



Community Waters Science Unit

Grade 4 Teacher Manual

This stormwater engineering unit incorporates Next Generation Science Standards*, and the Ambitious Science Teaching framework. In addition to this manual, there are Seattle school-specific teacher guides, maps, videos, and additional support materials available on our website: communitywaters.org.

It was developed with funding from Seattle Public Utilities, King County, Boeing and the Department of Ecology through a collaboration between IslandWood and Seattle Public Schools.

Email us at communitywaters@islandwood.org.



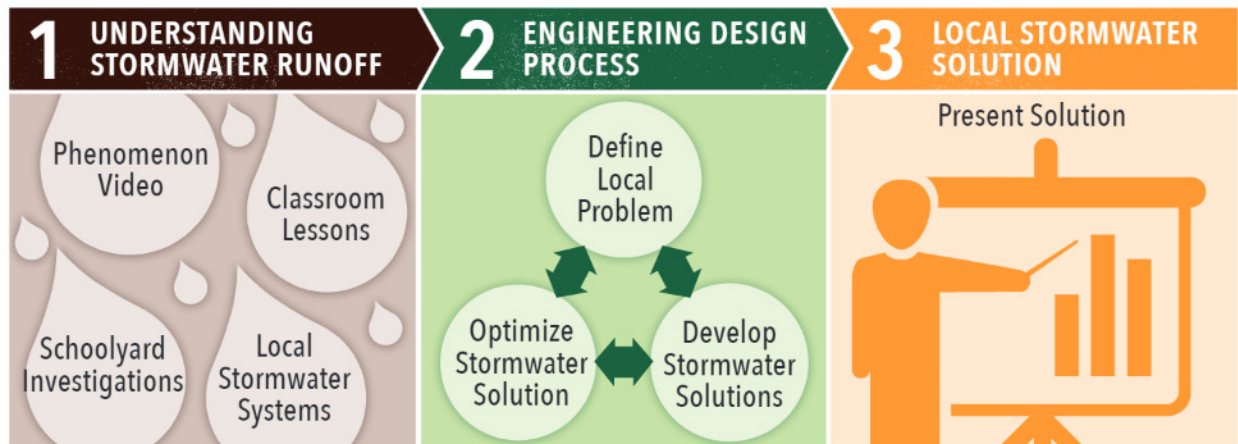
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Unit Overview

The unit engages students in science and engineering to understand and develop a solution for a real world stormwater runoff problem in their community. Students begin the unit trying to understand why stormwater can cause flooding in an urban setting. Then they use an Engineering Design Process to come up with a proposal towards solving a specific local stormwater problem:



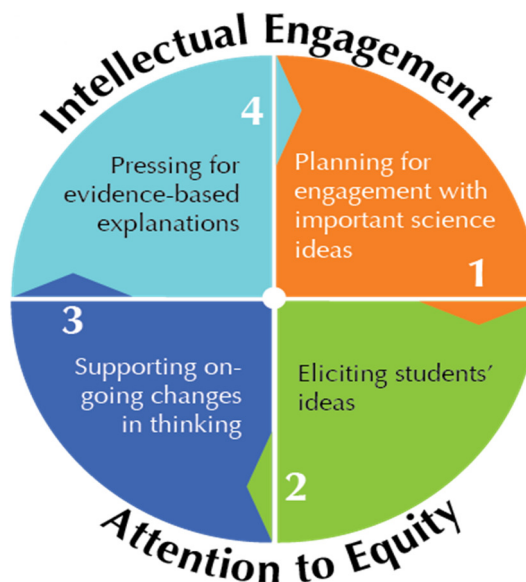
- **Understanding Stormwater in the City:** In the first part of this unit, teachers use an Ambitious Science Teaching approach as they elicit student’s ideas, support changes in thinking, and press for evidence-based explanations. The students watch a video showing short clips of problems caused by stormwater and then add their personal understanding of stormwater to an explanatory model. Classroom lessons and outside investigations help them refine their understanding and revise their explanatory model.
- **Using Engineering to Solve a Stormwater Problem:** Once their understanding is built, students apply it towards coming up with a solution for a stormwater runoff problem at a specific site (likely in their schoolyard). During this part of the unit, an Engineering Design Process is used to define the problem, develop solutions, and optimize the solution they select.
- **Sharing their Solution:** At the end of the unit, the students share their solutions with their classmates and/or local stakeholders.

Incorporation of the Ambitious Science Teaching Framework

This curriculum was written to fit to the Ambitious Science Teaching (AST) Framework as developed by the University of Washington. For more details about the Framework see Appendix 1 in this manual and their website:

<http://ambitiousscienceteaching.org/>

The graphic on the right is used throughout this manual to highlight when each of the four AST practices are being addressed. To highlight those connections here:



- 1) **Planning for engagement with important science ideas** started with the designing of this unit being framed around the phenomena of stormwater flooding in student's communities and the problems it can cause. To assist teachers in the planning for engagement, the Unit Overview section includes the unit's goals, the Next Generation Science Standards addressed, background information for the teacher, and a storyline outline of the lessons in the unit.
- 2) **Eliciting of students' ideas** occur in the first lesson including them representing their ideas in an "explanatory model" that they can continue to update as their thinking changes.
- 3) The remainder of the first half of the unit is focused on **supporting ongoing changes in thinking** with each lesson providing opportunities to dig deeper into student's understanding of the urban stormwater phenomena. Most lessons provide teachers some "Back Pocket Questions" that can be used with students to support their changes in thinking, and there are also a variety of tools provided in Appendix 2 of this curriculum (page 1).
- 4) **Pressing for evidence-based explanations** is important as students explain their changes in understanding throughout many of the lessons, but is particularly highlighted when students add to and/or redo the explanatory models they created in lesson 1 to represent how their thinking has changed, and at the end of the unit when students are making claims about what solution will best address the stormwater problem at their site.

Unit Goals

1. Students will develop an understanding of stormwater runoff and the problems it can cause in an urban setting.
2. Students will apply an Engineering Design Process towards solving stormwater related problems in their schoolyard or neighborhood.
3. Students that might not otherwise be interested in science will be motivated and engaged by applying science and engineering on a real problem in their own community. *(See the “Engineering Design in Relation to Student Diversity” excerpt below)*



What students figure out by the end of the unit:

- Water moves rocks, soils, and sediments and faster water moves larger rocks.
- Plants affect the physical characteristics of their region by reducing the movement of soils (erosion) and using and storing water.
- Flooding is a natural hazard that is made worse in an urban setting.
- Humans can take steps to reduce the flooding and its impacts.
- The criteria and constraints for a specific stormwater problem in their community.
- Certain solutions will work better than others to solve a problem.
- A solution can be improved to work better in a specific situation.

Put another way:

| If students understand... | | Then, students can explain... |
|---|---|--|
| ...how water moves across and through the land and how plants and different surfaces affect it. | ➔ | ...what happens to stormwater in an urban environment and how people’s actions can change the amount of stormwater runoff. |
| ...what happens to stormwater in an urban environment and the problems caused by too much stormwater runoff in their community. | ➔ | ...what is happening to cause a specific local stormwater runoff problem and why they want to fix it. |
| ...what is happening with their problem and the desires of those who care about their problem. | ➔ | ...the criteria and constraints of their problem. |
| ...the criteria and constraints of their problem and the advantages and disadvantages of different possible solutions. | ➔ | ...why they picked a certain solution as the best one for their specific problem. |
| ...why they picked a certain solution and whether a model of it meets their criteria for success. | ➔ | ...how well it works and what they would change to make it work better. |
| ...why the solution they designed will help with stormwater runoff in their local community. | ➔ | ...how science and engineering can be relevant to their lives. |

Next Generation Science Standards

The Next Generation Science Standards that this unit is focused on are included below. The relevant standards are also listed within each lesson with the components of the performance expectation that are a part of that lesson underlined. The Practices, Disciplinary Core Ideas, and Crosscutting Concepts listed in a lesson are ones used during that lesson (they are not limited to the dimensions that are a part of that lesson's performance expectation(s)).



Targeted NGSS Performance Expectations...

- 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.]

- 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.]

- 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.**

| Dimensions from the targeted NGSS Performance Expectations... | | |
|---|--|---|
| Science and Engineering Practices (SEP) | Disciplinary Core Ideas (DCI) | Crosscutting Concepts (CC) |
| <p>Asking Questions and Defining Problems</p> <ul style="list-style-type: none"> • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (4-ESS2-1) • 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) <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> • 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) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> • 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-ESS3-4) | <p>ESS2.A: Earth Materials and Systems</p> <ul style="list-style-type: none"> • 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. (4-ESS2-1) <p>ESS2.E: Biogeology</p> <ul style="list-style-type: none"> • Living things affect the physical characteristics of their regions. (4-ESS2-1) <p>ESS3.B: Natural Hazards</p> <ul style="list-style-type: none"> • 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. (4-ESS3-2) <p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> • 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. (3-5-ETS1-1) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> • 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) • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) • Testing a solution involves investigating how well it performs under a range of likely conditions. (secondary to 4-ESS3-2) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3) | <p>Cause and Effect</p> <ul style="list-style-type: none"> • Cause and effect relationships are routinely identified, tested, and used to explain change, (4-ESS2-1 & 4-ESS3-2) <p>-----</p> <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Influence of Engineering, Technology, and Science on Society and the Natural World</p> <ul style="list-style-type: none"> • People’s needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1) • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (4-ESS3-2, 3-5-ETS1-2) |

Disciplinary Core Idea Progressions

These progressions show what students are expected to know as they advance through the grade bands.

From <http://nextgenscience.org>.

| DCI | K-2 | 3-5 | 6-8 |
|---|---|---|--|
| ESS2.A Earth materials and systems | Wind and water change the shape of the land. | 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. | All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. |
| ESS2.E: Biogeology | Plants and animals can change their environment. | Living things affect the physical characteristics of their regions. | |
| ESS3.B Natural hazards | In a region, some kinds of severe weather are more likely than others. Forecasts allow communities to prepare for severe weather. | A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts. | Mapping the history of natural hazards in a region and understanding related geological forces. |
| ESS3.C Human impacts on Earth systems* | Things people do can affect the environment but they can make choices to reduce their impacts. | Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth's resources and environments. | Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. |

* This DCI is in a 5th grade performance expectation (5-ESS3-1) but is relevant to this unit.

Engineering Disciplinary Core Idea Progressions

These progressions show what students are expected to know as they advance through the grade bands

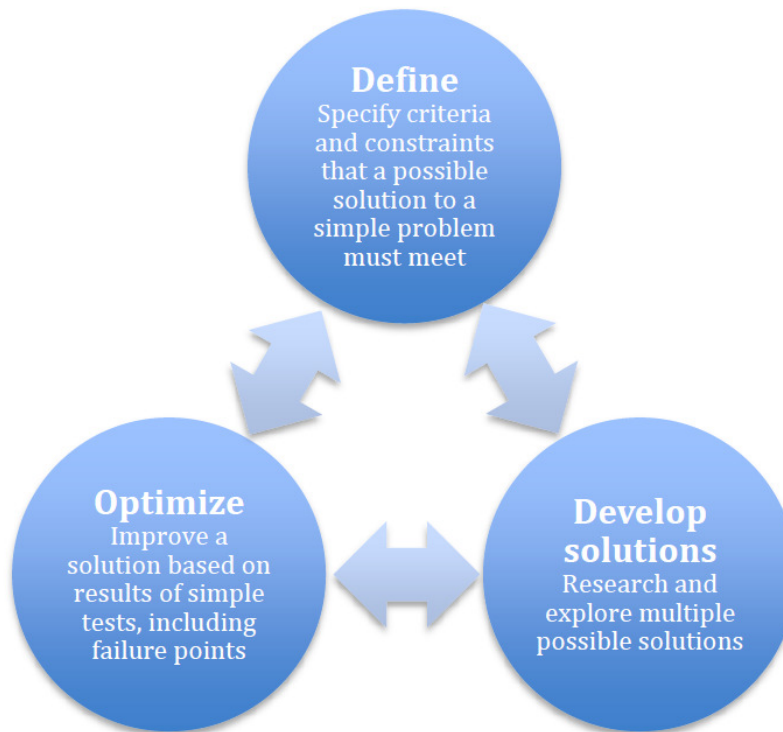
| DCI | K-2 | 3-5 | 6-8 |
|--|--|--|---|
| <p>ETS1.A Defining and Delimiting Engineering Problems</p> | <ul style="list-style-type: none"> • A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. • Asking questions, making observations, and gathering information are helpful in thinking about problems. • Before beginning to design a solution, it is important to clearly understand the problem. | <ul style="list-style-type: none"> • 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 based on how well each one meets the specified criteria for success or how well each takes the constraints into account. | <ul style="list-style-type: none"> • 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 is likely to limit possible solutions. |
| <p>ETS1.B: Developing Possible Solutions</p> | <ul style="list-style-type: none"> • Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people | <ul style="list-style-type: none"> • Research on a problem should be carried out before beginning to design a solution. • 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. • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. • Testing a solution involves investigating how well it performs under a range of likely conditions. | <ul style="list-style-type: none"> • A solution needs to be tested, and then modified based on the test results in order to improve it. • A solution needs to be tested, and then modified based on the test results in order to improve it. • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. • Models of all kinds are important for testing solutions. |
| <p>ETS1.C: Optimizing the Design Solution</p> | <ul style="list-style-type: none"> • Because there is always more than one possible solution to a problem, it is useful to compare and test designs. | <ul style="list-style-type: none"> • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. | <ul style="list-style-type: none"> • 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 the characteristics may be incorporated into the new design. • The iterative process of testing the most promising solutions and modifying what is proposed based on the test results leads to greater refinement and ultimately to an optimal solution |

Grades 3-5 Engineering Design

From: <http://nqss.nsta.org/3-5-engineering-design.aspx>

Students' capabilities as problem solvers build on their experiences in K–2, where they learned that situations people wish to change can be defined as problems than can be solved or goals that can be achieved through engineering design. With increased maturity students in third through fifth grades are able to engage in engineering in ways that are both more systematic and creative. As in earlier and later grades, engineering design can be thought of as three phases. It is important to keep in mind, however, that the lively 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 considered when creating the designed solution. In the classroom, constraints are often the time and materials that are available.



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 in Relation to Student Diversity

From Appendix I – Engineering Design in the NGSS:

http://www.nextgenscience.org/sites/default/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL_V2.pdf

The NGSS inclusion of engineering with science has major implications for non-dominant student groups. From a pedagogical perspective, the focus on engineering is inclusive of students who may have traditionally been marginalized in the science classroom or experienced science as not being relevant to their lives or future. By asking questions and solving meaningful problems through engineering in local contexts (e.g., watershed planning, medical equipment, instruments for communication for the deaf), diverse students deepen their science knowledge, come to view science as relevant to their lives and future, and engage in science in socially relevant and transformative ways. From a global perspective, engineering offers opportunities for “innovation” and “creativity” at the K-12 level. Engineering is a field that is critical to undertaking the world’s challenges, and April 2013 NGSS Release Page 3 of 7, exposure to engineering activities (e.g., robotics and invention competitions) can spark interest in the study of STEM or future careers (National Science Foundation, 2010). This early engagement is particularly important for students who have traditionally not considered science as a possible career choice, including females and students from multiple languages and cultures in this global community.

Teacher Background Information

This section provides science content knowledge and explanations to understand the general phenomenon of how water affects land. The last part of the section provides information from [A Framework for K-12 Science Education](#) describing knowledge corresponding to each Disciplinary Core Idea featured in this unit.



Hydrosphere – The world of water

Information for this section from:

<http://www.geography4kids.com/> and

<http://water.usgs.gov/edu/watercyclesummary.html>

Earth's water is always in movement and is always changing states, from liquid to vapor to ice and back again, cycling for billions of years. The sun heats water in the oceans and other places. Some of it evaporates as vapor into the air. Rising air currents take the vapor up into the atmosphere along with water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, and cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snow packs in warmer climates often thaw and melt when spring arrives, and melted water flows over land. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and groundwater seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground. Some of the water infiltrates into the ground and replenishes aquifers, which store vast amounts of freshwater for long periods of time. Some groundwater stays close to the land surface and can seep back into surface-water bodies and the ocean as groundwater discharge, and some groundwater finds openings in the land surface and emerges as freshwater springs. Yet more groundwater is absorbed by plant roots. Over time, though, all this water keeps moving.

More on groundwater. Groundwater starts on the surface. When it rains and the water moves through the soil, it's called infiltration. There are spaces between the dirt and rocks that allow the water to flow through. (Different soil types have different porosities.)

Video on water movement in soil:

<https://www.youtube.com/watch?v=vmo0FRAVgkM>

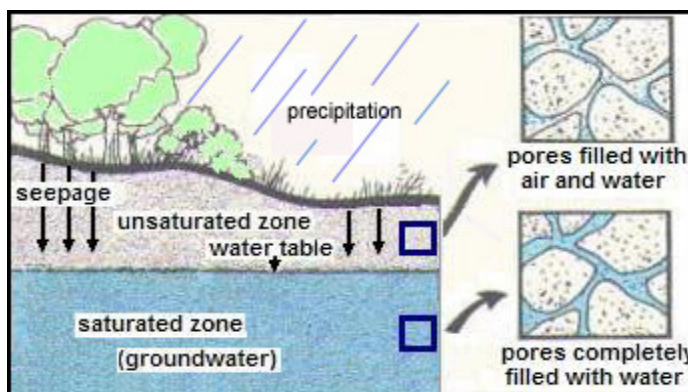


Figure 1: New York State Department of Environmental Conservation

Eventually it percolates deeper into the Earth. Under the soil layer, the zone of saturation has very small spaces between the rocks. The spaces

are so small they may even be the size of large molecules. When the water can go no deeper (because of impermeable rock layer), it creates an aquifer. An aquifer is an underground reservoir inside the rocks. Pollution seeps into the groundwater. Buried waste and landfills all let hazardous material seep into the groundwater. It happens naturally when water drains through the waste and seeps into the land. Eventually the groundwater will return to normal through natural filtration processes, but it will take several decades.

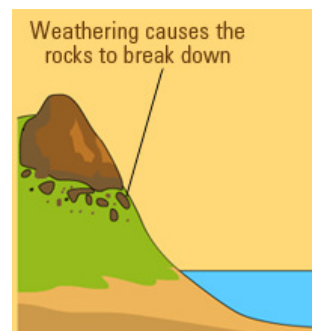
More on runoff. When rain hits saturated or impervious ground it begins to flow overland downhill. It is easy to see if it flows down your driveway to the curb and into a storm sewer, but it is harder to notice it flowing overland in a natural setting. During a heavy rain, water will flow along channels as it moves into larger creeks, streams, and rivers. As with all aspects of the water cycle, the interaction between precipitation and surface runoff varies according to time and geography. Similar storms occurring in the Amazon jungle and in the desert southwest of the United States will produce different surface-runoff effects. Surface runoff is affected by both meteorological factors and the physical geology and topography of the land. Only about a third of the precipitation that falls over land runs off into streams and rivers and is returned to the oceans. The other two-thirds is evaporated, transpired, or soaks into groundwater. Surface runoff can also be diverted by humans for their own uses.

- [Effects of Urban Development on Floods](#), USGS Fact Sheet 076-03
- USGS: [Surface-water data for the Nation](#)
- USGS: [Real-time streamflow data](#)
- USGS: [Surface-water information](#)

Weathering

Information for this section from: www.kidsgeo.com/geology

Weathering takes place as rocks are broken down into progressively smaller pieces. A large chunk of bedrock many hundreds of feet long is broken down into smaller and smaller pieces, until finally there are many tens of thousands of small rocks. Often rocks are broken down so much that they become part of the soil.



<http://pixgood.com/weathering-and-erosion-of-rocks.html>

Forces of weathering. Water is an important force that greatly effects weathering, but it is not the only force. Other forces include the atmosphere, and plant and animal life. Plant roots, microscopic animals and plants, and digging animals also help to break down rocks. To better understand the different forces that cause weathering, geologists separate them into three categories. These categories are mechanical, chemical, and biotic. This unit does not explore weathering, but details are provided here since so you can discuss it further with students if it becomes relevant to their thinking.

a. **Mechanical Weathering.** Mechanical weathering takes place when rocks are broken down by physical force, rather than by chemical breakdown. The forces that break rocks can be numerous, and include such things as pent up energy as the Earth's crust slowly moves. When great amounts of pressure build up, the resulting mechanical effect can be that very large joints, or faults are created.

- i. **Frost wedging.** In liquid form, water can penetrate the many holes, joints, and fissures within a rock. As the temperature drops below 32 ° F, this water freezes. As water freezes, it expands, becoming about 9% larger than it was in liquid form. The result is that the holes and cracks in rocks are pushed outward. Even the strongest rocks are no match for this force. As the water thaws, it is then able to penetrate further into the widened space, where it later freezes again. The expansion of holes and cracks is very slow. Month after month, year after year, water freezes and thaws over and over, creating larger holes and cracks in the rocks.

Urban Frost Wedging

In an urban setting, we often see this in the form of cracks in concrete. Potholes form when frost wedging is combined with the repeated pounding from cars. A quick video explains the process:

<https://www.youtube.com/watch?v=rg5Hwety4RU>

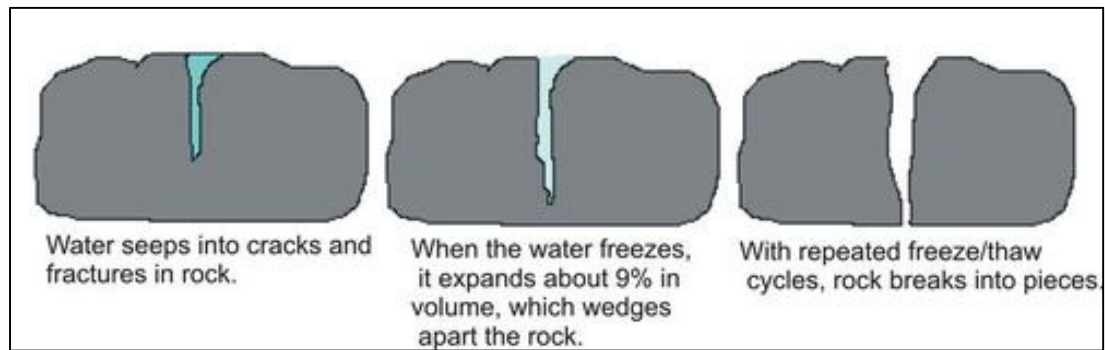


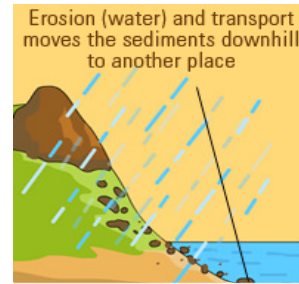
Image Source: <http://www.ck12.org/user:richb/book/Earth-Science-for-St.-Marys-School-Aiken/section/5.2/>

- ii. **Salt wedging.** As water enters the holes and cracks in the surface of rocks, it often carries salt with it. As the water later evaporates, the salt is left behind. Over time, these salt deposits build up, creating pressure that causes rocks to split.
- iii. **Temperature.** As temperatures rise, rocks expand slightly. As temperatures cool, rocks contract slightly. The effect of expanding and contracting over time weakens rocks, eventually causing cracks.
- b. **Chemical Weathering.** Chemical weathering takes place in almost all types of rocks. Smaller rocks are more susceptible, however, because they have a greater surface area. Chemical reactions break down the bonds holding the rocks together, causing them to fall apart into smaller and smaller pieces. Chemical weathering is more common in locations where there is a lot of water. This is because water is important to the chemical reactions that can take place. Warmer temperatures also speed up the rates of reactions. Warm and wet places have lots of chemical weathering.
- c. **Biotic Weathering.** Biotic weathering is any type of weathering that is caused by living organisms. Most often the culprit of biotic weathering is plant roots. These roots can extend downward, deep into rock cracks in search of water and nutrients. In the process, they act as a wedge, widening and extending the cracks. Other causes of biotic weathering are digging animals, microscopic plants and animals, algae and fungi. Though plant roots do widen cracks and break rocks, roots are also good at holding onto soil and preventing erosion.

Erosion

Information for this section from: www.kidsgeo.com/geology

Erosion takes place when materials in the landscape are moved from one location to another. This might happen as dust is blown off the side of a cliff face by wind, or as silt is carried downstream by a river. In the context of this unit, water erosion is our main focus.



<http://pixgood.com/weathering-and-erosion-of-rocks.html>

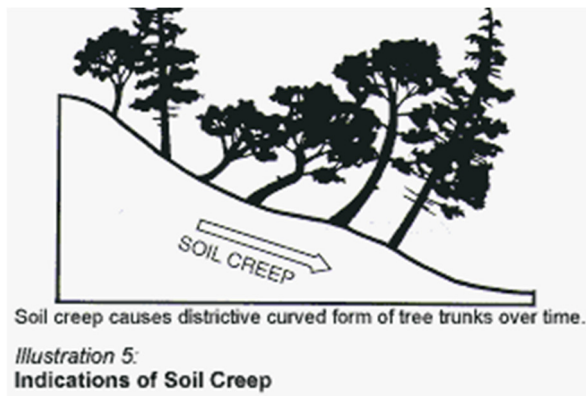
Erosion due to gravity:

Mass Wasting. The power of gravity on Earth is inescapable. Gravity pulls a rock lower and lower towards the lowest surface possible. Rocks, dirt, and soil lie on the side of a mountain or hill, apparently unmovable. For many hundreds or even thousands of years the rocks and dirt change very little. Over time, however, as small amounts of dirt and additional rocks are added to the pile, the weight and mass of the pile build up. Then, suddenly, the entire pile might move several hundred feet within only a couple of minutes or seconds, only to once again come to rest on the side of the mountain or hill, waiting for the next event.

- a. **Rock falls.** The most common type of mass wasting is falling. Rocks, boulders, pebbles, and dirt loosened by freezing, weathering, and other forces, simply fall downward, until they hit something that stops their descent. Often a pile of rocks forms at the bottom of a cliff or mountain. We call a pile of rocks, boulders, and dirt a talus. Often, taluses form a cone shape, as they ascend the side of the mountain.
- b. **Landslides.** Landslides take place when dirt, pebbles, rocks, and boulders slide down a slope together. Sometimes these landslides are small, and hardly noticeable. Other times however, they can be substantial, involving the entire side of a mountain. These destructive slides can be triggered by several different causes. Often rain, which adds additional weight to the side of a slope, can cause slides. Other times they might be caused by erosion, as the base of a slope is slowly removed by a stream, weakening the entire side of the mountain. As a slide progresses down a mountain slope, it can pick up tremendous speed and energy. Some slides have been reported to travel at speeds approaching 200 miles per hour. The resulting winds can be so forceful that they are known to strip the leaves off surrounding trees. The momentum of falling material has been known to cause some of the materials to roll several hundred feet back up the other side of a valley. The amount of material moved in a landslide can be tremendous. In some cases, this material is so substantial that it is measured in cubic miles. This much material falling across a stream can be the cause for the formation of a new natural lake.
- c. **Flows.** Flows take place much more slowly than do slides, and usually involve great amounts of water. After a heavy rainstorm the ground can become too wet to absorb any additional water. The result is that the water is forced to run off on the surface, gathering dust, dirt, rocks, and in some cases, even boulders as it builds up. The leading edge of a flow gathers

the most debris, causing it to be thicker and slower moving. This acts as a slow-moving dam. Eventually, such as in a wide area on a slope, the more liquid mud from behind breaks through the dam and rushes outward creating a muddy plain.

- d. **Creeps.** The slowest type of mass wasting is referred to by geologists as a creep. The grass-covered slope seems to ooze downhill forming little bulges in the soil. This heaving of the soil occurs in regions subjected to freeze-thaw conditions. The freeze lifts particles of soil and rocks (because water expands when it freezes) and when there is a thaw, the particles are set back down, but not in the same place as before. Gravity always causes the rocks and soil to settle just a little farther downslope than where they started from. This is the slow movement that defines creep. Creep can also be seen in areas that



: <http://www.ecy.wa.gov/programs/sea/pubs/93-31/chap2.html>

experience a constant alternation of wetting and drying periods, which work in the same way as the freeze/thaw. Since the process is so slow, it can only be monitored in terms of flow over long periods of time. A creep takes place when the entire side of a hill or mountain moves downward under the weight of gravity, very slowly, usually much less than one inch per year. The rate of creep depends on the steepness of the slope, slope material and water absorption properties, and amount of vegetation. (Source: <http://earthsci.org/flooding/unit3/u3-03-03.html>)

Erosion due to water

Many types of erosion described above are, at the core, caused by how water interacts with land causing the land to move. Here are ways water more directly moves soil and rocks.

- a. **Rain.** As rain drops begin falling in a rain storm, they are first absorbed by the landscape. As the ground becomes saturated, the drops begin moving across the landscape above the surface. As this happens, small amounts of dust and dirt are carried with the water. This is known as splash erosion. As more and more water falls, the sheet of moving water becomes larger and larger. Large amounts of rain that cannot be absorbed into the ground either because the ground is supersaturated from prior rains or the land has been altered by pavement or deforestation, this rainwater carrying particles of silt and sediment runs off downhill into streams and rivers.
- b. **Streams & Rivers.** Because of their strength, streams and rivers can cause a great amount of erosion. Dirt and dust is carried away in the water of the river, leaving only pebbles and rocks. The rocks are constantly smacking into one another, as the force of the river moves them about. This causes them to be continually breaking into smaller and smaller pieces. Rivers have been known to carve deep canyons in the bedrock in only a few hundred thousand years (e.g. the Grand Canyon). As rivers carry dust, pebbles, and rocks downstream, this material is eventually deposited at some location further down. These deposits form at bends in a river, as well as in

locations where rivers dump water into lakes, seas, and oceans. The effect of deposits is that new land is created using materials from other locations upstream.

Land use, infiltration, and runoff

Information taken from: <http://omp.gso.uri.edu/ompweb/doe/teacher/pdf/act10.pdf>

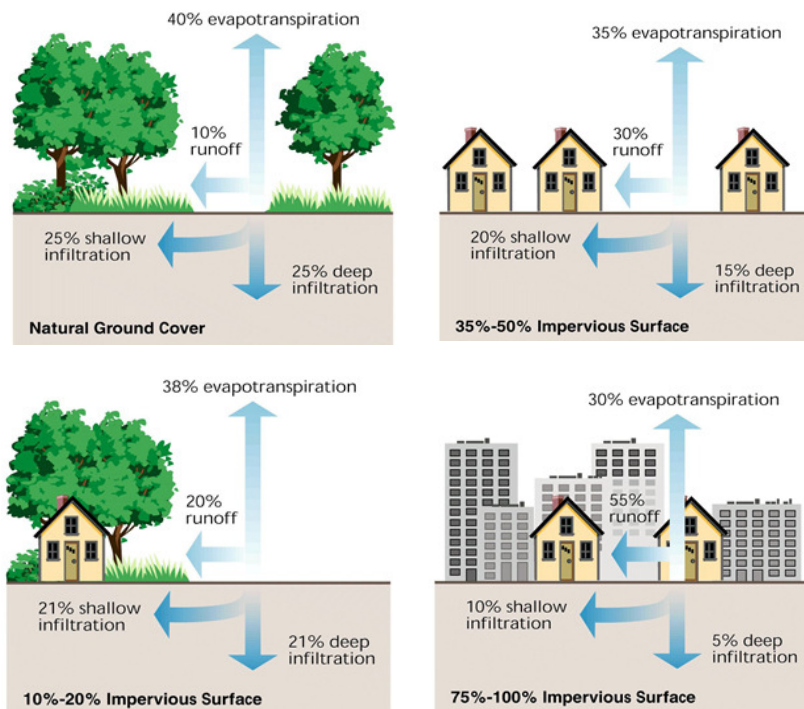
Changes in how we use and change the land affects our watersheds. Water may flow in a different direction, more water reaches the rivers, lakes, and oceans, and the water gets to these bodies of water faster without sediments and pollutants being removed by slow infiltration into the soil. The amount of nutrients, sediments, and toxic materials from increased runoff and soil erosion can seriously harm ponds, streams, and groundwater resources. Infiltration is when water seeps into the soil and rock and recharges an aquifer. Currently, aquifers are being depleted due to the huge water demand of American industries, farms, and families.

Forests have less runoff because leaves and trees slow down the rain before it hits the ground, giving plant roots time to absorb water and time for the water to soak into the earth. When land is paved or cleared for buildings, the vegetation is removed and the land is covered by blacktop or concrete. There is no longer any vegetation to slow down the rain hitting the ground and since the ground is covered, no water can soak into the soil. Instead, the water runs over the surface, often causing flooding and erosion. Our aquifers are also not being recharged with surface water as fast as they used to be.

Rates of infiltration for various land uses
 <-Greatest-----Smallest->
 forest > pasture > crop land > bare earth > buildings > pavement

Rates of runoff for various land uses
 <-Greatest-----Smallest->
 pavement > buildings > bare earth > crop land > pasture > forest

Figure 2: U.S. Environmental Protection Agency



Stormwater Runoff

Stormwater runoff is water from rain or melting snow that “runs off” across the land instead of seeping into the ground. In developed areas, the water that falls on hard surfaces like roofs, driveways, parking lots, or roads cannot absorb into the ground. These impervious surfaces create large amounts of runoff that can cause problems both locally and where it ends up. The runoff flows from gutters and storm drains to streams, sometimes causing flooding and erosion of stream banks, which can make the stream banks and areas around the stream unstable. Unstable streams can be problematic for the animals that depend on the stream for habitat, as well as humans that live near or depend on the stream. Flooding of streams and other bodies of water may also damage property and be dangerous to people.

Cities control stormwater runoff by channeling stormwater through pipes. Most modern pipes are designed to carry only stormwater runoff, however some older systems (including many areas of Seattle) combine runoff into the sewer system and carry it all to a sewage treatment plant. Combined sewer overflows (CSOs) are relief points in older sewer systems that carry sewage and stormwater in the same pipe. When heavy rains fill the pipes beyond normal capacity, CSOs release sewage and stormwater into rivers, lakes, or Puget Sound. Every year, rain washes millions of gallons of untreated sewage and stormwater into the city’s waterways, threatening human and aquatic health and our quality of life. Each year, on average, more than 300 sewage overflows send millions of gallons of raw sewage and stormwater into Seattle’s creeks, lakes, the Ship Canal, the Duwamish River, and Elliott Bay. These combined sewage overflows (CSOs) create significant health and environmental risks. In Seattle, King County, and the City of Seattle are working together to control CSOs and keep sewage and stormwater out of local waterways.

Polluted stormwater runoff is a major concern for our region. Stormwater runoff in urban settings picks up pollution, such as chemicals, bacteria, sediment, and trash, and washes these things into ditches and storm drains, and then into creeks, rivers, ponds, and lakes. Much of the “behavior change” efforts of cities and other agencies and organizations is aimed at decreasing the amount of pollutants that enter stormwater runoff by encouraging people to pick up dog waste, wash cars at carwashes instead of on driveways, and use fewer chemical yard care products.

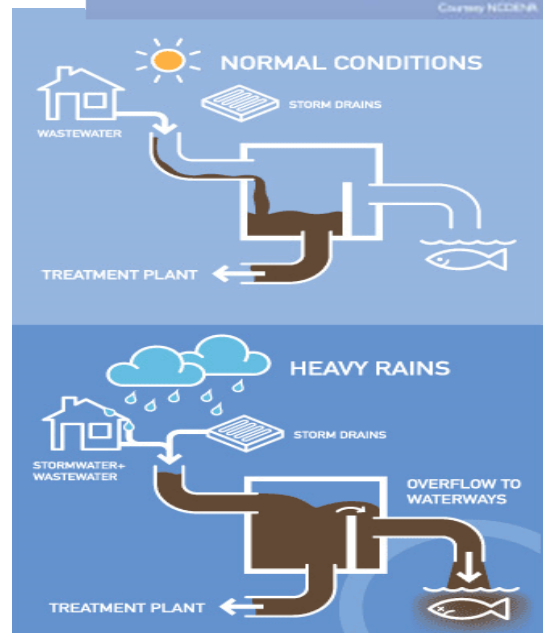
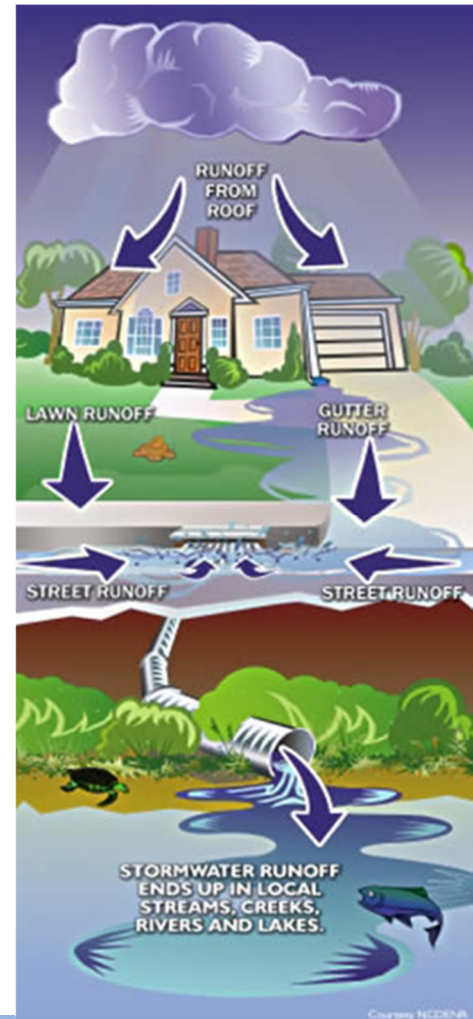


Figure 3: Seattle Public Utilities

While most regional efforts involve BOTH reducing the amount of stormwater runoff and the pollutants in the stormwater runoff, the focus of this unit is on the amount. This helps keep the focus on things the students can easily see and measure and leaves polluted water for the Middle School, “Solutions and Pollutions” science unit. Reducing the amount of stormwater runoff helps with pollution concerns, and pollution will likely come up in discussions, it just won’t be among the student’s criteria for success.

See also: <http://www.kingcounty.gov/environment/water-and-land/stormwater/introduction/science.aspx> and <http://www.700milliongallons.org/take-action/#learninglibrary>

Local Watersheds:

<http://www.kingcounty.gov/environment/watersheds/general-information/introduction.aspx>

<http://www.kingcounty.gov/services/environment/wastewater/cso/about.aspx>

<http://www.seattle.gov/util/EnvironmentConservation/Projects/SewageOverflowPrevention/index.htm>

Stormwater Runoff Solutions

Solutions to problems associated with stormwater often fall under what is termed “green stormwater infrastructure” (GSI) or more generally “low impact development” (LID). GSI involves some degree of engineering to address stormwater issues in ways that utilize nature (soils, vegetation) and natural processes. “Gray stormwater solutions” that do not utilize nature are also an option to solve stormwater problems. According to the Environmental Protection Agency, “green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits” (<https://www.epa.gov/green-infrastructure/what-green-infrastructure>). Treating water “at its source” involves features that slow down stormwater and spread it out in order to allow it to soak into the ground.

Seattle’s GSI approaches include trees, bioretention, pervious pavements, green roofs, and rainwater harvesting. In addition to the stormwater management functions of these practices, these technologies can also help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits.

Low-impact development (LID) is a stormwater and land use management strategy that strives to mimic pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation, and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.

Green stormwater infrastructure examples used in this curriculum:

- rain gardens
- green roofs
- soil improvements such as mulch and incorporating compost
- bioswales (also known as bioretention or swales)

Climate Change and Stormwater

As the intensity and frequency of storms increases in the northwest due to climate change, so does the need for solutions to prevent flooding and other stormwater runoff problems.

Climate change in the Pacific Northwest leads to wetter fall/winter seasons and drier spring/summer seasons; therefore, more water needs to be absorbed into the ground (especially in cities) in winter so it doesn't cause flooding. This increases the need for GSI and fewer impervious surfaces.

Seattle’s plan:

<https://www.seattle.gov/environment/climate-change/planning-for-climate-impacts>

- tree planting
- pervious surfaces (also called permeable pavement, or permeable surfaces)
- rainwater collection (also called rain barrels and cisterns).

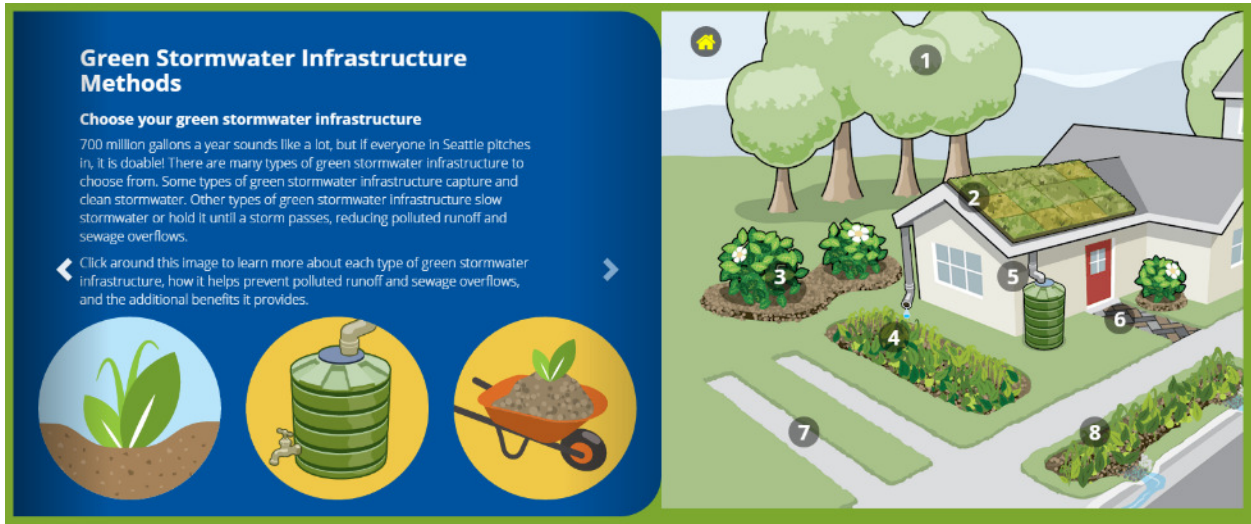


Figure 3: Image from <http://www.700milliongallons.org/types-of-gsi/>

As stormwater runoff becomes increasingly understood by scientists (for example, that polluted runoff has deadly effects on salmon) and green stormwater infrastructure is developed to manage runoff in our cities, education is needed for adults and youth to better understand the challenges and solutions. In schools around the country, especially in urban areas, stormwater is a “hot topic.” Students in many places are not only learning about stormwater, pervious and impervious surfaces, and green infrastructure, they are seeing and helping with stormwater projects in their schoolyards.

