plants that help with stormwater. We are also going to search for signs of animals. In your engineering team, you will have 10 minutes to explore this area and find one wetland plant and three signs of animals.*

b. Explain the Plant ID Cards: *Each team will get a card. It has the name of the plant and photos. Your job is to work with your team and find a plant that looks like the photos. Once you find the plant, read the card. The top section describes the plant. The bottom section lists things that the plant does that are good for water and animals. Choose one of each to write in your journal.*
c. Make sure students are in teams. Point out boundaries for exploration – option to have a chaperone be one boundary. Give 5-10 minutes to explore. Groups can change/ get additional cards if needed.

4. Gather the group back together - *What plants did you find?*
    a. Have each group share and read aloud a good thing that the plants do for water and animals. *What did you notice about how their plant looks or feels?*
    b. *If you were going to choose one plant to put in a wetland, which of the plants that we talked about would you pick?*
    c. *What signs of animals did you find? Did you see any animals?*

Soil Exploration (can be done in teams or as a demonstration depending on time)

1. Gather group near edge of pond. *Wetland soil is special and works with the roots of the plants to slow down the water. We are going to take a "soil core" to look at the wetland soil.* Hold up the soil corer.
2. Have the student watch you take a soil core for down in the wetland/ pond area. Show the soil corer to the group. Demonstrate how to turn it into the ground. Pull out the soil core. *What do you observe? What does it look like? Feel like? Smell like? What happens when I squeeze it?* (Water should come out)
    - Prompt students to write observations in their journal.
3. Place sponge on clipboard and pour water at an angle*. Pour water from top of clipboard.* (Option to have a volunteer pour the water). *What happens to the water?* Repeat with a second sponge and dirty water.
    a. *What happens to the water? What happens to the dirt?*
    (Wetland soil and plants work together to hold, slow down, and clean water like a sponge!)

SHARE RESULTS and DISCUSS POSSIBLE SOLUTIONS

1. Students answer question 3, "How does a wetland help with problems of dirty water or flooding?"
    Possible responses:
    - *Holds water for wildlife year-round so water doesn't drain out.*
    - *Slows down water, decreasing erosion and flooding elsewhere.*
    - *Plants and their roots can catch and hold onto dirt and pollution.*
2. Explicitly tie the learning form the wetland back to the problem(s) you identified during the introduction
    a. Show students the sponge and petri dish. *These are two tools you may choose to add to your models this afternoon. What do you think the sponge represents? What do you think the petri dish represents?*
    b. *On our walk back (or to the next station), start strategizing with your engineering team on how you might use these tools to solve the problems of dirty water and flooding.*

River Station

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Developing and **Using Models** • Planning and **Carrying Out Investigations**	• **Developing Possible Solutions** • **Biogeology** • Earth Materials and Systems	• **Structure and Function**

Big ideas at the River

- ✓ ***Plants store and slow down stormwater and retain water****. This helps keep sediment out of streams and reduces the amount of water moving quickly into them.*
- ✓ *The **Black River** is where rainwater collects from South Plant.*
- ✓ *Riverbanks can impact the amount of erosion from rainwater running over that surface.*
- ✓ *People can affect rivers in a positive or negative way-* ***engineered solutions like plants are an easy solution to the problem of river bank erosion***
- ✓ *Plants provide **habitat** for other creatures.*

EXPLORE AND OBSERVE - Circle up the at bank of the river.

Accessibility Note
The bank of the river can be muddy and slippery! Be careful here.

