7 Cutting Canyons and Building Deltas

MODELING

2–3 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students model the phenomenon of sediment movement in a river using a stream table that provides evidence for how geoscience processes change Earth's surface. They demonstrate how water's movements under the force of gravity contribute to the formation of landforms. The role of energy transfer by moving water explains the impact of water movement on landforms. Students then apply the scientific and engineering practice of asking questions and defining problems as they use criteria and constraints to design a system to hold sediments in place in the stream. They apply scientific knowledge of how the planet's systems interact over varying time scales to consider the human impact of stream control.

NGSS CORRELATIONS

Performance Expectations

Working towards MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

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

Working towards MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Disciplinary Core Ideas

MS-ESS2.A Earth's Materials and Systems: The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

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

Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.

Global movements of water and its changes in form are propelled by sunlight and gravity.

MS-ETS1.A Defining and Delimiting Engineering Problems: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.

Science and Engineering Practices

Asking Questions and Defining Problems: Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Constructing Explanations and Designing Solutions:

Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.

Apply scientific ideas or principles to design an object, tool, process or system.

Developing and Using Models: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Crosscutting Concepts

Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Energy and Matter: Within a natural system, the transfer of energy drives the motion and/or cycling of matter.

Influence of Science, Engineering, and Technology on Society and the Natural World: The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.

Stability and Change: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHAT STUDENTS DO

In Part A, students use a river model to investigate how flowing water erodes and deposits sediments to create common landforms. Part B is an engineering design challenge where students design erosion-control structures and then use the river model to test them. Based on the results of their initial testing, students redesign and retest their structures.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Visual Aid 7.1, "Street Map of Boomtown Today"
  - 1 Visual Aid 7.2, "River Model Drawings" (optional)
  - 1 Scoring Guide: ENGINEERING DESIGN SOLUTIONS (ENG) (optional)
  - *1-2 large containers or tubs
  - * 1 or more large syringes or turkey basters (optional)

- *For the class*
  - * KWL chart started in the activity "Where Should We Build?"

- *For each group of four students*
  - 1 river model
  - 1 river model stand
  - 1 river model catch basin
  - 1 rainmaker
  - 1 graduated cylinder (50-mL)
  - 1 spoon
  - 1 graduated cup (30-mL)
  - 1 plastic cup (9-ounce, to hold sand)
  - 1 supply of moist sand (about 125 mL)

- * water (150 mL)
- * paper towels and/or newspapers
- 1 channel maker
- 9 building bricks
- 2 mesh sleeves
- supply of small rocks
- * colored pencils (optional)

■ *For each student*

- 1 Student Sheet 7.1, "River Model Drawings"

**not included in kit*

Make sure that each group of four students has access to a level work surface that won't be damaged by spilled water or sand. Gather plenty of newspapers to cover the tables or desk tops.

Gather one or two large containers or tubs for sand setup and cleanup. Provide them in a common area where students can collect and return the sand. If your classroom doesn't have sinks, you should have an additional container available for students to dispose of their dirty water. Another useful cleanup method is to use a large syringe or turkey baster to remove the water from the catch basin.

This activity works best if the sand contains enough water to have the consistency of dough. The first time students use it, add just enough water to the dry sand to create the right consistency. After the first usage of the sand, it is likely to be wetter than is desirable. Drain off any excess water and mix in just enough dry sand until the original consistency returns.

TEACHING SUMMARY

GET STARTED

1. Introduce the effects of flowing water on landforms.
   a. (LITERACY) Support sensemaking by revisiting the KWL chart as a class.
   b. Review the term *sediments* presented in the introduction.
   c. Introduce the role of water in creating topography.
   d Prepare students for an engineering challenge.
2. Prepare students to begin the investigation
   a. Demonstrate how to set up and use the river model.
   b. Have students predict the outcome of the modeling.

DO THE ACTIVITY

3. Observe landforms created by flowing water.
   a. Facilitate student use of the river model.
   b. Focus student observations on the channels cut by the flowing water and the sand deposited in the catch basin.
   c. Assist students as they complete Student Sheet 7.1.
   d. Briefly review student observations from Part A.
   e. Relate the activity results to building sites.
   f. Introduce the crosscutting concept of stability and change.