Green stormwater infrastructure (GSI) projects at schools and involving students have many benefits beyond the ecological value that these projects provide. These projects can serve as models for other schools, school districts, and government agencies. Stormwater solutions that are at least partially engineered (designed) and/or implemented by students have a variety of benefits, such as:

- empowerment in learning through relevant, hands-on, team-based projects,
- skill-building and career development,
- experiential learning in STEM (specifically engineering),
- fostering engaged, knowledgeable citizen stewards.

<http://www.700milliongallons.org/wp-content/uploads/2015/04/RainWise-Practices-overview.pdf>

<http://www.700milliongallons.org/types-of-gsi/>

<http://www.700milliongallons.org/gsi-around-you/>

See also:

Video: “Runoff: Special Report” on stormwater engineering solutions: <http://vimeo.com/84964332>; and

12,000 Rain Gardens about rain gardens in our region: <http://www.12000raingardens.org/>

Please refer to your school-specific Teacher Guide for more details about where your stormwater goes!

Strategies for Outside Learning

Outside spaces provide tremendous learning opportunities, but can also present challenges that are very different from teaching in a classroom. This section includes things for a classroom teacher to think about both before and during the student's outside learning experience.

Setting Yourself up for Success

Planning

- **Scout the Site:** Any safety issues? What will your student boundaries be if you are letting them wander? What are potential distractions for the students? When is recess happening and can you avoid that time period?
- Set aside time the day before and just before you head out to prepare the students for the experience. Which portions of your lesson need to happen outside? Are there things you could do in the classroom before or after the outside time?
- Create a detailed schedule that includes time for students to use bathrooms and to walk to the location.
- Check the weather report and make a contingency plan for inclement weather.
- If the field study requires finding specific organisms, consider having pictures or pre-collecting organisms to be sure to have some on hand.
- Divide students into groups that will work well together. Do you have any students that need a specific job to keep them focused?
- If you are leaving the school grounds, get permission and permission slips for a walking field trip.
-

Arranging for Support

- Arrange for at least one Chaperone to be with you outside (3-5 is better). If parents aren't available, can your principal, student teachers, or other school staff assist?
- If you have students with special needs will they need their own assistant?
- Assign a chaperone to bring up the rear of the group.
- Make sure the office knows where you will be.

MATERIALS

- Whistle, megaphone or other noise maker
- Plastic sheet protectors for your notes
- Student Writing Surfaces (Clipboards or cardboard with binder clips)
- Teacher Writing Surface (Clipboard & a mini white-erase board)
- Extra pencils
- First Aid Kit
- Overhead sheets or sheet protectors can be clipped on top of student work to shed water on a drizzly day.
- Back up rain gear: Borrow items from your school's lost and found? Garbage bags with head and arm holes can also function as ponchos in a pinch.

Preparing the Students

Most students think outside means recess-time and all students find a lot more to distract them when outside. You can overcome this by setting up an expectation for learning and front loading as much as possible in the classroom before you head out.

1. Remind students the day before to bring rain gear and seasonally appropriate clothing.
2. Make it clear students will be outside for learning, not recess. Some teachers leave the building through a “science door” that is different than the door students use for recess.
3. Create and practice ground rules for going outside including an attention signal. A loud call-back is helpful amidst outside distractions.
4. Explain the outside plan in detail. Are there things you can practice inside?
5. If you anticipate distractions (like a recess or construction), prep the students to ignore them.

Outside with the Students

During Talk Time

- Gather students in a circle for group sharing.
- Sit students down (if dry) to focus them on you.
- Review what you went over inside including expectations and what they will be doing.
- Put the sun in your eyes to keep it out of the student’s eyes.
- Establish student boundaries (trees, sidewalks, fences, and posts all make good edges).

Adapting to the situation

- **Animals** are exciting! Let students focus on them and then segue back to the lesson.
- **Weather’s** impact depends on the students, amount of rain, and temperature. Can the students keep going? Do they need temporary shelter? Are you going to need to reschedule?
- **Lawnmower** noise can be overwhelming: relocate temporarily or provide some open exploration time and then continue once it has moved away.

Adapting to the students

- High energy students might benefit from running to a location and back.
- Moving students might be focused by sitting down.
- Shade, shelter, and location can all be changed to meet student needs.

STUDENT BARRIERS

Student’s outside experiences vary, and concerns interfere with their involvement:

- Modeling your comfort and excitement helps!
- Students could sit on plastic squares or garbage bags.
- Avoiding muddy areas can help with shoes.
- Garden kneel pads are great if you want the students to kneel on the ground.
- Check the ground for moisture, mud, and animal scat before asking students to sit.
- Gloves, plastic spoons, and/or yogurt lids are helpful for those who are worried about touching things.

Unit Vocabulary

Vocabulary in this list is called out as “new terms” listed in each lesson. We have translated these terms into six languages (Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese). They are available at <http://communitywaters.org>. There are also printable “Word Wall” cards available in the curriculum section of the website.

Stormwater Terms

| | |
|---------------------------------|---|
| Combined Sewer Overflow: | Occurs in a combined sewer system (one that collects stormwater runoff, sewage, and industrial wastewater in the same pipe) when the volume of water exceeds the capacity of the system. This can occur during heavy rain/storm events. |
| Erosion: | When rocks and soil are picked up and moved to a different place by ice, water, wind or gravity. |
| Groundwater: | Water that is in the soil, in the spaces between soil particles. |
| Impervious surface: | A hard surface that does not allow water to pass through or into the ground. |
| Pervious surface: | A surface that allows water to pass through or absorb into the ground. |
| Pollution: | The presence or introduction of a harmful substance into the environment (excess of a non-harmful substance can also become harmful; for example: too much noise = noise pollution). |
| Rain garden: | A garden which is designed with specific plants and an area for water to pool so that the water has time to soak into the groundwater. |
| Runoff: | Water that is not absorbed into the ground, and instead runs off the ground (usually off impervious surfaces) and into storm drains or bodies of water. |
| Storm drain: | A drain that carries away excess water from a street, parking lot, or other surface during times of heavy rain. |
| Stormwater: | Water that falls onto the ground in significant amounts. Usually from a heavy rain or snowstorm. |
| Urban: | Having to do with a city or town. |
| Weathering: | The breaking up of rock into smaller pieces by wind, water, plants, or other natural processes. |

Engineering Terms

| | |
|------------------------------------|--|
| Constraints: | Limitations on possible solutions often including cost, materials and time. |
| Criteria for success: | Requirements that a solution must meet to be successful. |
| Engineer: | Somebody who solves problems using science and an engineering design process. |
| Engineering Design Process: | A series of steps to follow to solve a problem. |
| Failure point: | A part of a system that will cause it to stop working if it fails. Finding a failure point in a solution permits changes improve the solution. |
| Optimizing: | Testing solutions to make a solution as effective as possible in meeting the criteria and constraints. |
| Problem: | What we are trying to fix. |
| Solution: | Something that meets a problem’s criteria for success and stays within its constraints. |
| Stakeholder: | People who care about a problem and would be affected by its solution. |

Experimental Terms

| | |
|-----------------------------|--|
| Changed Variable: | Factor that is intentionally changed during an experiment to affect the outcome (also called an “independent variable”). |
| Controlled Variable: | Factors that are kept the same each time an experiment is run. |
| Fair Test: | An experiment with one changed variable and all other variables controlled. |
| Measured Variable: | Factor that is measured to determine the outcome of the experiment (also called a “dependent variable”). |
| Variables: | Factors that can affect the outcome of the experiment. |

Unit Storyline

Phenomenon: When there are rainstorms in Seattle, problems happen. Why? What kinds of problems? What helps?

| Lesson <i>Focus Question</i> | Overview | Page Time | What should students be able to explain? | How does this add to their explanatory model? |
|---|--|----------------------------------|---|--|
| 1: Flooding in Seattle <i>“Why does flooding happen in Seattle?”</i> | Students watch a video about flooding in Seattle and flesh out their understanding of what is going on. | p. 37 60 min | <ul style="list-style-type: none"> • Their current understanding of stormwater and why they think it might form a puddle in a parking lot (the explanatory model). | <ul style="list-style-type: none"> • Students fill in the explanatory model with their initial explanation. |
| 2: Modeling rain on land <i>“What happens when rain falls on soil?”</i> | Students create “rain” on a tub with soil in it, record observations, and relate them to readings about groundwater & erosion. | p. 47 60 min + reading | <ul style="list-style-type: none"> • Rain is absorbed into soil and runs across it. • Rain can cause erosion by picking up soil and moving it to a new place. | <ul style="list-style-type: none"> • The flooding water was coming from somewhere. • Some water soaks into and moves through the soil (details could be shown in a Zoom In). |
| 3: Stormwater in the Schoolyard <i>“What happens to stormwater when it falls on our schoolyard?”</i> | Students walk their school grounds as a class to figure out where the water goes and problems it causes. | p. 59 60 min | <ul style="list-style-type: none"> • Water moves through the schoolyard. • Water flows across impervious surfaces and soaks in to pervious surfaces. • Water often flows into storm drains or stormwater ditches. • Stormwater causes local problems. | <ul style="list-style-type: none"> • Water flowed to the flooding area from the rooftops, sidewalks, and/or parking lot. • Impervious surfaces are the likely cause of the flooding. |
| 4: The Effects of Plants <i>“How do plants affect stormwater runoff?”</i> | Students compare what happens when “rain” falls on a tub with soil and a tub with grass growing on the soil. | p. 69 90 min | <ul style="list-style-type: none"> • Models with grass in them have less runoff and erosion. • Plant roots hold onto soil. • Plants slow down and soak up water. | <ul style="list-style-type: none"> • Plants roots help hold onto soil (could be shown in Zoom In). • The trees in the model are helping prevent problems in that area. |
| 5: Local Stormwater Systems <i>“Where does our stormwater runoff go and what problems does it cause?”</i> | Students analyze maps to determine where their stormwater goes and watch a video about the problems it causes. | p. 85 60 min | <ul style="list-style-type: none"> • There is a stormwater pipe (or ditch) system that carries the water away from our area. • Stormwater that leaves our site can cause problems where it ends up. | <ul style="list-style-type: none"> • Stormwater pipes could be drawn in underground sections in the model. • Water is affecting areas outside of where we are modeling. |
| 6: Stormwater in our Community <i>“What happens to stormwater in our neighborhood?”</i> | Students investigate what happens to stormwater in their neighborhood either on a walking field trip or with a take home assignment. | p. 93 60 min | <ul style="list-style-type: none"> • All the things we have been studying that happen with stormwater in our schoolyard also happen in our neighborhood. • Various features in our community affect how stormwater moves and/or soaks in. | <ul style="list-style-type: none"> • Stormwater flows through other areas beyond the school grounds. • Storm drains and other features could be added to the model. |

Engineering Challenge: Too much stormwater runoff is causing problems at our site and where it ends up. What is the best solution?

| Lesson <i>Focus Question</i> | Overview | Page Time | What should students be able to explain? | How does this help solve the problem? |
|---|--|---------------------------|---|--|
| 7: Choosing A Problem <i>“Where do we want to solve a stormwater runoff problem?”</i> | The class chooses a local site with a stormwater problem and explains what is happening through a model. | p. 109 60 min | <ul style="list-style-type: none"> Why the class chose the spot and what problems stormwater causes there. What is happening with stormwater runoff at their site. | Students understand what is causing the problem they are trying to solve. Engineers use science to understand the problems they are trying to solve. |
| 8: Defining our Problem <i>“What do we need to know before we research solutions for our site?”</i> | Students define the criteria for success and constraints on possible solutions for their problem. | p. 121 60 min | <ul style="list-style-type: none"> The Engineering Design Process and how it applies to solving their problem. Why their criteria for success are important and what constraints will limit their possible solutions. | The criteria and constraints will be used to choose among possible solutions for their problem. Engineers define the problem they are trying to solve. |
| 9: Modeling the Site <i>“How do we best model stormwater at our site?”</i> | Students build a model of their site in their soil tubs and class runs a baseline test for later comparison. | p. 133 0-60 min | <ul style="list-style-type: none"> How the model represents their site. Improvements they made to their model to better represent their site. Ways in which the model does not represent their site. | Creates baseline data they can use later when optimizing their solution. Engineers use models as a part of their work. |
| 10: Researching Solutions <i>“What solutions should we consider for our site?”</i> | Students brainstorm and research possible stormwater runoff solutions. | p. 145 45 min+ | <ul style="list-style-type: none"> The advantages and disadvantages of each solution they research. | Students research possible solutions. Engineers research possibilities as a part of developing a solution. |
| 11: Evaluating Solutions <i>“Which solution will best meet our criteria and constraints?”</i> | Students evaluate the solutions they researched to decide which one is best for their site. | p. 153 45 min | <ul style="list-style-type: none"> Why the solution they chose best fits their criteria for success and constraints. Which solution they are going to test. | Students choose a solution to test. Engineers compare possible solutions to pick the best option. |
| 12: Modeling Solutions <i>“How do we model our solution?”</i> | Students add their solution to the model of their site and add some water to it. | p. 161 60 min+ | <ul style="list-style-type: none"> How the model represents their solution. That testing a solution can be used to improve it and to compare it to other ideas. | It will provide a model they can test. Engineers test their solutions both to help choose one and to optimize the one they choose. |
| 13: Testing Solutions <i>“How can we improve our solution?”</i> | Students adjust their solution model and test its impact on stormwater runoff. | p. 169 60 min | <ul style="list-style-type: none"> Why any adjustments were made to their model. The variables they controlled and measured. How well their solution worked. | The data can be used to improve their solution. Engineers test their solutions |
| 14: Finalizing Solutions <i>How effective is the solution my group modeled?</i> | Students revise and refine their solution and analyze how effective it is. | p. 175 60 min | <ul style="list-style-type: none"> Whether the testing was a “fair test.” Whether their solution meets the criteria and constraints for their site. | Students decide whether their solution would work Engineers use data to evaluate their solutions. |
| 15: Communicating Results <i>“How will we share what we have learned with others?”</i> | Students communicate about the solutions they tested to peers and/or stakeholders. | p. 185 60 min+ | <ul style="list-style-type: none"> Whether their solution is a good choice and their evidence for their claim. | Ideas need to be shared by students and Engineers if they are going to be put into action. |

Implementation Planning

IslandWood Support & Field Investigations

IslandWood is collaborating with Seattle Public Schools to support implementation of this unit. Direct support includes large group professional developments for new and returning teachers, a planning session at your school, opportunities to review student work with other teachers, assistance with a Walking Field Trip and additional support as needed and available. IslandWood offers a free optional field trip to investigate a stormwater infrastructure site. IslandWood staff also monitor Seattle School's Community Waters Schoology Group and participate in any discussions that occur there.

All digital materials and additional supports can be found on communitywaters.org. Among other things, these include:

- Links and handouts specific to each lesson.
- School specific information and maps.
- Short training videos focused on materials set up and for specific lessons.
- Translations of many of the student worksheets into Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese.
- Additional resources, contacts for external field trips and curriculum extensions including ideas towards implementing a project with your students.

Things to schedule with IslandWood:

- **Planning Session:** IslandWood staff meet with all the teachers at your school after school for two hours. This is a follow up to the unit professional development and includes information specific to your schoolyard and surrounding neighborhood with a tour of your schoolyard to look at what is happening with stormwater and possible sites where stormwater runoff problems are visible.
- **Walking Field Trip (optional):** IslandWood staff can be scheduled to teach the outside portion of Lesson 6 with your students. IslandWood support is available for teachers doing it for the first time. Capacity and funding for this is limited so please schedule it right away!
- **Community Waters Field Study (optional):** This outdoor field study explores stormwater engineering at a Green Stormwater Infrastructure or stream site. It is funded by Seattle Public Utilities and space is limited. More details can be found at communitywaters.org.

Please go to communitywaters.org to schedule these items or email communitywaters@islandwood.org with any questions.

Timing & Checklists

Unit Planning:

- ❖ See the Unit Storyline (above) for an outline of all lessons in the unit. This unit includes 15 lessons requiring 16 forty-five to 60-minute sessions. Given time constraints and different classroom needs, we expect you will need to plan for 15-22 sessions to complete this unit.
- ❖ You may end up changing the sequencing of lessons two through six based on your student's understanding of stormwater.

To Schedule with IslandWood (teacher support section on communitywaters.org)

- Your school's **Planning Session** with IslandWood to occur before you start the unit (or at least ahead of doing the schoolyard investigation in Lesson 3).
- Optional: **Walking Field Trip from Lesson 6** for your class to occur between Lessons 3 and 7.
- Optional: **Community Waters Engineering Investigation** to occur after Lesson 5 in the unit.
- Be sure to reply to any emails from IslandWood to confirm your dates!

Arrange Chaperones

- 2+ (at least one) chaperones to be with you for Lesson 3 when you take students outside on to the school grounds.
- 2+ chaperones for the walking field trip if you do it.
- One or more chaperones for the Community Waters Engineering Investigation if you do it.
- If you have them, volunteers can also be a big help to assist with materials management (see below) and when students are working on their site and solution models (Lessons 9, 12, & 13).

Other Communications:

- Get permission forms signed for the Walking Field Trip and/or Community Waters Engineering Investigation.
- Arrange for stakeholders to interview or experts to consult with if you want to do so as a class when defining the problem in Lesson 8 and/or presenting your solutions in Lesson 14.
- Send home the Take Home Interview for students to do with an adult after Lesson 14.

Materials (see also materials section in each lesson):

- Arrange to get access to 11x17 paper for the student's explanatory models (2 pages per student).
- Once Kit Arrives:** Set up 8 soil tubs with seeds planted in 3 of them following the directions in "**Lesson 0**" below (consider whether you want to do this outside class time or with students). This needs to happen early so you have time to grow plants by Lesson 4.
- Before Lesson 9: Set up a tub to serve as an example of the site (and consider whether you prefer to create all 8 models outside of class time).

No Sinks? If you are in a portable or classroom without sinks, materials management is more challenging. Some things that can help:

- A large container that can hold and dispense water.
- A big tub to rinse off materials in.
- Extra towels and hand wipes for cleaning up.
- Planning enough time to take the class to the bathrooms for handwashing after Lessons 2, 4, 9, 12, and 13.

Lesson Details

Pre-Unit Prep & Take Home Assignment

OVERVIEW

This “lesson” focuses on things to do before starting the unit with the students. It is important to do these things ahead of time so students have time complete their take home interview and so plants have time to grow in three of the **stormwater tubs before Lesson 4**.

1. Students interview a family or community member about personal and cultural experiences with stormwater.
2. The teacher sets up stormwater bins (with help of student or parent volunteers if desired).

Focus Question: What experiences have others had with water?

New Terms: stormwater

Ambitious Science Teaching: Eliciting students' ideas



Information gathered by eliciting all students' initial hypotheses about a scientific idea, and making a public record of these can inform instructional decisions for upcoming lessons. For more about this practice of eliciting students' ideas, visit <http://AmbitiousScienceTeaching.org>

MATERIALS

Website



communitywaters.org

For each lesson in this curriculum all worksheets, links, and graphics can be found on the communitywaters.org website. There is a separate webpage for each lesson in the curriculum. Find them under the “Lesson Specific Materials” menu choice at the top of each page.

Print for each student:

- **Pre-Unit Take Home Interview** – one per student (There are Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese versions available on communitywaters.org). The Pre-Unit Take Home Interview is undergoing some community reviews and may be edited so we recommend getting the most recent version of the website.

For Stormwater Bins (see below)

- 8 clear tubs “stormwater tubs” with drain holes
- 8 rubber stoppers
- 8 “Rain Jars” with holes in screw on lids
- Permanent pen (s)

For planting in three of the stormwater bins

- Ryegrass and Mustard seeds
- Small graduated 1-ounce cup(s)
- Spoon(s)
- Plant mister (spray bottle)
- Plastic sheeting (3)

- Soil Materials per tub:
 - o Sand (1500ml)
 - o Gravel (750ml)
 - o Humus-Potting Soil (500ml))
- Water (200ml per tub)
- Trowel(s)
- Paper towels and/or rags for cleanup
- Large rubber band (3)

PREPARATION – 45-60 minutes

IMPORTANT NOTE: Please review the **Implementation Planning** section of the manual (above). You will find directions for signing up for IslandWood support and checklists to help you anticipate upcoming needs.

TEACHER DECISION POINTS



This symbol will be used throughout the curriculum when there are options for you to consider as a teacher.

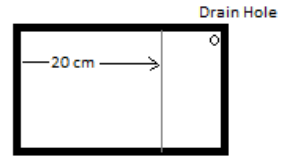
- **Interview Prep?** Review the **Pre-Unit Take Home Interview** (designed for students to ask questions of an adult in their home or community) at the end of this “lesson”. Decide if you want to dedicate any classroom time to have students practice it with each other and how much time you can give students to bring it back before you start teaching the unit.
- **Video:** watch the “Setting up your Stormwater Tubs” video (on communitywaters.org under Teacher Supports) if you want a visual walk through of the setup (described below).
- **Do you want to grow plants in the tubs?** If you have access to grass you can remove, we suggest digging up sections instead of growing plants. If you do so, you can wait to dig it up until after Lesson 2. When you dig up the grass, remove as much of the dirt from the roots as you can so the clumps don’t break loose during the Lesson 4 investigation. Don’t forget to use the spray bottle to water the grass frequently after you add it to the bins!
- **Help with stormwater tub setup?** The tubs can be set up without help, but parent or student volunteers might make the job easier. If you decide to do the set up with students we suggest doing the first two steps ahead of time and using the provided student friendly instruction sheet.

PROCEDURE FOR SETTING UP MATERIALS

1. **Organize Materials:** The bins currently provided by the district include materials that are not needed for this unit. We suggest printing the list of materials used during each lesson (available in the curriculum section on communitywaters.org) and setting aside the materials you won’t need. You could also move the materials you won’t need until lesson 9 into their own bin.
2. **Set Up a Materials Area:**
Prepare a materials distribution table or countertop area where students can store and access materials throughout the unit. Set out soil materials in containers

3. Draw Lines with Permanent Pen:

- In each of the 8 clear tubs, measure 20 cm from the side that does not have a hole and use a permanent pen to draw a line across the bottom and up the sides of the tub with permanent pen.
- On the outside of the 8 screw top containers with holes in lids ("Rain Jars"), darken the 1,000 ml and 500 ml lines. [With the smaller Ziploc brand jar, 1000 ml is when it is filled to the top].



4. Soil in Stormwater Tubs - Into each of the eight clear tubs:

- Put a small rubber stopper into the hole (from the inside).
- Use the 1,000 ml (1L) graduated cylinder and/or Rain Jars to add **1,500 ml of sand, 500 ml of humus, 750 ml of gravel, and 200 ml of water.**
- Mix all materials together with hands or trowel.
- Shape the materials in each bin into "blocks" between the black line and the side with no drain hole (20 cm long & 5 cm deep). The soil blocks should have a square cliff-like edge.



5. Plant Seeds in 3 of the 8 Stormwater Tubs you set up during step 3 (Keep the other 5 without seeds for use in Lesson 2).

- Sprinkle 30 mil of each type of seed over the soil block. Seeds should thickly cover the soil.
- Spread half a cup of humus in a thin layer over seeds.
- Use spray bottle to dampen the seeds.
- Cover with plastic sheeting* and secure with rubber band.
- Remove the rubber plug from tubs and stack each on top of an unplanted soil tub (angled a bit so excess water can drain into that tub).
- Leave in a sunny area and don't forget to water!



* The plastic sheeting helps the seeds germinate but can encourage the growth of mold in the tubs (see below). Once the plants are established, you can remove the sheeting to provide opportunities for the tubs to air out.

Materials Cleaning

It is important to keep sand and gravel out of classrooms sinks so they don't get clogged. Outside hose spigots are great, but otherwise, rinse materials into a larger bucket to empty outside.

At the end of the unit, used soil will need to be disposed of. Please do not disperse them in grass as they can interfere with lawnmowers. Instead disperse them under bushes under wood chips.

Mold in Your Tubs?

- **Water only when dry** – Mold normally happens when a plant is kept continually moist so check that the top of the soil is dry before you water.
- **Add more light** – Light helps reduce mold. Is there a location in your classroom with more of it?
- **Add a fan** – Good air circulation helps. Do you have access to a simple oscillating fan you could set on low?
- **Try Cinnamon?** – Cinnamon has natural anti-fungal properties. If you have some, you could *lightly* dust your soil with it and see if it helps.

Student Directions for Tub Set Up

Soil in Tubs

1. Put a small rubber stopper in each tub's hole (from the inside).
2. Use the 1,000 ml graduated cylinder and/or Rain Jars to add to each tub:
 - **1,500 ml of sand**
 - **500 ml of humus (potting soil)**
 - **750 ml of gravel.**
 - **200 ml of water**
3. Mix materials together with hands or trowel.
4. Move all the soil in each tub away from the hole so it is past the black line. Shape it into a block with a smooth top and a cliff-like edge.



Plant Seeds in 3 of the 8 Tubs

1. Sprinkle **30 mil of each type of seed** evenly over the soil block. Seeds should thickly cover the soil.
2. Spread **half a cup of humus** in a thin layer over seeds.
3. Use **spray bottle to dampen** the soil and seeds.
4. **Cover** with plastic sheeting and secure with rubber band.
5. **Remove the rubber plug from the tub and stack it** on top of an unplanted soil tub (angled a bit so excess water can drain into that tub).
6. Do this with JUST three of the tubs!

Community Waters Pre-Unit Take Home Interview

Date: _____

Student's Name: _____ Adult's Name: _____

Interview an adult in your household to see what they know about stormwater in your neighborhood.

Student reads to adult and records answers:

At school we are going to be studying what happens to rain after it falls in our city. Rain water that flows across the ground is called "stormwater runoff." My class will be investigating where stormwater goes in our schoolyard and neighborhood and the problems it can cause. Then our class will be choosing a location with a stormwater runoff problem and designing a solution for it.

I want to learn more about your experience with rain when you were my age. Can I ask you some questions?

1. What did you like to do when it rained? Did you like the rain? Why?

2. Where did the stormwater runoff go where you lived? Where did it end up?

3. What is a story about the rain you experienced or were told when you were my age? Do you remember rain causing any problems?

4. Does our family or culture have any traditions or stories that connect to water?

After recording your adult's answers, flip the page over and have them ask you the questions on the back.

Adult asks student:

1. What do you like to do when it rains?

2. What have you noticed happen to rain on the ground?

3. Do you go outside when it rains during recess at school? Does the rain ever cause any big puddles or other problems around your school?

4. How are my experiences with rain the same or different than yours? Why do you think so?

Lesson 1: Flooding in Seattle

OBJECTIVES & OVERVIEW

Students examine some of the effects of too much stormwater runoff in Seattle, and apply prior knowledge towards developing an explanation of the phenomenon.

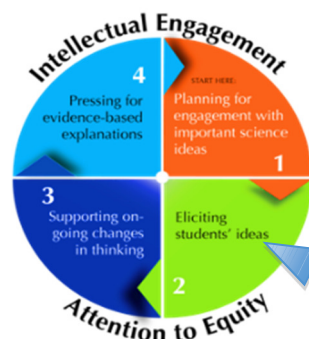
- Students will make and share observations about the effects of stormwater in an urban setting.
- Students will access prior knowledge to begin building an understanding of what is causing the stormwater runoff problem.

Focus Question: Why does flooding happen in Seattle?

Learning Target: I can create a model to share what I know about stormwater.

New Terms: stormwater, runoff

Ambitious Science Teaching: Eliciting students' ideas



Information gathered by eliciting all students' initial hypotheses about a scientific idea, and making a public record of these can inform instructional decisions for upcoming lessons. For more about this practice of eliciting students' ideas, visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

The students will address these standards in more depth later:

PE 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.

PE 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|---|---|
| <p>Asking Questions and Defining Problems.</p> <ul style="list-style-type: none"> • Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. • Use prior knowledge to describe problems that can be solved. | <p>ESS3.B Natural Hazards.</p> <ul style="list-style-type: none"> • 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. (4-ESS3-2) <p>ESS2.A Earth Materials and Systems.</p> <ul style="list-style-type: none"> • 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. (4-ESS2-1) | <p>Cause and Effect.</p> <ul style="list-style-type: none"> • Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS3-2) |

MATERIALS

For each lesson in this curriculum all worksheets, links, and graphics can be found on the communitywaters.org website. There is a separate webpage for each lesson in the curriculum. Find them under the “Lesson Specific Materials” menu choice at the top of each page.

For the class:

- Butcher/chart paper for Hypotheses and Questions
- Markers

Per student:

- Copy of the **Explanatory Model Worksheet**. Printing these on 11x17” paper will provide more space for student explanations and later additions.
- Colored pencils (optional) for students to use on their explanatory model.

PREPARATION – 20 minutes

IMPORTANT NOTE: Please review the **Implementation Planning** section of manual (above). You will find directions for signing up for IslandWood support, checklists to help you anticipate upcoming needs, and directions for the setting up of stormwater tubs and planting of seeds. (these things are not included in the preparation time listed for this lesson).

TEACHER DECISION POINT



Which Explanatory Model is best for your class?

Website



All worksheets, links, and graphics are on communitywaters.org

- **Review returned Take Home Interviews:** Consider what you learn about your student’s cultural and personal experiences with water. Is there anything you could tie in to the unit to inform understandings or increase engagement?
- **Decision Point:** Decide which version you prefer for the explanatory model. In addition to the one provided at the end of this lesson, we have a version without scaffolding on the website. We also anticipate providing additional versions on the website as we refine the model based on teacher feedback and student interactions with it. You can find all versions on communitywaters.org (in the Lesson 1 page from the “Lesson Specific Materials” menu option).
- **Video:** Queue up and test the “Flooding in Seattle” video (from communitywaters.org on the Lesson 1 page or at <https://vimeo.com/238148653>
- **Optional:** Later lessons ask for more preparation time – if you have time now you could create blank summary tables for each lesson and a consensus model (see Lesson 2 preparation).

PROCEDURE

Engage and Encounter

- **Introduction to Unit (whole class)**

This unit is all about “stormwater runoff” in our city. “Stormwater” is water that falls onto the ground as rain or snow. “Runoff” is water that travels across the surface of the land (not soaking in).

During this unit, the students will be examining the problems caused by too much stormwater runoff in their city, neighborhood, and schoolyard. Once they understand what causes the problems and what helps solve them, they will pick a specific problem site in their schoolyard or neighborhood and design a solution for it.

The students will have an opportunity to go outside and investigate what happens with stormwater, work with tubs of sand and dirt to build an understanding of what is happening, and create (and improve) their own models for solutions they come up with.

Turn-and-Talk



What have you observed after a big rainstorm?

- **Activate prior knowledge and experiences (whole class)**

Ask the students to talk with a partner about what they have observed after a big rainstorm in their neighborhood or the schoolyard.

Video Clip



“Flooding in Seattle”

Length: 2:03

communitywaters.org

- **Introduce and watch the video (whole class)**

Tell students they are going to see a video showing some effects of too much stormwater runoff in Seattle. While watching, they should be making observations: what problems are being caused in the video?

Direct link: <https://vimeo.com/238148653/>

Turn-and-Talk



What effects did you observe in the video?

- **Share observations about the problem (whole class)**

Start with a turn-and-talk to have students share observations about what they saw and heard with a partner. Then have individuals share what they noticed with the whole class (as you write them down on the board).

Has anybody in the class experienced any of these things themselves?

Reflect and Explain

Present visual



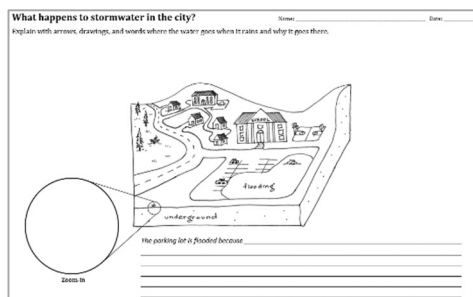
Explanatory Model



Initial Explanation

- **Develop initial models to explain the phenomenon (individually)**

To be able to solve flooding like what they saw in the video, students (and engineers) need to understand what is causing the problem. They need to understand how water flows through a city and what could increase or decrease the amount of flooding.



Project the “What happens to stormwater in the city?” model scaffold and explain the various pictures as needed for your class. Make sure students notice the hills and the flooding in the school’s parking lot.

Students will use arrows, drawings, and writing to explain what they think happens to the rainwater when it falls on the area shown. The “zoom in” can be used to show more detail or how something (like roots or soil parts) might be working.

This is to show THEIR understanding of what is happening; they won’t be graded on how “right” or “wrong” it may be and will be able to change their understanding as they learn more during this unit.

Different colors of pencils could be used to show differences in their model.

Intent of the model

The explanatory model scaffold is intended to help students explain **their** understanding of stormwater. It is a working recording that they can add to or start over as the unit progresses and their understanding builds.

It is important they have enough time working on this model to accurately represent their thinking.

Back-Pocket Questions



Observations & Modeling

These questions are provided for use with individuals or small groups while circulating

- **Pressing students for further explanation**

As students work on their explanatory models, circulate and ask them neutral questions (without judgement or correction) about their thinking. How could they show their thoughts in a picture or words on their sheet?

Back Pocket Questions

Observations

- What did you observe happening with the water in the video?
- What have you observed water doing when it rains around your neighborhood?
- You said you have seen water (insert students' observation). Why do you think it did that?

Modeling

- How can you show that on your model?
- How could you describe it in words on your model?



The YIELD symbol is used in this manual to suggest a spot you could stop for the day if you are out of time. We will leave it to you to reframe and review as needed when you return to the lesson later.

Explanatory Model



Gallery Walk

- **Pressing for possible explanations (whole class)**

Gallery Walk: Have students either place their models to be visible on their desks or tape them on the wall.

All students then circulate and look at each other's models. While circulating, they should be noticing what they see that is representing something they showed in their own model and what they see that is showing something different.

Public Record



List of Hypotheses

What hypotheses do students have about what kinds of things happen to stormwater in the city and why flooding occurs?

Discuss as a class and add ideas to the List of Hypotheses as you do so.

Apply and Extend

Public Record



List of questions

- **Students generate questions (individuals)**

On sticky notes, have students write at least one question they have about stormwater runoff in Seattle. Have students place the sticky notes on the Questions sheet.

You can then either sort and consolidate them as a class, or after class for later reference.

EXAMINING STUDENT WORK

Review the **Explanatory Model Scaffolds** the students created. They are intended to help you see what your students do and do not know.

What understandings are students showing they already have?

| Understandings desired: | How it might be shown by student | Lesson intended to help with this understanding |
|---|---|---|
| Water flows downhill | Arrows pointing downhill | Could be made explicit in many lessons |
| Water soaks into soil and moves through it. | Arrows or description of water “soaking in” or being “absorbed” | 2: Modeling Rain on Land |
| Rainwater causes flooding | Arrows converging on parking lot or rain described as part of the problem | 2: Modeling Rain on Land |
| Water moves across the surface of the land (runoff) | Arrows showing water movement | 3: Stormwater in the Schoolyard |
| Urban surfaces often prevent water from soaking in (impervious surfaces) | Listing concrete, rooftops or “impervious surfaces” as part of why the flooding might be happening. | 3: Stormwater in the Schoolyard |
| Water can move soil and other things like pollutants (erosion). | Mentioning “erosion” or “pollution” as a part of the problem. | 4: Effects of plants & 5: Local Stormwater Systems |
| Plants reduce erosion and increase infiltration | Zoom out of plant roots or mention of water soaking in where plants are present | 4: Effects of plants |
| Storm Drains move water into pipes | Adding in storm drains or presenting a clogged drain as a possible part of the problem | 5: Local Stormwater Systems |
| Water that goes into storm drains causes flooding and/or pollution problems elsewhere | Adding in stormwater pipes with a destination or a description in margin. | 5: Local Stormwater Systems |

Are there alternative conceptions students have that you will want to make sure they think about further during the unit?

| Common Alternative Conceptions | How it might be shown by student | Lesson intended to help revise this conception |
|---|--|--|
| The whole problem is too much rain | Describing only rain as the problem (not including mention of it not soaking in) | 4: Effects of plants |
| We need more storm drains [this could solve flooding but does not address that storm drains cause other problems] | Listing lack of storm drain as the problem or adding storm drains into the picture without saying where they end up. | 5: Local Stormwater Systems |

We have also provided a **“What-How-Why Assessment Tool”** designed to help you look at each individual student’s thinking and track how it changes between Lesson 1 and Lesson 7 of the unit. You can download a PDF or spreadsheet from Communitywaters.org. We suggest legal paper if you print either document. Using the spreadsheet for the scoring grid will make it easier to add evidence and compare results when you use it again in Lesson 7. The spreadsheet also has a tab with examples on it.

Fill in the first part as you go through student work. Sort what you find into each row.

- **What** = objects that students label or descriptions of what is shown. Examples: “flooding here,” “rain,” “impervious surface,” or “tree.”
- **How** = when students are naming a process and/or explaining how something is happening. Examples: “Soaking In,” arrows showing movement of water, “Erosion here,” or “plugged storm drain causes flooding”
- **Why** = students incorporating scientific concepts that explain what is happening. Examples: Students drawing a Zoom-In that shows water moving between particles or being taken up by roots, writing “water flowing downhill,” “fast water is eroding here,” or “impervious surfaces won’t let water soak in.”

When done, revisit your sorting to see if any categories need to change, then transfer key points from each category onto the **What-How-Why Scoring Grid** (2nd page of teacher worksheet). Write student names across the top and revisit each student’s explanatory model to check the boxes for what each student has represented in their model. There may be student representations you will want to follow up on with students to see what they were thinking when they wrote or drew them.

TEACHER WORKSHEET: WHAT-HOW-WHY Assessment Tool for Explanatory Model

Go through student’s explanatory models and record the explanations they provide in the appropriate category. When done, look over your lists and revise them as needed.

| Lens | Evidence Provided By Students in the Explanatory Model |
|---|--|
| “What” Lens Students describe or talk about what they see observe. What happened | |
| “How” Lens Students explain or talk about processes or relationships. How it happened | |
| “Why” Lens Students explain or talk about understandings or theoretical principles. Why it happened, using science ideas | |

TEACHER WORKSHEET: What-How-Why Student Scoring Grid for Explanatory Model

Below each lens, write in lens from previous worksheet. Write names in columns across top and then for each student, score their work on their explanatory model

| Lenses | Student Names | | | | | | | | | | | | | | | | | | | |
|-------------|---------------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| “What” lens | | | | | | | | | | | | | | | | | | | | |
| “How” lens | | | | | | | | | | | | | | | | | | | | |
| “Why” lens | | | | | | | | | | | | | | | | | | | | |

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

Consider the Understandings and Alternative Conceptions of your students (identified above): It is not important that your students have certain understandings at this stage, but it is helpful to see how their

understandings might inform future lessons. It may also be that certain concepts are clear enough already for you to shorten or skip upcoming lessons. Are there understandings students clearly have in their explanatory models? Are there things missing that you want to make sure to highlight in the appropriate lesson? Are there alternative conceptions that students will need to explore in more detail before they can consider other explanations?

Review the **Public Records**. Do the student's hypotheses and/or questions lead naturally into the lessons to come? If so, they could become the focus question of the lesson and make the unit more student driven.

In the next lesson, students use models to make basic observations about how rainwater interacts with soil and use some readings to build their understanding of groundwater and erosion. This gives them an opportunity to look closely at what is happening in a controlled environment.

If your students would benefit more from observing water interacting with soil in the real world first, you could skip to lesson 3 where they investigate (and pour water on surfaces in) the schoolyard, and then come back to the readings (and potentially the water on soil investigation) afterwards.

If you move lessons around: Don't forget to create the Class Summary Table (and possibly Consensus Model) as described in the preparation section of Lesson 2.

TEACHER REFLECTION WORKSHEET

Teacher Reflection



Task, Talk, Tools & Equity

Use the prompts to reflect on the lesson in order to track student thinking and make changes to improve future lessons.

Keep a record of these reflections for your professional portfolio.

1. TASK, TALK, & TOOLS.

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load? How does the task relate to students' lived experiences or funds of knowledge?

Talk. What was the nature of talk in this lesson? What structures and routines supported student participation in talk?

The students talked to each other during (name particular parts of lesson) which allowed students to...

During turn-and-talks, I observed _____ which makes me wonder if/how...

Tools. Tools scaffold student thinking and can house student ideas. Tools in this lesson included the explanatory model scaffold and public records/charts. How did tools support students in communicating and capturing their ideas/thinking?

The explanatory model allowed students to...

Overall, reflecting on task, talk, and tools together:

Talk, task, and tools supported students to share their thinking because...