1. Tribal Recognition - *Today we have been talking and thinking a lot about how people use this place, how they have changed it, and how it looks now. It is important for us to pause and think about this history of this land. Who lived on this land before us and even our grandparents?* […] (*Native Americans- specifically the Duwamish people*.)
    a. *This river we are next to is called the Black River. It used to be a part of a network of "highways" the Duwamish people used to move from the Puget Sound, through the Duwamish River and to Lake Washington by canoe. The Duwamish people moved based on seasons and available resources. Because of their **connection and respect for the land and water**, they developed techniques and systems for **sustainable harvesting**. This river used to be connected to Lake Washington, but it isn't anymore. I wonder why might that be? European colonizers took over the region and displaced indigenous communities. These colonizes stole the native's land and changed the natural way rivers and water moved. Today, the rivers and lakes look very different than they did 200 years ago: both their physical shape and their health have changed a lot. We are on the land of the Duwamish, **who still live** and fish from local rivers. There are many Native Americans who still call this area home, and **continue to be stewards (taking care) of the land and water.***
2. *Let's make some observations of the river and the banks to help us understand how rainwater and people can make a negative or positive impact on it.*
    a. Option: Do 1-2 minutes of silent observation time (spread out and find a spot to take in the land around you)
    b. Ask students to share some observations about this place using all their senses.
    What do you see? What do you hear?
3. *This area of plants along the edge of the river is called a **riparian zone.** (CFU: What's the zone called?)*
    The health of the riparian zone affects the health of the river.
    What are some things that plants and trees can do or provide for the river/ animals that live here?
    a. Whole group share. Listen for examples such as providing shade, oxygen, food, shelter, slowing down or soaking up stormwater, etc.
4. *This place has changed a lot because of people. We are going to **investigate** the riparian zone along the Black River and see whether or not it is healthy. A healthy riparian zone has lots of different types of plants and trees, including different species and different sizes. More plants and more variety support more wildlife.*

- ➢ Students turn to page 4 in their journals. Explain page, tell students they will have time to explore and look for different riparian zone features. Depending on how many of each they observe will help them determine if the riparian zone health is "excellent", "medium" or "poor". They can ✓ or circle their choice.
    - Set boundaries at the river station before exploration time. Students can be near but <u>not</u> in the water. If it is really wet outside, have students stay off the slope leading down to the river.

5. Give students 5-10 minutes for teams to explore. After time is up, gather group back up.
    a. *Look at your data. Show me a thumbs up if you think this is a healthy riparian zone, thumbs down if you think it is unhealthy*. (Encourage all to participate by showing thumbs).
        - Using their data, have a few students explain why it is healthy or not
6. *Believe it or not, this area was restored or improved by people. Years ago, this area looked very different, and even more so right after the river was disconnected from Lake Washington. Many of these plants and trees were put here by people to improve the amount of habitat available, as well as the water quality of the river.*

COLLECT & RECORD DATA

1. *Having a healthy riparian zone is not only **good for life in and around the river**, but also for **controlling stormwater runoff**. Tree canopies and leaves act like umbrellas, catching and slowing rain as it falls. Once on the ground, the roots of plants soak up some water and help the soil hold together to prevent erosion.*
2. **PRACTICE HIGHLIGHT:** Students **carry out an investigation** in their engineering groups:
    a. Explain that students will work in teams to answer the two questions under riparian zone assessment table.
        - Each team takes two soil samples, one on the bare ground near river, one where there are a lot of plants.
          *If it is really wet outside, have educator take the soil core sample near the river to show the group.
    b. Demonstrate (or review) how to use a soil corer. Remind students to take turns twisting.
       Hand tool to each group's adult and send them off to collect their data.
3. Gather big group: Ask students to share observations about soil samples. Emphasize not just what the sample looked like, but <u>what was in it.</u> Encourage the use of descriptive words for the color, texture, and contents. Direct the conversation towards the **moisture** of their samples.

SHARE AND DISCUSS POSSIBLE SOLUTIONS:

1. *What did you discover in this investigation?* Questions to guide discussion:
    - *What do you notice about the banks of the river?* (Sloped)
    - *What do you notice about the number of plants on each side?*
    - *How do the number of plants along the banks help the river?*
      More plants= more roots.
      More roots= more water gets soaked up and filtered by plants.
    - *Would there be more erosion in an area with more or fewer plants?*
    - *How do plants interact with stormwater?*
    - *How do the plants help solve the problem of dirty water?*
    - *What would the river bank look like if there were no plants and roots to slow water down?*

How do plants help control runoff?
If students need help visualizing why plants help control runoff <u>focus on the plant's roots:</u>
- Roots are like tiny fingers holding onto the soil
- Plants keep some water from getting to the soil below (like an umbrella).
- Roots are also like straws - suck up some water for the plant to use.

2. Explicitly tie learning from the river back to the problem(s) identified in the introduction.
    a. Show students the cheese cloth. *This is another tool your team may choose to add to your model this afternoon. What does the cheesecloth represent?* (Roots).
    b. *On our walk back (or to the next station), talk with your engineering team about how you might use this tool to solve the problems of dirty water and flooding.*

Urban Station

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Developing and **Using Models** • Planning and **Carrying Out Investigations**	• **Developing Possible Solutions** • **Biogeology** • Earth Materials and Systems	• **Structure and Function**

Big ideas at the Urban Station

- ✓ Surfaces where water doesn't infiltrate increase problems with stormwater.
- ✓ Drains keep areas (roads/ parking lots) from flooding, moving water elsewhere (retention ponds, wetlands, rivers)
- ✓ However, drains allow pollutants from surfaces where water doesn't soak in to enter those other bodies of water.