      This crosscutting concept relates to how objects can remain stable or can change due to external forces. Review the symbol used for Stability and Change in Appendix G,
4. Prepare students for Part B, the design and testing of erosion-control structures.
   a. Discuss the engineering challenge, criteria, constraints, and testing procedure.
   b. (ENG QUICK CHECK) Introduce the ENGINEERING DESIGN SOLUTIONS (ENG) Scoring Guide.
5. Facilitate the design and testing of erosion-control structures.
   a. Guide students as they decide upon their initial designs.
   b. Help students use their prototype results to optimize their designs.
   c. Support students in the iterative process of evaluating, redesigning, and retesting.

BUILD UNDERSTANDING

6. Review student responses to Analysis items 1 and 2.
   a. Discuss the use of models and the process of erosion.
   b. Support the application of knowledge in Analysis item 4.
   c. Emphasize the role of gravity.
   d. Analyze the use of erosion-control devices.

7. Relate students' observations to Boomtown's building sites.

   a. Ask students, "What part of Boomtown corresponds to the top of the river model?" and "What part of Boomtown corresponds to the bottom of the river model?"

   b. (LITERACY) Support sensemaking by revisiting the KWL chart as a class.

   c. Discuss the ongoing nature of earth processes.

TEACHING STEPS

GET STARTED

1. Introduce the effects of flowing water on landforms.

   a. (LITERACY) Support sensemaking by revisiting the KWL chart as a class.

      Have students record what they have learned in the last few activities, such as the role of nutrient contamination in the decline of macroinvertebrates in a river and the effects shown in the case study of the Mississippi Delta. Solicit student questions to fill in more of the "Want to know" column, and let students know the class will revisit the last column at the end of the activity.

   b. Review the term *sediments* presented in the introduction.

      Review the key terms presented in the content-rich introduction before starting the activity. Specifically, discuss the meaning of the term sediments. Students will continue to use this term throughout the unit.

   c. Introduce the role of water in creating topography.

      Thus far in the unit, students have investigated the role of water in dissolving substances that can affect its quality. In this activity, focus turns to how the energy transferred by moving water can move sediments (matter) and, as a result, change landforms. Brainstorm with students ways that water can change the land. Students will likely suggest that sediments could be deposited in the delta or that floods might dump mud and other sediments onto the flooded areas. Others might realize that the flowing water could erode the riverbanks or lead to mudslides. Accept their ideas, and explain that they will soon be investigating how flowing rivers can affect the areas they flow through.

   d Prepare students for an engineering challenge.

      Make clear that in Part A, students will be modeling natural conditions, and in Part B, they will assume the role of engineers as they design, test, and redesign a structure to alter the natural conditions. This activity starts a sequence of learning around the fifth driving question identified on the Phenomena, Driving Questions, and Storyline document and introduced in the beginning of this unit. Revisit students' ideas and add/revise as needed.

This is the first of three design challenges in the unit, so discuss the terms *criteria* and *constraints* as they pertain to the activity. These concepts are central to Performance Expectation MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

2. Prepare students to begin the investigation

   a. Demonstrate how to set up and use the river model.

   Set up a river model so that all can clearly see it, but do not add any water just yet. Demonstrate how to determine the proper sand consistency and how to measure and pack the sand into the model. Explain how once the river model is all set up, they will be adding water to the rainmaker and then observing, sketching, and describing in words what happens. Emphasize the need to be careful and to do everything in their power to avoid spilling sand or water. Point out that they will do multiple trials and between trials they will have to re-set up the model. Show them how to remove, and where to dispose of, the “used” water.

   This experience of working with the model supports the crosscutting concept of scale, proportion, and quantity because students recreate events that happen over time at a scale that is too large to observe all at once.

   b. Have students predict the outcome of the modeling.