Overall, this combination of talk, task and tools, allowed most/all students to...

EQUITY.

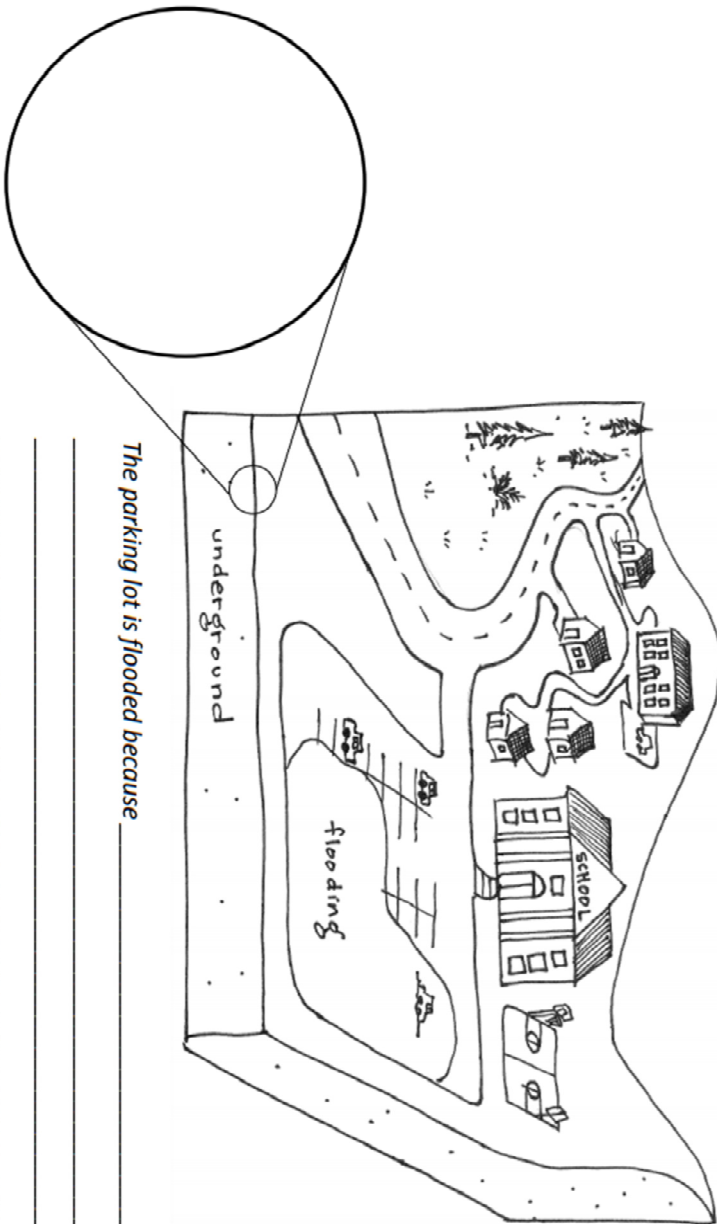
Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. Here are some categories to help you name a specific issue of equity:

- Developing relationships & forming an inclusive, trusting community
- Scaffolding for full participation in the culture and language of science
- Recognizing our own and others' worldviews & developing critical consciousness about our own assumptions and beliefs
- Addressing power dynamics (how a person is seen and responded to by others) to disrupt stereotypes and privilege

What happens to stormwater in the city?

Explain with arrows, drawings, and words where the water goes when it rains and why it goes there.

Name: _____ Date: _____



Zoom-in

The parking lot is flooded because _____

Lesson 2: Modeling Rain on Land

This lesson was adapted from the STC Land and Water Teacher's Guide, Lesson 3 "Modeling Rain on Land" by Carolyn Colley for an Oso Landslide unit and then adapted to this unit.

OBJECTIVES & OVERVIEW

Students use a model to make "rain" fall on soil and observe what happens. Students have many experiences with rain and the effects of rain on land from their own lives without necessarily thinking about what is happening to cause the mud, puddles, and flow that they see. This lesson gives them the opportunity to explore that more deeply.

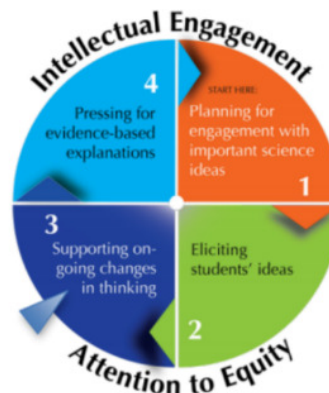
- Students make and share observations about the effects of rain on land.

Focus Question: What happens when rain falls on soil?

Learning Target: I make observations and read texts to understand what happens when rain falls on soil.

New Terms: erosion, groundwater

Ambitious Science Teaching Framework: SUPPORTING ONGOING CHANGES IN STUDENT THINKING



This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

Standards Note: This lesson is the first time students make observations and/or measurements of how water affects land through erosion using a physical model. Students have additional opportunities in later lessons to make real world observations and measurements.

PE 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.

Science & Engineering Practices

Planning and Carrying Out Investigations.

Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (4-ESS2-1)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems. 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. (4-ESS2-1)

Cross-Cutting Concepts

Cause and Effect - Cause and effect relationships are routinely identified, tested, and used to explain changes.

Common Core Connections: ELA/Literacy: RI 4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.

MATERIALS

- 5 “Stormwater Tubs” (set up directions are in the **Implementation Section** of this manual):
 - clear tub with drain hole
 - small rubber stopper in drain hole
 - sand, gravel, and hummus (see Implementation Section for quantities)
- 5 “Rain Jars” (container with holes in lid) filled with 1000 ml of water in each. With the Ziploc rain jars, 1000 ml is the top of the jar.
- 5 catch buckets
- 5 trowels
- 5 large & 5 small absorbent pads
- Cleanup supplies (paper towels and/or rags)
- Two different readings about erosion and/or groundwater, possible options:
 - 2 readings in this lesson
 - library books on water, rainfall, erosion, runoff, saturation, etc.

Eight Tubs or Five?

If you are growing plants, three of the eight tubs provided with your kit are occupied with that process. If you have decided to dig up grass instead of growing the plants, you could do this lesson with eight groups instead of five.

OPTIONAL: Digital camera or smart phone with photo capabilities

PREPARATION – 15-30 minutes

- **Class Summary Table:** Create the first row in the class summary table* (on butcher or poster paper):

| Activity | What did we observe? | What did we learn? | How does it help us explain and/or solve stormwater in the city? |
|---|----------------------|--------------------|--|
| 2: Rain on Land <i>“How does rain affect soil”</i> | | | |
| | | | |

Website



All worksheets, links, and graphics are on communitywaters.org

* Adjust the Focus question if students came up with an appropriate hypothesis or question in Lesson 1.

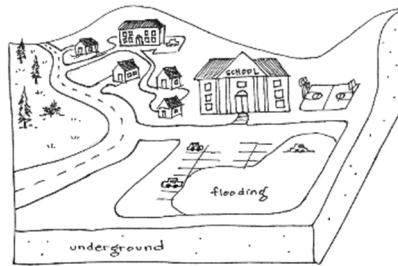
**TEACHER DECISION
POINTS**



What to read and how to best structure the reading task?

Use Consensus Model with Class?

- Queue up the “**Making Rain on Land Investigation Procedure**”, **Journal Example**, and **Just-In-Time** graphic for projecting (at end of lesson and communitywaters.org)
- **Procedure Run Through:** If you have not done this activity before, follow the procedure (end of unit) so you know what students are likely to do and observe.
- **Decide on Readings:** Select 2 appropriate readings about groundwater, runoff, and erosion that students can read and compare to the physical model they create. These readings could be from Appendix 3: Student Readings (also on communitywaters.org) or similar short readings from library books or other sources.
- **Consensus Model (optional):** Project and trace the Explanatory Model (without the Zoom-in and text prompt) onto butcher paper.



Using a Consensus Model

While students have and can update their own models with their understanding about stormwater, a classroom consensus model can be a good way to visually review and record the main concepts and key terms from each lesson.

PROCEDURE

Turn-and-Talk



What have you observed when it rains on soil? Is the effect different with light and heavy rain?

Present visual



Modeling Rain on Land Procedure Sheet



1. Activate prior knowledge and experiences (whole class).

Today students will have the opportunity to observe the effects of rain on soil by pouring water onto a physical model.

Focus Question: What happens when rain falls on soil?

Have students turn-and-talk about their experiences and prior observations of when it rains lightly and when it rains heavily on bare ground (not covered with concrete or plants). What happens to the soil? What does the soil look like before and after it rains?

OPTION: Have students independently write/draw about their experiences first before partner talk.

Listen in as students talk in partners about how rain splashes, creates mud, makes puddles, forms streams, or soaks into soil – these are all observations students may make today using their small physical model.

2. Explaining the Activity (whole class)

Show a “rain jar” (with holes in the lid) and “stormwater tub” with soil mixture.

Share the directions sheet and how to set-up their notebooks to record what happens at the start, midway through, and at the end (both are at end of this lesson).

Things to emphasize:

- The soil in the tub should be shaped into a cliff shape (5 cm deep x 20 cm long) opposite the side with the drain hole.
- We want to keep things the same (control variables) among the different models so we can compare the differences between groups. **Controlled variables include:** shape of block, amount of soil and what is in it, amount of water being added, how water is dispensed....
- Do not squeeze the water bottle – just shake it up and down until there is just a little bit of water left in the lid.
- Do not poke or touch the soil once you start the rain.
- They will make a sketch of what happens before the rain, when the water is ½ gone from the bottle, and at the end (when bottle is empty).

GROUP ROLES (optional)

1. Materials Manager
2. Water Filler
3. Bucket Holder
4. Water Shaker
5. Water Shaker
6. Sketcher: ALL

Divide class up into five investigation teams.

Small Groups



Investigation Teams with
Group Roles

Assign (or have students choose) group roles and have students get started.

OPTIONAL: Give one group a digital camera to take photos of their rainfall simulation every minute (use classroom clock or stopwatch, if available). The more frequent photos can be posted in the room or next to the summary table to capture just how rain water affects land over time.

3. Making observations and uncovering patterns using questions (small groups).

Circulate as students set up the experiments. Redirect and help students with set-up as needed.

As students make observations, circulate and ask questions to focus students on observations and patterns. The “Back Pocket” questions provided here are suggestions for what you might ask students while circulating. →

Make sure students sketch how the land changes before, during, after rain.

Groups use their rain jar to measure the amount of water (not including sand and gravel) that ended up in their bucket and record the amount they started and ended with.

The water will be less than they started with. From what they observed: What happened to that water? How did sand and gravel get into the bucket?

Back Pocket Questions

Observations

- What did you see happen to the soil as it rains?
- What happens as the rainwater hits the land?
- Where did the water end up?
- How does the tub look different?

Cause and Effect

- Why did less water end up in the bucket than was poured over the soil?
- Where did the water go?
- How did sand and gravel get into the bucket?
- Are there more of some materials than others in the bucket?
- Why were some materials moved more than others?

Small Groups



Discuss observations

Back-Pocket Questions



Observations
&
Cause & Effect



Pause here?

If you are out of time, you could pause the lesson here. If you are able to wait to pause until after the students have seen each other's models (#5 below) you won't need to preserve the models as carefully.

Present visual



Just-in-Time Instruction

4. Provide terms to leverage (whole class)

Project the “Just-In-Time Instruction” box (at end of lesson) to present runoff, erosion, and groundwater as terms that students can use to describe how water interacts with soil.

Just-in-Time Instruction – Runoff and Groundwater

When rain falls to earth, gravity pulls it down hillsides and into soil.

Scientists use the term **runoff** to refer to water that flows over the top of the land. **Erosion** occurs when fast moving runoff picks up soil and moves it.

Groundwater is water that soaks into soil and seeps gradually downward, in the spaces between soil particles.

You’ve been using the term **runoff** already when referring to “stormwater runoff,” but the idea of fast runoff causing **erosion** may be a new one for many students. In addition, some water moves down into the soil as **groundwater**. These are all terms they can use to help describe what they observed.

Add erosion and groundwater to your Word Wall Cards.

5. Publicly sharing observations (pairs and whole group)

Have students circulate to each table group for about 15 seconds per group to see whether the other models look like theirs.

Introduce the Class Summary Table as a place where the class will be recording their observations and learning after each lesson. Having a shared summary on the wall provides the students something they can look back on when they are trying to understand what is happening with stormwater in their schoolyard or neighborhood.

What did students **observe** from their own models and other’s models that could be recorded on the table? Students can look at their sketches and written observations as well as the runoff water they poured back into their rain jars.

Are there any other observations students would add from their own experiences outside of this investigation?

Public Record



Class Summary Table: Introduce and record observations

If the models look different

You could have students write some observations they made under their sketches using the following sentence starters:

- *Our rain model looked like others because they all had...*
- *Our rain model looked different than the model in group because ours and theirs*

| Activity | What did we observe? |
|--|--|
| 2: Rain on Land “How does rain affect soil” | <ul style="list-style-type: none"> – Puddles – The soil turned wet and muddy – Some water went over the land like a river and out the drain hole – Some soil in the bucket. – Less water came out than we put in. |

Turn-and-Talk



What do the readings help us understand about our observations?

6. Readings about how water affects land (whole group or individual)

NOTE: This reading task could happen during reading time as an ELA activity.

Provide students the two readings you chose earlier. Scaffold the reading as appropriate for your class.

Review the observations recorded on the Class Summary Table (with emphasis on observations that relate to runoff and groundwater) and have students turn and talk about anything they learned from the readings that helps them explain their observations.

Students pick something that was in the readings that is supported by their observations of the models and write about the connection in their science journals (scaffold this writing as appropriate for your students).

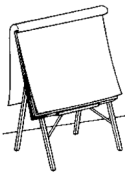
A Specific Claim

If your student's need a specific claim to focus their thinking on, have them address the different amount of water that came out of the water than went in. Why did that happen? What is their evidence and reasoning?

7. Discussion of learning (whole group)

Encourage students to share explanations for what they observed. What evidence can they provide to support their explanation? Do other students have a different explanation for what they observed?

Public Record



Class Summary Table
Learning

As the discussion progresses, write down provided answers in the learning column of the class summary table. Example of what a class might come up with:

Students return materials to the materials area. Stack tubs crisscross to leave space for soil in tubs to dry out.

What did we learn?

From the experiment:
 - soil absorbs rain water
 - water can carry soil with it

From the reading:
 - Erosion = water and wind carry bits of soil to new places; plants hold onto soil and can prevent erosion
 - deforestation = cutting down trees in a forest; this can increase erosion

Public Record



Class Summary Table
Complete the Row

8. Connections to the phenomenon (individual and whole class)

Provide sticky notes to students to write down one idea on how today's learning can help us explain what happens to stormwater in the city. After writing their idea down they can put the sticky note in the last column on the class summary table.

Then sort the provided ideas and decide as a class what to write in that column.

Example of that your finished summary table row might include:

| Activity | What did we observe? | What did we learn? | How does it help us explain and/or solve stormwater in the city? |
|---|--|--|---|
| <p>2: Rain on Land</p> <p>"How does rain affect soil"</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 10px auto;"> <p>Tape a photo or sketch of tub</p> </div> | <ul style="list-style-type: none"> - Puddles - The soil turned wet and muddy - Some water went over the land like a river and out the drain hole - Some soil in the bucket. - Less water came out than we put in. | <p><i>From the experiment:</i></p> <ul style="list-style-type: none"> - soil absorbs rain water - water can carry soil with it <p><i>From the reading:</i></p> <ul style="list-style-type: none"> - Erosion = water and wind carry bits of soil to new places; plants hold onto soil and can prevent erosion - deforestation = cutting down trees in a forest; this can increase erosion | <ul style="list-style-type: none"> - Stormwater can soak in to soil but if there is too much it can move across the surface and cause erosion. |

Note: If students took digital pictures during this lesson, print them and add them to the summary table after class.

9. OPTIONAL: Adding to a Class Consensus Model (whole class)

Public Record



Consensus Model

Introduce the poster-sketch of the explanatory model you created earlier and pose the question to the class as to how today's learning might be represented on the model.

Where could you show water going into groundwater?

Are there places you might add some erosion?

Use a colored pen for the additions and star items on the class summary table with that same color (later lessons you can use a different color so the lesson connections are clear).

This is a great opportunity to use a Zoom-in to show water moving through the soil!

Don't worry about adding runoff arrows to the model at this stage (since you haven't introduced impervious surfaces yet).

Timing

This could also be done before the start of your next lesson to review today's learning (and catch up students who were absent).

EXAMINING STUDENT WORK

Examine students' notebooks entries to see student thinking about why the water level in the runoff wasn't as much as the starting level in the rain jar. Use this as well as evidence from discussion about the reading and data table to assess students' progress in understanding erosion and groundwater.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

In the next lesson, students explore the difference between pervious and impervious surfaces by pouring water onto them in their schoolyard. They will also be showing where water travels across the surface on a map of their schoolyard and possibly labeling some "problem locations."

The schoolyard investigation can be adapted as desired but does not *require* certain understandings before doing it. For example, if your students are unclear about concepts from this lesson around water soaking in or eroding soil, you can make a point of visiting specific locations in their schoolyard where they could explore those ideas further before pouring water onto impervious surfaces.

Other ideas to Investigate?

The provided stormwater models are easily adapted to additional investigations. If your students came out of this lesson with additional questions they could potentially investigate, (like how much the amount of water or slope impacts erosion), make sure those questions go onto the public record, and decide when and whether to use the models to investigate them. See the "What's Next?" section in Lesson 3 for more ideas.

In Lesson 4 the students have an opportunity to investigate how erosion is different on a bare slope than on one with vegetation. There is also more about expanding on students' understanding of weathering and erosion at the end of Lesson 4.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Modeling Rain on Land Procedure

SETUP

Gather Materials: Materials Manager brings materials to group area (soil tub, bucket, large and small pads, trowel and graduated cylinder)

Water Filler fills rain jar (with holes in lid) with 1000 milliliter (ml) of water.

Set up the materials:

- Place large pad on table with slick plastic side down (absorbent side up) and put tub on the large pad.
- Locate the drain hole (with a plug in it) and move the tub so the drain hole sticks over the edge of the table.
- Place the small pad on the floor with the plastic side down and put the bucket on the pad under the drain hole so that the bucket will catch any water that comes out of the drain hole.

Prep the tub:

- Shape the soil in the tub to create a block of soil between the line and the edge that does not have a hole (20 centimeters long x 5 cm deep).
- Remove the drain plug from the tub and place it on the table.

All: Before adding water, sketch how the soil looks in your science notebook.

PROCEDURE

1. **Make it rain.**
 - a. Bucket holder holds the bucket under the tub's drain hole.
 - b. First water shaker holds the water jar upside down over the soil and shakes the jar to make it rain on the soil (don't squeeze). Move it around so all areas of the soil block get equal amounts of water.
 - c. STOP shaking when the water is about halfway gone from the jar.
 - d. Plug the hole and set down bucket on pad.
2. **All:** Sketch how the soil looks in a "during rain" box.
3. **Finish the rain**
 - a. Bucket holder holds the bucket under the tub's drain hole.
 - b. Second water shaker shakes the remainder of water onto the soil.
 - c. When done, set down bucket on pad in location where water can drip and empty any bits of water left in rain jar.
4. **All:** Sketch how the soil looks in an "after rain" box and use your rain jar to record the amount of water you collected in the bucket.

GROUP ROLES

1. **Materials Manager**
Brings materials
2. **Water Filler**
Fills water bottle
3. **Bucket Holder**
Holds bucket under drain hole
4. **Water Shaker #1**
Shakes first half of water evenly across tub.
5. **Water Shaker #2**
Shakes 2nd half of water.

EXAMPLE OF WHAT THIS MIGHT LOOK LIKE IN STUDENT NOTEBOOKS:

Making Observations

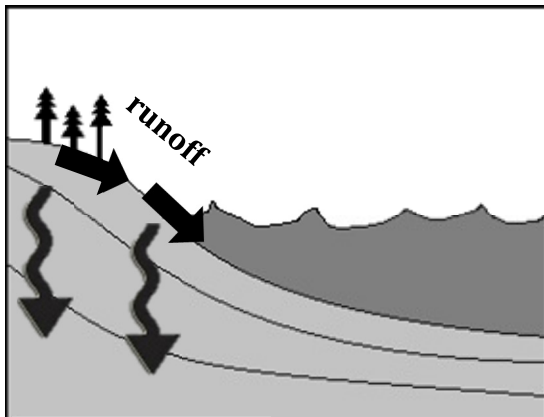
(Sketch soil before, during, and after rain and describe in your notebook.)

| Before the rain | During the rain | After the rain |
|-----------------|-----------------|----------------|
| | | |

Amount of water added to model: _____ ml

Amount of water collected at end: _____ ml.

Just-in-Time Instruction – Runoff and Groundwater



When rain falls to earth, gravity pulls it down hillsides and into soil.

Scientists use the term **runoff** to refer to water that flows over the top of the land. **Erosion** occurs when fast moving runoff picks up soil and moves it.

Ground water is water that soaks into soil and seeps gradually downward, in the spaces between soil particles.

Lesson 3: Stormwater in the Schoolyard

(Adapted from Project WET’s ‘Rainy-Day Hike’ and Pacific Education Institute’s Drain Ranger Curriculum Lesson 4: Define the Problem and Stormwater Pollution)

OBJECTIVES & OVERVIEW

Different features around schools and neighborhoods can increase or decrease the amount of stormwater runoff that eventually empties into the Puget Sound. By mapping stormwater runoff related features at school, students will better understand how water flows through an urban setting and begin to identify smaller problems it may cause in their schoolyard.

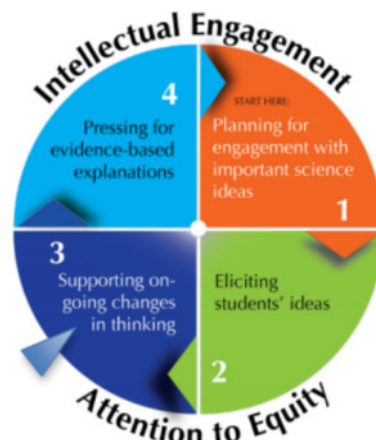
- Students use a map of the school grounds to record observations about stormwater runoff.

Focus Question: What happens to stormwater when it falls on our schoolyard?

Learning Target: I can do an investigation to understand where stormwater flows and causes problems in our school yard.

New Terms: pervious surface; impervious surface; storm drain

Ambitious Science Teaching Framework: SUPPORTING ONGOING CHANGES IN STUDENT THINKING



This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

Standards Note: Students may begin to identify ways flooding impacts them around their schoolyard, but won’t be defining the problem in detail or generating solutions for it until much later in this unit.

PE 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.

PE 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|---|---|
| <p>Planning and Carrying Out Investigations.</p> <ul style="list-style-type: none"> • 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. | <p>ESS3.B Natural Hazards.</p> <ul style="list-style-type: none"> • A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). <p>ESS2.A Earth Materials and Systems.</p> <ul style="list-style-type: none"> • 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. | <p>Cause and Effect.</p> <ul style="list-style-type: none"> • Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS3-2) |

MATERIALS

- Water bottles or other containers with water – Ideally one for every two people if water bottles or one per four if buckets.
- For each student:
 - **Mapping the Schoolyard Worksheet** – version specific to your school found in Teacher Guide
 - Clipboard or cardboard with rubber band to hold the paper in place & pencil (plus a highlighter if available for coloring impervious or pervious surfaces)

PREPARATION – 30-45 minutes

Website



All worksheets, links, and graphics are on communitywaters.org

SAFETY ALERT



Are there areas (or roads) to establish boundaries or avoid? Chaperones are important to help corral students.

- **Chaperones:** Secure at least one other adult to act as support for the walk around the school grounds.
- **Watch the 5 minute “Leading an Investigation of your Schoolyard”** video available on Communitywaters.org (under Teacher Support).
- **Review the Teacher Guide** provided for your school (can be found on communitywaters.org if you don’t already have it). The Teacher Guide includes a map of the schoolgrounds with suggestions about places and features around the school to visit during this lesson. Pictures are accompanied by short descriptions of the feature and questions you might pose to your students to encourage further thinking or connection-making. It also contains the **Mapping the Schoolyard worksheet** for your school.
- **Familiarize yourself with the school grounds:** Reference your school teacher guide as you walk around the school grounds. Can you locate the things pictured in the guide? Are there any things that weren’t included you want to make sure your students see? If the school has bordering neighborhood streets with features of interest, make notes on them as well. Of special interest are nearby creeks or streams, which the storm drains may lead to.
- **Plan how you will manage students outside:** you may want to refer to the “Strategies for Outdoor Learning” found in the Teacher Background section. Depending on students and the area, establish physical boundaries to let students explore the campus at their own pace as they search for water features. Students can work alone, in pairs, or small groups. Alternatively, flag features in advance and lead students altogether in a simple tour.
- **Queue up impervious-pervious graphic** (project page at end of lesson or use graphic from communitywaters.org)
- **Review students’ explanatory models:** and think about whether there are concepts they represented that need a little bit of encouragement (like the effects of vegetation or flow of water) you can make a point of visiting relevant locations, pouring water onto them, and discussing the effects they have on runoff.

PROCEDURE

Engage and Encounter

Turn-and-Talk



What happens to stormwater at our school?

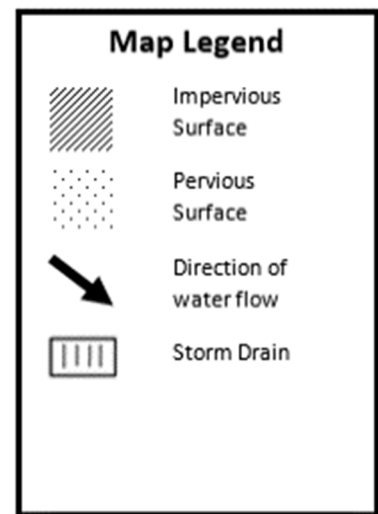
1. Activate prior knowledge and experiences (whole class)

What happens to the school grounds on rainy days? Are students' favorite places at risk for flooding? Why or why not? Have students turn and talk about what happens to rainwater at the school.

2. Introduce map key and map (whole class)

Review your school's **Mapping your Schoolyard worksheet** under document camera.

Discuss what students see, including helping them to orient the map (rotating it to match up with the direction they are facing). Have them put an x on the map where their classroom is.

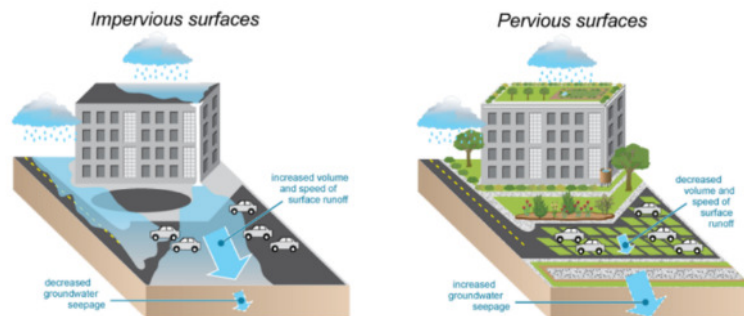


Point out the legend and project the graphic that shows impervious and pervious surfaces to discuss them further. Point out the differences: pervious surfaces are places where water can soak into the ground while impervious surfaces do not allow water to absorb into the ground.

Show visuals



Mapping Your Schoolyard Worksheet & Impervious-Pervious graphic (at end of lesson and communitywaters.org)



Return to the Mapping your Schoolyard worksheet and demonstrate drawing the symbols from the legend in appropriate places on the on map:

- Put in dots and lines for surfaces, arrows for flow of water, and storm drains.

- If you have a highlighter for each student, they could use it instead of lines to show impervious surfaces.
- Partially pervious surfaces can be shown with fewer dots.
- They can also label locations of litter, visible pollutants (like oil stains) and places where puddles form.
- Label a specific stormwater problem area if you are aware of one.

3. Set clear expectations for having class outdoors (whole class)

This is not recess time; students will be investigating, doing science class outside, not playing.

They need to gather up when asked and stay within boundaries.

Explore and Investigate

4. Get the activity started (OUTSIDE BUILDING, whole class)

When you get outside, review the plan: Set the physical boundaries, remind them of behavior expectations, and orient them to the schoolyard map.

Adjust approach depending on whether it is raining.

- *DRY day:* search for features to add to the map. Students will predict or remember the direction of water flow, and how each feature might affect the rate of water flow. Students will use the key to mark each item they find on their map.
- *RAINY day:* record their observations about the direction of water flow, any pollution they see in the water, and any areas of flooding. Students could keep maps under covered areas and write on them after exploring OR use a plastic bag to cover the map while writing. Features shown in the stormwater key and observations about the water they see could be recorded on the map.

Back-Pocket Questions



Observations & Inferences

Back Pocket Questions

Observations

- Which features at the school might slow down the water?
- Which features might increase the speed of the water?
- Which places at the school allow water to absorb into the ground?
- Do you notice any pollution concerns?
- Where are places that you have seen puddles form?

Inferences

- Where would the water move from here?
- Where did the water causing this problem come from?
- Where does all the water flowing off this surface end up?

Your school's Teacher Guide may have other location-specific questions.

5. Make observations (whole class) – allow at least 20 minutes

Give students time to map what they find outside using the key. Encourage students to take notes about what they see (space on worksheet).

In small groups or with the whole class, find places to experiment with pouring water on the ground: what happens to the water when it’s poured on the ground on different surfaces? Which surfaces cause the water to flow faster if on a hill?



If you are out of time, you could wait to fill in the Class Summary Table.

Reflect and Explain

Turn-and-Talk



What did you put on your map and what else could you add to it?

6. Back in the classroom (pairs)

Give students time to share/review their maps with someone who hasn’t seen it yet and discuss their findings. Turn-and-talk: “What did you put on your map and what else could you add to it?”

Encourage students to add things to their maps based on conversations with their peers.

Public Record



Class Summary Table

7. Apply understanding and phenomenon connections (whole class)

Return to the Class Summary Table to add what you observed while in the schoolyard and what they learned today.

Break out the discussion as needed with turn-and-talks, small group discussions, and/or individual post its.

| Activity | What did we observe? | What did we learn? | How does it help us explain and/or solve stormwater in the city? |
|--|--|--|--|
| <p>3: Schoolyard Stormwater</p> <p>“What happens to stormwater when it falls on our schoolyard?”</p> <p>Blank schoolyard map</p> | <ul style="list-style-type: none"> – Water soaked in some places better than others. – Water flowed across impervious surfaces – Storm drains (or ditches) – Places where puddles form | <ul style="list-style-type: none"> – Water soaks into pervious surfaces. – Water flows across impervious surfaces. – Stormwater runoff causes <Specific problem identified by students> in our schoolyard | <ul style="list-style-type: none"> – Water moves across impervious surfaces. – Impervious surfaces increase the amount of stormwater runoff. – Stormwater runoff travels through our schoolyard. – Water goes into storm drains. |

Public Record



Consensus Model

8. OPTIONAL: Adding to Class Consensus Model (whole class)

Return to the Consensus Model and quickly sketch in water flow lines with class input as desired. Use a different colored pen and star related items on the class summary table.

If somebody brings up storm drains, you could also add them to the consensus model.

Timing

This could also be done before the start of your next lesson to review today's learning (and catch up students who were absent).

EXAMINING STUDENT WORK

Look at the maps students filled in and take note if students have focused on certain things to the exclusion of others. Do they have all the following?

- Have they noted where water travels during a rainstorm?
- Did they identify any storm drains?
- Did they identify any specific problems that occur when there is a lot of rain?
- Did they distinguish accurately between pervious and impervious surfaces?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

Student Maps: If some students left things off their maps, you have some options:

1. Provide additional time to compare maps with others.
2. Revisiting the site in different conditions (i.e., heavy rain, light rain, sunny day, etc.) could also provide opportunities to grow their understanding.
3. Lesson 5 provides an opportunity to revisit storm drains; you could have students revisit their maps after the lesson to see what else they might add.

Returning outside on a Rainy Day (individual or class)

If the student survey was completed on a clear day, suggest to students on the next rainy day to visit each feature and compare their observations with their predictions. If class time permits, take the class to visit each feature on a rainy day to make these observations.

If you are fortunate to have a large rainstorm later in this unit, you could take students for an impromptu walk outside to see more clearly what happens to the stormwater and where it runs off (or challenge them to investigate during recess and report back). If raingear is an issue, garbage bags and/or your school's lost and found can provide a temporary solution.

What's Next? Does the current student thinking lead naturally into exploring the effect of plants in the next lesson or are there understandings that need to be explored first? Do you need more time for the plants to grow in half the stormwater models?

You could provide students the opportunity to further investigate using the models you have available. Ideally, the students would generate their own investigation but here are some ideas as to what the investigations could look like:

- Slope? Set up models with different slopes (and use the procedure from Lesson 4 to explore how erosion and/or amount of runoff varies between them.
- Impervious surfaces? Use tinfoil to model impervious surfaces on all or part of a model and see how it changes the amount of water that soaks in. Does putting it on the upper half of the model change the amount of erosion?
- Amount of rain? Use the same amount of water on the model but disperse it more quickly (using multiple containers).
- Differences in soil materials? Create models from the base materials in the kit (instead of a mix). How do the different materials change the amount of water that comes out and the amount of erosion?

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

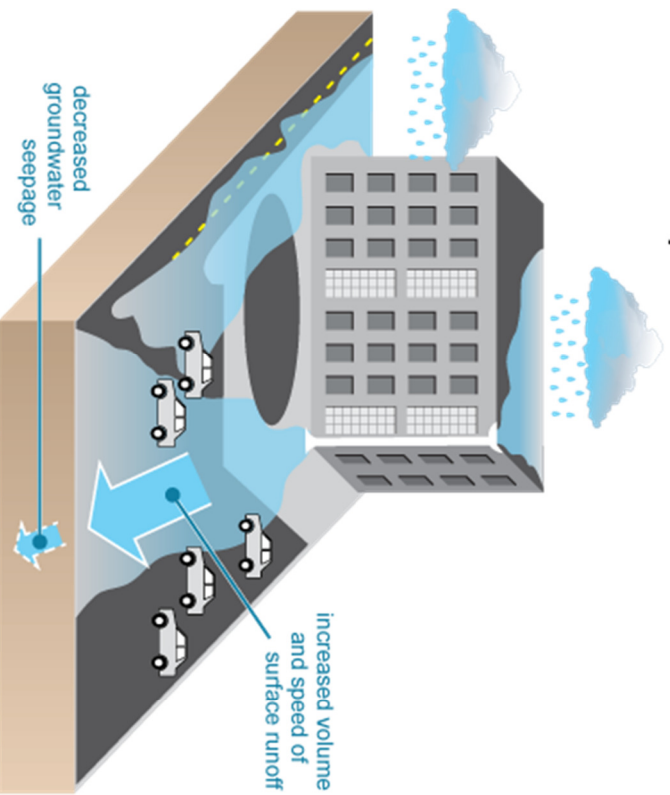
Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. schoolyard maps, class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

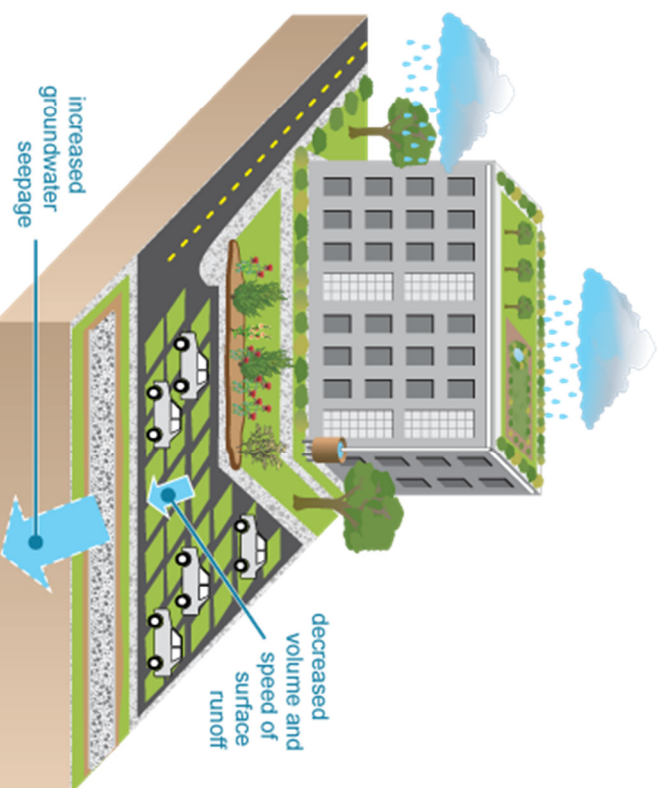
EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Impervious surfaces



Impervious 'hard' surfaces (roofs, roads, large areas of pavement, and asphalt parking lots) increase the volume and speed of stormwater runoff. This swift surge of water erodes streambeds, reduces groundwater infiltration, and delivers many pollutants and sediment to downstream waters.

Pervious surfaces



Pervious 'soft' surfaces (green roofs, rain gardens, grass paver parking lots, and infiltration trenches) decrease volume and speed of stormwater runoff. The slowed water seeps into the ground, recharges the water table, and filters out many pollutants and sediment before they arrive in downstream waters.

Conceptual diagram illustrating impervious and pervious surfaces. Impervious surfaces are hard and increase stormwater runoff, causing pollutant and sediment delivery in downstream waters. Pervious surfaces are soft and decrease stormwater runoff, which filters out pollutants and sediments before they arrive in downstream waters. Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Chesapeake and Atlantic Coastal Bays Trust Fund, 2013. Stormwater Management: Reducing Water Quantity and Improving Water Quality. IAN press, newsletter publication.

Lesson 4: The Effects of Plants

This lesson was adapted from the *STC Land and Water Teacher's Guide*, Lesson 14 "Plants: Protecting Sloped Land from Erosion" by Carolyn Colley for an Oso Landslide unit and then adapted to this unit.

OBJECTIVES & OVERVIEW

IMPORTANT NOTE: You will need plants growing on three models for this lesson. Digging up some grass sod is an option. Please see the **Implementation Planning** (pg. 28) section and this lesson's preparation section for options.

Students explore how plants interact with stormwater runoff. They compare a bare slope with one covered with vegetation.

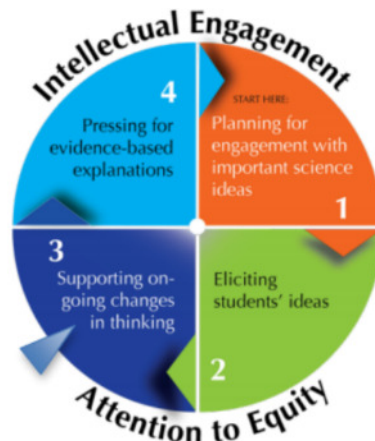
- Students make predictions and share observations about how plants on a slope affect the amount of runoff, what the runoff carries with it, and the changes in the slope.

Focus Question: How do plants affect stormwater runoff?

Learning Target: I can make observations and measurements to provide evidence of how plants affect erosion and stormwater runoff.

New Terms: weathering

Ambitious Science Teaching Framework: SUPPORTING ONGOING CHANGES IN STUDENT THINKING



This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

PE 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.]

Science & Engineering Practices

Planning and Carrying Out Investigations.

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (4-ESS2-1)

Using Mathematics and Computational Thinking

- Organize simple data sets to reveal patterns that suggest relationships.

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems.

Rainfall helps to shape the land and affects the types of living things found in a region.

Cross-Cutting Concepts

Cause and Effect

Cause and effect relationships are routinely identified, tested, and used to explain changes.

- Describe, measure, estimate, and/or graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems.

Constructing Explanations and Designing Solutions.

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Identify the evidence that supports particular points in an explanation.

Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1)

Patterns
Patterns can be used as evidence to support an explanation.

MATERIALS

Part I: Making Observations

For the class:

- Chart paper for class data table
- Newspaper
- Cleanup supplies (Paper towels and/or rags)
- Water supply (sink or tub of water)
- Centimeter ruler or measuring tape

Investigation Materials:

- 5 stormwater tubs with soil mixture
- 3 stormwater tubs with plants
- 8 rain jars with 1000 ml of water
- 8 white catch buckets
- 8 large & 8 small absorbent pads
- 16 spoons
- 8 graduated cylinders (for storing runoff)
- Textbooks for each team to put one end of their stormwater tub on.

For each student:

- **Observing the Effects of Plants on Erosion** worksheet.

Part II: Data Discussion & Summary Table

For the class:

- Copies of readings
- Class Summary Table
- Markers

PREPARATION – 30-60 minutes

Website



All worksheets, links, and graphics are on communitywaters.org

Watch the 4 ¾ minute “Conducting the ‘Effects of Plants on Erosion’ Investigation” video available on Communitywaters.org (under Teacher Support).

PREP MATERIALS:

1. Three tubs need to have plants growing in them. If you haven’t been growing plants, you could dig up sections of grass and put them on top of the soil blocks. If you do so, remove as much of the dirt from the roots of the grass as you can so the clumps don’t break loose and during the Lesson 4 investigation.
2. If the stormwater tubs that don’t have plants are dry, mix 200 ml of water into the soil.

3. Fill each group's rain jar with 1000 ml of water (top of the jar if Ziploc brand jars).
4. Set up materials area: Depending on timing and your room's layout, set up each station ahead of time or put each teams' materials into their own white bucket (see picture on right).
5. Tub setup: If you have time and/or volunteers, you can streamline class time by fully setting up tubs ahead of time. Each tub needs a soil block (5cm deep x 20 cm long) like in lesson 2.
6. Use one of the tubs to get comfortable with how the procedure works (make sure it has time to dry out afterwards).