Logistical Considerations for this site

- Most of this exploration takes place is near a road
- Position chaperones in the middle of the road at the boundaries to look out for oncoming vehicles.
- If it's raining, you may not need water bottles.
- Bring a flashlight to look in the drains!

EXPLORE AND OBSERVE:

1. *Right outside our classroom is the urban station! Here is (another) opportunity to investigate engineered solutions. This site is most similar to what most people see around cities.*
2. **PRACTICE HIGHLIGHT:** Have students turn to page 2. Students will **carry out an investigation** to learn about how water moves over surfaces at South Plant, and how retention helps control flooding.
    a. Explain that pavement can have a big effect on where water ends up and how clean it is.
3. Have groups spread out. Each group gets "How water gets dirty" poster. *What do you notice happening on the poster? What types of pollutants could get picked up by rainwater?*
    - ➢ Students answer question 1 in their journals.
4. *First, we'll explore this area, and start making observations to help us understand what the engineers did here.*
    a. Define **Impervious** and **Pervious** surfaces. Show visuals and have students repeat the words
    b. Introduce students to the map key and read question 2-
    - Teams find 5 impervious surfaces (mark "I" on maps) to show where the water does <u>not</u> soak in and 5 pervious surfaces (mark "P" on maps) to show where water does soak in. Students will also add sources of pollution, arrows to show where water travels, and storm drains.
    c. Provide each team water bottles and point out they can pour them on various surfaces to **investigate** where water soaks in and where it moves.
    d. Set up boundaries and safety parameters, since some of the time will be spent in the road.
    e. While students explore, they'll discover that **<u>water runs downhill towards the storm drains</u>**.
    f. Encourage students to look in the storm drains to see if there clues as to where it travels next. If they can see the pipes in the storm drains, have them add them to their map, showing direction of water.
5. Gather students back together and ask students to sit with their groups.
    - ➢ Read Question 3, then give each group red and green colored pencils.
    a. After a few minutes of coloring (quick sketching, doesn't have to be perfect or complete), discuss: *Where does all the impervious surface water go?* (Down the storm drains)
    b. Explain that all the water that falls on hard surfaces at South Plant gets piped to WaterWorks Garden pond.
6. Show (or review) pictures of the WaterWorks Garden pond during construction.

a. *After the pond, the water goes through a pipe into the Black River. We need to figure out why the engineers would bother building an entire pond, instead of making these pipes just go straight to the river.*

COLLECT & RECORD DATA

1. **PRACTICE HIGHLIGHT:** *Engineers have come up with other solutions so that more water can soak into the ground. We're going to* ***use a model*** *to understand how this option might help with our problems of too much water and dirty water for urban areas like this.*
    a. In engineering groups, students will get one pervious pavement model and one bottle of water
    b. Show students how to add water to model and pour water on the sidewalk or impervious surface.
    - *Have students answer Journal question #4*

SHARE & DISCUSS POSSIBLE SOLUTIONS

1. Bring students together and discuss what they discovered in their investigation
    a. *Which type of pavement do you think is best?*
    b. *What are the benefits to pervious pavement? What are the limitations of it?*
    c. *Why would engineers use a pervious pavement instead of a regular road?*
    - *Where could you use pervious pavement at your school? Students record their answer in question #5.*
2. Explicitly tie the learning form the urban station back to the problem(s) you identified during the introduction
    a. *Show students the metal mesh. This is a tool you may choose to add to your model this afternoon. What do you think the mesh represents?* (pervious pavement)
    b. *How does pervious pavement help solve the problem of too much water? Your team will decide if you want to use this tool as part of your solution.*

Conclusion

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
• Asking Questions and Defining Problems. • **Developing and Using Models** • Planning and **Carrying Out Investigations** • Constructing Explanations and **Designing Solutions** • **Engaging in Argument from Evidence**	• **Defining and Delimiting Engineering Problems** • **Developing Possible Solutions** • **Optimizing the Design Solution** • Natural Hazards • Earth Materials and Systems	• **Structure and Function**