   Distribute Student Sheet 7.1, “River Model Drawings,” and ask students to predict what will happen when the water is allowed to flow. Have students draw what they predict will happen with the water and the sand after it “rains” at the X on the top of the diagram. Optionally, you can allow students to used colored pencils to better distinguish between sand and water in the diagrams. Students should label their diagrams with terms such as “water” and “sand,” where appropriate, as well as any landforms they think will form, such as “river” or “stream.”

   When students have finished their drawings, discuss with them their ideas about what they think will happen when the water is released and why. Students may draw multiple water channels, a distributed water flow, or simply a straight line from top to bottom. Accept all reasonable ideas about their predictions, and encourage them to elaborate on what they predict will happen to the sand as a result of the force of the water.

DO THE ACTIVITY

3. Observe landforms created by flowing water.

   a. Facilitate student use of the river model.

   Distribute the needed materials to each group. Make sure students cover their work areas with newspaper before setting up their models. Point out that although it is almost impossible to avoid small spills, it is really important to be as careful as possible to avoid any major spills. Check that each group has prepared their workspace correctly, and then encourage them to begin Part A of the Procedure.

   b. Focus student observations on the channels cut by the flowing water and the sand deposited in the catch basin.

   Ask students to suggest ways to describe their observations, and help them with the language needed for their descriptions. Ask them what kind of landforms are modeled by the activity, such as islands, riverbeds, and valleys.

   c. Assist students as they complete Student Sheet 7.1.

   As students complete Part A, remind them to record their findings on Student Sheet 7.1. Students should label the different parts of their drawings as they did in their predictions, but should not also include landforms such as islands, river channels, canyons, and riverbanks. See Sample Student Response to Student Sheet 7.1 at the end of this activity.

   d. Briefly review student observations from Part A.

   Emphasize the evidence of sediment movement, and make the point that any time material erodes from one place, it is eventually deposited somewhere else. For example, sand removed from the top of the model was carried down the slope and deposited in the catch basin. Point out the roughly triangular, fan-shaped area of land that was deposited in the catch basin at the river's mouth that bulges into the water. Tell students that any triangle-shaped or fan-shaped area like this is called a *delta*. Ask students why they think the delta formed where it did. If no one suggests that sediments are moved downward and get deposited when flowing water slows down, point this out. This relates to the crosscutting concept of matter and energy as gravity is the driver of matter moving in this process.

PROCEDURE STEP 10 SAMPLE STUDENT RESPONSE

When the rainmaker started the water flowing on the top of the river table, it eroded the sand. The water carried the sand to the bottom of the tray where it was deposited. The fan-shaped pile that was formed in the tray modeled a delta.

e. Relate the activity results to building sites.

Ask students to think about how moving water could create conditions in some areas that could cause those areas to be troublesome for all the building sites. Point out that both erosion and deposition can pose problems Identify how erosion and deposition are related to each site, such as deposition in the Delta Wetlands and erosion at Seaside Cliffs.

f. Introduce the crosscutting concept of stability and change.

This crosscutting concept relates to how objects can remain stable or can change due to external forces. Review the symbol used for Stability and Change in Appendix G, "Crosscutting Concepts." The concept of stability and change applies from the atomic scale to the astronomical scale. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. In this activity, students model the effects of change in a river that have accumulated over time.

4. Prepare students for Part B, the design and testing of erosion-control structures.

a. Discuss the engineering challenge, criteria, constraints, and testing procedure.

Read aloud, or have students read, Part B of the Procedure. Distribute the additional Part B materials, and make sure that students are clear about the criteria and constraints for the challenge. Demonstrate how to use the channel maker to prepare a river channel, and emphasize the need for using a standardized river channel for testing and comparison.

b. (ENG QUICK CHECK) Introduce the ENGINEERING DESIGN SOLUTIONS (ENG) Scoring Guide.

Part B of the Procedure prepares students for the NGSS Performance Expectation MS-ETS1-1. This is supported by a design assessment using the SEPUP ENG Scoring Guide. Although the task does not prompt a Level-4 response, you may want to use it for students to achieve a Level-3. Optionally project or distribute the Scoring Guide. Point out how it has the same levels as previous guides but different descriptions for each level. Review the levels as needed. For more information, see Teacher Resources III, "Assessment." A sample response is shown below the next teaching step.