**TEACHER DECISION
POINTS**



Student Input?
Use Math Time?

DECISIONS TO MAKE

Part I: How much student input and involvement?

1. Is there a specific question, disagreement, or understanding that could shape the wording of the Investigative Question? For example, would they want to better understand whether plants affect the amount of water that runs off or are they more focused on what happens to slopes with no plants on them?
2. Do you want to provide the students the investigation procedure (provided below) or have them write their own as a class? Do you want students to have enough understanding of fair tests and controlled variables to figure out on their own what should be done during the investigation to make it a fair test?
3. Small groups each doing the investigation? We recommend each small group running the procedure on their own bin, but understand this can be very challenging with some classes. Some teachers have had success leading the investigation for the whole class themselves.

Part II: Data analysis during math time?

At the beginning of Part II students will be using mathematics as they analyze and interpret data. This is a Science and Engineering Practice that overlaps nicely with math standards. Depending on the timing of your week and/or where your students are in their math lessons, this section could be done as a part of your math class.

Turn-and-Talk



How would plants on a slope affect stormwater runoff? Why do you think so?

1. Activate prior knowledge and experiences (whole class).

Introduce today’s focus question. **“How do plants affect stormwater runoff?”**

The explanatory model students used in Lesson 1 included some trees and a slope. Are there any plants or sloped areas around your schoolyard? Could they have any influence on stormwater runoff?

Students turn-and-talk about how they think plants might affect stormwater runoff.

2. Getting the Activity Started (whole class)

Tell students that they will be running an investigation to compare plants on slopes with bare soil and see if there is any difference in the soil erosion and runoff. Share the investigation question and have students write it in their science journals:

What is the effect of plants on runoff and erosion?

Three of the student groups will test the rain models with plants and the remainder with bare soil. To be able to compare the data we’ll want to make it a fair test.

What variable is being changed? (*presence of plants*)

What variables need to be kept the same? (*slope, amount of water, how the water is poured....*)

What is the measured variable? (*amount of soil moved*)

Show students the set up with land block and assign groups to tubs:

- *Groups 1, 2, 3 = plants*
- *Groups 4-8 = bare soil*

Create the procedure as a class or project the provided procedure and review it with students.

Students should make a prediction in their science journals: What do they think will be different between the two models? How much erosion will each model type have? They could write out what they think will happen and/or sketch what they think the plant and soil only tubs will look like.

Assign or have students choose group roles.

TEACHER DECISION POINT



Do you want the students to develop the procedure as a class?

Present visual



If using the provided procedure: *“What is the Effect of Plants on Erosion Procedure”*

Small Group



Investigation Teams with Group Roles

| GROUP ROLES | |
|-------------|--|
| 1. | Materials Manager Brings materials and clears drain blocks |
| 2. | Tub Holder Keeps tub from sliding off books |
| 3. | Water Filler Fills water bottle |
| 4. | Water Shaker Shakes all of water evenly across tub. |
| 5. | Water Collector Collects 50 ml runoff |

If not already set up in room, have groups follow the procedure set up to lay out pads and give all the models the same slope. (e.g. height measured to the top of the soil = 10 cm).

Release groups to follow the procedure (or run it with everybody simultaneously if you prefer).

Back-Pocket Questions



Observations & Inferences

3. Making observations and uncovering patterns (small groups)

Circulate as students set up and follow the procedure. Redirect and help as needed.

Students will need to sketch their model and another group's model of the other type before seeing how much soil moved. The sketches could be top down or side views (or both if desired).

As students make observations, listen and ask questions to focus students on observations and patterns.

Make sure students sketch and collect data on their data sheet for their group.

BACK-POCKET QUESTIONS

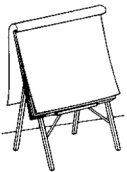
Observations & Patterns

- What is the water doing?
- Where does the water go?
- How fast is the water moving?
- How did the land block change?
- What does your water sample look like?

Inferences & Connections

- Is there soil in your bucket? How did it get there?
- How do you think your observations will be different than another group's observations?
- How does this help us understand stormwater runoff?

Public Record



Class Data Table to go on Class Summary Table

4. Share observations and make a class data table (whole group)

Place a copy of the data table under the document camera and have each group share their results to be added to the table.

Each student should also record each group's data on their own sheet.

When completed add the class data table to the "What did we observe" section of the class summary table.

If time permits, you could have students share their initial observations about the class data.

By the end of Part I, students have filled in the data table on the front of the student handout. Students will complete the remainder in Part II.

5. Clean Up: IMPORTANT!!!

Save the grass! You will need grass when students start modeling their problem site and solutions later in this unit. Don't forget to water it to keep the grass alive.

Make sure tubs are plugged. Stack tubs crisscrossed on top of each other in the materials area.

Save water samples. Label the samples "plants" and "no plants" and put them in a safe place. You will want to be able to look at these again in the second part of this lesson.



We expect you will do Part II another day. If you are running out of time before this point, you could also wait on filling in the Class Summary Table.

PART II: Constructing an Explanation

1. Analyzing the Data

Investigating Data



Looking for patterns and relationships

Remind students of the investigation they did in Part I, and their investigative question.

Show the water samples (that you saved with runoff in them) to the class and review the class data chart.

If there is any contradictory ("outlier") data, discuss why data might not be reliable.

After collecting data, scientists need to analyze and interpret it to see what they learned from it.

Back-Pocket Questions



Observations & Inferences

Have student groups discuss what patterns they see in the data. What do they notice about differences between the slopes with plants and no plants? How did the amount of erosion change? Did the water samples look any different?

TEACHER DECISION POINT



Do the mathematical analysis during Math Time?

Circulate while student groups discuss and ask probing questions

Either in small groups or as a class, discuss how you could use mathematics to interpret the data. Would you want to put it in a chart, or find the mean or median

BACK-POCKET QUESTIONS

Observations & Patterns

- Which model had more materials moved?
- Did the water from each model look any different?
- How did the soil look different?

Inferences & Connections

- How does this relate to a real-world storm?
- Is it an accurate model? What would they change to make it more accurate?
- What have the seen plants do in the real world that could affect stormwater

of the numbers for each slope? If you average the numbers could you subtract one from the other to show the difference between the two?

Write out the chart or averages on the board and/or have students write it in their science notebooks.

Turn-and-Talk



What can we conclude from our data?

Public Record



Class Summary Table - Observations

2. Conclusions

Give students think time, then turn-and-talk with a partner about their answer to the investigative question: How do plants affect stormwater runoff? What evidence from the investigation supports their conclusion?

Give students time to write a conclusion on the front of the data sheet (question 1) to answer the investigation question.

3. Recording observations (whole class)

Prompt students for observations as you add them to the Class Summary Table.

Take a few observations from students that includes numeric data and a relationship between plants and runoff.

Tape a copy of the class data table in the summary box.

| | |
|---|---|
| <p>5: Plants</p> <p><i>"How do plants affect stormwater runoff?"</i></p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> <p>Photo or sketch of tubs</p> </div> | <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> <p>Class Data Table</p> </div> <ul style="list-style-type: none"> - <i>Runoff filtered through plants moved less soil (___ ml).</i> - <i>The soil-only water was a lot dirtier looking than the one from the plants tub.</i> |
|---|---|

4. Examining Reasoning (pairs/individuals)

It is important for scientists to think through the reasoning behind their conclusions. Why do they think the plants had the effect that they did? Have the students think about it and then turn and talk to their partner. What happened to the water and the soil that resulted in what happened?

Turn-and-Talk



How did the plants affect the erosion and runoff?

5. Provide information for students to use as leverage to explain data.


Have students pull up some of the ground cover in the tubs and observe the roots and soil.

- *What do you notice?*
- *What do the roots look like?*
- *Where do you see soil?*


Just-in-Time Instruction

Project the information about plant roots.

Just-in-Time Instruction: Plant Roots



Roots anchor plants into the ground and gather water and nutrients for the plant. By draining water from the soil, they help keep the soil from staying too wet. When the soil gets too dry, roots can draw up water for the plant from deeper underground.



Roots also help soil. By reaching through and holding onto the soil, roots make it hard for fast moving water or wind to carry the soil away which reduces **erosion**. Roots can also make more soil when they grow into cracks in the rocks and break them apart. Some plants roots produce a weak acid that also wears away the rocks. Roots breaking up rocks into smaller bits is one type of **weathering**.

How can knowing about roots help us explain our data?

Optional: “Erosion and Soil” Video

The video goes through a similar experiment to what the students did during this lesson and could be an option for a student who missed the experiment.

For a close-up on some roots, skip to 5:00 and watch from there. Link can be found at

communitywaters.org or <https://www.youtube.com/watch?v=im4HVXMG168>

6. Explaining their Reasoning (pairs/individuals)

Turn to the back of the sheet with students.

The box is a place for them to use a drawing to show what was happening in the soil. Remind them how they used “zoom in” in the groundwater and runoff lesson to show something at a smaller scale. Provide another example if needed.

On this side of the sheet, the students should show how/why plants interact with the water and how it affects runoff and erosion using what they learned from patterns in the data as well as prior videos or readings.

Give students time to fill in the sheet, while you circulate and press students to explain how/why fewer plants might result in cleaner runoff, and less erosion.

Select two students to share their drawings/explanation under the document camera and explain their reasoning to the class. Encourage students to ask questions to each other and compare what is similar and different about each students’ explanations with their own.

Public Record



Class Summary Table – Finish Row

7. Connections to the phenomenon (whole class)

Learning: Help students craft generalizable statements about what they learned from the investigation. They could also put questions or wonderings here.

Explaining Stormwater Runoff: How could what we learned about plants help us understand what happens to stormwater in the city? Would the removal of forests as a city grows increase the amount of stormwater problems or decrease it? How could plants help with stormwater runoff?

Example of what the Summary Table might look like:

| Activity | What did we observe? | What did we learn? | How does it help us explain and/or solve stormwater in the city? |
|--|--|--|--|
| <p>4: Plants</p> <p>“How do plants affect stormwater runoff?”</p> <p>Photo or sketch of tubs</p> | <p>Class Data Table</p> <ul style="list-style-type: none"> – Runoff filtered through plants moved __ ml less soil. – The soil-only water was a lot dirtier looking than the one from the plants tub. | <ul style="list-style-type: none"> – Plant roots hold onto soil making it harder for water to move the soil – Plants slow down water and soak some of it up. | <ul style="list-style-type: none"> – Plants help slow the water down and soak it in. – Plants can help make stormwater cleaner. – Plants can be a big help with stormwater! |

8. Pressing for ongoing changes in thinking (individuals)

TEACHER DECISION POINT



Update explanatory models now or later?

Explanatory Model



Updating Models

Back-Pocket Questions



Changes in Thinking

Return explanatory models to students.

Has their understanding of stormwater changed?

Point out the class summary table on your wall and challenge the students to think about how the learning referenced there could be incorporated in their models.

Offer the students the options of writing new thoughts on the old model with a different colored pencil, using post it notes, or starting the model over on a new sheet of paper.

Give students time to update their models to better explain what is happening to stormwater and why the pond is flooded. Remind them that they can use arrows, drawings, and/or text.

As students work, circulate and ask questions. Also, if you will be doing the consensus model, take note of commonalities you can help call out later.

Timing

It is important for students to revisit their thinking as the unit progresses, but it doesn't have to happen at this moment. It could alternatively be done in a separate mini-lesson, or just before the start of your next lesson. You could also choose to wait to do it until after the next lesson.

Consensus Model?

If you have been doing a consensus model as a class, consider covering it up during this activity to avoid students directly copying what you have previously added to it.

It is not critical that students get everything down at this stage, this is “an opportunity, not a test.”

Back Pocket Questions

- What do you understand now that you didn't before?
- What is missing from your model?
- What else happens to stormwater in the city that you haven't shown yet?
- How can you show your thinking with pictures on your model?
- How could you describe it in words?

Explanatory Model



Gallery Walk

9. Sharing Understandings (whole class)

Gallery Walk: Have students either place their models to be visible on their desks or tape them on the wall.

Students circulate and look at models. What matches with their understanding and what is showing a different understanding?

If you have time this is a great opportunity for students to argue different points of view and present the evidence they have that supports their point of view.

Public Record



Consensus Model

10. OPTIONAL: Adding to Class Consensus Model (whole class)

Uncover the class Consensus Model and either discuss what to add to it as a class or ask students to write on post its things they feel should be added.

Where on the model could you show plants keeping soil from eroding with their roots?

Add to the model while talking through the additions with the class. Try to continue to use colored pens to match up additions to specific lessons.

EXAMINING STUDENT WORK

Examine students' worksheets, particularly questions 1 and 2. How do they explain their findings? How do students show an understanding beyond a 'what' level and moving into explaining how or why plants affect stormwater runoff and erosion? What questions/wonderings did students have?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

The upcoming lessons in this curriculum expand beyond the more immediate effects of stormwater to look at what happens to it in the broader community. If your students have more ideas to explore about how it moves or what it does where it falls, you might want to do that first. The Next Steps section in lesson three discusses other ways the models could be used.

One type of urban weathering that could come up during your investigations are the **cracks in concrete** created by frost wedging and the **potholes** created when you add in cars. There is more information on these processes in the teacher background section of this manual as well as a reading about it in the Appendix.

- You could have students read about it (in Appendix) and/or watch a quick video with your students: <https://www.youtube.com/watch?v=rg5Hwety4RU>
- Alternatively, it could be interesting to develop an experiment to explore the phenomenon further.

If you would like to provide your students a broader range of information about the many types of erosion, you could watch the **Bill Nye the Science Guy video** on Erosion with them:

<https://www.youtube.com/watch?v=0e3D2RB-bqI>

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

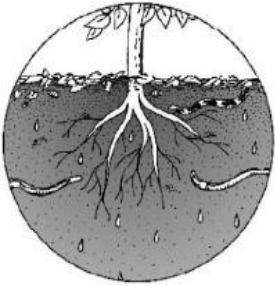
Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Just-in-Time Instruction: Plant Roots



Roots anchor plants into the ground and gather water and nutrients for the plant. By draining water from the soil, they help keep the soil from staying too wet. When the soil gets too dry, roots can draw up water for the plant from deeper underground.



Roots also help soil. By reaching through and holding onto the soil they reduce **erosion**. Roots can also make more soil when they grow into cracks in the rocks and break them apart. Some roots also produce a weak acid that wears away the rocks. Roots breaking up rocks into smaller bits is one type of **weathering**.

Effects of Plants on Erosion Procedure

SETUP

Gather Materials:

Materials Manager brings materials to group area: tub with grass or dirt, bucket, large and small pad, 2 spoons, plastic cup, and graduated cylinder.

Water Filler fills rain jar with 1000 milliliter (ml) of water and screws on lid.

Set up materials:

- Cover a book with the large pad with slick plastic side down (absorbent side up).
- If needed, create soil block between the line and edge with no hole (20 cm long x 5 cm deep).
- Place the tub with dirt end of the tub on stack of books.
- Top of soil in tub should be 10 cm above the table (adjust book size as needed).
- Make sure the drain hole sticks over the edge of the table.
- Place the small pad on the floor with the plastic side down and put the bucket on the pad under the drain hole so that the bucket will catch any water that comes out of the hole.
- Remove the drain plug from the tub and place it on the table next to the tub.

GROUP ROLES

1. **Materials Manager:**
Brings materials and clears drain blocks
2. **Tub Holder:** Keeps tub from sliding off books
3. **Water Filler:** Fills rain jar
4. **Water Shaker:** Shakes all of water evenly across tub
5. **Water Collector:** Collects cup of runoff

PROCEDURE



1. **Make it rain over the tub.**
 - a. Water collector holds the clear plastic cup under the tub's drain hole until it is mostly full (the rest of the water can go in bucket).
 - b. Water shaker shakes the jar over the soil to make it rain on the soil (don't squeeze). Move it around so all areas of the soil block get equal amounts.
 - c. If the drain hole plugs, materials manager clears the blocking material.
 - d. Once jar is mostly empty and most of the water has drained, plug the hole.
2. **Sketch observations on your worksheet:**
 - a. Sketch the contents of your cup and the changes in the tub on your data sheet. Label the drawing. Pay attention to where the water went in the tub and how it changed the soil.
 - b. Then sketch a cup and tub from a group that was different than yours (with plants if you had bare soil).
3. **Measure and record erosion on your worksheet** (after everybody is done sketching):
 - a. Use your trowel and spoons to separate all the dirt that moved past the 20 cm line and measure the amount with your graduated cylinder or rain jar if it is a large amount.
 - b. Use the ml markings on side of graduated cylinder or jar to measure to top of solids in the jar (not water) and write amount in the data table.
 - c. Be prepared to share your data with the class for the class data table.

Observing the Effects of Plants on Erosion

Name: _____ Date: _____



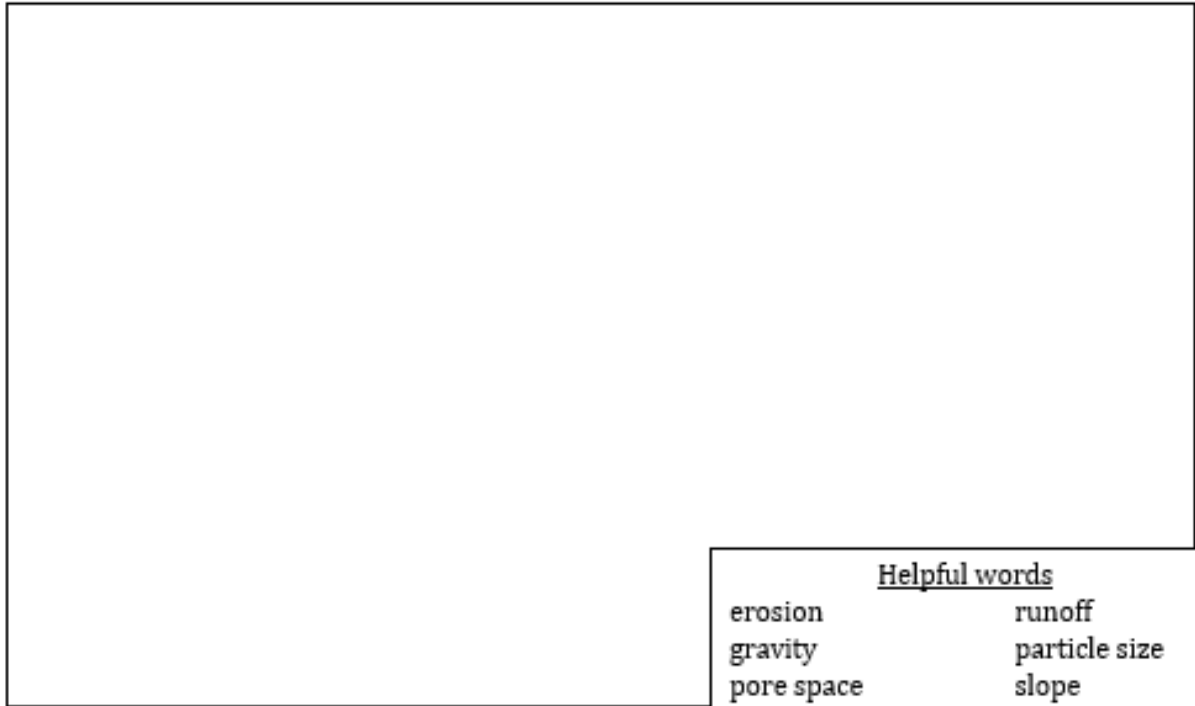
Investigative Question: What is the effect of plants on soil erosion and runoff?

| Model | Draw water sample contents | What does the soil in the tub look like AFTER? Sketch both a tub with plants and one with just soil. | Amount of Soil Moved (include unit of measure) |
|--------------------|---|--|---|
| Plants on slope |  | | G1: _____ G2: _____ G3: _____ |
| NO Plants on slope |  | | G4: _____ G5: _____ G6: _____ G7: _____ G8: _____ |

Based on the data what can you conclude about the effect of the plants on the amount of erosion that occurred?

Write your conclusion: *Include evidence from your data to support you claim.*

2. **Explain your reasoning.** *Why did we get the results that we did? How do plants affect soil erosion?* Draw and write to share your thinking. Use zoom-ins on your drawing to include ideas about plant roots, pore space, and particles size of soils.



| <u>Helpful words</u> | |
|----------------------|---------------|
| erosion | runoff |
| gravity | particle size |
| pore space | slope |
| speed (fast/slow) | absorb |
| groundwater | |

Helpful sentence stems (optional):

- *We observed that on the covered slope...*
- *I think this happened because...*
- *The slope with/without plants absorbed the most/least water because...*

Lesson 5: Local Stormwater Systems

OBJECTIVES & OVERVIEW

Students learn about the impact the stormwater runoff has after it leaves the site through a storm drain or ditch. Depending on your location, the stormwater runoff impacts local creeks, lakes and the Puget Sound with flooding, pollutants carried by the stormwater, and/or “combined sewer overflows.” This is important towards understanding why adding more storm drains does not solve our region’s stormwater runoff problems. It will be used when students are considering criteria for their stormwater solutions later in the unit.

- Students analyze maps to identify where water goes after it lands on the ground in their neighborhood.
- Students use videos and/or graphics to identify the effects the stormwater from their neighborhood has elsewhere.

Focus Question: Where does our stormwater runoff go and what problems does it cause?

Learning Target: I can use maps to help me figure out what happens to the stormwater runoff from my neighborhood.

New Terms: combined sewer overflow (some neighborhoods)

**Ambitious Science Teaching Framework:
SUPPORTING ON-GOING
CHANGES IN STUDENT THINKING**



This practice supports on-going changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

PE 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

PE 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.

| Science & Engineering Practices | Disciplinary Core Ideas (DCI) | Cross-Cutting Concepts (CCC) |
|--|---|---|
| <p>Obtaining, Evaluating, and Communicating Information.</p> <ul style="list-style-type: none"> • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. | <p>ESS3.B Natural Hazards.</p> <ul style="list-style-type: none"> • A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2) <p>ESS2.A Earth Materials and Systems.</p> <ul style="list-style-type: none"> • 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. (4-ESS2-1) | <p>Systems and System Models.</p> <ul style="list-style-type: none"> • A system can be described in terms of its components and their interactions. • A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. |

MATERIALS

For each group:

- Maps of the area around the school (copies of the maps should be provided to you but can also be found with your school specific-teacher manual on communitywaters.org)
- If laminated: Wet erase markers for use on the maps (dry erase does not erase well from lamination)

PREPARATION – 30 minutes

Website



The teacher manual for your school as well as all worksheets, links and graphics can be found on communitywaters.org

TEACHER DECISION POINT



Go outside?

Use digital maps?

- **Video:** Review the “When it Rains it Pours” video (from communitywaters.org or at <https://vimeo.com/238134756>)
- Review the Lesson 5 information in your school specific teacher manual to learn where the stormwater from your school’s neighborhood goes and which additional video(s) are suggested for watching with your students:
 - OPTION A = “Effects of Urbanization on Stream Ecosystems.” <https://www.youtube.com/watch?v=BYwZiiORYG8>
 - OPTION B = “Drained: Urban Stormwater Pollution.” <https://vimeo.com/51603152>
- If the school-specific manual says your school’s water goes into a **Combined Sewer Overflow**, prepare the diagram for projecting.
- **Make the maps less abstract?** Maps of underground pipes can end up being too abstract for some 4th graders. Depending on your local area and time available, consider whether you want to take students outside with the maps in hand to point out how they match up with the storm drains and land around the school. This could be especially useful if you have visible hills, ditches, ponds, or other terrain around the school that interacts with the pipes. You could also do this as part of the Walking Field Trip during your next lesson.
- **Digital Maps?**

The local pipes maps for your school were created from King County’s online WaterMaps website.

You can learn more about it and find a link on communitywaters.org.

The website was created for teacher and student use but is somewhat complex. Consider whether you would want to use the site directly with students. Would you want to project it or have students play with it during computer lab time?

PROCEDURE

Engage and Encounter

1. Activate prior knowledge and experiences

Students have investigated as a class what happens to water that falls in their schoolyard.

They know from the investigations they have done that runoff can pick up and move materials like dirt and sand.

Ask students to think about what they've noticed around their own neighborhoods. *What kinds of things are on streets and sidewalks that stormwater runoff might pick up as it builds up speed? Where do they think that water would end up? Would it cause problems there?*

Have students create a T-chart in their science journals. On one side they should list where stormwater would go in a city. On the other they should list any problems stormwater runoff might cause as it travels and wherever it ends up.

Example T-Chart:

| <i>Where might stormwater go?</i> | <i>What problems might stormwater cause?</i> |
|-----------------------------------|--|
| <i>Into the ground</i> | <i>Flooding</i> |
| <i>Into storm drains</i> | <i>Erosion</i> |
| <i>Into Puget Sound</i> | <i>Pollution</i> |

Explore and Investigate

2. Introduce and watch the video (whole class)

Direct link: <https://vimeo.com/238134756>

This video is about what happens with stormwater runoff in the city. The very beginning will be review for them, but the rest helps answer the question of where stormwater might go and the problems it could cause. They should watch for those things.

After watching it, provide students the opportunity to add to their T-charts.

Then watch it again as a class with students adding additional things to their T-charts as they watch.

3. Introduce the activity (whole class)

The video talks about cities in general but does not address what is going on in YOUR neighborhood.

Project one of the maps that shows the pipes around your school and point out your school (plus other important landmarks) on the map.

Video Clip



"When it Rains, It Pours"

Length: 2:47

communitywaters.org

Present visual



Local Pipes Maps

The map shows where stormwater goes in your neighborhood. As appropriate to your map, point out the different items on the map's key and an example on the map.

Zoom in on your school on the map. Where is the playground? Do the storm drains shown match up with any they have noticed?

If your maps include a larger scale map on the back, show it to the students but tell them to refer to it once they figure out where the water leaves the local map.

Student groups will get a copy of the map and will use wet erase markers to trace the path water would take from their schoolyard (or another location of their choice).

Small Groups



Where does the water in the schoolyard end up?

Back-Pocket Questions



Observations



Present visual



Combined Sewer Overflow Diagram is at end of lesson and on communitywaters.org

4. Interpreting the Maps (small groups)

Provide students the opportunity to trace where water from the school would go on each of their maps to figure out where it ends up.

BACK-POCKET QUESTIONS

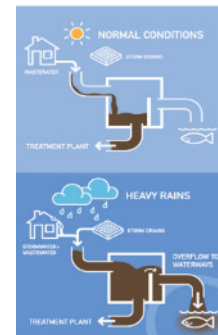
- What are the different ways stormwater leaves the area?
- Did we find storm drains when we were exploring around the school? Where do those storm drains lead?
- What happens to the water when it leaves the edge of their map?

This could be a place to pause if you are out of time.

5. Provide ideas to leverage (whole class)

By using the map, students have identified where the storm drains in your school's neighborhood go. Do they enter the combined sewer system? Do they drain directly into a stream, lake, or the Puget Sound?

If the student's water goes into a Combined Water pipe, project the **Combined Sewer Overflow Diagram** talk them through why the water would end up overflowing when there is too much of it.



Video Clip



Use option A or B depending on your school's location. Links can be found on communitywaters.org

Depending on where the water ends up, use the appropriate video (see your school-specific teacher manual for suggestions):

OPTION A (stream, creek, or river):

View **"Effects of Urbanization on Stream Ecosystems."**

Watch from 0:00 to 2:11.

Also available at <https://www.youtube.com/watch?v=BYwZiiORYG8>

This video focuses on the ecosystem impacts of urban pollution. It uses some big words and is pretty dense, so we recommend either rewatching 1:21 to 2:11 several times with pauses to identify the problems the video is identifying.

OPTION B (lake or Puget Sound):

View **"Drained: Urban Stormwater Pollution."**

Watch from 0:00 to 2:57.

Also available at <https://vimeo.com/51603152>

The Drained video is specifically about stormwater outfalls into Puget Sound; you will need to provide some additional thoughts if your school's stormwater goes into a combined water pipe or ends up in a lake.

- **Combined Sewer Outflow (CSO)?** If the stormwater from your area goes into a combined sewer, point out to the students that the CSO during a big storm would have everything described, PLUS everything from the sewers (including human waste).
- **Lake?** If the stormwater from your area empties into a lake, point out that the creatures impacted may be different but the impact is similar. PLUS, there is less water in the lake than in the Puget Sound to dilute the pollution, and people swim more often in lakes

Later in the unit when considering Solutions:
If students are having trouble connecting the solutions to the bigger problem of pollution in Puget Sound, you could watch the rest of the "Drained: Urban Stormwater Pollution" video.

Reflect and Explain

Turn-and-Talk



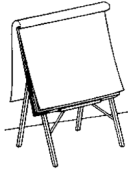
What problems does OUR stormwater cause?

6. Discuss observations from the maps and video (whole class)

Have student turn to a partner to look back at T-Chart they created earlier. Which of the possible things that they wrote on their chart actually happen with THEIR water?

Each student should add any missing items and underline on their lists the items that are relevant.

Public Record



Class Summary Table
Complete the Row

7. Connections to the phenomenon (whole class)

Return to the Class Summary Table to fill in a row for this lesson. Observations would be things they noticed on their maps. Learning could be general but also should include the things students underlined on their T-charts.

Example of what your finished summary table row might include:

| Activity | What did we observe? | What did we learn? | How does it help us explain and/or solve stormwater in the city? |
|---|---|--|---|
| <p>5: Local Stormwater Systems</p> <p>"Where does our stormwater runoff go and what problems does it cause?"</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 10px auto;">Pipes map</div> | <ul style="list-style-type: none"> - There are a lot of stormwater <pipes and/or ditches>* in our area. - Water in our neighborhood goes into <stormwater pipes or combined pipes or stormwater ditches>* - Our water ends up in <a creek, or the lake, or the Puget Sound>* <p>* Will vary depending on neighborhood.</p> | <ul style="list-style-type: none"> - There are hidden pipes that help move stormwater. - Our water ends up in <a creek, or the lake, or the Puget Sound>. * - Our water causes problems when <too much floods the creek or it causes a combined sewer overflow or it carries pollution into the lake or sound>. * <p>- * Will vary depending on neighborhood.</p> | <ul style="list-style-type: none"> - Stormwater runoff in the city goes into pipes and ditches. - Putting stormwater into stormwater pipes causes problems elsewhere. |

TEACHER DECISION POINT



Assessment opportunity: will students draw, write, or discuss with others? See "Examining Student Work below".

8. Make the Connection (individual)

Challenge students to sketch a picture showing an effect the stormwater from their community could have **after** it flows into a storm drain. They should include labels.

OR

Have students write a story about a place and the people and/or animals that would be affected by too much stormwater runoff (could be flooding or pollution).

OR

In pairs or small groups: Discuss why stormwater runoff matters to people and places. Who or what might be affected? How?

Public Record



Consensus Model

9. OPTIONAL: Adding to Class Consensus Model (whole class)

What should be added to the model to represent what you learned today? How can we best represent the storm drains connecting to underground pipes? How might we show where the water ends up when it leaves the area shown in the model?

EXAMINING STUDENT WORK

Examine what students have drawn on their maps with the markers. Were they able to mark a path to the edge of the map?

From your observations after the video of the discussion and public record, are students understanding what happens to the stormwater runoff from their neighborhood? Do they care?

From your observations when students are examining and discussing the maps, are they able to relate them to the real world?

The pictures students draw, stories they write, or discussions they have offer an opportunity to see whether they are making the connection between the water going into their local storm drains and the problems it can cause further away. Do the pictures, stories or discussions reveal whether they care about the effects of the stormwater runoff?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

If the maps were too abstract for the students, consider bringing the local ones with you as you walk the neighborhood in the next lesson (if you choose that option). You could then have students find the storm drains on the map and walk the route taken by the underground pipes.

If students are not making the connection to the effects downstream or are not caring about it, consider whether that has an impact on your Decision Points in the next lesson. Is the stormwater outflow a place you could visit during the next lesson, might you have a guest speaker who is impacted by it or working on the problem, or could you otherwise investigate the impact it has?

Examples (neighborhood-specific information provided by IslandWood might provide additional ideas):

- A nearby stream that floods could end up as a walking field trip to examine the erosion caused by the flooding or you could have a local person in to share how the flooding has affected them.
- If you are raising salmon in your school, you (or a staff person more involved with the salmon) could talk further about how stream flooding or CSO overflows might impact the salmon.
- If the students swim or otherwise recreate in or on a nearby lake, it is likely that CSO overflows impact that lake at times.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

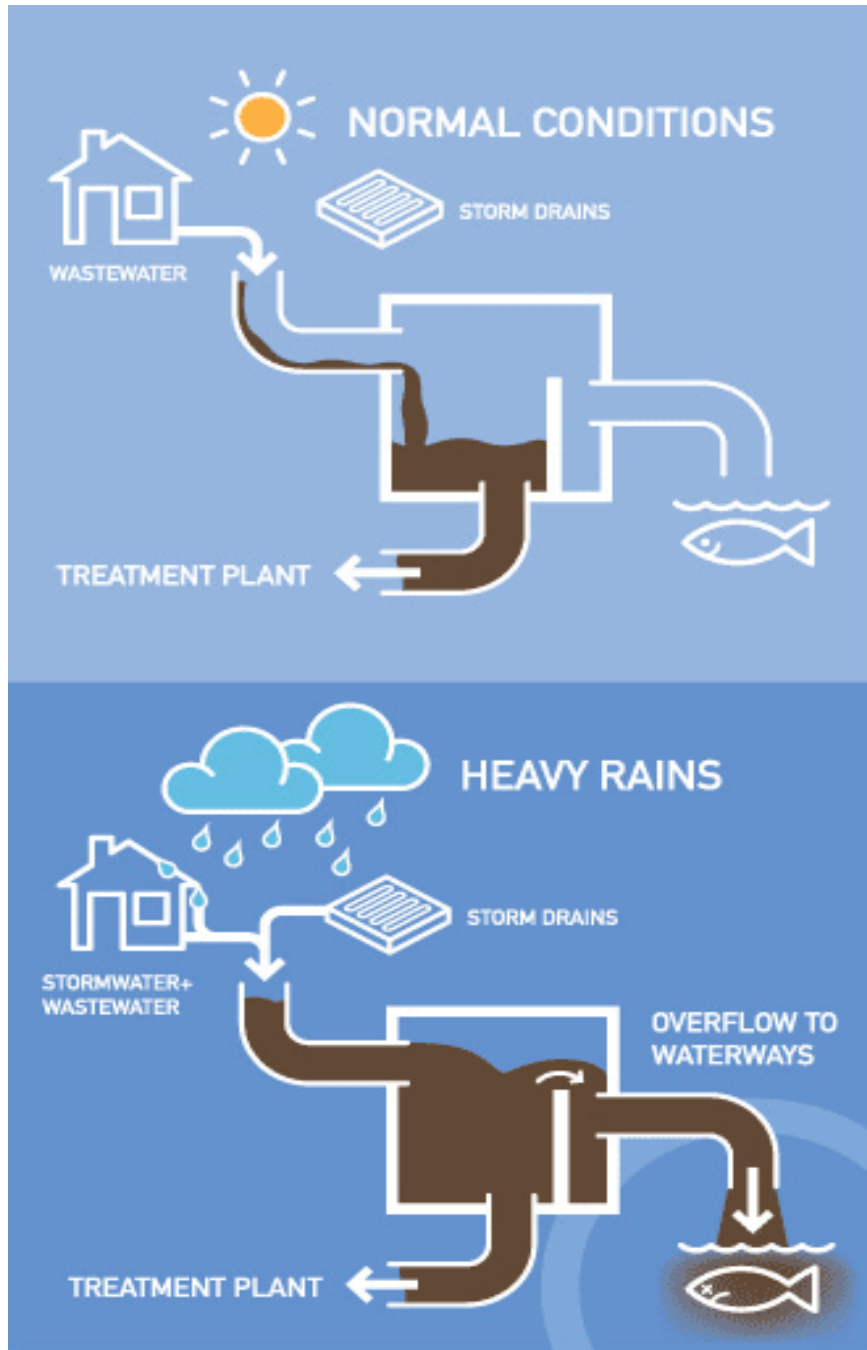
Tools. How did the tools used (e.g. neighborhood maps, class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Combined Sewer Overflow Diagram

In many parts of Seattle, both wastewater from within the home and stormwater runoff from impervious surfaces are combined into the same sewer pipes. A big storm can result in more water entering the pipes than the treatment plant can handle - this results in sewage water overflows directly in lakes, streams and Puget Sound.



Lesson 6: Stormwater in our Community

OBJECTIVES & OVERVIEW

IMPORTANT NOTE: If you are teaching this lesson for the first time and would like it modeled for you, IslandWood can help! See the preparations section below. This lesson can be done any time between Lesson 3 and Lesson 7.

This lesson provides students an opportunity to see and think about what is happening to stormwater in their neighborhood. They will look for where water goes, what effects it has, and if there are ways people are trying to deal with stormwater.

- Students explore their neighborhood to gather data about where water goes.

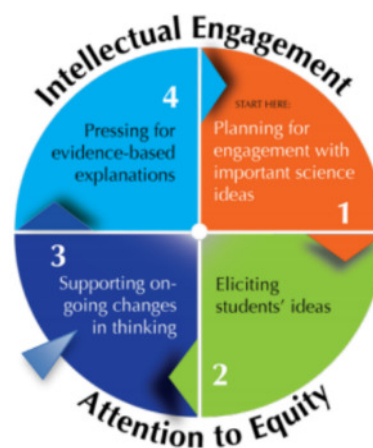
Two options are presented for this lesson (see next section).

Focus Question: What happens to stormwater in our neighborhood?

Learning Target: I can make observations to understand what happens to stormwater in my neighborhood.

New Terms: None

Ambitious Science Teaching Framework: SUPPORTING ONGOING CHANGES IN STUDENT THINKING



This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit <http://AmbitiousScienceTeaching.org>

WHICH OPTION TO USE?

TEACHER DECISION POINT



Walking Field Trip or
Take-Home
Assignment?

You will need to decide which of two options you prefer for this lesson:

1) WALKING FIELD TRIP (whole class, during school day):

The whole class walks around the neighborhood and fills out a bingo sheet as they search for specific things connected to stormwater. If you haven't done this lesson before, IslandWood staff can be requested to facilitate this lesson (must be scheduled at least 2 weeks in advance). If interested, you can sign up on communitywaters.org.

2) TAKE HOME ASSIGNMENT (individual, homework)

Individual students do a "Stormwater Scavenger Hunt" on a walk with an adult around their neighborhood to gather information about what happens to stormwater in their home neighborhoods. Students should think from the perspective of the water: "If I were a raindrop, where would I travel to? What would get carried along with me as I go? What would slow me down?" They will also look for an area that may help or have problems with too much stormwater.

NEXT GENERATION SCIENCE STANDARDS

PE 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.

PE 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.**

PE 4-ESS3-2. Generate and **compare multiple solutions to reduce the impacts of natural Earth processes on humans.**

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|---|--|--|
| <p>Asking Questions and Defining Problems.</p> <ul style="list-style-type: none">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) <p>Planning and Carrying Out Investigations.</p> <ul style="list-style-type: none">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. | <p>ESS3.B Natural Hazards.</p> <ul style="list-style-type: none">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. (4-ESS3-2) <p>ESS2.A Earth Materials and Systems.</p> <ul style="list-style-type: none">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. <p>ESS2.E Biogeology.</p> <ul style="list-style-type: none">Living things affect the physical characteristics of their regions. | <p>Cause and Effect.</p> <p>Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS3-2)</p> |

MATERIALS

Materials for Walking Field Trip (Option 1 above):

- Bottles with water – student water bottles? more is better, but at least five.
- “**Stormwater Features Guide**” printed to have with teacher and/or chaperones during walk.
- “**Neighborhood Stormwater Cards**” ready for projection for students to view (or project Stormwater Features Guide).
- Walking Field Trip Map and “Points of Interest” from your school’s **Teacher Guide** (this is school/neighborhood-specific things to look for).
- For each student:
 - Clipboard & Pencil
 - Print **Neighborhood Stormwater BINGO** Worksheet*

OR

Materials for Stormwater Scavenger Hunt (Option 2 above):

- Stormwater Scavenger Hunt** worksheet (one per student)*
- Neighborhood Stormwater Cards:** to project for viewing

BOTH

Per 4 students:

- Print “**Discussion Diamond Group Worksheet**” on 11x17 paper.

*There are versions of the BINGO sheet on CommunityWaters.org that have been translated into Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese.

PREPARATION – Varies depending on the option chosen

See the “Which Option to Use” section above.


Website



Scheduling for the Walking Field Trip can be done on communitywaters.org

Worksheets can also be accessed on the website.

Preparation for Walking Field Trip (Option 1):

- **In advance:**
 - **Schedule with IslandWood:** If you haven’t done the Walking Field Trip before and you would like help, coordinate with other teachers who are also interested at your school to schedule the same day for an IslandWood educator to lead the trip. Then follow up to confirm date and time.
 - Arrange for chaperones (as many as possible, but at least one)
 - Send home permission forms (if needed) for walking field trip
 - Remind students to bring appropriate clothes for the weather.
- Assemble clipboards or other hard surface for students to write on
- Fill 5 or more bottles with water
- **Review the Strategies for Outdoor Learning** section in the Teacher Background section of this curriculum
- **If you are leading the walk without help of an IslandWood Educator:**
 - In the Teacher Guide for your school, review the provided path of the walking field trip and consider any other options you are aware of beyond what is suggested.
 - Review the **Neighborhood Stormwater Cards** to see information about different features. It also has back-pocket-questions and activities that can be used as you look over each feature. Note the features with the  symbol as good places to pour water with students.
 - Drive or walk the route. During your review, identify safety concerns and areas you’ll want to include or exclude on your walk.