Learning Target: **I can use the Engineering Design Process to solve a stormwater problem.**

Stormwater Runoff Model

1. ****Make sure you've re-set the models for the afternoon test.****
2. **[Slide 11]** End of the day- *Great job investigating, scientists and engineers! Look at all the hard work you have done outside researching solution.*
   - Students turn their journals to page #5.
3. **[Slide 12]** Pass out 1 "Tools" visual to each table. Explain that each group will have available the following tools to add "engineering features" in their model. The goal is to design a solution that meets the [TPR] **criteria for success** [(1) less water and (2) cleaner water]
   Petri dish (represents a pond), Sponge (represents a wetland), Cheese cloth (represents roots and plants), Replace the tinfoil road with metal mesh (pervious pavement)
   a. But because of [TPR] **budgetary constraints** student's groups only get to **pick 3 tools**
4. Students will have a few minutes as a team to brainstorm a solution based on what they saw in the field.
5. One instructor is in charge of passing out the tools. Student must explain how they are going to use the items in the model to us each of the three items in the model.
6. Students have 5 minutes to use the tools and add features to their models. Where could they place items in the models to maximize their effectiveness?
7. **PRACTICE HIGHLIGHT:** Review the same **procedure they used to carry out the investigation** at the start of the day, this time collecting water in the "After" cup.
   a. Make sure everyone has an assigned job
8. Comparison- groups compared their runoff from the engineered model to the unaltered model for the morning.
   a. Record observation in journal

Stormwater Model Redesign

1. Gather the group's attention. Have students stay with their models.
2. Check on Criteria (Thumbs up/ Thumbs down): *Does your design have less water? Does it have cleaner water?*
3. Point out to the class the Engineering Design Process, note that it is circular:
   a. *It's ok if we didn't meet our **criteria for success**. Engineers look for things that don't work so they can improve them. They call those **failure points**. This is part of the engineering design process! Failure points help us redesign our solutions to improve our results.*
   b. *Did anybody find any problems with their models? Maybe you **identified new problems**, so we're going to **research possible solutions** by learning from other engineering teams.*
4. **PRACTICE HIGHLIGHT***: Using **evidence** from your own investigation, along with anything you learned at other engineering teams, take 5 minutes to come up to us and trade out any items you need to redesign your model.*
5. After passing out new collection cups, have students carry out a 3rd and final test of their model.

Final Wrap-Up

1. Remind students about the problems they identified in the morning
2. *We've spent most of our day thinking about stormwater here at South Plant. I'm curious are there any stormwater problems that you notice at your school?*
3. After hearing a few examples, decide one for the class to work on.
    a. *Have you learned any solutions today that could help with this stormwater problem at your school?*
    b. Have students discuss at their tables.
4. If a class has signed up for a post lesson, let them know that several educators will be coming to visit them, and they'll get to dig into a stormwater problem at their school.
5. Thank students and chaperones for joining us, and help the teacher get students ready to head back to the bus.

APPENDIX I: WaterWorks Garden and Black River History

WaterWorks Garden

Waterworks Garden, completed in 1999 is an 8-acre facility that naturally filters stormwater collected from more than 40 acres of impervious surface at the South Treatment Plant through the use of 11 ponds and enhanced existing wetlands. The ponds are connected by a series of pipes that allow for up to a 4.5-cfs flow rate as delivered by the stormwater pump station, which adds up to about 2.2 million gal. a day. The ponds are fed by both a variable speed pump and a constant speed pump, which can serve as a backup. Valves at the plant can be set to divert flow to the wastewater treatment plant rather than to the wetlands to allow for inspection, draining, and servicing. Before the waterworks were built, all of the stormwater runoff from the plant went into the wastewater treatment system.

Waterworks Gardens was built as part of the third phase of the South Treatment Plant. The plant opened in 1965 and now serves a population of more than 600,000 people in south and east King County.

The ponds are designed to hold a total of 642,327 gal., including room for 15.9% sediment storage. Sediment is removed from the ponds, however, when it exceeds 10% of the total volume. Some of the ponds have emergency drains to catch overflow water. The paths around the ponds also were built in a way to create a flood drainage system. The park is designed to handle a peak 24-hour, two-year storm.

All of the ponds are constructed with a layer of indicator rock on the final, exposed bottom surface. This protects the underlying impermeable layer of polyvinyl chloride sheeting.