5. Facilitate the design and testing of erosion-control structures.

   a. Guide students as they decide upon their initial designs.

      For Procedure Step 16, encourage students to review the results of Part A and pinpoint the location(s) where the most erosion is occurring. If students are not sure how to choose an initial design, ask them to brainstorm a list of potential designs and the reasoning behind each one. As a group, they can go through the list, eliminate the weakest ideas, and select the strongest.

   b. Help students use their prototype results to optimize their designs.

      For Step 19, if students are not sure how to optimize a design, ask them to brainstorm a list of potential design improvements and the reasoning behind each improvement. As a group, they can go through the list, eliminate the weakest ideas, and select the strongest.

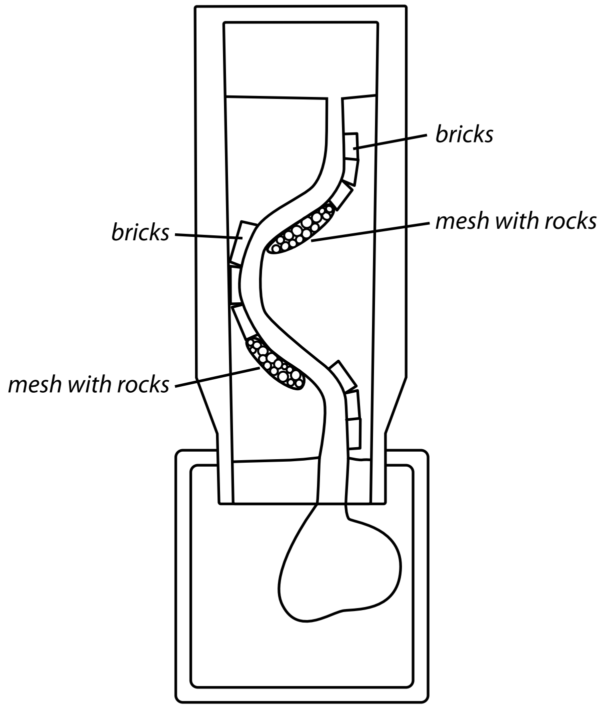
   c. Support students in the iterative process of evaluating, redesigning, and retesting.

      As students complete Part B, if time permits, encourage them to continue to test, evaluate, and redesign their structures. The Student Book indicates to do this once, but if time permits, repeating it is acceptable. Throughout this Procedure, help students gain the understanding that repetitively testing and redesigning is a natural part of the design process.

      PROCEDURE STEPS 16–20 SAMPLE LEVEL-4 RESPONSE

      Our first structure used building bricks placed at the river bends. This structure reduced erosion but didn't prevent it.

      Through testing, we realized that the building bricks seemed to work better than the rocks and that the position of the building bricks and rocks wasn't the best. For our final design, we changed the position of some of the building bricks and rocks. We were happy to see that this resulted in less erosion than the original. Based on our observations, we think we would need to put building bricks along the whole channel for the best possible results.



BUILD UNDERSTANDING

6. Review student responses to Analysis items 1 and 2.

   a. Discuss the use of models and the process of erosion.

      When discussing item 1, review the strengths and weaknesses of the river model. A model helps us understand a process we cannot investigate directly, but this model does not completely represent an actual river.

      When discussing item 2, make the point that any time sediment is removed from one place, it is eventually deposited in another location. For example, the sand removed from the top of the model was carried down the slope, and some of it ended up in the catch basin. Also emphasize that the time and site of where the sediment ends up may be either near or very far from the site of erosion. For example, small particles of rock from a river may end up at a nearby bend in the river or hundreds of miles downstream when the river flows into the ocean. The relationship between erosion and deposition is a clear cause and effect.

   b. Support the application of knowledge in Analysis item 4.