OR

Preparation for Take Home Assignment (Option 2):

- Send a note home to let families know about the assignment.

BOTH FOR BACK IN CLASSROOM AFTERWARDS

- Queue up **Discussion Diamond Directions** to project (end of lesson or on communitywaters.org).

PROCEDURE

Small Groups



What happens in your neighborhood when it rains a lot?

1. Activate prior knowledge and experiences

(FOR EITHER ACTIVITY) Thinking back to the previous lessons, where does our stormwater end up? Review the Stormwater Runoff table.

Have small groups discuss what they have seen in their neighborhood when it rains a lot: Where does the water go? Are there puddles that cause problems? Flooding? Areas that get washed away? Other problems?

OPTION 1: WALKING FIELD TRIP (whole class, during school day)

2. Introduce Activity (IN CLASSROOM, whole class):

Students will be filling in a scavenger hunt “bingo sheet” during their walk around the neighborhood.


Focus Question: What happens to stormwater in our neighborhood?

Project the Neighborhood Stormwater Cards or Stormwater Features Guide (from printed or online copy) to show students what they should be watching for. Go over at the pace that best meets needs of students. Example of a card (*front and back*):

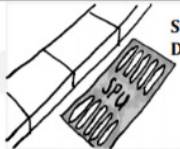
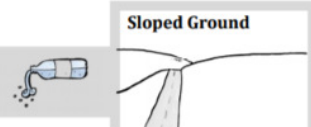
Present visual



Neighborhood Stormwater Cards Or Stormwater Features Guide

| | |
|---|--|
|  | Storm Drain Storm Drains move water into underground pipes to take it somewhere else. Anything that gets carried into the drain may end up in a local stream, lake, or Puget Sound. <ul style="list-style-type: none">• Why do you think the drain was built in this location?• Is there anything about the drain that isn't working? Investigation: Do you see anything IN the drain? Anything on top of it? What might end up flowing into the drain other than rainwater? |
|---|--|

Stormwater Features Guide example:

| | |
|--|--|
|  | Storm Drain <ul style="list-style-type: none">• Is there anything about the drain that isn't working? Anything on/in it?• What might end up flowing into the drain other than rainwater? |
| <ul style="list-style-type: none">• What kind of surface is on the slope? (grass, dirt, gravel, concrete?)• How quickly does water soak in or run off?• Does the water carry anything with it? |  |

Review expectations for being outside and off campus:

- Students should stay together between adults.
- Students must stay on sidewalks and only cross roads when adults have given permission.
- Students should not go up to people’s homes or in yards (out of respect for private property).

Divide students into pairs or groups to work together on finding things (each student will fill out their own “BINGO” sheet).

When ready to go outside, make sure students have weather-appropriate attire, a writing tool, and a clipboard as needed. Each small group should have at least one bottle of water.

| |
|--|
| <p style="text-align: center;">Chaperones</p> <p>Pull chaperones aside to give them a copy of the BINGO sheet and Stormwater Features Guide and review their role:</p> <ol style="list-style-type: none">1. Ensure student safety!<ul style="list-style-type: none">• Watching for cars• Reminding students to stay on sidewalks• Managing street crossing2. Keep students off private property.3. Remind students to look for items on the Bingo sheet.4. Ask questions about things students find.5. Not spending time texting or talking on cell phones. 😊 |
|--|

3. Get the activity started (OUTSIDE BUILDING, whole class)

Gather or circle class together to remind students of the rules for safety and their task.

Assign a chaperone to bring up the rear of the class.

4. Make observations (OUTSIDE, whole class and individuals)

Stop periodically at the “points of interest” indicated in Teacher Guide as well as any things you or students find interesting (and relevant).

Do suggested activities and ask questions from Teacher Guide as focus and time permits.

Have students pour water on different types of slopes (paved, gravel, grass, mulch, etc.) to test how each type of surface would interact with stormwater. For example: How much water soaks into grass compared to mulch or gravel? How fast does it travel downhill on different surfaces?

Return to classroom for discussion (“Reflect and Explain” section below).

OPTION 2: TAKE HOME ASSIGNMENT (STORMWATER SCAVENGER HUNT):

Skip this section if you are doing the Walking Field Trip

2. Introduce Activity (**IN CLASSROOM**, whole class):

Each student will be doing a scavenger hunt to figure out what happens to stormwater in their OWN neighborhood. They can talk with their adult at home to decide whether they do it on a walk together, do it themselves in an area they are allowed to go, or fill in what they can see from where they live.

Focus Question: What happens to stormwater in our neighborhood?

Review with students the instructions printed on the **Stormwater Scavenger Hunt**.

Challenge students to find and draw an example of each of the scavenger hunt items in their neighborhood. You may want to use the Neighborhood Stormwater Cards to show students visuals of what they might find or look for. Make sure they know that they may not be able to find every item in their neighborhood.

They will be drawing a location that could have stormwater runoff problems – or be helping with stormwater runoff - in the box under #9. They will label things that might slow down or speed up stormwater, and include arrows showing the direction of water flow.

Have students turn-and-talk to practice explaining the assignment to an adult at home.

Provide a due date to have completed the assignment (we suggest including at least one school night and a weekend in the time available).

Present visual



**Stormwater
Scavenger Hunt
Sheet**

Turn-and-Talk



Practice explaining the assignment.

Reflect and Explain (BOTH OPTIONS)



Timing of This Activity:

Do this after the walking field trip or after students have had time to complete the take-home assignment. This can easily be done on a different day. If an IslandWood educator is leading the outside portion of the Walking Field Trip for you, you will likely need to do this yourself as a follow up activity.

Small Groups



Discussion Diamond to record and share observations

1. Discussion Diamond observations (small groups)

Divide students into groups of 3-4.

Have student worksheets from the previous activity on their desks for review.

Project the questions and procedure (at end of lesson):

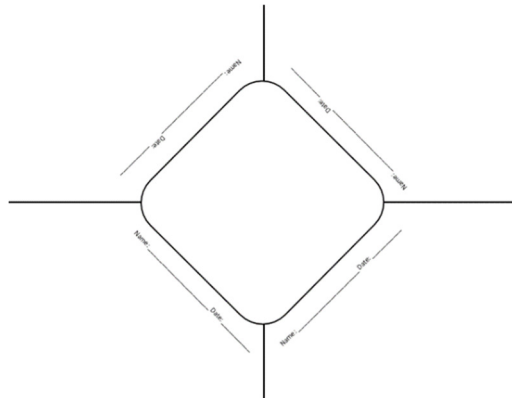
- *What did you notice or wonder about stormwater during your walk?*
- *What did you find that would increase or decrease stormwater runoff in your neighborhood?*
- *What problems did you find, if any?*

Hand out **Discussion Diamond sheets** to each group of 3-4 students and explain how the sheet will be used.

Present visual



Discussion Diamond Questions and Procedure



Discussion Diamond

This AST strategy uses a writing scaffold to capture individual thinking as well as the group's consensus or summary of what was discussed.

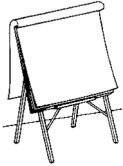
- Students will have about 3 minutes for silent thinking and writing time. Each student writes or draws in their corner of the paper.
- Then individuals will share what they wrote or drew in their small groups for a total of around 4 minutes. After each person shares, they should take some time for other students to ask questions, add on, or connect to what they wrote.

As students write, circulate and press deeper for students who claim they're done or help others get started who seem stuck.

- After all students have shared their corners, remind them of the question prompts, and then one member records a summary of things multiple members of the group observed or agreed on. Teams work together to help the recorder do this in 1-2 minutes.
- Designate or ask for one person to present their common idea to the class.

2. Apply understanding (whole class)

Public Record



Class Summary Table – fill in row

Have one student from each group share their group’s observations while you write them in the observations section on the class summary table. Problems students found could be put in the learning column and things that decrease stormwater could go in the last column.

Prompt students to provide additional things they learned and ways what they learned or observed inform their model.

See below for some examples:

| Activity | What did we observe? | What did we learn? | How does it help us explain and/or solve stormwater in the city? |
|--|--|---|--|
| <p>6: Neighborhood Stormwater</p> <p>“What happens to stormwater in our neighborhood?”</p> <div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p>Tape map or blank scavenger hunt sheet</p> </div> | <ul style="list-style-type: none"> – Our neighborhood has a lot of impervious surfaces. – There are steep hills* in our neighborhood. – We saw <*> storm drains. – Gravel moved on to the road by stormwater runoff.* – There is a stormwater ditch* near our school – <p>* Observations could vary widely depending on the neighborhood.</p> | <ul style="list-style-type: none"> – What we have been studying actually exists around our neighborhood(s). – We can identify what is going on with stormwater no matter where we are. – Stormwater runoff causes <Specific problem identified by student(s)> in our neighborhood. <p>– * Will vary depending on neighborhood.</p> | <ul style="list-style-type: none"> – We need to also be thinking about what is happening with stormwater outside the schoolyard. – We should add storm drains to our explanatory model. – There are things that help with stormwater already existing in our neighborhood.* – * Will vary depending on neighborhood. |

3. OPTIONAL: Adding to Class Consensus Model (whole class)

Public Record



Consensus Model

Uncover the class Consensus Model and either discuss what to add to it as a class or ask students to write on post its things they feel should be added.

What did we observe around our neighborhood(s) that should be included on the model?

Add to the model while talking through the additions with the class. Try to continue to use colored pens to match up additions to specific lessons.

EXAMINING STUDENT WORK

Review the discussion diamonds for each group to see what each student contributed and what stands out. The student worksheets are another opportunity to see student thinking around stormwater. Is each student's work reflecting understanding of stormwater runoff? Are they able to identify what kinds of things are making it worse or better?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

The next lessons shift into applying student's understanding of stormwater to develop an explanatory model of a stormwater runoff problem at a local site.

If students' understanding of "too much stormwater" is incomplete, what additional work needs to be done? Some ideas for further work are:

- Students could draw a model of the stormwater system as they understand it, from school or home to the stormwater "end" point.
- You could review student's original explanatory models and/or a class consensus model to have students explain what they would add to the model to help it more accurately reflect what happens to stormwater.
- You could show more videos of stormwater, flooding, or storm events.

Neighborhood Stormwater BINGO

Name: _____

Search for each of the features below. How many can you find?

When you find an item, draw an example in the box or answer the question.

Keep an eye out during your search for an area you think helps or causes stormwater runoff.

| | | | |
|---|--|--|---|
| <p>Gutter / downspout from roof</p> <p><i>Where does the water go when it leaves the gutter?</i></p> | <p>Ditch or Bioswale</p> <p><i>Where does water in the ditch go?</i></p> | <p>People walking by</p> <p><i>Ask them what happens to the rain here when it storms.</i></p> | <p>Stormwater pond, lake, stream or creek</p> <p><i>Where do you think this water came from?</i></p> |
| <p>Water coming out of a pipe</p> <p><i>Where do you think the water comes from?</i></p> | <p>Trees</p> <p><i>What do you notice around the tree? Draw it!</i></p> | <p>Storm drain</p> <p><i>Do you see anything IN the drain or on top of it? Draw it!</i></p> | <p>Something that stores rainwater for later use (rain barrel or cistern)</p> <p><i>What is the water used for?</i></p> |
| <p>Garden that could hold water (rain garden)</p> <p><i>What kinds of plants are growing in there?</i></p> | <p>Lawn or Playing Field</p> <p><i>Pour some water on the grass. Does it soak in quickly or slowly?</i></p> | <p>Oil on the ground</p> <p><i>Where is this oil going to end up when it rains?</i></p> | <p>Pour some water!</p> <p><i>(you choose where)</i></p> <p>Where did you pour it?</p> <p>What did it do?</p> <ul style="list-style-type: none"> <input type="radio"/> Soak in <input type="radio"/> Stay on surface <input type="radio"/> Run downhill |
| <p>Sloped ground</p> <p><i>What do you see that might slow the water down?</i></p> | <p>Interesting Find (you pick!)</p> <p><i>Something that has to do with water.</i></p> | <p>Animals interacting with water</p> <p><i>What are they doing?</i></p> | <p>Paved surface</p> <p><i>Pour some water on it: Where does it go?</i></p> |

Stormwater Scavenger Hunt - *What's in my neighborhood?*

Name: _____ **Date:** _____

We have been studying water runoff around our school. The purpose of this assignment is to gather information about the places and things that affect the amount and rate stormwater runoff in your community.

Directions: Take a walk with an adult around your neighborhood and search for the items listed in each of the boxes on this page and the next - how many can you find?

When you find an item, draw an example in the box and label your drawing. Keep an eye out during your search for an **area you predict or see could help or cause problems with stormwater runoff**. When you find one, draw a picture of it in box 9 on the back of this sheet.

Stormwater Scavenger Hunt Items:

| | |
|--|--|
| 1) Storm drain | 2) Stream/creek, pond, or lake Do you know its name? |
| 3) Garden or rain garden | 4) Drain from a roof |
| 5) Steep slope with plants | 6) Steep slope with pavement |
| 7) Something that might get carried into a storm drain | 8) Something that collects stormwater runoff from a roof or pavement |

Stormwater Scavenger Hunt - *What's in my neighborhood?*

9) Draw a picture of an area that is helping or causing problems with stormwater runoff:

Label the things that might **speed up** the water:

- ✓ Slopes or hills
- ✓ Rooftops
- ✓ Concrete or asphalt

Label the things that might **slow down** the water:

- ✓ Trees
- ✓ Other plants
- ✓ Ponds or other places for the water to sit

Use arrows to show the direction water is or would be flowing.



How well does this area handle stormwater runoff? Use evidence to support your answer.

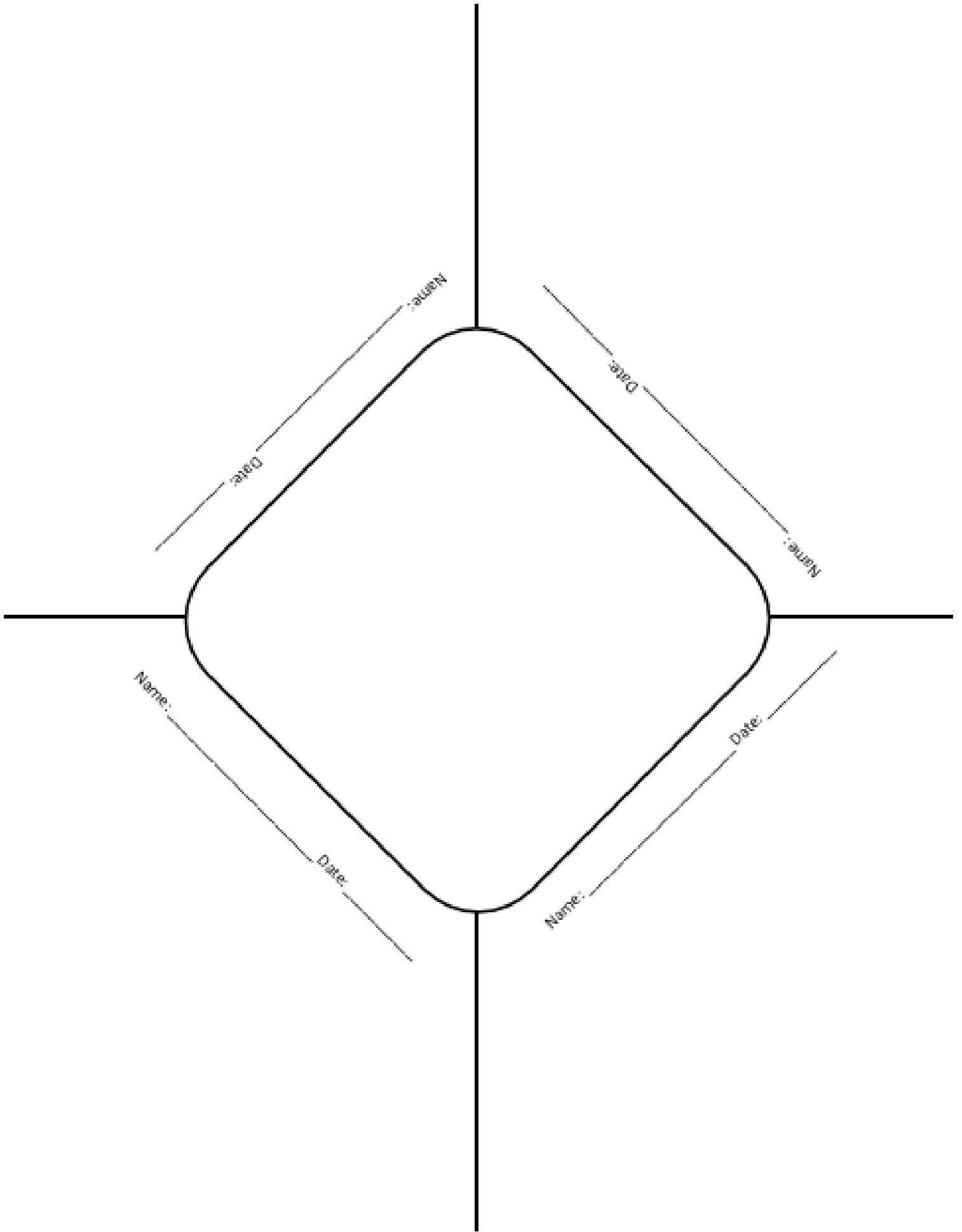
Discussion Diamond

Questions to Answer:

- What did you notice or wonder about stormwater during your walk?
- What did you find that would increase or decrease stormwater runoff in your neighborhood?
- What problems did you find, if any?

Using the Diamond:

1. Write your name and the date on your corner of the diamond then take 3 minutes to write or draw your answers in your corner.
2. Each group member shares their answers and answers other's questions.
3. Record a summary of discussion in center Diamond.
4. Share your group's summary with class.



Lesson 7: Choosing a Problem Site

OBJECTIVES & OVERVIEW

This lesson begins the shift from scientific understanding to engineering design. Students (or the teacher) choose a specific site with a stormwater runoff problem and apply the understandings they have built to explain what is happening with stormwater there.

- Students model their understanding of stormwater on a map of their site.

Focus Question: Where do we want to solve a stormwater runoff problem?

Learning Target: I can use what I know about stormwater to model what is happening at a specific site.

New Terms: Engineer

Ambitious Science Teaching Framework: PRESSING FOR EVIDENCE-BASED EXPLANATIONS



This practice happens as a summation, but parts can be introduced at other times when students talk about evidence. This requires that several tools be available to students: 1) their current models, 2) an explanation checklist, 3) the summary table, and 4) a scaffolded guide to help students create, in writing and drawing, their final model. For more visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

Students begin this performance expectation in this lesson, but fill in more details in the next one:

PE 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.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|---|--|
| <p>Analyzing and Interpreting Data - Analyze and interpret data to make sense of phenomena using logical reasoning. (4-ESS2-2)</p> <p>Developing & Using Models: Develop a model to describe phenomena.</p> <p>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, and/or cost. (3-5-ETS1-1)</p> | <p>ESS2.A: Earth Materials and Systems - 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. (4-ESS2-1)</p> <p>ESS2.E: Biogeology - Living things affect the physical characteristics of their regions. (4-ESS2-1)</p> <p>ESS3.B: Natural Hazards - 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. (4-ESS3-2)</p> | <p>Patterns - Patterns can be used as evidence to support an explanation. (4-ESS2-2)</p> <p>Cause and Effect - Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-1)</p> |

MATERIALS

For the class:

- Butcher/chart paper for Problem-Constraint-Criteria Table and Explanation Checklist
- Markers

Per Student:

- Copy of the “**What Happens to Stormwater at Our Site?**” Explanatory Model. Printing these on 11x17” paper will provide more space for student explanations. If you anticipate having time to photocopy the teacher drawing after creating the site map with the class, you could wait to make these copies (see lesson).
- Colored pencils (optional) for students to use on their explanatory model.

PREPARATION – 30 minutes

TEACHER DECISION POINTS



Who chooses site?

Website



All worksheets are on communitywaters.org

- **Choosing a problem site:** Consider possible sites in your schoolyard that the class might focus on for the remainder of the unit (see criteria in lesson). Do you want to choose the site, or do you want the class to decide (within parameters)? Ideas to consider:
 1. Do you have locations around your schoolyard or neighborhood that form puddles that cause problems for people? If not, is there another related problem you could focus students on (e.g. location where erosion is occurring because of stormwater runoff or an area with visible oil leaks, Astroturf rubber or other pollutants that go into a storm drain)
 2. Are there options the students would be especially engaged in solving?Some schools do not have obvious locations to focus on as a problem site. If that is true for you, IslandWood staff would love to help. Please email them or post your need on schoology.
- On butcher paper create a **Problem-Criteria-Constraints Table** as follows:

OUR SITE: _____

| Problems to Solve | Criteria for Success | Constraints on Possible Solutions |
|-------------------|----------------------|-----------------------------------|
| | | |

Turn-and-Talk

What kinds of stormwater runoff problems have you seen that could be solved by an engineer?

Engage and Encounter**1. Activate prior knowledge (whole class)**

Now the students are going to shift focus towards doing something about the problems caused by stormwater runoff.

Engineers solve problems and stormwater engineers all over the region are working right now to solve stormwater runoff problems. The students will be acting as engineers to come up with a solution for a local problem

Have students turn-and-talk: What kinds of stormwater runoff problems have the students seen so far that could be solved with some engineering?

Explore and Investigate**2. Decide on an area of focus (whole class or teacher)**

Stormwater runoff is a BIGGER issue for our city and our region than we are going to solve with a single engineering solution.

Depending on the location, and the specifics of the problem, the best possible solution can be very different. To engineer a solution, we need to choose the location we want to focus on.

Write the criteria on the board and review it with the students.

The site we pick should:

- Include impervious surfaces that produce stormwater runoff.
- Include a couple possible areas where a solution could be constructed.
- Be nearby so we can walk to it.
- Be a site we care about.
- Have a local problem (like puddles during rainstorms or erosion from stormwater runoff).

Have students review the maps of their schoolyard (that they filled in during Lesson 3) as they think about possibilities.

Brainstorm site locations as a class to create a list of ideas.

Revisit what the site should include and then choose a location to work on as a class.

**TEACHER
DECISION
POINT**

Depending on your students, either tell them the site they will be focusing on, or work with them to choose a site.

Example:

Possible Ideas for our Site:

- *Portables and adjacent big play toy that floods when it rains*
- *Front of school including roof, sidewalks, and bus drop off*
- *Building exit to playground and surrounding area (floods)*
- *The road and eroded stream bank across from the school*

3. Develop a shared understanding of the site (whole class)

Once the site has been decided, refer the students back to previous explorations of the site.

Work with the class to agree on roughly rectangular boundaries (this will help when they create a model of it in their tubs later).

Visit the Site?

If location, timing, and student behavior permits, you could walk to the site with the class to look at what is there and decide on the area to include.

Project copy of “What Happens to Stormwater at Our Site” explanatory model template.

Solicit student input as you sketch a rough map of the buildings and areas in the box on the worksheet (the students will be able to refer to this later when they make their own maps).

The worksheet is titled "What Happens To Stormwater At Our Site?". It includes a line for "Name: _____" and "Date: _____". Below this, it says "The problems caused by our site's stormwater include: _____". There are two numbered instructions: "1) Draw a map of our site in the box. The map should include buildings, large objects, and the problem." and "2) Explain with arrows, drawings, and words where stormwater runoff goes when it rains. What is causing the problems at the site?". A large empty rectangular box is provided for drawing the map.

Refer to previous explorations of the site and possibly the schoolyard map that students created.

Explanatory Model



Creating example map

TEACHER DECISION POINT



Photocopy the teacher version of the map?

Decision Point: Either have students copy the map you have created onto their worksheets or, if the timing works out, photocopy the teacher worksheet for them to use when creating their explanatory models (below).

4. Name the Problem(s) they will try to Solve (whole class)

Start by introducing the big picture problem of there being too much stormwater runoff in the city as a whole.

Then include any specific stormwater runoff problems they have identified at the chosen site.

Public Record



Problem-Criteria-Constraints Table

Add both the general Seattle-wide problem and any site-specific problems that students come up with to the **Problem-Criteria-Constraints Table**.

Later the class will be filling in the additional columns and then picking one of the additional things they have come up with in each column to use when comparing possible solutions.

Example Problem-Criteria-Constraints Table:

OUR SITE: School play area and surrounding space

| Problems to Solve | Criteria for Success |
|--|----------------------|
| <i>City wide:</i> <ul style="list-style-type: none"> • Too much stormwater runoff in Seattle. <i>Site specific:</i> <ul style="list-style-type: none"> • Puddles in play area. | |

We expect you will do Part II another day. If you are running out of time before this point, you could also wait on filling in the Problem Criteria-Constraints Table.



PROCEDURE

PART II: Explanatory Model

Explanatory Model



A new site-specific explanation

5. Introduce the new Explanatory Model

Project a blank “**What Happens to Stormwater at Our Site**” explanatory model and explain that students will be creating a new version of the model they created at the start of the unit. This one will be specific to their site.

They will be using the knowledge they built up during this unit to explain what is happening to stormwater at the site when it rains. Where does it go, why does it go there, and why does it cause the problems the class just added to the table?

Public Record



Class Summary Table and/or Consensus Model

6. Generate Explanation Checklist (whole class)

To help us use what we know to fully explain what is happening at our site, the class will create a shared checklist with everything we think should be included in the model.

Explanation Checklists: Can be used to create a list of things that all students should be sure to show and explain on their explanatory models.

The **Class Summary Table**, original explanatory models, and/or **Consensus Model** (if you’ve been using it) are all resources to help our thinking about what should be included.

Turn-and-Talk



What ideas do we need to include in our explanation of what happens to stormwater at our site?

Use the first column from the class summary table to offer an example of what should go on the checklist (e.g. “Locations where stormwater moves on the surface and any spots where erosion occurs.”)

Give private think time and then have students turn-and-talk to discuss what ideas will be important to include in our explanations.

Share some ideas and generate an explanation checklist on chart paper with markers.

Example Explanation Checklist

We should...

- Show where runoff goes and where water moves into groundwater.
- Include any storm drains.
- Explain where the water ends up off map.
- Explain the effect of any plants at our site.
- Explain what could be causing too much runoff.
- Show and explain any places where erosion has occurred.

7. Creating Explanatory Models (Individual) – 20 mins

Explanatory Model



Explaining
Stormwater at their
site

Students will be filling in their explanatory model (either the map they copied from what the class agreed upon or a photocopy of that map) with what is currently happening with stormwater in the area. The map should be something they could use to explain the problem to others.

Visit the Site?
This could be an even better time to visit the site to look at what kinds of surfaces are present and where water goes.

Students should:

- Refer to the schoolyard maps they created earlier; they may use the same symbols for the key, including identifying which surfaces are pervious and impervious.
- Make sure to include everything on the explanation checklist.
- Make this from the current situation (NOT ideas they might have to solve the problem – that comes later).
- Fill in the problem statement at the top before they begin.

After students begin working, circulate and interact with students asking them about what they are

BACK-POCKET QUESTIONS

Observations & Modeling

- What have you included on your model so far?
- Where do you think stormwater travels through the site? How are you going to represent that?
- Where are the impervious surfaces in this site? How are you going to represent them?
- What role does [insert idea or concept] have in your explanation?
- How have you included _____ from the explanation checklist?

Back-Pocket Questions



Observations &
Modeling

including to help represent what happens to stormwater in that area. How could they sketch it or represent it with words?

Redirect students as needed to the explanation checklist, the summary table, or their notebooks to help them make progress on their models.



If you are running out of time, you could do stop here and do the collaborative revising of models with the optional activities in part II of this lesson.

Turn-and-Talk



What have you included in your model?

8. Collaboratively revising models (pairs)

Have students turn-and-talk to share their models and see what they agree or disagree on. How might they adjust their models based on what their partners did?

PROCEDURE

PART II: OPTIONAL COLLABORATION

9. OPTIONAL: Public Comparison of Models (whole group)

TEACHER DECISION POINT



Continue or stop here?

Physically orient students towards each other: Have students bring their model sheets to the gathering area and sit so students can see and hear each other and the screen easily.

Set the purpose of today's discussion: Say something like: We are coming together to see ways to represent ideas in models and how we use evidence to support our ideas. Give each other feedback by agreeing or disagreeing and saying why you think the evidence they picked supports their idea or if you think another piece of evidence from our summary table would be stronger. After the discussion, you will have time to add more evidence or clarify your ideas on your models.

Allow students to use talk norms and lead and manage the talk: Remind students of talk norms and encourage them to call on each other and not look to the teacher.

Choose one pair to start the conversation and have them share one claim and the evidence they selected to support it. Encourage students to agree or disagree, in either case, saying what evidence they used or would use and how it supports their idea. Students should be sharing work under the document

More Collaboration?

The remainder of this lesson is a great opportunity for further collaborative revision of ideas, but could be skipped if your time is short.

NGSS Note: In Appendix F: Science and Engineering Practices, one performance of developing and using models for grades 3-5 students is to collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.

Whole-class discussion



Collaboratively revise a model based on evidence

cameras as they have a discussion. Peers could suggest changes to either their ideas or the evidence they selected.

10. Make Adaptations to Models (pairs/individuals) – 10 mins

Have students go back to working individually (or in pairs) and make changes to their models to clarify their ideas, add new ideas they heard during the discussion they agreed with, and to add or change the evidence they selected to support some of their claims.

By the end of the lesson students should have drawn and written about their ideas to explain the phenomenon and have at least two sticky notes with evidence to support two of their claims.

11. How Has My Thinking Changed? – 10 mins

Pass back initial models and let students look over them. Have students write how their thinking has changed in this unit.

At first, I thought.... Now, I think...

I used to think.... Now, I know...

Before I didn't know how... But, now, I learned that...

Quick Write



How has my thinking changed?

Be sure to keep the students' Explanatory Models for use in later lessons!

EXAMINING STUDENT WORK

What understandings have the students represented in their models? Did they accurately represent the things from the explanatory checklist?

Return to Understandings Table and the **What-How-Why Assessment Tool** used on models after Lesson 1 to examine how each student's depth of understanding and capacity to represent it has changed (found on communitywaters.org). Go through your student's new explanatory models and add any new items to rows in the same sorting sheet you used before.

When done, revisit your new items to see if you are still happy with the row you put them in. Move them as needed.

Then either add any new key points to the spreadsheet you used before or print a new copy of the **What-How-Why Scoring Grid** (2nd page of teacher worksheet) and fill it in for this new round with items and student's names. Revisit each student's explanatory model to check the boxes for what each student has represented in their model. There may be student representations you will want to follow up on with students to see what they were thinking when they wrote or drew them.

TEACHER WORKSHEET: What-How-Why Student Scoring Grid for Explanatory Model
Below each lens, write in items from previous worksheet. Write names in columns across top and then for each student, score their work on their explanatory model.

| | Student 1 | Student 2 | Student 3 | Student 4 | Student 5 | Student 6 | Student 7 | Student 8 | Student 9 | Student 10 | Student 11 | Student 12 | Student 13 | Student 14 | Student 15 | Student 16 | Student 17 | Student 18 | Student 19 | Student 20 | |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|--|
| "What" lens | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| "How" lens | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| "Why" lens | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |

Examine students' model revisions and see how their thinking has changed over the unit. What additional understandings are they representing and how has the depth of representation changed?

Key ideas for student teams to understand as they start trying to solve their stormwater runoff problem, include:

- Stormwater runoff causes problems.
- Water moves across the surface when it can't soak in (impervious surfaces).
- Water soaks into the ground where there are pervious surfaces.
- Plants help with stormwater runoff.
- Water that leaves the site by pipes or ditches is going to cause a problem where it ends up.

Important things to understand about their specific site include:

- What the site looks like and what is there that interacts with stormwater.
- Where the water at their problem location is coming from.
- The specific problem (if any) caused by stormwater runoff at their site.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

In the next lesson students begin using the Engineering Design Process towards solving the problem at the site they have identified. If you have a few students that are lacking the understandings desired, could they be matched up in engineering teams with students who have a solid understanding? If the lack of understanding is widespread and/or you have capacity to work with some smaller groups on understandings, you could consider the following:

- **Need for more understanding of stormwater?** Is the lack of understanding something you could revisit with additional information or investigations? Consider, conducting an investigation in which you are pouring water outside as a way to make the learning more real.
- **Understanding of the larger problem?** Not getting that the stormwater causes problem elsewhere can lead students to conclude that their best solution is more storm drains to get the water off the site. Consider watching the video again from Lesson 6 that talks about where your school's stormwater ends up.
- **Understanding the specific site?** If students' models don't show a sufficient grasp of the site they will be focusing on, you could work with students to do more revisions and refinement of their explanatory models, revisit the site with the students **and/or** do the physical modeling of the site (Lesson 9) now instead of after the next lesson.
- **Accurate maps of site?** If students are not successfully mapping the problem, you will likely need to provide more support and explanation about what things represent when they create a physical model of the site in Lesson 9.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson? Did it help students clarify and explain their thinking?

Tools. How did the tools used (e.g. explanatory model and your back-pocket questions) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

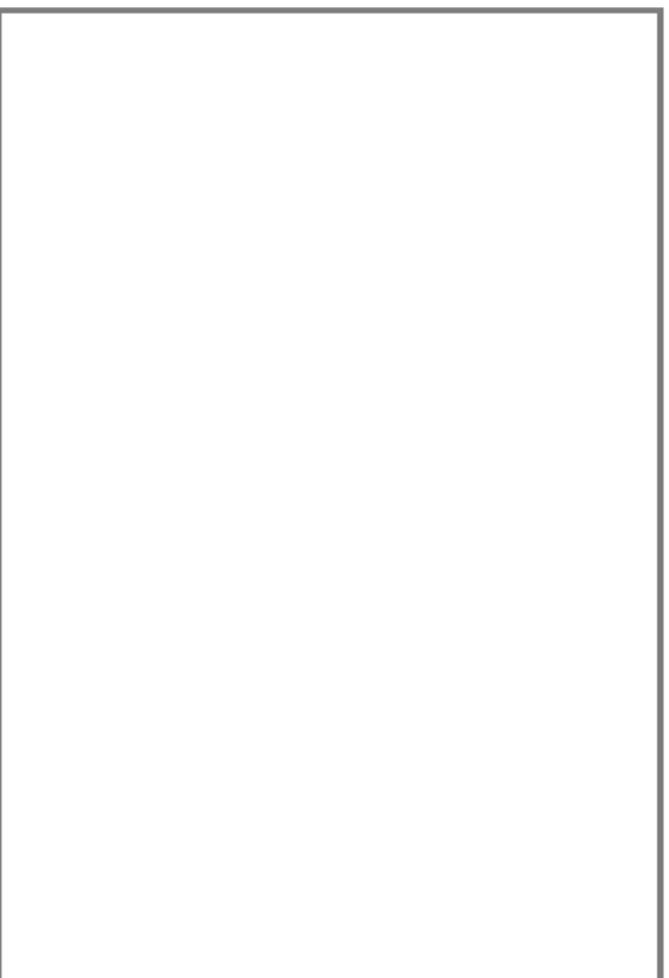
EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

What Happens To Stormwater At Our Site?

Name: _____ Date: _____

The problems created by our site's stormwater include: _____

- 1] Draw a map of our site in the box. The map should include buildings, large objects, and the problem.
- 2] Explain with arrows, drawings, and words where stormwater runoff goes when it rains. What is causing the problems at the site?



Lesson 8: Defining our Problem

OBJECTIVES & OVERVIEW

In this lesson the students define the criteria for success and constraints that could limit the possible solutions for their stormwater problem site.

Students take the opinion of stakeholders into account as they define their specific criteria for success and constraints on any solutions.

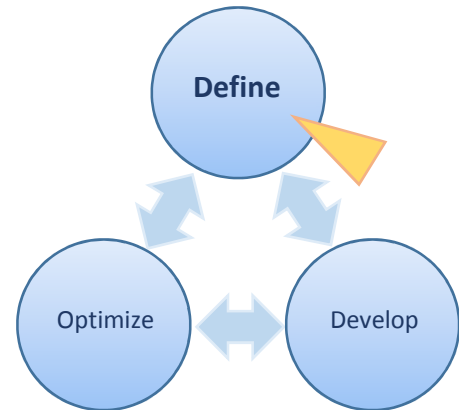
- Students represent a stakeholder perspective when discussing their site.
- Students decide on the criteria and constraints for a solution to too much stormwater runoff at their site.

Focus Question: What do we need to know before we research solutions for our site?

Learning Target: I can define a solvable local stormwater runoff problem.

New Terms: engineering design process, criteria for success, constraints, optimize, stakeholder

Engineering Design: DEFINE PROBLEM



Define a problem: specify criteria and constraints that a possible solution to a simple problem must meet.

NEXT GENERATION SCIENCE STANDARDS

PE 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.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|--|--|
| <p>Asking Questions and Defining Problems.</p> <ul style="list-style-type: none"> • 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, and/or cost. (3-5-ETS1-1) | <p>ETS1.A Defining and Delimiting Engineering Problems.</p> <ul style="list-style-type: none"> • 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) | <p>Influence of Science, Influence of Engineering, Technology, and Science on Society and the Natural World.</p> <ul style="list-style-type: none"> • People’s needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1) |

MATERIALS

Per Student:

- **Stakeholder Interview Worksheet** (optional – see below)

For Class:

- **Problem, Criteria, Constraints Table**

PREPARATION – 30 minutes

Website



Worksheets, links, videos, & graphics on communitywaters.org

TEACHER DECISION POINT



Interview stakeholders?

- Prepare the **Engineering Design Process** image for projecting (either the example at end of lesson or image on communitywaters.org)
- Queue up and test **Engineering Solutions – Stormwater Runoff** video (on communitywaters.org) or at vimeo.com/238855219.
- **Decision Point:** Identifying stakeholders who care about a site and incorporating their feedback into the design process is an important part of thinking about community problems and solutions, but how you approach it will depend somewhat on your students and the time you have available:
 - Is it feasible for your students to interview stakeholders on their own?
 - Would you want to invite a specific stakeholder relevant to the site into your classroom?
 - Would you rather have the students' roleplay being various stakeholders?

PROCEDURE

Engage and Encounter

Turn-and-Talk



When have you had to solve a problem? What did you do, and how did you do it?

1. Activate prior knowledge (whole class)

Reference the **Problem-Criteria-Constraints** table and students' Explanatory Models (“**What Happens to Stormwater at Our Site?**”) as you revisit with students the problems they are trying to solve at their site.

Now they have a problem to solve....

Partners turn-and-talk to share an example of a problem they have had to solve and what they did to solve it. Have some students share their examples with the class.

2. Provide information to leverage (whole class)

Real-life engineers solve problems and use an “Engineering Design Process” to do so. The process has steps.

Project the **Engineering Design Process graphic** (on communitywaters.org and at end of lesson) as you introduce the Engineering Design Process to the class.

Define stakeholders, criteria for constraints, constraints, and optimize as you go through the information.

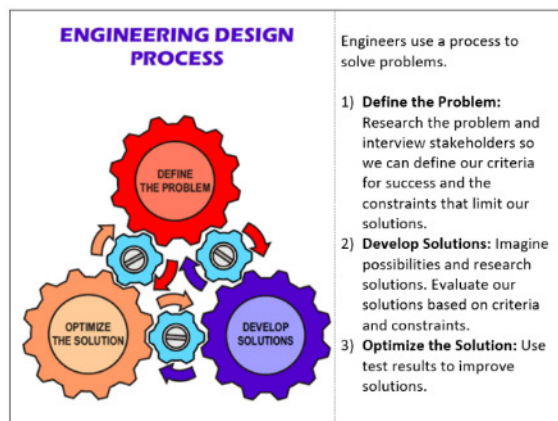
Point out that the arrows in the diagram point both ways as engineers often have to circle back as a part of the process. For example, an engineer might have progressed to the optimize stage but must return to developing other solution ideas if the chosen one doesn't work.

Present visual



Engineering Design Process

Just-in-Time Instruction



3. Introduce and watch the video (whole class)

This video shows an example of a student solving a stormwater runoff problem at their house. In the video the girl follows an engineering design process in just the same way as an actual stormwater engineer would.

Can students spot the steps in the process as they watch the video?

Also at <https://vimeo.com/238855219>

<Pause it when “Betsy the Engineer” comes on at 1:57>

Can any students point out when she followed the steps?

Video Clip



“Engineering Solutions - Stormwater Runoff”
Length: 3:25
communitywaters.org

Watch it again from the beginning to the very end.

4. Make a plan (whole class)

Outline the remainder of the unit in the context of the Engineering Design Process:

Define the Problem:

- You have already selected the problems you are trying to solve and built an understanding of what is causing the problems.
- We'll interview others who care about the site we have chosen to get their perspective on the problem.
- Then we will decide on the problems we want to address at the site, what their criteria will be for success, and any constraints on our possible solutions.
- After that we'll build models of the chosen site that we'll use later to test our solutions.

Develop Solutions:

- Students will brainstorm possible ideas and do research to find solutions that could work at their site.
- Then they will get into small groups to compare the different solutions and choose which one each group wants to test.

Optimize Solutions:

- We'll add our solutions to our models and run tests to see how they do.
- Depending on the results, we'll redesign and come up with an optimized solution.

Develop Solutions:

- We'll also use the data from tests as a part of comparing the various solutions our class has considered to see which ones we would recommend for our site.

Public Record



Problem-Criteria-Constraints Table

5. Get the Activity Started (whole class)

Revisit the **Problems-Criteria-Constraints table** you started filling in earlier. Remind students of the site chosen and the problems identified. To finish this stage in the Engineering Design Process (“Defining the Problem”), they will need to determine the criteria for success and constraints on any solution.

BEFORE they can do so, it is important to take into account the people who care about the site you are considering.