The Black River Riparian Forest and its History:

Before 1916 Lake Washington emptied from the south end into the Black River, which was joined by the Cedar River. The confluence of the Black and White River created the Duwamish River, which emptied into Elliott Bay in the Puget Sound. Today, Lake Washington water empties into the Puget Sound via the Lake Washington Ship canal.

In 1916 with the completion and opening of the Lake Washington Ship Canal the lake's level dropped nearly nine feet and the Black River dried up. Today, the once Black River forms the Black River Riparian Forest and wetland.

The loss of the Black River had some important ecological changes for migratory fish, including salmon who had to find a new route into Lake Washington.

It's unclear if fish adapted to the new route and how many were lost to the new migration, but Williams said there were channels added in the 1880s that could have initially got fish rerouting before the big change. This also mattered culturally for the people who had lived off fish at the Black River. The Duwamish people lived along the Black River for many centuries. Archaeologists found evidence of the Duwamish in the area at least 1,500 years ago. In 1792, there were three recorded Black River settlements, and appeared to have been wealthy and well-connected. Duwamish settlements remained along the river until it dried up in 1916. Several indigenous villages were located near the confluence of the Black and Duwamish rivers. The area was called "Inside Place", referring to its location inland from Puget Sound. Long used as a place of refuge, the area became home hundreds of indigenous people displaced by the growing city of Seattle. The Black River was also a big fishery for the Duwamish people, until the river dried up. https://uw.manifoldapp.org/read/duwamish/section/f70fd136-a9f6-4a6c-9ce7-339ec2786313

Appendix II: Next Generation Science Standards

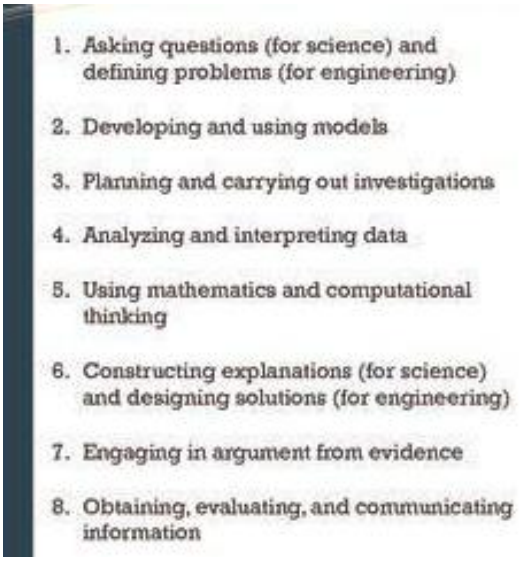
The Next Generation Science Standards (NGSS) are made up of Performance Expectations that incorporate three dimensions: the **science and engineering practices**, **disciplinary core ideas**, and **crosscutting concepts.** For more in depth information on the NGSS, visit the Equip or NSTA websites.

All three dimensions are used during the course of this program. To help educators recognize where we are using them, the relevant dimensions are listed at the beginning of each lesson. In addition, the dimensions are color coded when they show up in the text of the lesson. To keep it simple, full descriptions are not provided during the lesson, but below you can find specifics for each category including where it is used. We do not list all the parts of each dimension; just the specific bullets relevant to this lesson.

The program also supports (but does not replace), specific NGSS performance standards that should be a part of 4th grader's science units in the classroom. These can be found listed at the end of this section.

Science and Engineering Practices

There are eight key "practices" that are essential to the work of scientists and engineers. They are not used in any specific sequence, being applied as needed to build understanding (science) or solve problems (engineering). By reinforcing these practices and making our use of them explicit during this program we help students see that THEY can be engineers and to see how the practices can be applied towards building understanding and solving problems in the real world.



In this program: the students define the problem (including criteria for success) when using the model in the lab. They research the problem by visiting various field sites and looking for possible solutions at each of them and do some listing of possible solutions as they go. At the end of the day, they return to the lab to (quickly) brainstorm and choose a solution. Then they use their model to build and test a prototype. Finally they communicate to the rest of the class how the solution they tested did.

Science and Engineering Practices	Where it is used in our program?
Asking Questions and Defining Problems Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)	The criteria for success (less water and cleaner water) are laid out during the introduction and constraints on materials are added at the end of the day.
Developing and Using Models Develop and/or use models to describe and/or predict phenomena. Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.	The landform models are used at the beginning of the day to better understand the cause of the problem. At the end of the day prototypes of solutions are added to the models.
Planning and Carrying Out Investigations Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3)	Students conduct (but do not design) a fair test investigation on their landform models and when measuring stream speed at the stream.

Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	Students make observations and measurements at each of the field sites to better understand and compare the locations. Their work with the landform models lets them test a design solution.
Constructing Explanations and Designing Solutions Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2) Apply scientific ideas to solve design problems. (4-PS3-4)	Each team tries only one solution out, but with multiple teams creating solutions they have an opportunity to compare them. Understanding of how water moves over the land is applied as the students design and place their proposed solutions.
Engaging in Argument from Evidence Respectfully provide and receive critiques from peers about a proposed procedure, explanation or model by citing relevant evidence and posing specific questions. Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	Students should be doing this when they are discussing possible solutions for the groups to add to their model. After students finish testing their proposed solution, the have an opportunity to share with others how well it met the criteria for success.

Crosscutting Concepts

"Crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas." — Framework p. 233

Crosscutting Concepts	Where it is used in our program?
Structure and Function Substructures have shapes and parts that serve functions.	This concept is used throughout the program as students look at various structures that have been built on site by engineers and figure out how their structure helps serve the function of slowing down stormwater.
Cause and Effect Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-1)	At the stream and/or the retention pond students discuss the effect of too much stormwater on stream speed and erosion. Cause and effect is also a part of thinking about what solutions do and which will work in their model.

Disciplinary Core Ideas

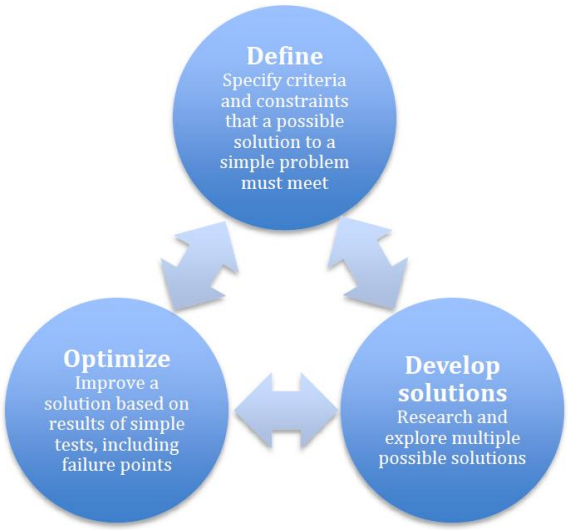
The Disciplinary Core Ideas we are teaching most clearly in this lesson are the ones related directly to engineering (ETS1.A-C). See the "3-5 Engineering Design" section below for more information about the Engineering Design Process. The remaining core ideas listed below are used during the lesson but only briefly. They are not taught in a deep way in our program.

Disciplinary Core Ideas	Where it is used in our program?
ETS1.A: Defining & 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). (3-5-ETS1-1)	Students Define the problem through discussions and observations of their models at the beginning of the program. They add a bit more to their understanding of the problem at the stream and bring in constraints (on amount of materials to use) when designing their solution.
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. (3-5-ETS1-2) 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. (3-5-ETS1-2)	Research is occurring as the students look at possible solutions at each site they visit. They test their solutions in their models (but do not test a range of possible solutions). Student teams should discuss pros and cons of possible solutions before they decide on what they want to model.
ETS1.C: Optimizing the Design Solution (3-5-ETS1-3) Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	Student sharing about how their solutions did at the end of the program is an opportunity to compare how well various solutions met the critieria. If they have time to improve their solutions they are putting the idea into action.
ESS3.B: Natural Hazards (4-ESS3-2) A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts.	This comes up at the start of the program: Floods are a natural hazard that we make worse in an urban setting. When possible we connect it to flooding in the student's own communities.
ESS2.A: Earth Materials and Systems (4-ESS2-1) Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.	The landforms unit spends a lot of time with this core idea. We reinforce it when we are talking about stormwater and the resulting fast water affecting the land and causing erosion. It also relates to sediments being carried by the water.
ESS2.E: Biogeology (4-ESS2-1) Living things affect the physical characteristics of their regions.	At the hill, we talk about how the roots of plants help keep soil from being washed away. At the wetland, plants are helping filter the water and make it cleaner. This idea can also be applied to humans and our effects on increasing and decreasing stormwater problems.