      This question can be challenging for students, and it may be difficult for them to infer on their own. Guide students to the understanding that it takes a long time to cut a deep canyon into hard rock. The erosion process transfers small amounts of energy from the water to the rock over a very long period of time—quite possibly thousands or even millions of years. Point out that because solid rock is more cohesive than sand, flowing water removes the particles much more slowly and the walls of the canyon can be steep because they do not slump down as softer walls might. The extension to this activity provides an opportunity for students to further explore these concepts.

c. Emphasize the role of gravity.

Emphasize that erosion and deposition are a result of the transfer of matter and energy. Gravity provides the force that moves water. Fast-flowing water transfers energy that wears away, or erodes, the land to produce sediments. As the water loses energy, it slows down and can no longer carry the sediments, causing deposition to occur.

d. Analyze the use of erosion-control devices.

Analysis items 3 and 4 relate to students' engineering projects. Lead a discussion so that students understand that erosion, like most large-scale, long-term earth processes, cannot totally be controlled. In the short term, we can slow it down, but eventually nature will run its course. Attempts to prevent erosion are not usually that successful without significantly altering the natural landscape and its environment. Engineers often try to design the most effective structures that involve the fewest changes to the environment. Ask students how their erosion-control devices changed the flow of energy and movement of matter. They should realize that successful devices interfered with energy transfer and, as a result, reduced the amount of matter eroded.

7. Relate students' observations to Boomtown's building sites.

a. Ask students, "What part of Boomtown corresponds to the top of the river model?" and "What part of Boomtown corresponds to the bottom of the river model?"

Students should respond that the top of the model is most like the north-west portion of Boomtown, where the river flows down from the hills; the bottom corresponds to the marsh area where the river meets the bay. Have students suggest how their observations could relate to one or more of Boomtown's potential building sites. Students should be able to infer that runoff from the hill area heads towards the river, which then carries it to the ocean. For example, if excess fertilizers are used on a field placed on top of the hill, the nutrient runoff will flow into Boomtown River.

b. (LITERACY) Support sensemaking by revisiting the KWL chart as a class.

Discuss and fill in the things students have learned from this activity, and connect it to previous knowledge. Students should add a description of sediments being moved around Boomtown by the process of erosion and deposition. Connect this concept to the changes seen in the water quality and the macroinvertebrates from earlier in the unit.

c. Discuss the ongoing nature of earth processes.

When discussing Analysis item 6, be sure to emphasize that earth processes happening today are similar to those that have occurred for many millions of years. For example, water's continual cycling causes erosion and deposition to happen year after year. Because of this, the small changes to Earth's surface that we can observe over several years can add up over millions of years to create huge changes, such as the formation of the Grand Canyon.

EXTENSION 1

Have students model a steeper river. They should compare their results from the steeper slope with their results from Part A. Students should find that the steeper model increases the erosion rate, causing the delta to build up significantly. You might wish to emphasize that the steeper model leads to a greater transfer of energy, even with the same amount of water, which leads to the faster rate of erosion.

EXTENSION 2

Consider allowing students to bring in additional materials and/or provide them with some materials not available in the kit to use to rebuild and retest their models.

SAMPLE RESPONSES TO ANALYSIS

1. Thinking about your river model in this activity, answer the following:

a. How is the model like a real river?

The river model contains a river bottom, sand, and water. This is like a real river, with earth materials at the bottom and water flowing in it. It has erosion and deposition.

b. (ENG QUICK CHECK) How is it different from a real river?

The model is straighter and much smaller than a real river, and it contains much less water. Unlike most rivers, it does not flow constantly. It also contains less varied earth materials. For example, it does not contain pebbles or rocks.