6. Who are the Stakeholders (whole class)?

When engineers are thinking about problems, they need to figure out who might be affected and how. We call the people who care about the solution “stakeholders.”

Stakeholders are important resources in thinking about the possible solutions for Seattle’s stormwater problems. We need to know what they think about it because they

may have important criteria or constraints for us to consider. We also want to make sure they are not unhappy with the solution we come up with.

Who are the stakeholders that use, own, care about, or otherwise interact with the site?

Students brainstorm a list with a partner

Then create a list as a whole class.

Who Else?

This is a great time to encourage students to be inclusive in their thinking:

Are there other stakeholders outside of our school who we aren’t thinking of as stakeholders? What about other children or community members who might use the site? Native American groups who have historical claims to this land?

Depending on your site, and your student’s thinking you might also include birds and other animals as “stakeholders” (or as things human stakeholders might care about).

Turn-and-Talk



Who are the stakeholders who might own, care about, or use the site?

Stakeholder examples:

- *Students*
- *Teachers*
- *The Principal*
- *District Staff*
- *Custodian*
- *Grounds crew*
- *Neighbors*
- *Local Businesses*

TEACHER DECISION POINT



Students interview stakeholders?

7. Optional: Interview the Stakeholders (individuals, pairs, or whole class)

The best way to understand what a stakeholder wants is to ask them. This can be done in an interview. They can explain what stormwater is and use their models of the problem to describe the site. Then they should ask the following questions:

- Why do you care about this site?
- How do you use the site?
- Do you have any concerns about stormwater runoff or too much water in the area?
- Is there a project to help with these problems that you would recommend?
- Are there any concerns you have about changes to this site?

Stakeholder Interviews?

Options for stakeholder interviews include personal one-on-one interviews, recess time surveys, inviting somebody in to be interviewed by the class, and interviewing each other.

You could alternatively skip doing actual interviews and have students speak on their behalf instead.

If students **will** be doing stakeholder interviews, you will need to continue this lesson after they have sufficient time to complete the assignment (or after you interview somebody as a class).

Hand out the **Stakeholder Interview worksheet** and walk through with students how they would use it when doing interviews.



You could pause the lesson before incorporating stakeholder input. If you are running out of time but still want to do stakeholders interviews, that whole section (above) could be its own mini lesson (or fill a full session if you are bringing somebody into your classroom).

8. Incorporate Stakeholder Input (pairs)

Turn-and-Talk or Discussion Diamond



What does the stakeholder you represent want to have happen at the site?

Challenge the students to represent the stakeholders they interviewed about the site and/or imagine themselves as one of the stakeholders. Have them pair off (or use a discussion diamond process like the one in Lesson 6) to consider: *What do the stakeholders want included in any solution? What are they going to want to make sure stays the same?*

Either ask the partners to represent their stakeholders as you continue, or compile the key stakeholder inputs onto a large sheet and then decide as a class which ones are especially important to keep in mind (underlined).

Stakeholder Input:

Students:

- Hate the puddles in the play area
- Want another 4-square court

Principal:

- More plants would be nice
- District will have to approve changes

9. Consider Criteria for Success (larger group)

When engineers are defining a problem that they can come up with a solution for, they ask themselves what success will look like. These “criteria for success” are then something they can use to consider solutions, test their solutions, and ultimately decide if they succeeded. They are asking the question: How will we know when we’re successful?

Ultimately for our Seattle-wide problem, **less water leaving the site is success.** (Write that down as a #1 criteria). Are there other things that should be considered? Any other problems at the site that need to be addressed or desires of stakeholders that would be important to consider?

Add to the table additional criteria students come up with.

Public Record



Problem-Criteria-Constraints Table

Turn-and-Talk



What limits would you and/or the stakeholders you interviewed want to put on possible solutions?

10. Consider Constraints on possible solutions (larger group)

Students need to figure out the boundaries in which their solutions must fit. What limitations are there when it comes to materials, costs, or amount of space? Are there any other things about their site, or that they learned from stakeholders that limit which solutions they can choose?

Provide the students with two constraints that are a given (and write them on the chart):

- 1) **Work within the space available at the site:** Students need to find solutions that can work within the limits of the space available in the site.
- 2) **Keep costs low:** The solutions should be as inexpensive to build and maintain as possible given the criteria for success.

Considering the location and stakeholders involved, what other constraints should be considered? Have students turn to a partner and talk about whether the stakeholder they interviewed would want to set any limits on possible solutions. Would they have any concerns if any parts of the site were no longer able to be used in the same way?

Discuss ideas with the class as a whole and add those agreed upon to the table.

Public Record



Problem-Criteria-Constraints Table

Example Problem-Criteria-Constraints Table:

OUR SITE: School play area and surrounding space

| Problems to Solve | Criteria for Success | Constraints on Possible Solutions |
|---|--|---|
| <p><i>Citywide:</i></p> <ul style="list-style-type: none"> • Too much stormwater runoff in Seattle. <p><i>Site specific:</i></p> <ul style="list-style-type: none"> • Puddles in play area. | <p><i>Citywide:</i></p> <ul style="list-style-type: none"> • The amount of stormwater runoff leaving the site is reduced. <p><i>Site specific:</i></p> <ul style="list-style-type: none"> • No puddles in the play area when it rains. | <p><i>General:</i></p> <ul style="list-style-type: none"> • Work within the space available at the site. • Keep costs low. <p><i>Site specific:</i></p> <ul style="list-style-type: none"> • Students don't want to lose any play space. |

| | | |
|--|--|---|
| | <ul style="list-style-type: none"> • <i>Water available for school garden.</i> • <i>Add more play space.</i> | <ul style="list-style-type: none"> • <i>District will have to approve any changes to the site.</i> |
|--|--|---|

Reflect and Explain

Explanatory Model



Add to “**What Happens to Water at Our Site?**” model

11. OPTIONAL: Add to models (individually or in partners)

You could have students return to their Explanatory Models to add additional location-specific things that came up when discussing stakeholder’s input, criteria, and/or constraints.

EXAMINING STUDENT WORK

The stakeholder interviews (if you did them) are for students' reference more than yours. To assess their success, take note whether students can represent stakeholders during their discussion. Have they included any stakeholder-focused criteria or constraints on the table? If the students are not doing this on their own, you can remind them of the importance of community voices in decision making and prompt them for more thoughts.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

Also consider the following:

- Are the problems, criteria, and constraints the class agreed upon clear?
- Are there any that are not actually solvable?
- Are any going to preclude making a physical model of the site and solution in a stream table (happening in the next lesson)?

If any of the problems, criteria, or constraints end up being insurmountable, you can revisit them as a class later. Remind students that the Engineering Design Process is not linear, and even professional engineers sometimes need to go back to the Define Stage of the process to rethink what they have come up with.

If you feel like students are not getting the idea of stakeholders, you could invite a stakeholder to come into your classroom and look over with the class what you have come up with so far. Your principal or janitor or a student from another grade that uses the area might provide some interesting perspectives on the problem and possible solutions that the students wouldn't otherwise consider.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

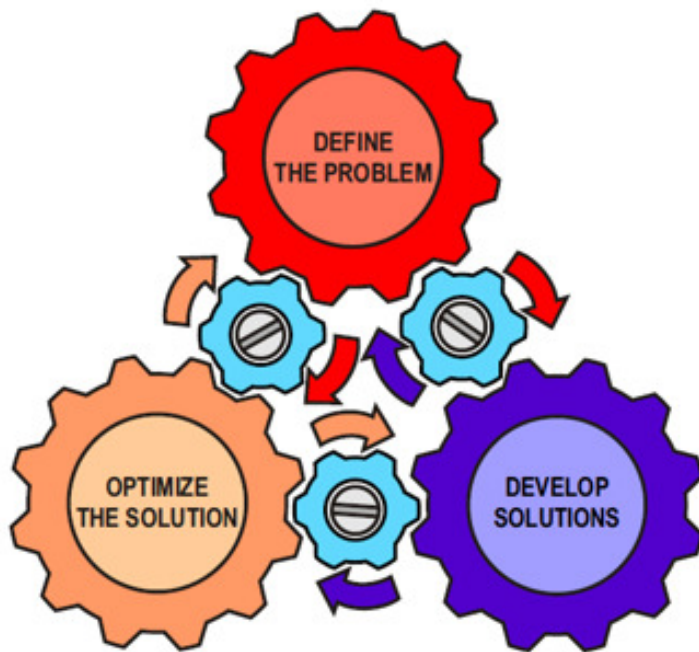
Tools. How did the tools used support students?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Just-in-Time Instruction

ENGINEERING DESIGN PROCESS



Engineers use a process to solve problems.

- 1) **Define the Problem:** Research the problem and interview stakeholders so we can define our criteria for success and the constraints that limit our solutions.
- 2) **Develop Solutions:** Imagine possibilities and research solutions. Evaluate our solutions based on criteria and constraints.
- 3) **Optimize the Solution:** Use test results to improve solutions.

Stakeholder Interview

Your name: _____ Date: _____

Name of person interviewed: _____

What is their role or job? (student, parent, school staff, something else?) _____

Explain what you've been learning about (stormwater runoff in the city) and show the person you're interviewing your map of the site. Explain that it's showing a place that your class decided to focus on when thinking about solutions.

Questions for the stakeholder:

How do you use the site?

Why do you care about this site?

Do you have any concerns about stormwater runoff or too much water in this area?

Is there a project to help with these problems that you would recommend?

Are there any concerns you have about changes to this site?

Don't forget to thank the person you've been talking to for their time!

Lesson 9: Modeling the Site

OBJECTIVES & OVERVIEW

NOTE: This lesson could be done any time before Lesson 12.

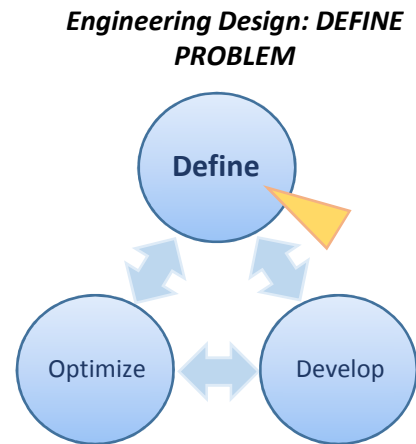
In this lesson, the teacher provides (or creates with class input) an example of a physical model of the problem site in one of the stormwater tubs. Pairs of students each then create a duplicate of the model in a stormwater tub. The teachers model then has water added and its runoff measured to form a baseline against which student groups can compare their proposed solution.

- Models are built to represent what happens to stormwater at a specific location.
- An investigation is run with one of the models.

Focus Question: How do we best model stormwater at our site?

Learning Target: We will use our understanding of impervious surfaces to build a working model of our site.

New Terms: fair test, changed, measured, and controlled variables



Define a problem: specify criteria and constraints that a possible solution to a simple problem must meet.

NEXT GENERATION SCIENCE STANDARDS

The students will address this standard over several lessons. In this lesson, they plan and carry out a fair test to form a baseline. In Lesson 16 the procedure is repeated with their prototypes to identify aspects that can be improved.

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.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|--|---|
| <p>Developing and Using Models</p> <ul style="list-style-type: none"> • Identify limitations of models. • Develop and/or use models to describe a phenomenon. • Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> • 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. • Evaluate appropriate methods and/or tools for collecting data. | <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) | <p>Cause and Effect.</p> <ul style="list-style-type: none"> • Events that occur together with regularity might or might not be a cause and effect relationship. • Cause and effect relationships are routinely identified, tested, and used to explain change. |

MATERIALS

Materials to lay out in distribution area (for possible use when modeling the site):

- Gravel, Sand, and Humus
- Toothpicks and popsicle sticks
- Tinfoil (represents impervious surfaces)
- Sponge pieces (represents trees)
- 1-ounce and 9-ounce cups (represent rain barrels, cisterns, and ponds)
- Plants saved from Lesson 4 (grown previously and/or brought in)

Additional materials that could help represent the site or solution materials might include:

- Rocks (boulders)
- Lunch room milk cartons (small buildings)
- Wooden blocks (different size buildings)
- Large milk cartons or wooden blocks (large buildings)
- Small plastic items, boxes, lids, etc.

2 per team:

- Stormwater tub with $\frac{1}{2}$ of the soil in it from Lesson 4
- Trowel and 2 spoons

For test of teacher's model:

- Stormwater tub with site model built in it
- Catch bucket
- Absorbent pads (large and small)
- Trowel and 2 spoons
- Rain jar (with holes in lid) with 500 ml water
- **Measuring Stormwater Runoff Procedure and Data Sheet** (half sheet)

PREPARATION – 45-60 minutes

Engineering Teams: You will need the class to be in 7 groups – Try to create teams that will lead to good outcomes when they need to come to agreements and share tasks. Evenly distribute those with greater and lesser understanding of stormwater runoff among the teams.

Watch the Lesson 9 Teacher Training Video: It shows the creation of an example model and talks about considerations you will want to consider when creating an example model for your class.

Short on Class Time? We have students build the site models in this lesson but you (and/or students and/or parent volunteers) COULD do so outside of class time and then skip to #6 “Discuss Procedure Variables” in the lesson. If time is very tight, you could also have your volunteers do the investigation procedure with each model (recording the data for students to compare with later).

How much do you want to involve students in creating the example model? Pick an option:

- Build the example model ahead of time yourself.

TEACHER DECISION POINTS



- Involve the class in the design process by doing the first three steps in the lesson and having the class make suggestions as you build an example for them to duplicate. If you are going to build it during class, we recommend thinking through the dimensions and likely materials needed to represent the site ahead of time, so you can be ready to go.

Provide Investigation Procedure? There is a provided example Investigation Procedure. You could provide it to students or have the students create their own (see notes about this in lesson).

Materials Set Up:

- **Distribution Area:** Prepare a distribution area with materials to be used for models (see list above), ensuring there are enough items for all student groups. Look over the additional materials list above and think about whether there are any other materials (like lunchroom milk cartons) that would be helpful to use in site models for your site.
- **Plants:** Gently remove and set aside any plants still growing in bins from Lesson 4 (you will likely need them). If the plants have died, consider digging up some grass and/or other plant bits (moss off the sidewalk works!). It is helpful to have both small plants with roots and bigger sections of turf.
- **Re-divide Stormwater Tubs:** Remove any grass still growing in tubs and set aside. Stir up the soil in each tub and put half of it (~1350 ml) into each of the remaining empty tubs. You should end with a total of **15 tubs** with ~1350 ml in each. One tub will be used for the example model (see below) and each of the 7 engineering teams will use 2 tubs.
- **Build Example Model** (or at least think through what it might look like if you want to design it with your students). There are a variety of things to keep in mind when building the model:

Why Create FIFTEEN (15) Site Models?

You will need two tubs set up with the site model for each of your 7 engineering teams. They will add an initial solution to the first tub (lesson 12) and then create an optimized version in the second (lesson 14). This is a change from the 2017-18 SY designed to address fair test issues that occurred - when we added water multiple times to the same model, the soil didn't dry out between tests.

Tub Set Up

- **Keep the drain hole clear:** The drain hole in the model will represent the water that leaves the site.
- The tub should be left flat on the tables with any hills in the site represented by sloping the materials in the tub (otherwise water moves too quickly through the dirt and out the drain hole). This means impervious surfaces that normally drain into a storm drain should be sloped towards the drain hole.

Modelling Surfaces

- **Impervious Concrete:** Use the tin foil. It can be cut and shaped as needed. Gravel on the edges of the tinfoil will help hold it down.
- **Packed gravel** and hard-packed soil can be represented by tinfoil with a thin layer of sand or gravel on top of it.

- **Grass surfaces:** Grass is only partially pervious so don't model it with the plants you have grown. Instead put down a layer of tin foil and then some moss or thin grass over the top.
- **Gardens and other highly pervious planted areas** could be represented by the groundcover from Lesson 7.
- **Pervious surfaces** could also be represented with gravel.
- **Muddy areas** could be represented with humus (the black soil) on top of tin foil. Don't add a lot of humus to a model as it will make it messy and hard to dry out between tests.
- If you have some existing things on the site that are helping with stormwater, you could check out the ideas for representing them in the preparation section of lesson 12 (e.g. trees can be represented by one of the narrow sponge pieces "planted" in the ground with a toothpick in it to hold it up).

Modeling Buildings

- Wood or plastic blocks could be useful to represent buildings. Lunch room milk cartons could also work for buildings (with peak facing up or buried depending on the roof).
 - Tinfoil on top of blocks or milk cartons can be shaped to create gutters.
- **Test Example Model.** If you are creating the model ahead of time, use 100 ml of water in a rain jar to test that water is flowing through it appropriately. Adjust the model as needed (often by lifting up tin foil and changing the shape of the land underneath) after testing it.

PROCEDURE

Engage and Encounter

1. Set the Purpose (whole class)

Students will be constructing a physical model to represent what happens to stormwater at their site. For now, we are only modelling what is currently happening with stormwater runoff at the site. Later, **after** engineering teams have researched and chosen a possible solution, they will be adding their chosen solution to the model and testing how well it works.

When creating a model of our site, we need to keep in mind that **a model does not (and cannot) represent the real world perfectly**. The model only needs to represent the surfaces and where water goes in a general way. These models are not going to be precise and that's okay. What we will want to watch for is that they We do not need to exactly represent each object and do not need perfection; a rough approximation is enough.

Divide class up into 7 engineering teams.

2. Activate Prior Knowledge (individual)

Have students pull out the "What is Happening with Stormwater at Our Site?" explanatory model they created during Lesson 7 and think individually about what they would want to be represented in a physical model of their site.

Explanatory Model



What to represent

3. What to Represent in Models (whole class)

Work with the class to compile a list of what needs to be represented by the model. Some key points:

- Water will need to runoff and soak in at the appropriate locations. This makes representing **pervious and impervious surfaces** important.
- The **citywide criteria for success** is less stormwater runoff leaving our site, so we will want to measure how much water is leaving the models. To do so, we will measure the amount of water that leaves the tub through the drain hole in the bottom. The students will be representing how stormwater moves through the site.
- The **site-specific problem** will need to be included in some way as well as how runoff flow is contributing to the problem.

4. Sharing Teacher Model (whole class)

Share the model you created with students and talk through with them what each part represents. Make sure to note:

- The rain jars used earlier in the unit will continue to represent rain.
- The drain hole in the model will represent the water that leaves the site.
- What surfaces each material is representing (e.g. tinfoil is the impervious concrete playground at their site).
- This model is NOT a physical representation of everything in the site. Instead, it is focused on the amounts of various surfaces in the site. Where are pervious or impervious surfaces in the site? How much of each is there?
- Nobody will be adding solutions yet. That comes later!

Designing With Students?

If you are having students design the example model with you, you will want to go through the possible materials that could be used (as listed in the preparation section above). You will also need to shake 100 ml of water on the model to make sure the water is moving through the model the way it does at the actual site.

Challenge the students to duplicate the model as closely as possible. If all the models function the same, it will be possible to compare the data from the solutions students will be adding to them later.

Present visual



Example Site Model

Explore and Investigate

2-3 Student Groups



5. Duplicate the model (each engineering team is divided into two groups for this)

Distribute a tub with soil and plug to each pair of students and have them set it on top of a small or large pad.

Each engineering team is split in half to create a duplicate of the model

Have the students shape the soil in their tub to match the example model and circulate to make sure the slope and any indentations needed for puddle or water flow match up.

If it is helpful you could walk the students through each step of setting up the model. Otherwise, give time for student groups to craft the rest of the model using materials available.

As groups work, circulate and ask them appropriate questions to challenge their thinking:

Back-Pocket Questions



Modeling



BACK-POCKET QUESTIONS

Modeling

- What does this part of the model represent?
- What specifically is the drain in the model representing at the site?
- Is there anything about your model that is different than the example model?
- Do you think your site model will have the same results as the example model?
- Is there anything not represented in the model that should be there?

You could pause the lesson here (or after the next task) if needed.

6. Test Water Flow in models (engineering teams)

Give each team 100 ml of water to shake onto their model with a rain jar (they will need to take turns since there are only 8 jars). They should keep the holes in their models plugged and drain it at the end into a bucket.

Back-Pocket Questions



Observation & Modeling

BACK-POCKET QUESTIONS

Observations

- Where did you observe water runoff in your model?
- Where did puddles form in your model?

Modeling

- Does the water flow in the model match what happens at our site when it rains? Why or why not?
- Do you think the site model would have the same results as the example model?
- Is there anything you need to change to help the water flow be more accurate?

While shaking they should note where the water is flowing. Is it flowing in the right directions? Are things like roof gutters working correctly?

TEACHER DECISION POINTS



You could do the remaining parts of this lesson now or wait to do it until the students are testing their solutions in Lesson 13.

7. Creating an Investigation Procedure

Engineers use repeatable **fair test** procedures to test, compare and optimize various solutions. By making their investigations a fair test they can get data that helps them determine if their solutions are successful.

Having a class procedure to test the original site model and using the same procedure on the solutions modeled by each engineering team will make it possible to compare the data between different solutions.

8. Discuss Procedure Variables

When testing solutions in the real world, there are always variables (like weather) that can't be controlled. Engineers do the best they can and take note of things they couldn't control.

Similarly, the materials we are using for these models are limited representations and will not permit total control over all the variables that could affect our results but we still want to pay attention to where we can and cannot make it a fair test so we know how we can use the data we get.

We want to set up an investigation that will let us compare the **amount of water that**

Fair Test?

The intent in having students create these site models and then add their solutions (in Lesson 12) is for them to be able to go through the process of thinking about how the solution works and the optimizing of it (13 & 14).

In reality, the models the students create are unlikely to be precise enough to truly compare the data they get from their investigations.

They also won't be able to run three tests of each solution (unless you decide doing so is a priority and have the class test just two solutions).

Treat this as an opportunity to talk about the challenges of a fair test with the students while keeping them focused on how they would redesign their model to improve it.

Turn-and-Talk



What variables do we need to control?

drains out in the original site model to the amount of water that drains after we add and optimize our solutions.

The **measured variable** in this investigation is the amount of water that drains out of the hole.

The **changed variable** will be the changes we make to the model to represent a solution (this comes later).

Students turn and talk to discuss what **variables they need to control**.

Discuss the need for multiple trials and the importance of resetting the wet models between trials.

Have students walk around and look at the various models groups have created. Do they look similar enough that we will be able to compare the data between groups? If not, do they have any suggestions for how the models could be more similar?

Controlled variables:

- Amount of water poured over the site.
- Parts of the model that are not changed for the solution.
- Amount of time the water coming out of the hole is collected.

9. Discuss procedure (whole class)

TEACHER DECISION POINT



Either discuss the provided procedure or create one together.

Creating Procedure as a Class?

Depending on your students, you could create the procedure together as a class. If you do so, you could have smaller groups start off generating ideas with brainstorming or a discussion diamond like the one used in Lesson 6.

If Developing Own Procedure:

- Don't forget to include setting up the pads and buckets.
- The provided example procedure has the students *add the stoppers immediately after the rain jars are empty*. This is because the water in the models drains out of the sand and gravel in the models over time. By putting the stoppers in right away we don't measure as much of the water that soaked into the soil.

Present visual



Procedure sheet and/or Example of Data Table

If you are using the provided procedure, project it for the class and have them help identify where variables are measured and controlled during the procedure.

Have students create a data table on which to record their tests in their science journals. Project example if desired.

The procedure provided is built around roles for each person. They include:

1. **Materials Manager**
2. **Measurer**
3. **Rain Maker**

Example of Data Table:

Data Table for Testing of Site Model

| Trial #: Description | Amount Added | Amount Collected | Observations |
|--------------------------------|--------------|------------------|--------------|
| 1: Site Model without solution | | | |
| 2: | | | |
| 3: | | | |

4. **Bucket Holder**
5. **Observer - Recorder**

See procedure for details on each.

10. Run test and record results (whole class)

The test will ONLY be run on the example model this time.

Assign students to the roles for the test of the teacher model and run the investigation. When finished, provide time for the observer to share with the class what they noticed.

Have students record the results (and observations) in the data table in their science journals.

Reflect and Explain

11. Review the procedure (whole class)

Gather all groups' data to find the range (difference between the highest and lowest amount of runoff) & the median (middle number). The range provides an idea of how similar the models are to each other and the median.

Questions to consider with the class:

Models can never fully represent the real world and don't need to. Does this model represent enough of what it needs to for us to be able to add solutions and test their effect on stormwater?

Is there anything that should be changed in it to improve its representation?

Math Time?

It is not needed for the purposes of this unit, but consider whether you want to do any deeper analysis of the differences in student results during math time. Could it help you reinforce the Measurement & Data standards you are working on?

[CCSS.MATH.CONTENT.4.MD.B.4](#)
[CCSS.MATH.CONTENT.4.MD.A.1](#)
[CCSS.MATH.CONTENT.4.MD.A.1](#)

TEACHER DECISION POINT



More math analysis?

EXAMINING STUDENT WORK & PLANNING NEXT STEPS

Look over the models each group created and consider whether they are similar enough to provide roughly equivalent results. If not, make changes to them as needed (or follow up with the students to make the changes).

Measuring Stormwater Runoff Investigation Procedure

Purpose of investigation: To (eventually) test how effective our solution is in solving the problem of too much stormwater runoff.

Criteria tested: Reduction of stormwater runoff.

Materials: tub set up to model the site, bucket, large and small pad, trowel, 2 spoons, and rain jar (with holes in lid).

Set Up:

- Materials Manager brings over materials.
- Measurer fills rain jar to 500 ml (milliliter) mark & screws on lid.
- Place the large pad on the table with absorbent side up.
- Put the tub with the site model on the large pad with the drain hole over the edge of the table.
- Place the small pad on the floor with the plastic side down and put the bucket on the pad under the drain hole so that the bucket will catch any water that comes out of the drain hole.

Get Ready:

1. Materials Manager removes the drain plug from the tub and holds it ready to replace in hole.
2. Rain Maker checks that the rain jar lid is screwed on **tightly!**
3. Bucket Holder holds bucket under drain hole.

During:

1. Rain Maker holds the rain jar upside down over the model and shakes the bottle to make it “rain” on the model. Do not squeeze the bottle. Move the rain jar around to all parts of the model so that rainfall is evenly distributed.
2. Materials Manager: Unplugs the drain hole in the model if it gets plugged.
3. Rain Maker continues shaking the rain jar over the model until only the lid has water in it.
4. Materials Manager: As soon as the Rain Maker is done, return the plug into the hole (preventing remaining water from continuing to drain into the bucket).

Afterwards:

- Measurer empties any water left in the rain jar and uses the jar to measure the amount of water in the bucket. Then rinses out rain jar.
- Observer records any important observations of what happened to the water in the model and the amount of water that ended up in the bucket.
- Bucket Holder drains any remaining water into the bucket, then empties the bucket and places it back under the drain hole.
- Restore any parts of the model or solution that were changed by the water.

GROUP ROLES

1. **Materials Manager**
Brings materials, clears drain blocks, and plugs drain hole when rain maker done.
2. **Measurer**
Fills rain jar to 500 ml and measures runoff afterwards.
3. **Rain Maker**
Shakes rain jar evenly around tub.
4. **Bucket Holder**
Holds bucket under drain hole to collect runoff. Rinses out bucket afterwards.
5. **Observer - Recorder**
Notes what happens during procedure and records group data on data sheet.

Example of Data Table:

Data Table for Testing of Site Model

| Trial #: Description | Amount Added | Amount Collected | Observations |
|-----------------------------------|-------------------------|-----------------------------|---------------------|
| 1: Site Model without solution | | | |
| 2: | | | |
| 3: | | | |

Lesson 10: Researching Solutions

OBJECTIVES & OVERVIEW

Engineers research possible solutions before they propose a solution. Students will gain an understanding of different types of solutions that are used to help with stormwater runoff problems and take notes that they will reference in the next lesson when they evaluate the solutions based on how well they address the site’s constraints and criteria for success.

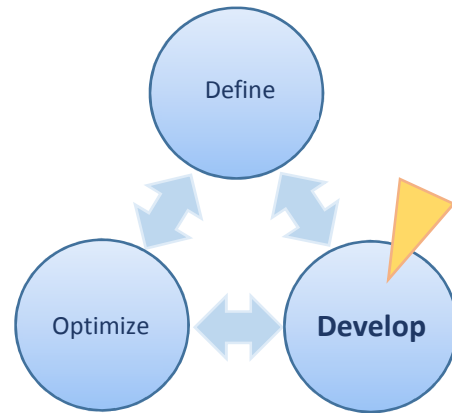
- Students research potential stormwater solutions.

Focus Question: What solutions should we consider for our site?

Learning Target: I can do research to learn more about stormwater solutions.

New Terms: none

Engineering Design: DEVELOP SOLUTIONS



Develop solutions: research and evaluate multiple possible solutions.

NEXT GENERATION SCIENCE STANDARDS

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.

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|--|--|
| <p>Obtaining, Evaluating, and Communicating Information.</p> <ul style="list-style-type: none"> • Compare and/or combine across reliable media to support the engagement of engineering practices. • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. • Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. | <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> • Research on a problem should be carried out before beginning to design a solution. <p>ESS3.B Natural Hazards.</p> <ul style="list-style-type: none"> • A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2) | <p>Influence of Engineering, Technology, and Science on Society and the Natural World.</p> <ul style="list-style-type: none"> • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (3-5-ETS1-2, 4-ESS3-2). |

Common Core Connections:

[CCSS.ELA-LITERACY.CCRA.R.1](#) - Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

[CCSS.ELA-LITERACY.RI.4.1](#) - Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

[CCSS.ELA-LITERACY.RI.4.3](#) - Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.

[CCSS.ELA-LITERACY.RI.4.7](#) - Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, timelines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.

From <<http://www.corestandards.org/ELA-Literacy/RI/4/#CCSS.ELA-Literacy.RI.4.4>>

MATERIALS

- 1 set per Group:
 - **Stormwater Solutions Research Sheets** (printed 2-sided – see preparation section below before printing)
- Per Student:
 - **Solutions Research Note-taking worksheet**

PREPARATION – 15 minutes

Website



All worksheets, links, and graphics are on communitywaters.org

TEACHER DECISION POINTS



What resources to use and how to do the research?
Use ELA time?

- Queue up and review video: “**Green Stormwater Solutions.**”
- Review the **Stormwater Solutions Research Sheets** to see if they are at the right level for your students. Do you want to use all seven ideas provided in the resource sheets or narrow them based on your own judgement? If you would like other research options, you can find them with the other links for this lesson on communitywaters.org.
- Look over the **Solutions Research Note-taking worksheet** and consider if you prefer a different note-taking approach.
- Decide how you want to divide up the student research. Some possible approaches:
 1. Have individuals each research some of the possible solutions and then share them with their team (this provides an opportunity for differentiation in which research options you provide each student).
 2. Divide up the solutions among the members of each engineering team for individuals to research and then share with their team.
 3. Divide solutions so each group gets one solution to research and present to the rest of the class (listeners take notes).
 4. Review all the solutions being considered as a whole class.
- Consider whether the reading and taking notes that is done in this lesson could fit into your ELA time.

PROCEDURE

Engage and Encounter

Public Records



Problem-Criteria-Constraints Table & Class Summary Table

1. Activate Prior Knowledge (whole class and pairs)

Review the problems listed for your site on the **Problem-Criteria-Constraints Table**.

Return to **Class Summary Table**, to look at the “How does it help us explain and/or solve stormwater in the city?” column. What have they learned so far that would help them think about possible solutions for their site’s problems? If students did a walking field trip to a rain garden or other stormwater feature, have students think back to what they saw, and what was doing the work to reduce stormwater runoff.

2. Brainstorming Ideas (whole class or engineering teams)

When developing solutions for a problem, engineers apply their scientific understanding towards both reading what others have done and brainstorming their own ideas.

This brainstorming session is to begin applying our understandings toward thinking about solutions, but does not replace the value of researching solutions others have already used. These ideas are not final!

Brainstorming after Video?

The video below provides students a review of what the problem is and some ideas for possible solutions.

If your students have a pretty good handle on this, you could do brainstorming before the video.

If they need a bit more guidance in thinking about what might help with runoff, show the video, then do the brainstorming.

Students create their own list of ideas in their student notebooks and then turn-and-talk to see what a partner has come up with.

Ask students to share ideas with the whole class. Students can add ideas they like to their list as they are shared.

3. Overview of solutions (whole class)

Video: Green Solutions to Stormwater Runoff

This video provides a quick review of the causes of stormwater problems and some of the solutions engineers are using to address stormwater runoff problems. This video is focused on a type of solution called “Green Stormwater Infrastructure” (GSI). GSI refers to solutions that use nature and natural processes. For example, instead of cleaning water with chemicals and filters, it would use plants and soil to do so.

TEACHER DECISION POINTS



Brainstorming before or after video?

Turn-and-Talk



What might a solution look like for this location and problem?

Video Clip



“Green Solutions to Stormwater Runoff”

Play to 1:09

communitywaters.org

Stop video at 1:09 and notice with students the many different possible solutions pictured.

Can also be found at: <https://www.youtube.com/watch?v=bsNjkOgp4>



You could pause here if out of time. You could also split the student research time up over several days as desired.

4. Introducing the activity (whole class)

Students will be reading about possible solutions and taking notes about each. Notes will be used later to compare the various solutions and see which ones best fit the criteria and constraints of our site.

The **Stormwater Solutions Research** pages provide information about common stormwater runoff solutions. They include information on one side about what the solution is and how it works. On the other side is an example and some of the benefits and challenges of the specific solution.

Show Visuals



A page from the Solutions Research pages

Solutions Research pages cover the following solutions:

- Rainwater collecting
- Bioswales
- Planting trees
- Green roofs
- Rain gardens
- Pervious surfaces
- Improving soils

Additional Research Options

There are links to videos about some of the solutions and other research options on communitywaters.org.

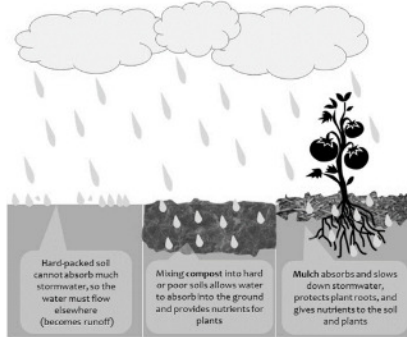
Web-savvy students could also do a search for “green stormwater infrastructure” or “stormwater solutions.”

Example Research page (front and back):

Solution: Improving Soils

How it works:

Soils in urban communities are often compacted (hard-packed), which makes it hard for water to soak in or for plants to grow. Improving the soils using compost (decomposed plants that have become soil) or mulch (plant material like wood chips, compost or dead leaves put on top of the soil around plants) helps stormwater runoff to absorb into the ground. Compost and mulch are rich in nutrients and helpful soil organisms, which help plants grow.



Solution: Improving Soils

Community Example: Portland, Oregon

A team of community members removed a section of the pavement outside this ice cream shop in Portland, Oregon. They brought in some compost and mulch, which they put on top of the dirt that was underneath the asphalt. This new soil is healthy enough to grow plants in, and will absorb runoff that the pavement did not.



Find it near you:
The Highland Park Improvement Club in Seattle also de-paved some of its parking lot to put in healthy soil instead. Around the city, look for sidewalks covered in dark dirt—they are probably using compost or mulch to control erosion!

Improving Soils Benefits and Challenges

Adding mulch and compost to improve soil is a cheaper option than most – it doesn't take too much time to do and the materials are affordable or sometimes free. It takes some work and needs to be done every few years, but can be done by anyone. It doesn't take additional space or take away space from anything, and the mulch and compost will help soil and plants be healthier.

Amount of space needed: low
Amount of money needed: low
Time for building and maintaining: low

TEACHER DECISION POINTS



Use ELA Time?

How best to divide up the research among students?

5. Introducing the Research Plan (Whole Class):

Students will collect notes using the **Solutions Note-Taking worksheet**. They will use information they uncover to determine the benefits or advantages of a solution, and the challenges or disadvantages of a solution. Students should attempt to summarize these in their own words.

On the Solutions Research pages, the primary location to find information about advantages and disadvantages is in the box about “Benefits and Challenges.” It also includes a rating of the amount of space, money, and time a solution might need. For example, in *Improving Soils*:

- Amount of space needed: low
- Amount of money needed: low
- Time for building and maintaining: low

This information can be used when comparing solutions to each other.

There is space for up to seven solutions with advantages and disadvantages for each. They do not all need to be done.

Use the table to write down notes from your research on stormwater solutions:

| Solution & Description | Advantages | Disadvantages |
|------------------------|------------|---------------|
| Example | | |
| | | |

Project a research sheet and do one example with the class (with them making notes in their own worksheets).

NOTE: Don’t forget to add advantages or disadvantages for a solution that are not outlined in the Solutions Research but were identified by stakeholders or discovered through videos, readings, or personal experience!

Explain the approach you will be using (see preparation section at the start of this lesson for ideas).

Example of Notes:

Solution & Description: Green Roof – a roof top planted with plants to absorb and slow down rainwater

Advantages: they can be different sizes, large or small, and they can be out of the way of people

Disadvantages: very expensive, take special materials and people to install it.

Explore and Investigate

ELA Connection



Read and interpret informational text and graphics

6. Conduct research (individual, engineering teams, or whole class)

Give students time to read and take notes about the different solutions presented in the Stormwater Solutions Research.

Circulate to check for understanding and help interpret graphics as needed.

Next time, we will evaluate our solutions to identify which ones might work best for our problem.

EXAMINING STUDENT WORK

Look at the Stormwater Solutions Research Note-taking worksheets:

- Are they successfully pulling out the key advantages and disadvantages of each solution? Can students summarize those differences?
- If you ask, can they tell you why the solution would be good or bad at the site?
- Can they tell you what problem(s) they are trying to solve?
- Has every student filled out information for at least two possible solutions?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

Students need an idea of the advantages and disadvantages to be able to figure out which solutions will fit the criteria and constraints of their site. If students are struggling with the research, you could revisit it as a whole class or work with them individually.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Solutions Research Note-taking Worksheet

NAME: _____

Date: _____

Use the table to write down notes from your research on stormwater solutions:

| Solution & Description | Advantages | Disadvantages |
|------------------------|------------|---------------|
| Example | | |
| | | |
| | | |
| | | |

Next, you'll use the Evaluating Solutions worksheet to figure out which of these stormwater solutions might work at your site!

Lesson 11: Evaluating Solutions

OBJECTIVES & OVERVIEW

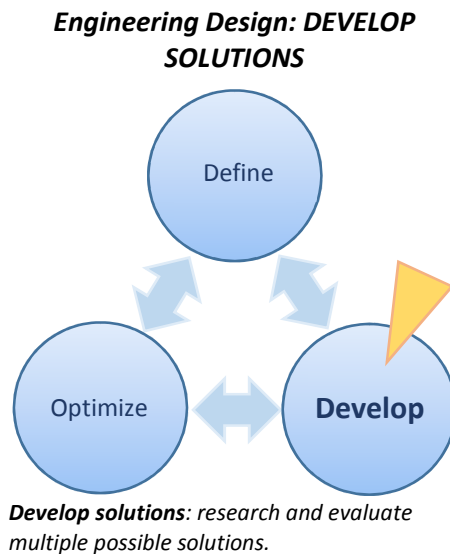
Engineers choose to develop solutions that meet the needs of stakeholders and the most important criteria for success and constraints. Students evaluate the solutions they researched earlier based on how well they address the constraints and criteria for success.

- Students evaluate potential solutions by considering how they meet the constraints and criteria for success.
- Students write a proposal for their solution using the analysis of their research.

Focus Question: Which solution will best meet our criteria and constraints?

Learning Target: I can evaluate the solutions I researched to identify which solution we should build in our model.

New Terms: none



NEXT GENERATION SCIENCE STANDARDS

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.

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

| Science & Engineering Practices | Disciplinary Core Ideas (DCI) | Cross-Cutting Concepts (CCC) |
|--|---|--|
| <p>Obtaining, Evaluating, and Communicating Information.</p> <ul style="list-style-type: none"> • Obtain and combine information from books and/or other reliable media to explain solutions to a design problem. • Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. <p>Constructing Explanations and Designing Solutions.</p> <ul style="list-style-type: none"> • Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-ESS3-2) (3-5-ETS1-2) | <p>ETS1.A: Defining and Delimiting Engineering Problems</p> <ul style="list-style-type: none"> • 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. (3-5-ETS1-1) <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> • 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. | <p>Influence of Engineering, Technology, and Science on Society and the Natural World.</p> <ul style="list-style-type: none"> • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (3-5-ETS1-2, 4-ESS3-2). |

Common Core Connections:

[CCSS.ELA-LITERACY.CCRA.R.1](#) - Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

[CCSS.ELA-LITERACY.RI.4.1](#) - Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

[CCSS.ELA-LITERACY.RI.4.7](#) - Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time-lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.

[CCSS.ELA-LITERACY.RI.4.9](#) - Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.

From <<http://www.corestandards.org/ELA-Literacy/RI/4/#CCSS.ELA-Literacy.RI.4.4>>

MATERIALS

- 1 set per Group:
 - **Stormwater Solutions Research Sheets** from Lesson 10
- Per Student:
 - **Solutions Note-Taking** worksheets from Lesson 10
 - **Evaluating Solutions** worksheet (on communitywaters.org)
- Materials for drawing the solution on Evaluating Solutions worksheet, per student:
 - Pencils
 - Colored pencils and/or markers
 - Pens

PREPARATION

- See materials section

PROCEDURE

Choosing a Solution

Engage and Encounter

Public Record



Problem-Criteria-Constraints Table

1. Activate Prior Knowledge (whole class)

Now that students have researched possible solutions, they need to decide which will be appropriate for the site the class is focusing on.

Review the terms and content of the Problem-Criteria-Constraints Table the class created. Review the definition of criteria and constraints and the perspectives of the stakeholders represented by the site-specific items the class added.