Engineering Design

The Engineering Design Process is the focus of the **Disciplinary Core Ideas that focus on engineering (ETS1.A-C).** It overlaps with specific Engineering Practices designed to reflect the skills engineers use as a part of engineering.

The Engineering Design Process is integral to this unit as students **define** the stormwater runoff problem they are trying to solve, look at examples around the Brightwater Campus to research possible solutions, model and **develop their solutions** as they explore their options, and then have a conversation at the end on how they might **optimize** a final solution. *From: http://ngss.nsta.org/3-5-engineering-design.aspx*



In K–2, students learn that situations people wish to change can be defined as problems than can be solved or goals that can be achieved through engineering design. 3rd-5th graders are expected

to engage in engineering in ways that are both more systematic and creative. The rest of this section describes the expectations of what 3-5 graders do with Engineering Design.

Engineering design can be thought of as three phases. It is important to keep in mind, however, that the process of design does not necessarily follow in that order, as students might think of a new solution during the testing phase, or even re-define the problem to better meet the original need. Nonetheless, they should develop their capabilities in all three phases of the engineering design process.

Defining the problem in this grade range involves the additional step of specifying criteria and constraints. Criteria are requirements for a successful solution and usually specify the function that a design is expected to perform and qualities that would make it possible to choose one design over another. Constraints are the limitations that must be taken into account when creating the designed solution. In the classroom constraints are often the materials that are available and the amount of time students have to work.

Developing possible solutions at this level involves the discipline of generating several alternative solutions and comparing them systematically to see which best meet the criteria and constraints of the problem.

Improving designs involves building and testing models or prototypes using controlled experiments or "fair tests" in which only one variable is changed from trial to trial while all other variables are kept the same. This is the same practice as in science inquiry, except the goal is to achieve the best possible design rather than to answer a question about the natural world. The broader message is that "failure" is an essential and even desirable part of the design process, as it points the way to better solutions.

Engineering Design Vocabulary

Constraint: a limitation to a possible solution, often related to materials and resources
Criteria for success: desired features of a solution
Engineering (EDP): engagement in a systematic practice of design to achieve solutions to particular human problems
Optimize: test solutions in order to determine which of them best solves the problem, given the criteria and constraints
Solution: a way (object, tool, process, or system) to address or solve a problem; in engineering, solutions take into account constraints and criteria for success

***** Definition based on NGSS – 3-5 ETS-1 Engineering Design, *NGSS APPENDIX G – Crosscutting Concepts*, or *NGSS APPENDIX I – Engineering Design in the NGSS*.

Engineering Design "Talk Moves"

These questions may be used to guide students' thinking as they work through different aspects of the Engineering Design Process. *Adapted from Kirk Robbins, https://teachscience4all.org/2014/11/05/engineering-design-talk-moves/* .

Goal	Talk Moves
Initiating Engineering Talk	● *Can you tell me about your design?* ● *What are you working on?* ● *Do you think this will solve the problem?* ● *How did you arrive at this design?*
Maintaining focus on the Problem	● *What is the problem we are trying to solve?* ● *What are the criteria (goals)?* ● *What are our constraints (limits)?*
Examining Materials and Tools	● *What will you use for _____?* ● *What materials did you pick? Why?*

Maintaining Stamina & Sticking with an Idea	• *How could you make this even better?* • *If you kept working, what would you do next?* • *What might you change about this design?* • *Did you fail or did the design fail?*
Uncovering Scientific Thinking	• *Why do you think that might work?* • *What science ideas did you use to figure that out?* • *How are you using science to solve this problem?*
Increasing Effective Collaboration	• *How did your group decide on this?* • *Have you heard from everyone in your group?* • *What could you do to work together more successfully?* • *Does everyone agree with this idea?*
Making Sense of Testing	• *What did you notice when you tested this?* • *What happened when you tested your design?* • *What did you do to make sure it was a fair test?* • *What specifically didn't work?*
Considering Trade Offs	• *What do you think is the most important criteria?* • *What tradeoffs might you need to make?*
Pushing for Optimization	• *How could you make this even better?* • *What do you need in order to improve your design?* • *What ideas could you borrow to make your design even better?*

NGSS Performance Expectations

The following Next Generation Science Standards are supported by this lesson. This lesson reinforces the material in these standards but does not replace the need for them to be learned and practiced more deeply in a larger curriculum.

Students who demonstrate understanding can…

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.

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans. [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*]

4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [Assessment Boundary: Assessment is limited to a single form of weathering or erosion.]