2. What were the biggest changes that occurred
   a. at the higher elevations? Explain why you think this happened.
      The moving water causes erosion such that the sand gets carried down the hill. We observed the formation of river channels and gullies. This happens because the force of the moving water is strong enough to carry the sand particles along with it.
   b. at the lower elevations? Explain why you think this happened.
      Sand gets deposited or "dropped down" in parts of the river bed model that started out empty. This is especially apparent where the delta forms as the river enters the catch basin. Deposition happens where the force of the moving water is no longer strong enough to carry the sand particles along with it.
3. How well did your redesigned erosion-control structure work compared with your original? Use evidence from your tests to explain why your design changes did or did not make a difference.
   Student responses may vary. One sample response is shown here:
   Our redesign worked better than our original design because we noticed fewer changes to the course of the water flow and less sediment being deposited in the catch basin.
4. What do you think are the biggest challenges when building effective erosion-control structures on real rivers? Use evidence from this activity in your response.
   Student responses may vary. One sample response is shown here:
   The biggest challenge we encountered was keeping the river environment as natural as possible while trying to stop the erosion. To best control erosion, we would need to line the entire channel with bricks or stones.
5. How could the movement of sediments cause a problem if someone builds on
   a. Delta Wetlands.
      Movement of sediments could wash away the soil of the marsh and make the soil less stable for buildings. Alternatively, movement of sediments could result in undesired earth material in people's yards.
   b. Green Hill.
      Movement of sediments away from the hillsides could cause the hillside to collapse and weaken buildings above them. The sediments could also end up on homes below.
   c. Seaside Cliff.
      The movement of sediments from the cliff could weaken or wash away the cliff.

6. Observe the photograph at right. It shows a river at the bottom of a canyon with hard rock walls.

   a. Explain how the water flowing down the river created the canyon.

      The water in the river cut the canyon by slowly eroding pieces of rock as it flowed downhill. As it eroded the rock, a channel was formed and then deepened over time.

   b. Explain what happened to the rock that once filled up the canyon.

      The water carried tiny pieces of the rock and other dissolved materials downstream, eventually depositing them when and where the water slowed down. This probably happened at the mouth of the river where a delta was formed by the sediments.

REVISIT THE GUIDING QUESTION

How does moving water affect the areas through which it flows?

During the process of erosion, the energy transferred by moving water removes material from some areas. During the process of deposition, moving water adds material to other areas.

ACTIVITY RESOURCES

KEY VOCABULARY

constraint

criterion, criteria

delta

deposition

erosion

model

sediments

BACKGROUND INFORMATION

EROSION

Erosion is a naturally occurring process on Earth's surface that transports weathered rocks and soil from one place to another. Erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate, causing serious loss of land.

Erosion has played an important part in the development of many landforms, such as gullies, canyons, arches, natural bridges, sea stacks, and buttes. One of the most spectacular examples of erosion in the United States is the Grand Canyon. Although there are rocks in the canyon as old as 2,000 million (2 billion) years old, the erosion of the canyon itself occurred in the past 5–6 million years. In terms of geologic time, the canyon is fairly young. Erosion is responsible for the development of the hoodoo land formations in Bryce Canyon and for revealing the hard rock of Devil's Tower. Erosion has also played a role in creating steep jagged mountains and, as time goes by, wearing them down to produce rounded mountains and hills.

DELTAS AND OTHER DEPOSITIONAL ENVIRONMENTS

The faster that water flows, the more sediment it can carry along with it. Deltas form when flowing water that is carrying a load of sediment particles drops most of its sediments in a fairly small area. This happens when flowing water suddenly slows down as it reaches still waters and no longer has the power to carry much of its sediment load. As the sediments settle out, the particles form a fan-shaped deposit at the mouth of the river. These deposits build up over time and may continue to change by ongoing erosion and deposition. Stream deposits can also accumulate in areas where water flow diminishes as a river widens or bends.

Human activities can interfere with water flow and the course a river takes, thus altering the patterns of either erosion or deposition.