Remind students of the citywide and general items and underline them as you do so.

Work with the class to choose one site specific item from each column to be considered (in addition to the citywide item) as they compare the possible solutions they researched. Underline one in each column when agreed upon:

Problem-Criteria-Constraints Table example:

OUR SITE: School play area and surrounding space

| Problems to Solve | Criteria for Success | Constraints on Possible Solutions |
|---|--|---|
| <p><i>Citywide:</i></p> <ul style="list-style-type: none"> • <u>Too much stormwater runoff in Seattle.</u> <p><i>Site specific:</i></p> <ul style="list-style-type: none"> • <u>Puddles in play area.</u> | <p><i>Citywide:</i></p> <ul style="list-style-type: none"> • <u>The amount of stormwater runoff leaving the site is reduced.</u> <p><i>Site specific:</i></p> <ul style="list-style-type: none"> • <u>No puddles in the play area when it rains.</u> • <u>Water available for school garden.</u> • <u>Add more play space.</u> | <p><i>General:</i></p> <ul style="list-style-type: none"> • <u>Work within the space available at the site.</u> • <u>Keep costs low.</u> <p><i>Site specific:</i></p> <ul style="list-style-type: none"> • <u>Students don't want to lose any play space.</u> • <u>District will have to approve any changes to the site.</u> |

2. Comparing and evaluating solutions

This could be done as a whole class, in engineering teams, or in pairs. The team (or pair or teacher) should **choose three or four solutions to evaluate.**

Hand out and project the **Evaluating Solutions worksheet** and explain they will be using it to compare the solutions they have researched.

Add the additional criteria and constraints on your projected version while the students fill it in on their own sheet (you may end up with only 1 or 2 of the 3 possible Criteria/Constraints).

Across the top of the grid, write the names of the solutions researched (there is room for 4 solutions but leave columns blank as needed). Using notes as

reference, the student puts a smiley face 😊 in the box if the solution clearly meets the criteria or constraint. If it doesn't clearly meet the criteria or constraint, they write down why.

Once the grid has been filled in, students should evaluate their findings: which solution looks like a good option? If several solutions are close, would any of the criteria or constraints that weren't considered help tip the balance?

| Evaluating Solutions Worksheet | | | | |
|---|-------------|-------------|-------------|-------------|
| NAME: _____ | | Date: _____ | | |
| The problem that this solution will help is _____ | | | | |
| Does the solution meet the criteria for success? Put a smiley face if yes. If not, write why. | | | | |
| | Solution #1 | Solution #2 | Solution #3 | Solution #4 |
| Criteria #1 | | | | |
| Criteria #2 | | | | |
| Criteria #3 | | | | |
| Does the solution fit within the constraint? Put a smiley face if yes. If not, write why. | | | | |
| Constraint #1 | | | | |
| Constraint #2 | | | | |
| Constraint #3 | | | | |

Students could circle or star the solution they are considering incorporating into their overall solution plan.



If comparing solutions ends up taking a long time, you could pause the lesson before asking groups to choose a solution.

3. Choosing a solution (engineering teams)

Small Groups



Engineering Teams:
“Which solution might work well for our site?”

Each engineering team will need to come to a consensus on one solution to test in their models. Before starting, lay out your guidelines for how they can share ideas and come to a consensus based on any norms you have established for your class. Consider emphasizing that it is not critical that they pick the “best” choice, but for them to come up with a choice they would like to test as a group in the next lesson based on their evaluation of the solutions.

Ideally, not all the engineering teams will be testing the same solution. You could choose to have the class test just two top solutions if you feel making the testing a fair test (with multiple trials of each solution) is a priority.

Once a team has decided on their solution, they work together to write out their solution proposal on the back of the Evaluating Solutions worksheet (see example below). *It is important that they state why that solution is a good option **based on criteria for success**, not just that they like it.*

Solution proposal example:

“After evaluating the solutions based on our research, our idea for a solution would be a small rain garden.

This solution would meet the criteria for success because it will fit the space and we can plant native plants that we can study. The plants and soil will help absorb rain water, so it doesn’t end up in the storm drains.

Evidence from the summary table that supports my thinking is that plants help to slow down runoff.”

4. Draw solution

Have students draw what they imagine the proposed solutions might look like in the real world, in their problem site. This will help them prepare to model the solution later. Give students a couple minutes to discuss what the solution might look like, but each student will draw their own vision of the solution.

Back-Pocket Questions



Maintaining Focus & Collaboration

Back-Pocket Questions

Maintaining Focus on the Problem

- What is the problem you are trying to solve?
- What are the criteria for success we are focused on?
- What are our constraints on possible solutions?

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?

EXAMINING STUDENT WORK

While students are working on the **Evaluating Solutions Worksheet** you can circulate to see:

- Are students successfully transferring their research notes into the table?
- Can they explain why a possible solution would be a good or poor choice for your site?
- Are they using the table to compare possible solutions?

Review the solution proposals each group writes to see if they were able to explain why their proposal would meet the criteria for success. When reviewing their drawings, how different are each student's images of what the solution might look like? This may be useful to help guide what scaffolding is needed when they model the solution.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

Comparing solutions based on criteria and constraints is key to this stage of the engineering design process (and the 3-5 ETS1-2 standard). If students are not grasping this, consider providing more examples, and walking them through a comparison.

It is also important for the next stage of the process that more than one solution is tested by the class. If all groups have chosen the same solution, consider asking for a group to volunteer to test another solution and/or consider modeling another solution yourself.

Be sure to hold on to student work for the next lessons.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools &
Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Evaluating Solutions Worksheet

NAME: _____

Date: _____

The problem that this solution will help is _____.

Does the solution meet the criteria for success? Put a smiley face if yes. If not, write why.

| | Solution #1 | Solution #2 | Solution #3 | Solution #4 |
|-------------|-------------|-------------|-------------|-------------|
| Criteria #1 | | | | |
| Criteria #2 | | | | |
| Criteria #3 | | | | |

Does the solution fit within the constraint? Put a smiley face if yes. If not, write why.

| | | | | |
|---------------|--|--|--|--|
| Constraint #1 | | | | |
| Constraint #2 | | | | |
| Constraint #3 | | | | |

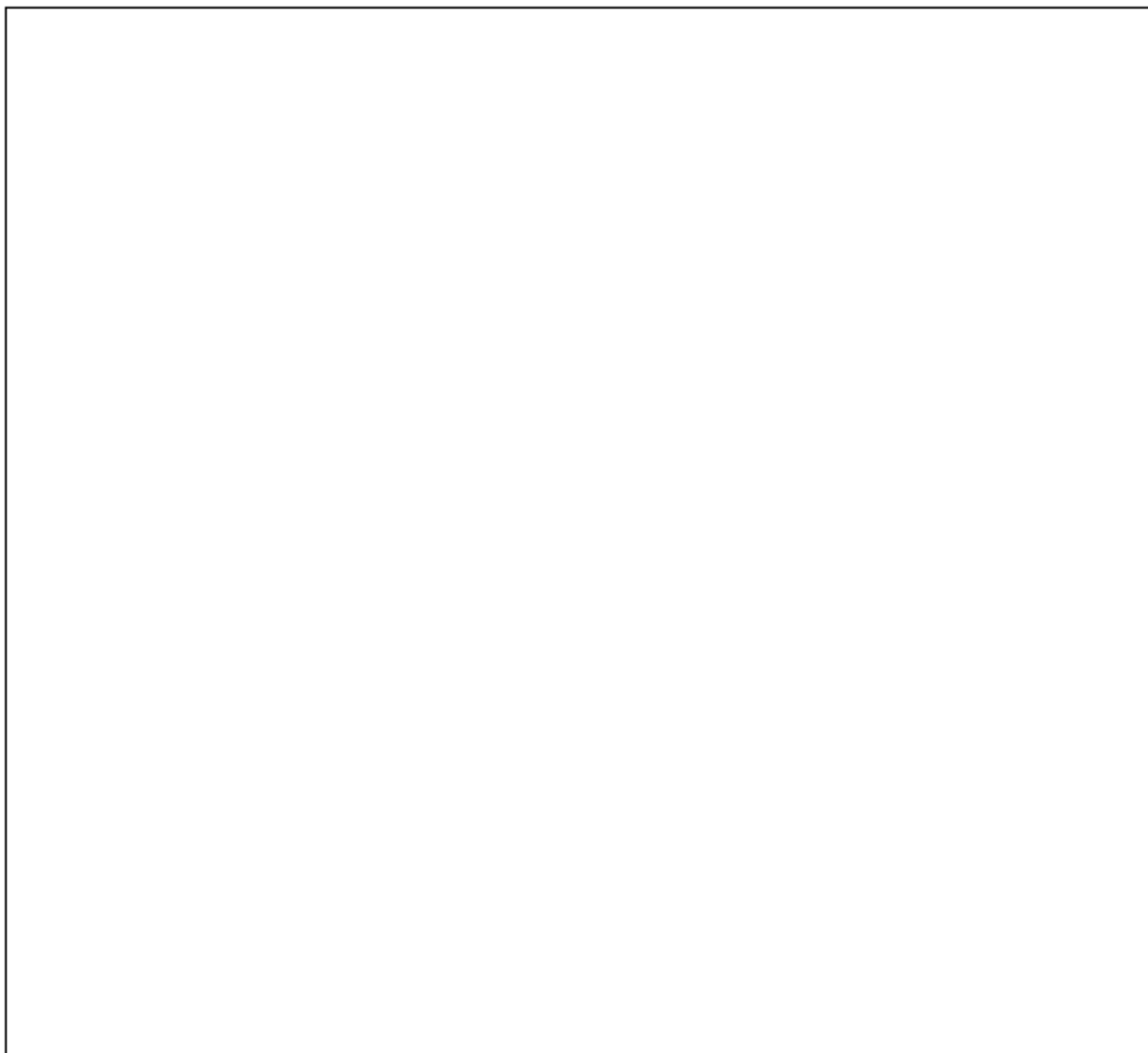
Solution proposal

After evaluating the solutions based on our research, our idea for a **solution** is:

This solution would meet the **criteria for success** because:

Evidence from the summary table that supports my thinking is:

Draw what your proposed solution might look like at your site. Don't forget to label your drawing!



Lesson 12: Modeling Solutions

OBJECTIVES & OVERVIEW

In this lesson the engineering teams plan how they are going to represent their solution and add it to one of the site models they created earlier.

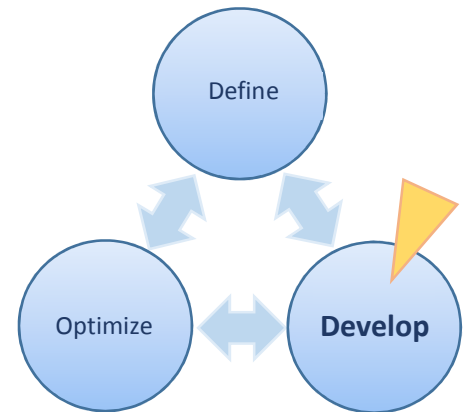
- Student engineering teams design a model of the solution they want to test and add it to their site model.

Focus Question: How do we model our solution?

Learning Target: I can design and create a model of a solution that represents how it would function in the real world.

New Terms: failure point

Engineering Design: DEVELOP SOLUTIONS



Develop solutions: research and evaluate multiple possible solutions.

NEXT GENERATION SCIENCE STANDARDS

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.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|---|---|
| <p>Developing and Using Models</p> <ul style="list-style-type: none"> • Limitations on models. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design a solution. | <p>ESS2.A: Earth Materials and Systems - 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. (4-ESS2-1)</p> <p>ESS2.E: Biogeology - Living things affect the physical characteristics of their regions. (4-ESS2-1)</p> <p>ESS3.B: Natural Hazards - 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. (4-ESS3-2)</p> | <p>Cause and Effect</p> <ul style="list-style-type: none"> • Cause and effect relationships are routinely identified, tested, and used to explain change. |

MATERIALS

Materials to lay out in distribution area (for groups to use when designing solutions):

- Gravel, Sand, and Humus
- Toothpicks and popsicle sticks
- Tinfoil
- Sponge pieces (you may need to cut larger sponges into ½ x ½ inch pieces & 2x2 inch pieces)
- 1-ounce and 9-ounce cups
- Grass saved from Lesson 4 (grown previously and/or brought in)
- Other small plants (optional but useful – brought in?)

Per group:

- Tub with site model created in Lesson 9
- Catch Bucket
- Graduated cylinder
- Absorbent pads (large and small)
- Trowel and 2 spoons
- Rain Jar (with holes in lid)
- Measuring Stormwater Runoff Procedure and Data Sheet from Lesson 14
- Solutions resources from Lesson 15 as reference material
- **Discussion Diamond** worksheet (optional)

PREPARATION – 20 minutes

Website



Pictures of example solutions (and graphics) can be found on communitywaters.org

Watch the 3 minute “Solution Explanations” video if you would like a better idea of what solutions might look like and how exemplary students might describe what they have done. It can be found on communitywaters.org under “teacher supports”.

Print Discussion Diamonds for each team.

Queue up the **Engineering Design Process graphic** from Lesson 8 and the **Materials Set Up Directions** to be projected

Distribution Area: Lay out materials that students could use to model their solutions (see above).

Review list of **Solution Suggestions:** It can be challenging for students to effectively model their desired solutions in this lesson. To prepare yourself to help guide them, review the solution suggestions below and/or on website (with pictures) and think about questions you could ask to help guide students as they are designing their solutions.

Ideas for Modeling of Solutions:

- **Bioswale** = dig a deep trench and stand popsicle sticks on edge to slow down water flow through trench. Add sand to represent the engineered bottom of a bioswale. Add additional popsicle sticks on top of the initial ones. Top off with small clumps of grass.
- **Improve Soils** = If the soils being improved were impervious they should be represented with tinfoil (possibly with sand on top of it) before the solution is implemented. The tinfoil could be removed, some humus mixed in, and a layer of wood chips added to the top. Be aware that if a lot of humus is added it will be messy and hard to dry out.
- **Pervious Concrete** = use toothpicks to poke holes in tinfoil.
- **Pervious Pavers** = lay popsicle sticks side by side.
- **Planting Trees** = Poke a toothpick through the center of a long sponge piece (easier to do when wet). Dig a deep hole and “plant” the bottom of the sponge in the soil with the rest sticking straight up. Popsicle sticks can also be used to support the sponges if they are drooping over.
- **Rain Garden** = dig a hole and put humus in the bottom of it. Place plants with roots on top and around sides. Alternatively, dig a hole and put sponge pieces in it.
- **Rainwater Harvesting** (rain barrel or cistern) = Use small or large cups from kit. Cover building with tinfoil and shape its edges to create a “gutter” that directs rain to where the cup is. Make a hole in the tinfoil over the cup and angle everything so roof water drains to the hole. [getting drainage to work can be challenging for students.]

PROCEDURE

Engage and Encounter

1. Activate Prior Knowledge (whole class)

Each engineering team will be adding the solution they decided to test to one of the models that the class created earlier in the unit. The extra models will be used later when they optimize their solution.

Engineering teams review their notes from the previous lesson so everybody in the team understands which solution their team decided to test and why they think it is a good option.

When everybody is ready, call on a member of each team to share which solution they will be testing and why it is a good choice.

Too Abstract?

You could take your students outside to look again at the problem site and think about where their chosen solution could be built. You could give them chalk, flags, and or cones to mark out where they want to put their solution.

2. Set the Purpose (whole class)

Project the **Engineering Design Process graphic** (from Lesson 8). Testing solutions is an important part of developing and optimizing solutions. While developing a solution, our tests can help us figure out which parts of the

solution could be improved. Then we can use that data during the optimizing stage to decide which solution will best solve our site’s stormwater runoff problem.

By carefully observing the tests, the students may be able to find “**failure points**” in their designs; if so, they can make changes to improve them. They will also be recording data from their procedure to assist in figuring out which of the many possible solutions would be best for their site.

The **models students create will clearly not be perfect representations of their solution**; the students’ task will be to represent their specific solution to the best of their ability.

Share the materials the students will be able to use (see distribution area materials above). There may also be other items in the room that could be used (only with teacher’s permission).

Remind students of constraints from the class that could impact their solution’s location or size within the model (like maintaining an area to play).

Public Record



Important constraints from Problem-Criteria-Constraints Table

Explore and Investigate

3. Discussion Diamond for solution design (engineering teams)

Each group will fill in a discussion diamond like the one used after their Walking Field Trip. This time, they will be thinking about how they might model the solution with the materials they have available. By the end of this activity, groups need to have an agreed upon plan on how they want to represent their model.

Discussion Diamond?

Feel free to use a different strategy for small group consensus if desired.

Hand out Discussion Diamond sheets to each group. If a group has more than 4 members, you could provide additional members with a large post it to record their ideas on.

- Students will have about 3 minutes for silent thinking and writing time. Each student writes or draws ideas for how to model their solution in their corner of the paper.
- Then individuals share what they wrote or drew in their small groups for a total of around 4 minutes. After each person shares, they should take some time for other students to ask questions, add on, or connect to what they wrote.
- After all students have shared their corners, the team should discuss which ideas they want to incorporate into their model. It is not important that every idea is included in the model, what is important is that the model accurately represents how their proposed solution would actually interact with stormwater. This will likely take time.
- When they are ready, they should raise their hands for the teacher to come to their table and hear their plan.

Small Groups



Engineering Team: Discussion Diamond to find consensus on a design for their solution.



Back-Pocket Questions



Maintaining Focus on the Problem & Modeling

Back-Pocket Questions

Maintaining Focus on the Problem

- What is the problem you are trying to solve?
- What are the criteria for success we are focused on?
- How are the criteria being measured when we test this model?

Modeling

- What solution are you modeling?
- How does that solution help with stormwater?
- How are you going to represent your solution?
- What materials are you going to use?
- How will those materials help with the problem?



You could pause the lesson here if needed. Adding the solutions to model (below) can take a lot of class time depending on your students.

Small Groups



Engineering Teams:
Building solution models

4. Add solution to model (engineering teams)

Project the **materials set up directions** (available at end of lesson or on communitywaters.org).

Once they have an agreed upon a plan and have shared it with the teacher, engineering teams can set up their tubs and start work on adding their solutions to their models.

While groups are working on their models you can circulate and continue to check in on their thinking (see Back Pocket Questions above).

5. Run an initial test (engineering teams)

Students can come get their rain jar (with 100 ml) from the teacher when their solution design is ready.

This initial testing does not need to be precise or recorded in their data table. Encourage students to observe where the water is flowing. Is it flowing into the solution they modeled?

If students have extra time while others are building their solutions, they could adjust their models.

Model Saturation

To avoid over soaking the models and control variables, we suggest limiting all groups to 100 ml.

If you haven't yet run the example model through the investigation procedure (Lesson 9) or otherwise want to keep it available as a control you should make a point of adding the same amount of water to it.

Reflect and Explain

Turn-and-Talk



What should we change about our model to make it better?

6. Discuss results (pairs or engineering teams)

What happened to their solutions as the water was added? Did any “**failure points**” come up in their initial tests? How could they adjust their design to do a better job of capturing stormwater runoff?

Next time, students will have an opportunity to make adjustments to their models before using the same procedure as was (or will be) used on the example model. This will let them gather data about how well their solution works.

EXAMINING STUDENT WORK

Look over the student models and consider whether their solution design is likely to interact with stormwater in the way intended. Will it soak up water or help it soak in?

Examples of problematic designs include trees represented by toothpicks and rain barrels that aren't going to get runoff from a roof.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Did any issues come up for groups trying to work together? Was everybody heard? Are there changes in approach you want to make going forward to address any concerns?

If there are models that are clear misses, consider whether you want to press further about their design before or after students can see the results for themselves. If you do it after the next lesson, will students have sufficient time to redesign the model to better reflect what they are attempting?

If you would predict there will be significant student stress around their models “failing” and you didn't read it yet, consider reading [Rosie Revere, Engineer](#) by Andrea Beaty. The main character in this book is an inventive girl who gets frustrated at failure but then learns how engineers design, test, redesign, and retest over and over again. See <https://teachscience4all.org/ngss-resources/> for a teacher guide.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. diamond discussion and group work) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Materials Set Up

Do all the following before working on modeling your solution:

1. Materials Manager brings materials to work area.
2. Place the large pad on the table with absorbent side up.
3. Put the tub with the site model on the large pad with the drain hole over the edge of the table.
4. Place the small pad on the floor with absorbent side up and put the bucket on the pad under the drain hole so that the bucket will catch any water that comes out of the drain hole.
5. Make sure the drain plug is in the hole.

Leave the rain jar in materials area.

Once your tub is set up, let an adult know what additional materials you will need from the class supply.

Lesson 13: Testing Solutions

OBJECTIVES & OVERVIEW

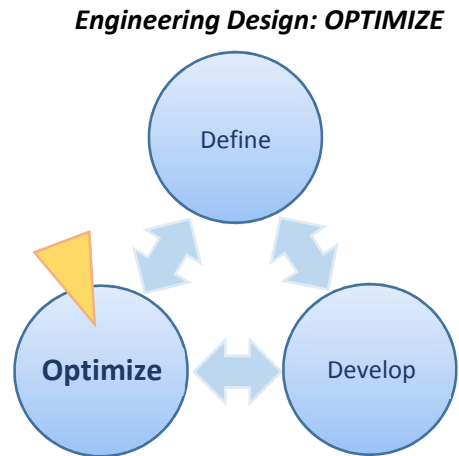
In this lesson student groups adjust the solution models they built in their previous lesson. Then they run the same procedure as earlier to record data about the runoff that occurs with the solution in place.

- Students use an investigation procedure and record data.

Focus Question: How can we improve our solution?

Learning Target: I can run an investigation to improve my solution.

New Terms: none



Optimize the solution: improve a solution based on results of simple tests, including failure points.

NEXT GENERATION SCIENCE STANDARDS

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.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|---|---|---|
| <p>Developing and Using Models</p> <ul style="list-style-type: none"> • Limitations on models. <p>Planning and Carrying Out Investigations</p> <ul style="list-style-type: none"> • 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). | <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3) | <p>Cause and Effect</p> <ul style="list-style-type: none"> • Cause and effect relationships are routinely identified, tested, and used to explain change. |

MATERIALS

YOU WILL NEED THE SAME MATERIALS AS PREVIOUS LESSON

OPTIONAL per group

- Print **Team Observation Sheet** (see below)
- Colored pen

PREPARATION

TEACHER DECISION POINT

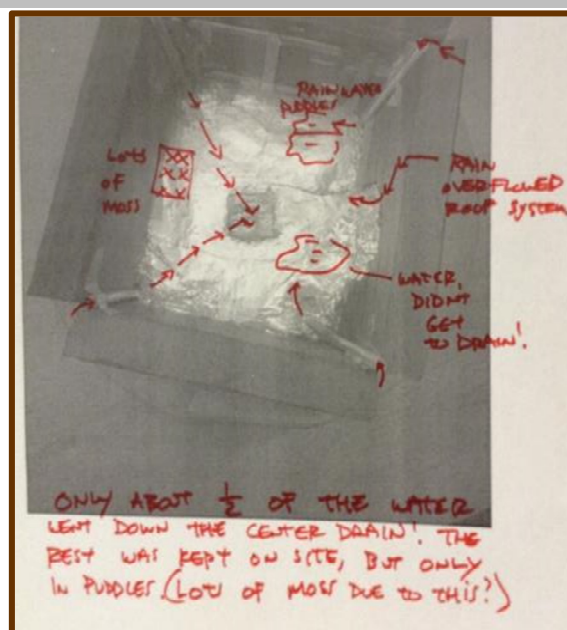


Print photos for recording observations?

OPTIONAL: Create Team Observation Sheets

You could take a digital picture of the solution built by each engineering team and print it on a sheet of 11x17" paper for the team to record observations. If you do this, make one also of the teacher's example model to use as a demo.

Example →



Engage and Encounter

Present visual



Procedure Sheet

Small Groups



Engineering Teams
assign roles and set up
materials

**Back-Pocket
Questions**



Maintaining Focus

1. Set up for the activity (whole class, engineering teams)

Students will have the opportunity today to improve their models and test how they do. They will use the same procedure as was (or is now being) used on the example model of the site.

Why is it important to follow the procedure exactly?

Project the **Measuring Stormwater Investigation Procedure** from Lesson 9 and have groups decide on group roles (they will have a chance to switch the next time this is done):

1. **Materials Manager**
2. **Measurer**
3. **Rain Maker**
4. **Bucket Holder**
5. **Observer – Recorder**

Class Procedure?

If you developed a different investigation procedure with the class, use that one again this time (and adjust group roles as needed).

Depending on the group size, the measurer could also be the bucket holder and the materials manager could be the observer.

Hold on to the rain jars but otherwise, follow **set up portion** of the procedure.

2. Refine solutions (engineering teams)

Groups look over the solution they modeled in the previous lesson and see if there are any small adjustments they want to make before running the test.

Back-Pocket Questions

Maintaining Focus on the Problem

- What is the problem you are trying to solve?
- What are the criteria for success we are focused on?
- How are the criteria being measured when we test our solutions in the model?

TEACHER DECISION POINT



Using Team Observation Sheets?

Explore and Investigate

3. Review procedure (whole class)

To review the procedure, run the teacher “control” model through the procedure with student’s assistance.

Emphasize with students the importance of carefully observing what happens in their model as water is added. If they are watching closely they may be able to identify “failure points” in which some part of their solution isn’t working properly, or problems occur.

Optional: Team Observation Sheets

If you created the optional **team observation sheets** (see preparation section above), have an observer add to the teacher model version as an example.

Provide each team’s observer the sheet and a brightly colored pen to record observations. Other team members can add to the observations after the procedure is complete.

Small Groups



Engineering Teams run procedure

4. Run test and record results (engineering teams)

Provide time for students to follow the procedure and record results (or lead them through each step if desired).

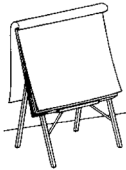
Groups should record results in the data tables they created in their science journals earlier (and if using the observation sheets, they can add observations to them).

Example Data Table for Runoff from Model

| Trial #: Description | Amount Added | Amount Collected | Observations |
|---------------------------------|---------------------|-------------------------|---|
| 1: Site Model without solution | 1,000 ml | 800 ml | Water collected in large and small puddles on tinfoil. |
| 2: Rain Garden | 1,000 ml | 750 ml | Not much water went into rain garden. There were still puddles. |

Reflect and Explain

Public Record



Create a class data table and record each group’s results on it.

5. Analyze the data (engineering teams)

The designs and models engineers create often “fail.” A big part of engineering is looking at how your tests went and considering what failures can tell you about what needs to be improved or redesigned. Nobody will be graded based on how well their models did; what is important is what you can learn from them.

Back-Pocket Questions



Observations &
Optimizing

Questions for each group to consider:

How did your results compare to the results from the example model?

What did you observe during the procedure?

Does anything you observed help explain the results of the trial?

Does anything you learned earlier in the unit help explain the results of the trial?

Are there changes you could make that would help your solution work better?

Have each team share with the class something they learned from the test.

Back-Pocket Questions

Observations

- Where did you observe runoff occurring?
- Was there a certain point that the solution stopped working?
- Was your solution able to handle the amount of water added to the model?
- What happened when there was more water added than your solution could handle?

Optimizing

- Does your model seem to be working?
- What is working well?
- Were there failure points you need to fix?
- Did the solution cause any new problems?
- What do you need to do to improve your design?

EXAMINING STUDENT WORK

Look over the results from the tests and consider whether the amount of runoff was reduced from the test of the model that didn't have a solution in it. If any solutions didn't show any improvement, consider why that might be. Are there design features that could be changed? Did they identify what they need to do to fix it in their discussion afterwards?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

If there was a lot of student stress around their models "failing" and you didn't read it yet, consider reading *Rosie Revere, Engineer* by Andrea Beaty. The main character in this book is an inventive girl who gets frustrated at failure but then learns how engineers design, test, redesign, and retest over and over again. See <https://teachscience4all.org/ngss-resources/> for a teacher guide.

If investigation procedures didn't go well, you could lead a group discussion about why fair test procedures are important in science and engineering. What happens if the data isn't an accurate representation?

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Lesson 14: Finalizing Solutions

OBJECTIVES & OVERVIEW

In the first part of this lesson, students make changes to optimize the solution they are modeling and test how it is working. Then students analyze their own and other’s data to make a claim about the effectiveness of the solution they modeled.

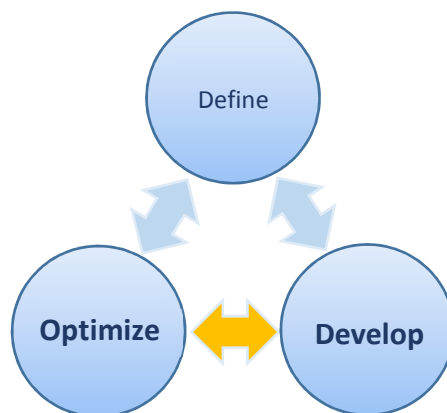
- Students engage in arguing from evidence and write a claim about their solution.

Focus Question: How effective is the solution my group modeled?

Learning Target: I can make a claim about my solution and support it with evidence and reasoning.

New Terms: none

Engineering Design: DEVELOP & OPTIMIZE



Develop and/or Optimize a Solution: Tests can help improve a solution when they identify failure points. They can also be used to determine which proposed solution will best solve a problem.

NEXT GENERATION SCIENCE STANDARDS

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.

PE 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

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.

| Science & Engineering Practices | Disciplinary Core Ideas | Cross-Cutting Concepts |
|--|--|---|
| <p>Developing and Using Models</p> <ul style="list-style-type: none"> • Limitations on models. <p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> • Analyze data to refine a problem statement or the design of a proposed object, tool, or process. • Use data to evaluate and refine design solutions. • Compare and contrast data collected by different groups in order to discuss similarities | <p>ETS1.B: Developing Possible Solutions</p> <ul style="list-style-type: none"> • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) <p>ETS1.C: Optimizing the Design Solution</p> <ul style="list-style-type: none"> • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3) <p>ETS1-B Developing Possible Solutions</p> <ul style="list-style-type: none"> • 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. | <p>Cause and Effect</p> <ul style="list-style-type: none"> • Cause and effect relationships are routinely identified, tested, and used to explain change. |

and differences in their findings.

Common Core Connections:

Writing

[CCSS.ELA-LITERACY.W.4.1](#) - Write opinion pieces on topics or texts, supporting a point of view with reasons and information.

[CCSS.ELA-LITERACY.W.4.1.A](#)

Introduce a topic or text clearly, state an opinion, and create an organizational structure in which related ideas are grouped to support the writer's purpose.

[CCSS.ELA-LITERACY.W.4.1.B](#)

Provide reasons that are supported by facts and details.

[CCSS.ELA-LITERACY.W.4.1.C](#)

Link opinion and reasons using words and phrases (e.g. *for instance, in order to, in addition*).

[CCSS.ELA-LITERACY.W.4.1.D](#)

Provide a concluding statement or section related to the opinion presented.

[CCSS.ELA-LITERACY.W.4.4](#) - Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1-3 above.)

[CCSS.ELA-LITERACY.W.4.5](#) - With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, and editing.

MATERIALS

Per group:

- Measuring Stormwater Runoff Procedure and Data Sheet from Lesson 14
- Solutions resources from Lesson 15 as reference material
- Print **Stormwater Solution (CER) Conclusion** template worksheet

PREPARATION – 20 minutes

TEACHER DECISION POINT



Differentiation Needed?

Differentiation Needed for CERs?

Writing out a full Claim-Evidence-Reasoning can be beyond the capacity of some students. Consider alternatives for students who do not have the writing skills to effectively right out a full claim with evidence and reasoning:

- Would they be helped by more scaffolding with sentences mostly written out for them?
- Could they instead explain it to you or an assistant who could write it out?
- Could they better represent their thinking with diagrams or pictures?

Any of these alternatives could still be evaluated with the rubric (below) used for written CERs. We also have several whole class CER alternatives linked under this lesson on communitywaters.org.

If you are going to use the CER, queue up the CER conclusion template to be projected.

Explore and Investigate

Back-Pocket Questions



Optimizing

1. Set up for the activity (whole class)

Engineers use the tests they do on their models to improve on (optimize) their solutions.

Students will have the opportunity today to recreate their solution in the second site model that their group created. They will then test their solutions using the same procedure as before.

2. Optimize the solution (engineering teams)

Groups review their results from the previous session and discuss how they want to change their solution when they rebuild it in the second model.

Given their test results, did any **“failure points”** come up in their previous test? How could they adjust their design to do a better job of capturing stormwater runoff?

Circulate while students are talking and press for deeper understanding.

Students could record the changes they are making to the model in their science notebooks (a “Change Log”).

If it would be helpful to do so, some groups could share with others what failure points they encountered and what they are changing to fix them. They could also share things they feel worked especially well in the models they designed.

When they are ready, they should raise their hands for the teacher to come to their table and hear their plan.

3. Add solution to model (engineering teams)

Once they have an agreed upon a plan and have shared it with the teacher, engineering teams can set up their tubs and start work on adding their solutions to their models.

Back-Pocket Questions

Optimizing

- Does your model seem to be working?
- What is working well?
- What specifically didn’t work?
- Are there any other failure points you need to fix?
- Is there anything you have learned about in previous lessons about stormwater runoff that provide ideas for improving your solution?
- What do you need to do to improve your design?
- Are there other materials you could use to better represent your solution?

While groups are working on their models you can circulate and continue to check in on their thinking (see Back Pocket Questions above).

4. Run an initial test (engineering teams)

Present visual



Investigation Procedure

Students can come get their rain jar (with 100 ml) from the teacher when their solution design is ready.

As before, this initial testing does not need to be precise or recorded in their data table. Encourage students to observe where the water is flowing. Is it flowing any differently than with their previous solution model?

If students have extra time while others are building their solutions, they could adjust their models.

You could pause the lesson here or after either of the next two steps.

Model Saturation

To avoid over soaking the models and control variables, we suggest limiting all groups to 100 ml.

If you haven't yet run the example model through the investigation procedure (Lesson 9) or otherwise want to keep it available as a control you should make a point of adding the same amount of water to it.



5. Run tests and record results (engineering teams)

Project the **Measuring Stormwater Investigation Procedure** (from Lesson 9) or your class version if you created one.

Engineering Teams switch roles.

Provide time for students to follow the procedure and record results in their science journals.

Reflect and Explain

6. Analyze the data (engineering teams)

Focus question on board: **“How effective is the solution my group modeled?”**

After testing solutions, engineers need to analyze and interpret their data to determine how well the solution worked. Sometimes, despite efforts to optimize their solution, the data might tell them their chosen solution is not the right one for the job. Finding that out is not a failure for the engineer; it is just telling them they need to look for other possible solutions.

Engineering Teams should compare the results from the first and last trials on their data table:

- *Did the tests they did of their solution result in less stormwater runoff in their bucket? What was the difference in the amount they collected?*

Investigating Data



Looking for patterns and cause and effect

Small Group



How effective was the solution you modeled at reducing the amount of stormwater runoff?

- *What do their observations during the tests and understanding of stormwater tell them about the test results? Do they feel the test results showed how well the solution would work at the site?*
- *Was the solution they modeled effective at reducing stormwater runoff?*

Back-Pocket Questions



Maintaining Focus

Teams should be prepared to share what they learned from their tests with the rest of the class.

Back-Pocket Questions

Maintaining Focus on the Problem

- Does the solution you tested solve the problem?
- How well does your solution meet the criteria for success?
- What have you learned that others need to know about this solution at our site?

Investigating Data



Looking for patterns and cause and effect

7. Share results and compare solutions (whole class)

Provide time for each team to share their conclusions about their test results.

Discuss whether it is fair to compare the data from the different teams:

- *Were the original models similar enough to each other?*
- *Did everybody control the same variables?*
- *Were there enough trials?*

Whole-class Discussion



How do the different results compare?

If the answer to any of those questions is no, we can still look at the differences in data to see what we notice, we just can't use the differences as evidence in claiming one is better than the others.

Discuss the different results as a group.

If helpful, put the results into a bar graph or other graphical representation to help compare the data.

What are the implications of the data?

Framing as an Engineering Company

Some teachers have had success framing the sharing as the class representing a single engineering company that is trying to meet their criteria for success and constraints of a specific site.

Within the company, smaller teams have been modeling and investigating different possible solutions. Now they are coming together to look at how the different solutions compare. This is **NOT** a competition to see which group did "better," it is a discussion to see what we can learn about what would be good solutions for our site.

Public Record



Problem-Criteria-Constraints Table

Return to **the Problem-Criteria-Constraints table** and challenge the students to think beyond the data: How effective are the solutions in meeting all the underlined criteria for success and constraints?

Provide an opportunity for students to present a claim to the class about whether their solution is a good one. Their argument should include evidence that supports it. Other students then are given an opportunity to ask questions or present evidence that the original claimant may not have considered.

Providing students sentence starters can help students who are unfamiliar or uncomfortable with disagreeing with others publicly. There is a good example on: <http://uwcoeast.wpengine.com/tools-scaffolding/>

8. Make a claim from evidence (individual)

Each individual student will now be writing a conclusion about what they have learned about the solution their group modeled. They will be making a claim about the question: **“How effective is the solution I modeled?”**

Student’s claims should include the data they gathered as **one part** of how effective the solution would be at meeting each of the Criteria for Success and Constraints that the class is focusing on. In addition to the data, students should provide other evidence from what they have read that supports their claim about the solution.

Conclusions should take the form of a “Claim-Evidence-Reasoning.”

Differentiation?

See preparation section for discussion of differentiation approaches. If you are providing more scaffolding or other alternatives, share those during this time.

ELA Connection



Write a conclusion as a research-based argument essay

TEACHER DECISION POINT



CER Alternative or Differentiation?
[See Preparation Above]

For a scaffold, use the **Stormwater Solution Conclusion** template:

- a. **Claim:** A general statement about the effectiveness of the solution.
- b. **Evidence:** Possibilities to include:
 - Data from their tests of the solution.
 - Reference to where the solution has worked elsewhere.
 - Site specific criteria and constraints that it meets, partially meets, or does not meet.
- c. **Reasoning:** The reasons why the evidence meets (or does not meet) the criteria for success and the constraints (how the evidence supports the claim). Reasons may also include scientific understandings that help explain the evidence.

Example CER Exemplars:

CER Example #1

Claim: “Building a bioswale through the line of six storm drains on the playground would work as a solution for stormwater runoff at our site.”

Evidence: “Bioswales are being used by many cities around the United States and have been effective in reducing the amount of storm water runoff entering our waterways. When we tested a model bioswale in our stream tub models, the water from the model with the solution was 200 milliliters less than when we tested the model without a solution. In addition, bioswales include plants and can be narrow to avoid taking up too much space.”

Reasoning: “This shows that a bioswale would meet the criteria and constraints for our site. Stormwater will be absorbed by the ground and plants in the bioswale instead of entering the storm drain, people will like the plants, and there will still be space for children to play during recess.”

CER Example #2

Claim: “Building a rain garden is an option for our site, but it wouldn’t be very effective.”

Evidence: “Rain gardens are used in many yards and some schoolyards around Seattle. When we tested a model rain garden it reduced the amount of stormwater runoff by only 20 milliliters. Our research shows, it would have pretty plants but would require a lot of maintenance.”

Reasoning: “Therefore, a rain garden would not do a great job of meeting the criteria and constraints for our site. Rain gardens help water be absorbed by the ground and the plants in them, but would have to be much bigger than our model to make a difference. If the rain garden was bigger, there wouldn’t be enough space for children to play during recess and it would be hard for the school to maintain.”

EXAMINING STUDENT WORK

Review and score each student's Claim-Evidence-Reasoning, using the following rubric:

| | 0 | 1 | 2 | 3 |
|--|--|---|--|---|
| CLAIM <i>A statement that answers the original question.</i> | Does not make a claim or makes a claim that does not answer the question. | Makes a claim that addresses the question, but it is incomplete or vague. | Makes a complete claim that addresses the question. | X |
| EVIDENCE <i>Scientific data that supports the claim. Data needs to be <u>appropriate</u> and <u>sufficient</u> to support the claim.</i> | Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim). | Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence. | Provides appropriate and sufficient evidence to support claim. | Provides appropriate and sufficient evidence to support claim including evidence beyond what they gathered. |
| REASONING <i>Explain why your evidence supports your claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence.</i> | Does not provide reasoning or provides reasoning that does not link evidence to claim. | Provides reasoning that links claim to evidence, but does not include scientific principles. | Provides reasoning that links the claim to evidence using scientific principles, but not sufficient. | Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles. |

Student's succeeding at making a complete claim and supporting it with appropriate and sufficient evidence accomplishes what is expected for 3-5 graders in the NGSS "Engaging in Argument from Evidence" Science and Engineering Practice. Including scientific principles in their reasoning becomes expected in the Middle School band (6-8).

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

If students are not using evidence to support their claims or are not actually answering whether the solution they modeled is effective, you may need to revisit the CERs as a class. Consider whether clarifying the question, modeling more examples, or other re-teaching could help.

Also consider the CERs individuals completed together with other members of their engineering team:

- If students on the same team are coming to different conclusions in their CERs, you may need to provide more time at the beginning of the next lesson for the team to develop a consensus on the conclusion they are going to present.
- If students on the same team are showing widely different grasp of the evidence or reasoning, consider whether it might help to assign group roles during the next activity to support their strengths or provide opportunities for peer teaching.