Name____ Date__________

STUDENT SHEET 7.1

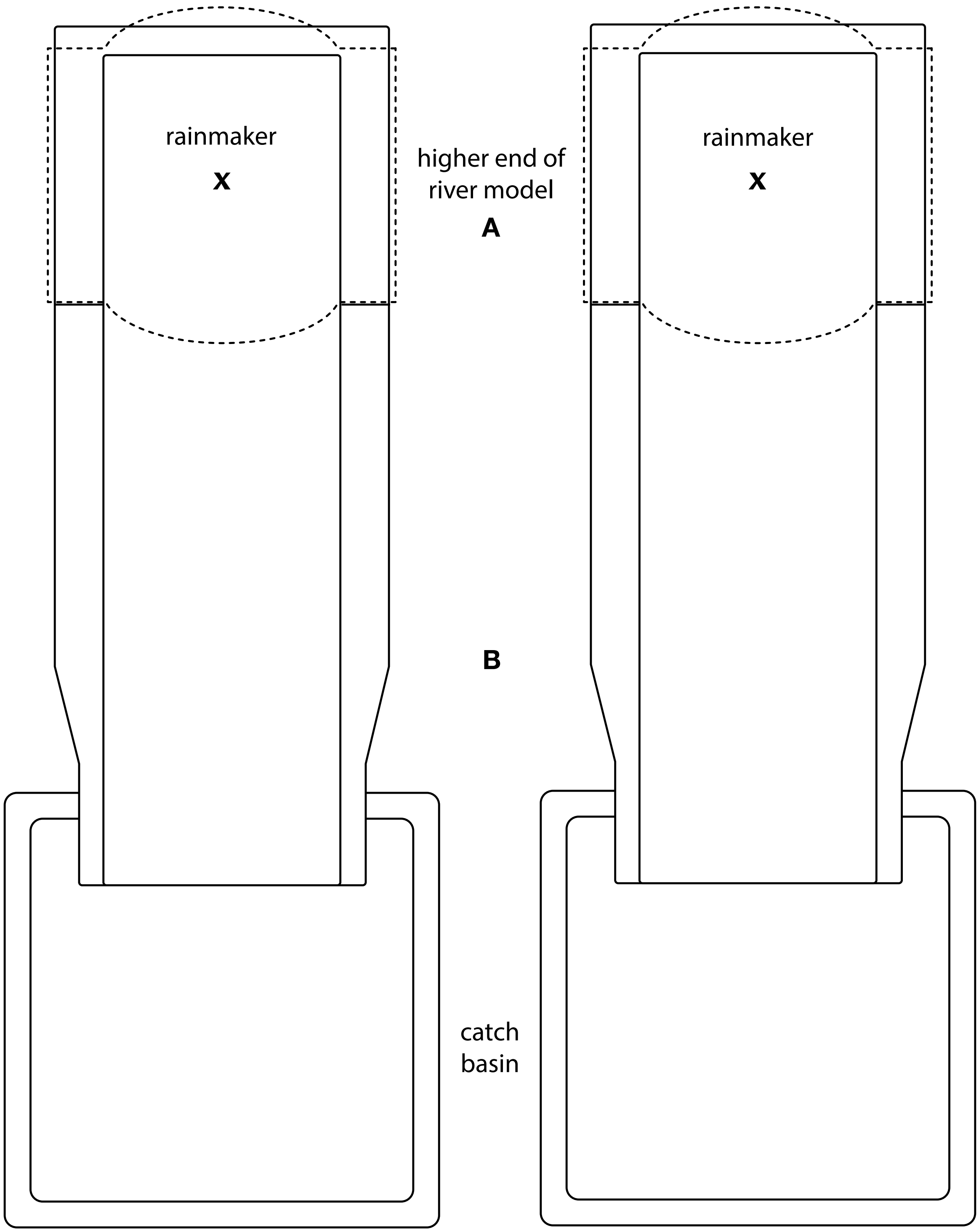
RIVER MODEL DRAWINGS

PREDICTION

Draw what you think will happen to the sand and water after it "rains" at Point X.

OBSERVATIONS

Draw what actually happened to the sand and water after it "rained" at Point X.