Be sure to hold on to student work for the next lesson.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools
& Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table and class consensus model) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Stormwater Solution Conclusion

Claim-Evidence-Reasoning (C-E-R)

Student Graphic Organizer

Name: _____

Date: _____

★ **Question:** How effective is the solution your group modeled?

| | |
|---|--|
| <p style="text-align: center;">C</p> <p style="text-align: center;">(Claim)</p> <ul style="list-style-type: none">• Write a statement that says what solution your group modeled and how effective it would be for our site. | |
| <p style="text-align: center;">E</p> <p style="text-align: center;">(Evidence)</p> <ul style="list-style-type: none">• Provide scientific data from investigations and research to support your claim.• Your evidence should be appropriate (relevant) and sufficient (enough to convince someone that your claim is correct). | |
| <p style="text-align: center;">R</p> <p style="text-align: center;">(Reasoning)</p> <ul style="list-style-type: none">• Begin your reasoning with "<u>Therefore,</u>" or "<u>Hence,</u>" or "<u>This shows.</u>"• Explain how your data proves your claim.• Use <u>scientific principles and knowledge that you have about the topic</u> to explain <u>why</u> your evidence (data) supports your claim. | |

Lesson 15: Communicating Our Results

OBJECTIVES & OVERVIEW

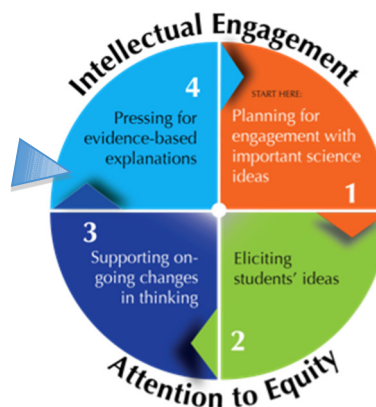
Evaluating and communicating solutions is an important part of the engineering process. Engineers share their design solutions with each other and stakeholders in order to evaluate the solutions based on how well they meet specific criteria or take into account constraints. Today’s class will provide an opportunity for students to share their proposed solutions for their site. Students will share their designs and discuss them with their classmates.

- Students communicate about their solutions to peers and/or stakeholders.

Focus Question: How will we share what we have learned with others?

Learning Target: I can share about my groups’ stormwater solution and why it might or might not work with others.

Ambitious Science Teaching Framework: PRESSING FOR EVIDENCE-BASED EXPLANATIONS



This practice happens as a summation, but parts can be introduced at other times when students talk about evidence. For more visit <http://AmbitiousScienceTeaching.org>

NEXT GENERATION SCIENCE STANDARDS

PE 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

| Science & Engineering Practices | Disciplinary Core Ideas (DCI) | Cross-Cutting Concepts |
|--|--|--|
| <p>Engaging in Argument from Evidence.</p> <ul style="list-style-type: none"> • Respectfully provide critiques about a proposed explanation by citing relevant evidence and posing specific questions. • Construct an argument with evidence, data, and/or a model. (4-LS1-1) • 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. <p>Obtaining, Evaluating, and Communicating Information.</p> <ul style="list-style-type: none"> • Communicate scientific information orally and/or in written formats, and may include tables, diagrams, and charts. | <p>ETS1.A Defining and Delimiting Engineering Problems.</p> <ul style="list-style-type: none"> • 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. (3-5 ETS1-1) <p>ETS1-B Developing Possible Solutions.</p> <ul style="list-style-type: none"> • 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. <p>ESS3.B Natural Hazards.</p> <ul style="list-style-type: none"> • A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2) | <p>Influence of Engineering, Technology, and Science on Society and the Natural World.</p> <ul style="list-style-type: none"> • People’s needs and wants change over time, as do their demands for new and improved technologies. • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (3-5-ETS1-2) |

Common Core Connections:

Speaking and Listening

[CCSS.ELA-LITERACY.SL.4.1](#) - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 4 topics and texts*, building on others' ideas and expressing their own clearly.

[CCSS.ELA-LITERACY.SL.4.2](#) - Paraphrase portions of a text read aloud, or information presented in diverse media and formats, including visually, quantitatively, and orally.

[CCSS.ELA-LITERACY.SL.4.3](#) - Identify the reasons and evidence a speaker provides to support particular points.

[CCSS.ELA-LITERACY.SL.4.4](#) - Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

MATERIALS

- **What Happens to Stormwater at our Site?** explanatory model from Lesson 7
- **Stormwater Solution Conclusion (CER)** from Lesson 14

Print for each student:

- **After-Unit Take Home Interview** – one per student (There are Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese versions of this document available on communitywaters.org).

PREPARATION – 45 minutes

Decisions to be made:

TEACHER DECISION POINT



Audience? Room
arrangement?
Presentation format?

- **Who will be in the audience?** Are there stakeholders you could invite to watch the student presentations? This could include people interviewed previously, or (if the site is on school grounds) someone from the district, facilities crew, or PTA. OR, will the audience be just your class, a younger class or other?
- **What will be presented?** Will students share a poster they create, or a poster and their models? (Or something else?)
- **How will the room be arranged?** Where will students present from, and how will they show their models and/or posters to the rest of the class?
- **How will presentations be shared?** What is the best way to have students share their work? You may want student groups to present one at a time to their audience, or you may choose a “gallery walk” format where the audience rotates to each group. Each is described below. Consider sharing, also, during your school’s science or engineering fair!

PROCEDURE

Engage and Encounter

1. Get the Activity Started (whole class)

After designing a solution, engineers present it to stakeholders who can then decide whether to implement it.

Each team will be responsible to put together an explanation of the solution they developed to share with the class and/or others (depending on who will be attending). Their job is not to convince others that the solution they tested is the right or wrong solution for the site; it IS to give people all the information they need to be able to consider the advantages and disadvantages of the solution in comparison to other possible solutions.

Their presentation should include:

- The problem they are trying to solve with the criteria for success and constraints to be considered.
- What the solution is and how it would work to help slow or absorb stormwater.
- How the solution would address (or not address) each of the criteria and constraints.
- Why they chose the solution (using evidence from multiple sources).
- What the solution would look like (using models and/or posters).

Explore and Investigate

ELA Connection



Students expand on written conclusion and communicate results with peers.

Small Groups



Groups will create their poster and plan their presentation

2. Develop presentations (engineering teams)

Create a checklist on board of all the things to include in their posters.

Creating a Poster: Draw the problem area and the imagined solution; incorporate pictures or other images cut and paste onto a poster.

Things to include:

- Diagram of current problem area (somewhat like a “before” picture). This could be copied from the drawing they did in the What Happens to Stormwater at our Site explanatory model, or be enlarged photos (printed on 8.5x11” paper). It should show:
 - Surfaces in the area that contribute to the problem
 - Arrows showing how water moves through the site during a storm.
- Diagram of Solution (like an “after” picture), showing the proposed solution and its features.
- Key (if using symbols in drawings)
- Claim-Evidence-Reasoning written conclusion

- Stakeholder needs, constraints and criteria for success, and whether each is addressed (could be included in conclusion).

The develop presentations time could be split up into multiple days if needed.

Create and Practice Presentation

- Introduction of Problem
- How they researched solutions and stakeholders
- Description of criteria for success and constraints
- Description of solution
- Results of testing solution

Student Jobs

You could provide student's assigned jobs for the poster and presentation.

Poster Creation Jobs:

- Title and decorating of poster
- Site with current problem (drawing or photograph)
- Solution with key (2 students?)
- CER written so that people can easily read and see it
- Perspective of stakeholders with the Criteria and Constraints being focused on and how the solution would (or would not) address each written out.
- Preparing model (if using)

Presentation Roles:

Could be presenting the section they prepared on the poster.



If needed, this would be a great place to pause the lesson.

Reflect and Explain

TEACHER DECISION POINT



Will you have stakeholder guests for the students to share with and how do you want to set up the sharing?

3. Deliver Presentations (whole class)

If you have stakeholders in attendance introduce them and the importance of bringing them on board to consider the feasibility of actual implementation. You could invite the stakeholders also to contribute questions as the presentations proceed.

Have each group stand by their posters or models. One group at a time presents about their proposed solution for approximately 5 minutes. The groups should plan out who will share which parts of their presentation.

Student listeners (audience) will write down the group name, the problem, and the proposed solution. They will write down something they notice about the solution and something they wonder. If they have any ideas that will help **optimize** (improve) the solution, they will take note of those.

After the group is finished presenting, the audience may ask questions, offer up things they appreciated, or suggestions for improvements.

Bring the whole class together again to reflect and explain interesting solutions and ideas for improvements.

OR

Gallery walk: posters/models placed around the classroom; half of the groups will stay with their poster, and half will be the audience; after the audience groups rotate to the presenters, the groups will switch so the audience groups are now the presenting groups. Audience groups will rotate to all presentations and ask questions and/or use sticky notes for comments and questions. A whole group debrief discussion might be useful to wrap up the gallery walk, when students have a chance to share appreciations (what they liked) about other groups presentations.

Reflect and Explain

4. Reflect on the unit (individual)

Have students reflect on this part of the unit (stormwater engineering), having them do a quick write or turn and talk, etc.

Questions you may want to use as prompts:

- What did they learn during this unit?
- What was the most fun part of the engineering process? The most challenging?
- Why should we care about stormwater?
- Did you prefer the science learning or the engineering and why?
- What other environmental or community problems can you think of that could use engineering solutions?
- What was their favorite part about their solution?

Apply and Extend

5. Take Home Interview

This homework assignment – available in English (below) and Spanish (on communitywaters.org website) – is designed for students to interview and be interviewed by an adult at home. Each in turn asks questions and writes down the answers on the sheet.

Present visual



Take Home
Interview

Turn-and-Talk



Optional Preparation for Take Home:

- Students practice answering the questions in the “Adult Asks Student” section with a partner.
- Walk the students through the “Extra Credit” section by looking up the school’s address on [700 million gallons.org](http://700milliongallons.org).

EXAMINING STUDENT WORK

The presentations of the students are the summative assessments of the unit, the culmination of learning about what is going on with stormwater at the school, local and city level, and how people are designing and building solutions to stormwater runoff problems using an engineering design process.

SAMPLE RUBRIC for Poster/Model

| | |
|--|----------|
| Title of Solution | _____ /3 |
| Problem, Criteria, and Constraints addressed | _____ /5 |
| Solution shown accurately | _____ /7 |
| Everything labeled | _____ /5 |
| Colorful, neat, and free of errors | _____ /5 |
| Complete C-E-R | _____ /5 |

| | 0 | 1 | 2 | 3 |
|--|--|---|--|---|
| CLAIM <i>A statement that answers the original question.</i> | Does not make a claim or makes a claim that does not answer the question. | Makes a claim that addresses the question, but it is incomplete or vague. | Makes a complete claim that addresses the question. | X |
| EVIDENCE <i>Scientific data that supports the claim. Data needs to be <u>appropriate</u> and <u>sufficient</u> to support the claim.</i> | Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim). | Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence. | Provides appropriate and sufficient evidence to support claim. | Provides appropriate and sufficient evidence to support claim including evidence beyond what they gathered. |
| REASONING <i>Explain why your evidence supports your claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence.</i> | Does not provide reasoning or provides reasoning that does not link evidence to claim. | Provides reasoning that links claim to evidence, but does not include scientific principles. | Provides reasoning that links the claim to evidence using scientific principles, but not sufficient. | Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles. |

(C-E-R) Rubric

TOTAL POINTS _____/35

PLANNING NEXT STEPS

Congratulations! You've completed the Community Waters Science unit!

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make in the future to address any concerns?

TEACHER DECISION POINT



Do you want to extend this unit into an action project? Having done all this work to think about solutions to a local problem, why not channel students' energy to bringing actual change?

Possible Extensions:

Sharing at school: Put up posters and models in the library or other common space at the school so that other students can learn about stormwater and engineering. Share during a Science Night.

Letter writing: Write a letter to a local or state elected official, letting them know about the work you've done and the importance of taking care of stormwater runoff in your community. This can really influence how money is spent in our region, and help get more funding for stormwater solutions!

Building solutions: Implementing the student's solutions is beyond the current scope of this unit. However, we are developing next step options for interested teachers. This is a work-in-progress, with ideas at: <https://communitywaters.org/implementing-a-project-at-your-school/>.

Community Waters Take Home Interview

Date: _____

Student's Name: _____ Adult's Name: _____

Ask an adult in your household to do this assignment with you. In the first section are some questions for them to ask you. The second section has an optional online activity you could do together. Use the back of page if needed.

Adult Asks Student:

Interview your student by asking the questions below to find out what they have learned in science class.

1. Why are there stormwater problems in cities? What kinds of things increase the amount of stormwater runoff?
2. What stormwater problem did you design a solution for? What was the solution you designed?
3. What could you and I do that would help with stormwater problems?

Additional Extra Credit you can do together

Go online to www.700milliongallons.org and select "GSI Around You" to see what "GSI" (Green Stormwater Infrastructure) projects people have done to help with stormwater in Seattle. Click the magnifying glass and enter an address to find out what's being done in your neighborhood.

1. What GSI project shown on the site is nearest to where you live?



2. Select "Take Action" to explore options including RainWise rebates that can help pay for projects in certain neighborhoods and things that can be done locally. What idea listed would you want to have helping with stormwater runoff where you live?

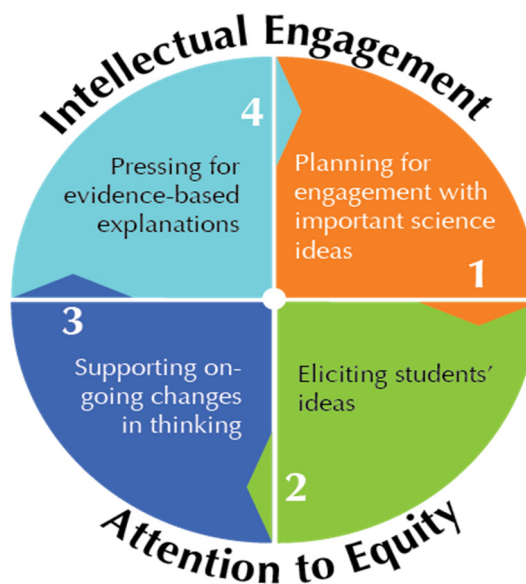
Appendix 1: The Ambitious Science Teaching Framework

Ambitious Science Teaching (AST) was developed at the University of Washington based on classroom research about how best to help students develop scientific understandings. See <http://ambitiousscienceteaching.org/> for in-depth information. The following is provided by AST:

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Ambitious Science Teaching is teaching that is effective, rigorous, and equitable. But more than that, it is a framework of research-based teaching and a wide range of tools that can transform how students learn in your classroom. The vision, practice, and tools will furnish a common language about teaching for a group of science educators committed to the improvement of teaching. You will be able to identify “what we will get better at” and how to get started.

Ambitious teaching aims to support students of all racial, ethnic, and social class backgrounds in deeply understanding science ideas, participating in the talk of the discipline, and solving authentic problems. This teaching comes to life through four sets of teaching practices that are used together during units of instruction. These practices are powerful for several reasons. They have consistently been shown through research to support student engagement and learning. They can each be used regularly with any kind of science topic. And finally, because there are only four sets of practices, we can develop tools that help both teachers and students participate in them, anyone familiar with the practices can provide feedback to other educators working with the same basic repertoire, teachers can create productive variations of the practices, and everyone in the science education community can share a common language about the continual improvement of teaching.



| The Four AST Practices | What does it LOOK like? |
|---|---|
| 1. Planning for engagement with important science ideas | <ul style="list-style-type: none"> • Planning a unit that connects a topic to a phenomenon that it explains • Teaching a topic within a real-world context |
| 2. Eliciting students' ideas | <ul style="list-style-type: none"> • Asking students to explain HOW and WHY they think a phenomenon happens (How did the bike change? Why did it change? What is happening at the unobservable level?) |
| 3. Supporting ongoing changes in thinking | <ul style="list-style-type: none"> • Using ALL activities/lessons to explain the phenomena. • Giving students opportunities to revise their thinking based on what they're learning |
| 4. Pressing for evidence-based explanations | <ul style="list-style-type: none"> • Allowing students to create a final model or explanation about the phenomena • Pressing students to connect evidence to their explanation |

What Ambitious Science Teaching Looks Like in the Classroom

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Many teachers want to know what their classrooms should look like and sound like—they want to understand how to interact with their students about science ideas and students' ideas. This is especially true now that the *Next Generation Science Standards* are being used in many states.

As a result of the last 30 years of classroom research, we know enough about effective instruction to describe in clear terms what kinds of teaching practices have been associated with student engagement and learning. This research tells us that there are many ways that teachers can design and implement effective instruction, but that there are common underlying characteristics to all these examples of teaching that can be analyzed, described, and learned by professionals. These practices embody a new form of “adaptive expertise” that EVERY science educator can work towards. Expert teaching can become the norm, not reserved for a select few. Ambitious teaching is framed in terms of practices that any teacher can learn and get better at over time. What would we see if we entered the classroom of a science educator using ambitious teaching? To give you a sense of what ambitious teaching looks like, we have described below some features common to all science classrooms where ambitious teaching is being implemented (listed on right). These features address everyday problems with learning and engagement that teachers face (listed on left).

| Common problems in supporting student engagement and learning | What you'd see in a science classroom where ambitious teaching is the aim |
|---|--|
| The problem: <i>Students don't see how science ideas fit together.</i> Each day is perceived by students to be the exploration of ideas that are unconnected with previous concepts and experiences. | At the beginning of the unit, students are focused on developing an evidence-based explanation for a complex event, or process. Students know that throughout the unit, most of the activities, readings, and conversations will contribute to this explanation. |
| The problem: <i>An oversimplified view of what it means "to know."</i> Science ideas perceived to be straightforward and learnable within a lesson—either you get it, or you don't. | An idea is never taught once and for all, but revisited multiple times. Students' science explanations are treated as partial understandings that have to be revisited over time to become more refined and coherent. |
| The problem: <i>Lack of student engagement.</i> Students' experiences and interests not elicited or seen as relevant. Student ideas treated as "correct" or "incorrect." | Students' ideas and everyday experiences are elicited and treated as resources for reasoning; students' partial understandings are honored as a place to start. They are made public and built upon. |
| The problem: <i>Students reluctant to participate in science conversations.</i> Teachers dominate the talk, ask primarily for right answers, get brief responses from students. | Teachers use a varied repertoire of discourse moves to facilitate student talk. Guides and scaffolds for talk help students feel comfortable interacting with peers. |
| The problem: <i>Some students have little support for accomplishing tasks that would otherwise be within their grasp.</i> Little or no guidance for students' intellectual work. Giving "clear directions" is seen as enough to ensure participation in activities. | There is scaffolding that allows students to participate in science-specific forms of talk, in group work, and in science practices. |
| The problem: <i>Invisibility of student ideas and reasoning.</i> Teacher does not know what students think—their heads are a black box. Cannot then work on students' ideas. Students cannot take advantage of the ideas or ways of reasoning by their peers. | Students' thinking made visible through various public representations (tentative science models, lists of hypotheses, question they have, etc.). The teacher can see how students think and how that thinking could change over time. Students benefit from seeing and hearing the reasoning of others. |
| The problem: <i>Illusion of rigor.</i> Students reproduce textbook explanations, lean on vocabulary as a substitute for understanding. Talk of evidence and claims are rare. | The teacher presses for complete, gapless explanations for unique real-life events or processes, and press for the use of evidence to support claims. |

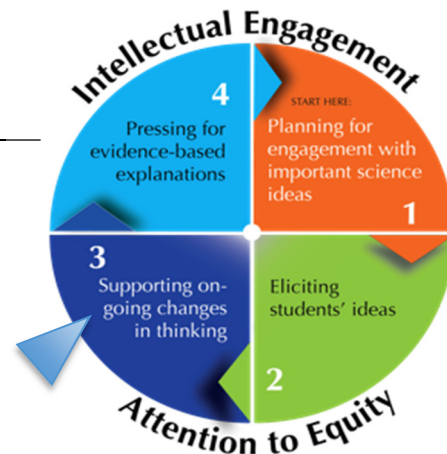
Ambitious teaching is not a "method," and the teaching practices are not scripts. It is a set of principled practices that must be adapted to your classroom needs. Coaches and other teachers can work with you to do this ambitious work.

Appendix 2: Tools for Supporting Ongoing Changes in Student Thinking

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Purpose of these tools

1. To ensure students understand *why the activity makes sense to do* at this point in the unit.
2. To help students *bridge the activity with a larger scientific idea*.
3. To *support the development of students' academic language*, using the activity as a context.



When providing students with an idea to use as leverage during the activity. Select some key idea from your target explanatory model. Provide a 10-15-minute presentation of content on this idea.

You need to plan to:

- Link verbally what was done by student previously to a “need to know” a new idea.
- Be explicit about new vocabulary being introduced.
- Use multiple representations of the idea, ask students to look across these and compare how the idea shows up.
- Plan for check-in questions to gauge understanding as you go.

Getting the activity started: Helping students uncover observation and patterns (use back-pocket questions).

Start activity, when students break into small groups, circulate among them and consider these questions.

You ask:

- “What are you seeing here?” (or similar broad observational question)
- “What might these patterns tell you?”
- “You may want to focus on...”

What you need to listen for, plan to respond to:

- What if students *can* cite relevant features of the activity?
- What if students are focused on extraneous features of activity?
- What if students mention patterns, but do not explain the significance?

Helping students connect activity to the anchoring event (use back-pocket questions).

Your second round of interactions in the small groups tests whether kids understand **why** they are doing this activity in the first place. It’s easier for them to discuss this after you’ve asked them what they are observing, inferring.

| | |
|---|--|
| <p><i>You ask:</i></p> <ul style="list-style-type: none">• “Can you explain what you are doing or what is happening in terms of [the anchoring event]?” | <p><i>What you need to listen for, plan to respond to:</i></p> <p>What if students hesitate or seem to rely on vocabulary? What if students <i>can</i> make connections between activity and some aspect of big ideas?</p> |
|---|--|

Whole class coordination of students’ ideas & their questions

You return to whole class conversation. This is where you can help kids see broad trends or patterns of data for different groups in the classroom. You then need to help students “map” these onto a real-world situation. Students’ new questions should be addressed, not put on the shelf.

| | |
|---|---|
| <p><i>You ask:</i></p> <ul style="list-style-type: none">• “What did you find?”• “I heard these three hypotheses, which ones do you agree with? Based on what evidence?” | <p><i>What you need to listen for, plan to respond to:</i></p> <p>What if students hesitate? How will you handle a conversation about evidence?</p> |
|---|---|

Creating or revising a public record of student thinking (see notes on the summary table on next page)

| | | |
|---|---|--|
| <p>Option 1: Add to, revise, consolidate an explanation checklist</p> | <p>Option 2: Use post-it notes to revise your small group models (you need to do this once or twice in the middle of a unit, not after every activity).</p> | <p>Option 3: You could cite one or two possible explanations for your anchoring event and ask the whole class, “Which of these do we think is now more likely? Why?”</p> |
|---|---|--|

After instruction, use the Rapid Survey of Student Thinking Tool (below) to analyze student responses and make instructional decisions

There is also a section at the end of each lesson in this unit with reflective questions to help you think about where the students are and what you want to do next.


A Summary Table is used as a “Public Record of Student Thinking”

WHAT: A summary table is a large chart that captures the learning progression of a unit. It has four columns: title of lesson, what did we observe, what did we learn, and how does it help us explain our phenomenon (the Oso Landslide in Part I). It is posted at the front of the classroom.

HOW: Each column builds on one another and each row is one lesson in a unit. At the start of each lesson, we take one moment to review the summary table to “prep our brains” for the new learning about to occur. At the end of a lesson, the students think-pair-share their ideas for each column. The teacher then records their ideas in their own wording on the chart.

WHY:

- It is a great way to wrap up a lesson to solidify students’ learning.
- It is a visual record of their learning progress throughout a unit. This allows students to reference past learning experiences, and then build upon those when gaining new learning experiences.
- It features key vocabulary words and definitions, as well as drawings, which support their learning. This component is especially helpful for English Language Learners.
- It pushes their thinking beyond what they see in front of them in their investigations. They synthesize information and apply their learning to explain a phenomenon.
- Students use their summary table to help them construct their final explanations of the unit’s phenomenon. They use the learning experiences as evidence to support their claims.

| Land and Water Summary Table | | | |
|------------------------------------|--|--|--|
| Learning Activity | What did we observe? ☉☉ | What did we learn? ☹☹ | How does it help us explain the Oso landslide? |
| Soil Components | sand gravel: ☉☉☉☉ humus clay | soil is not just dirt soil is made up of many different Earth materials | Oso hill made up of a material that does not hold together well. When mixed with water, it will slide. |
| Water Cycle Model | foggy dirt was absorbing the water water droplets under ice pack dripping down |  | Precipitation makes the land muddy. There was a lot of rainfall. |
| Precipitation Rain on land | land soaked up the rain like a sponge soil mixed with the water to make mud gravel stayed put light rain doesn't do much damage | a lot of rain makes a lot of mud and can cause damage | It had been raining a lot which made the land muddy and saturated. The soil was too heavy and slid down. |
| Rain on each soil component | when it rained on... sand = spread out gravel = stayed same humus = mushy, pieces in water clay = clumped, sticky | the smaller the soil particle, the greater affect rain has on it | The hill is made up of mostly sand and a little bit of clay. |
| Rain on soil with plants | when it rained the plants and soil did not move the water went into soil and soaked up in the roots | the roots of the plants hold the soil together without roots, the soil falls apart/down | With so much rain, the roots of the plants and trees were not strong enough to hold the soil together. Humans possibly cut down trees on the hill. |

| Rapid Survey of Student Thinking (RSST) | | |
|---|--|---|
| Directions: Complete the RSST either during class or right after a class. | | |
| Categories | Trends in student understandings, language, experiences [sample sentence starters included below] | Instructional decisions based on the trends of student understanding |
| <i>Partial understandings</i> What facets/ fragments of understanding do students already have? | List partial understandings: What approximate % of your students have these partial understandings? | ★ Star the ideas on the list that need action. Instructional options: <ul style="list-style-type: none"> • Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings • Do 10-minute whole class whole class conversation of 2-3 key points elicited • Write multiple hypotheses on board and/or develop an initial consensus model • |
| <i>Alternative understandings</i> What ideas do students have that are inconsistent with the scientific explanation? | List alternative understandings: What, if any, experiences or knowledge bases are they using to justify these explanations? | ★ Star the ideas on the list that you <i>really</i> need to pay attention to based on the following criteria... 1. Which alt. conceptions seem deeply rooted (kids seem sure about)? 2. What % of kids think this? 3. Which are directly related to final explanation (not just a "side-story") Instructional options: <ul style="list-style-type: none"> • Do further eliciting about what experiences/frames of reference students are drawing on • Pose "what if" scenario to create conceptual conflict about validity of alt. ideas • Challenge students to think further/give them a piece of evidence to reason with • Target a round of "Discourse 2" to address this alt. conception |
| <i>Everyday language</i> What terms did you hear students use that you can connect to academic language in upcoming lessons? | Cite examples: What approximate % of your students use these terms and phrases? | ★ Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: <ul style="list-style-type: none"> • Use language to reframe essential question in students' terms • Use as label in initial models that you make public. Work in academic versions of these words into public models and discussions later. • |
| <i>Experiences students have had that you can leverage</i> What familiar experiences did students describe during the elicitation activity? | What was the most common everyday or familiar experience that kids related to the essential question or task? What were the less common experiences students cited? | ★ Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: <ul style="list-style-type: none"> • Re-write the essential question to be about this experience • Make their prior experiences a central part of the next set of classroom activities • If kids cannot connect science idea to familiar experiences they've had, then provide a shared experience all kids can relate to (through lab, video, etc.) |

Making Responsive Instructional Decisions

This tool can be used when reflecting on any science lesson. It can help you organize what you noticed from students so that you can make instructional decisions that respond to and build on where they are.

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What resources did you notice?

Specific productive ideas or ways of reasoning from students? Positive group work dynamics? What did you see from students that you think was useful or could be useful moving forward?

What concerns came up for you?

Were there aspects of the lesson that didn't go as well as you hoped? Unanticipated difficulties?

How can these inform your instruction?

Can you capitalize on particular resources from students? Are there ways of drawing on items in the resources column to address concerns?

If you were to teach this same lesson again:

Moving forward instructionally:

Appendix 3: Student Readings

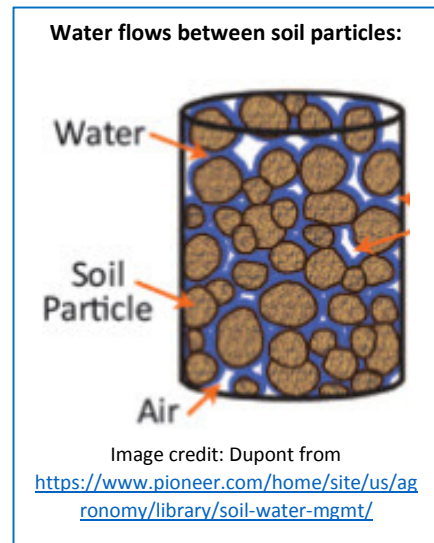
| Suggested Lesson | Title of Reading |
|-------------------------|---------------------------------|
| 2 | Groundwater |
| 2 | Earth Science for Kids: Erosion |
| 2 | Erosion: Human Impacts on Land |
| Optional Background | The Water Cycle |
| Optional | Urban Weathering |

Groundwater

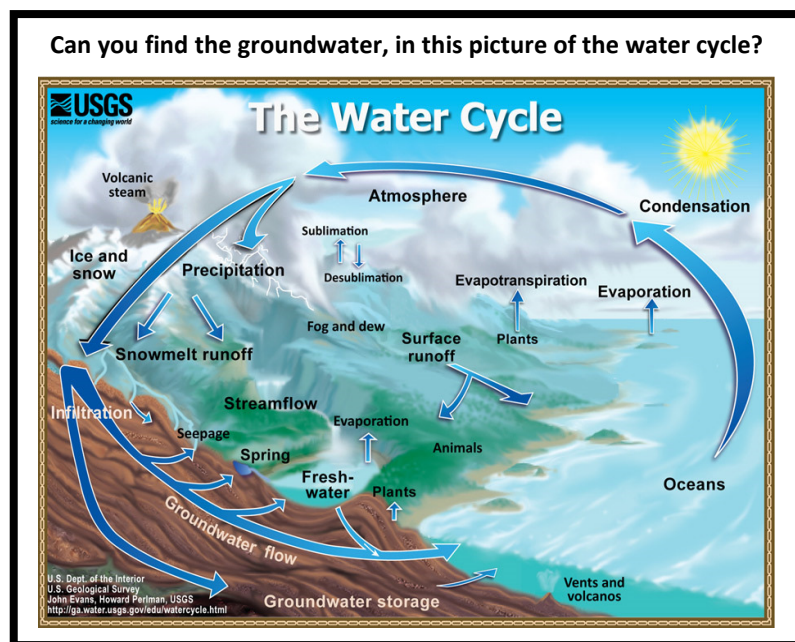
Groundwater is water that is moving or sitting in the soil. Most plants and soil organisms need the groundwater to live. As the water flows through ground it moves into streams, bubbles forth as springs, or is drawn up by wells for people and animals to drink. Groundwater is an important source of water for plants, animals, streams, and people!

Soil is made up of materials like rocks, sand, clay, and humus. Groundwater clings to these materials and moves through the spaces between them.

How fast groundwater moves through the soil or rock depends on the material. Some materials, like gravel, have interconnected cracks or spaces that are large enough to allow water to move freely. Materials with few spaces between them, like clay or solid rock, force the water to move very slowly or not at all. Groundwater may move several yards each day in gravel, but only a few inches in a hundred years through clay!



The source of most groundwater is rain and snow that falls on the surface of the ground. If there is a surface like concrete that the water can't soak through, then less water moves into the ground, and less water is stored there for later use by plants, animals, streams, and people.



Earth Science for Kids: Erosion

Text Source: http://www.ducksters.com/science/earth_science/erosion.php

Image sources: <http://www.drawingtutorials101.com/drawing-tutorials>

Edited and formatted by: C. Colley & B. Street

Word Study:

The word erosion comes from the Latin word "erosionem" which means "a gnawing away."

erosion - noun
erode - verb
erosive - adjective



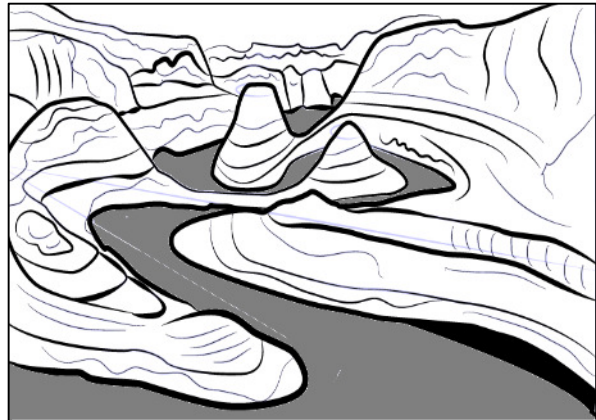
Erosion is the carrying away of land by forces such as water, wind, and ice. Erosion has formed many interesting features of the Earth's surface including mountain peaks, valleys, and coastlines. There are different forces that cause erosion. Depending on the type of force, erosion happens quickly or takes thousands of years. The major forces that cause erosion are water, wind, ice, and vegetation.

Water Erosion

Water is the main cause of erosion. Water is one of the most powerful forces on the planet. Some ways that water causes erosion include: rainfall, rivers, waves, and flooding.

Rainfall can cause erosion two ways. First, when the rain hits the ground and the drops move little bits of soil. This is called splash erosion. Second, raindrops land, roll together, and then flow as runoff across the surface in small streams that can carry pieces of soil.

Rivers also erode soil over time. They break up particles along the river bottom and carry them downstream. One example of river erosion is the Grand Canyon which was formed by the Colorado River. The size of earth materials that are carried away by rivers depends on how fast the water is moving. A fast-flowing river can carry large pebbles and rocks. A slow-moving stream might only be able to move very small bits like clay, silt, and sand.



The Colorado River created the Grand Canyon by washing away bits and pieces of rock over thousands of years.

Ocean waves can cause the coastline to erode. The energy and force of waves cause pieces of rock and coastline to break off and be carried away, changing the coastline over time.

Large floods cause erosion to happen very quickly, washing away loose soil and moving it to new places.

Other Types of Erosion

Other forces that cause erosion include wind, animals, vegetation, and gravity. Wind causes erosion, especially in dry areas. Wind can pick up and carry loose particles and dust from one place to another. Small animals, insects, and worms can help erosion by breaking up the soil so it is easier for the wind and water to move pieces around. Plant roots hold onto soil which prevents erosion. In areas where trees are cut down the soil is no longer held together and can more easily be carried away by water and wind. The force of gravity can cause erosion by pulling rocks and other particles down the side of a mountain or cliff. Gravity can cause landslides which can significantly erode an area.

Additionally, humans have increased erosion in some areas. This happens through farming, ranching, cutting down forests, and the building of roads and cities. Humans cause about one million acres of topsoil to erode each year. Planting trees around farmland and replacing trees that are cut down are two ways to limit the amount of erosion caused by human activity.

Erosion: Human Impacts on the Land

Text Source: http://www.ducksters.com/science/earth_science/erosion.php

Image sources: <http://www.drawingtutorials101.com/drawing-tutorials>

Edited and formatted by: C. Colley & B. Street

Erosion can cause problems that affect humans. Erosion is the process of natural forces moving rocks and soil. The natural forces that cause erosion are water, wind, ice, and gravity. Soil erosion, for example, can create problems for farmers. Soil erosion can remove nutrient-rich topsoil, leaving rocky soil behind. Erosion can also cause problems for humans by removing or weakening soil that supports buildings.

Water erosion happens when water moves the pieces of rock or soil downhill. Waves carry away small pieces of material. A wave can wash up onto the surface of rock or soil and carry away pieces of material as it flows back into the ocean or lake.



Homes built on a cliff near Pacifica, California collapse as ocean waves erode the cliff.

Ocean waves slowly erode cliffs near the beach. Many people like to live near the beach; however, this can be dangerous if they build their houses too close to the edge of the cliff. Over decades, ocean waves eat away at the soil, undercutting the cliff. Erosion destabilizes the cliff and can cause homes to fall down the cliff.



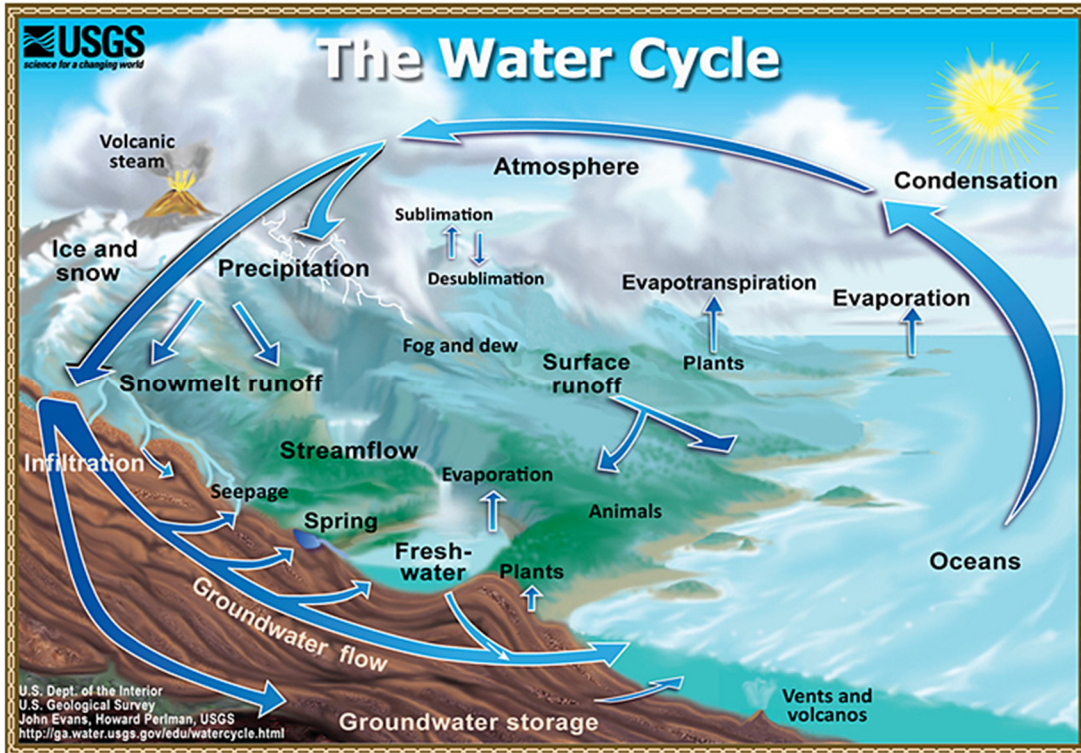
This landslide in El Salvador destroyed many homes in the valley below the hill. It happened after recent logging on the hill.

Human actions can increase the effects of water erosion. Clear-cutting trees to create farmland or to sell as timber can cause erosion problems. With no tree roots to hold soil, the topsoil easily washes away in heavy rains. Erosion caused by deforestation can lead to increased flooding because there is not as much topsoil there to absorb rain water. In hilly regions, deforestation can lead to increased likelihood of landslides.

The Water Cycle

Adapted from: <http://www.k12reader.com/worksheet/water-cycle/>

The water cycle is the continuous movement of water as it changes from one state to another throughout the Earth. Water on Earth can be found in three forms: ice, water, and water vapor.



When the heat of the sun shines on water, the water evaporates, rising into the air as water vapor. As it moves higher into the sky, it cools. The cooled water vapor begins to form water drops, which gather together as clouds. This process is called condensation. The drops of water join together in the cloud. Finally, the cloud becomes so heavy that the drops start to fall. Any form of water that falls from the sky is called precipitation. Precipitation will take on different forms such as rain, snow, sleet, or hail.

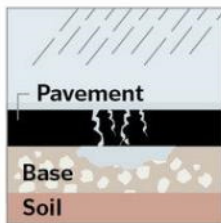
No matter what form the precipitation takes, much of it will become runoff and find its way back to the sea. Most of the water will join surface water in lakes and streams or soak into the ground and become groundwater. Some groundwater is absorbed by plant roots and ends up as water vapor from the leaves of plants. Some water will spend some time atop mountains as ice and snow. Over time, all water keeps moving and returns to the water cycle at different stages and in different states. The water cycle never ends.

Urban Weathering

Weathering is the breaking down of rocks and minerals on Earth's surface. Water, ice, acids, salt, plants, animals, and changes in temperature can all contribute to weathering. Weathering occurs over various periods of time and can affect surfaces either physically or chemically.

In cities weathering can be observed in potholes and cracks in pavement. Water contributes to creating potholes and other cracks in roads and sidewalks by seeping into the surfaces and then freezing and expanding. The space where the water expands when it is frozen leaves behind a hole under the pavement. This hole eventually collapses under the weight of traffic.

How potholes form



1. Water seeps through cracks in pavement and softens the road's base, collects, then freezes.



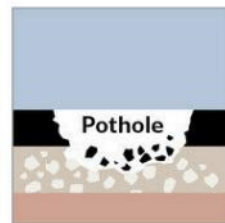
2. When the water freezes, it expands and forces the pavement up. Traffic further stresses the pavement.



3. The sun dries up the water, leaving a hole under the pavement.



4. With no base, the pavement is weakened and collapses under the weight of traffic.



5. A pothole is formed where the pavement collapsed. Wear from additional traffic expands the hole.

SOURCES: Virginia Department of Transportation; Better Roads magazine

KEN MARSHALL | THE PLAIN DEALER

Plants can also contribute to weathering as their roots grow up through the surface of the ground. Roots eventually push up on the surface with enough force that the surface weakens, causing cracks that can lead to breakage.

Many other chemical elements and physical structures affect weathering over long periods of time. This causes change to occur in both natural and human made structures.



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King County



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