Name *Sample student response* Date

STUDENT SHEET 7.1

RIVER MODEL DRAWINGS

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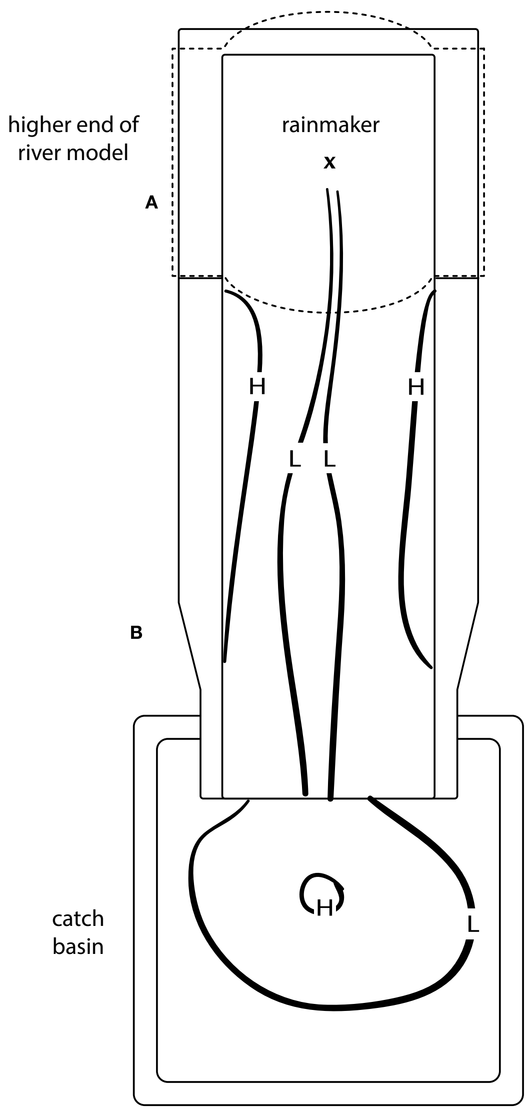

OBSERVATIONS

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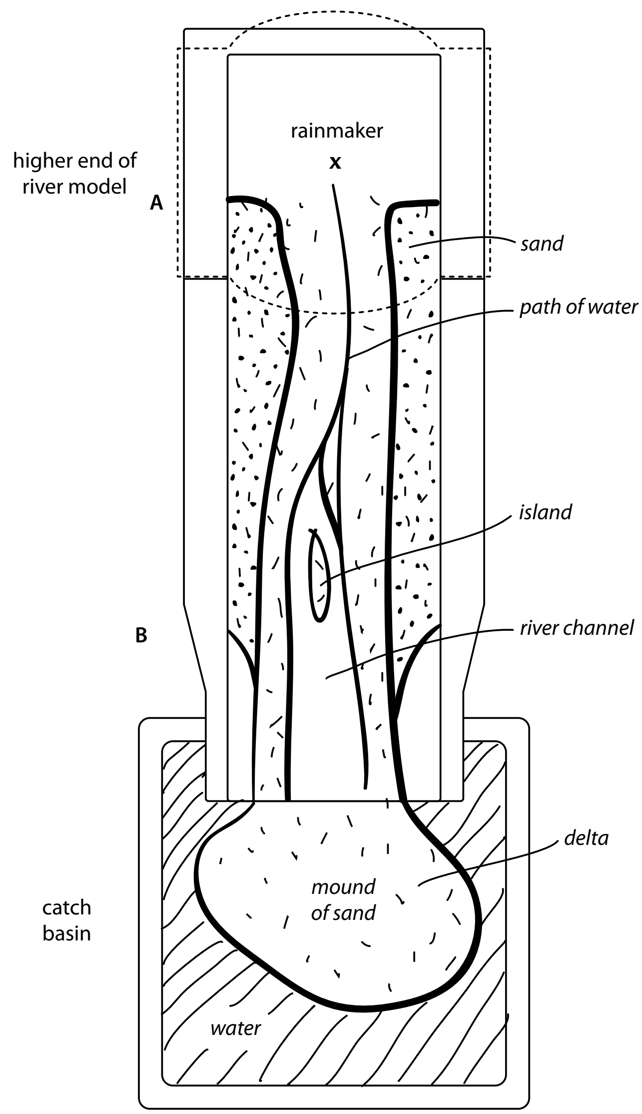


VISUAL AID 7.1

STREET MAP OF BOOMTOWN TODAY

VISUAL AID 7.2

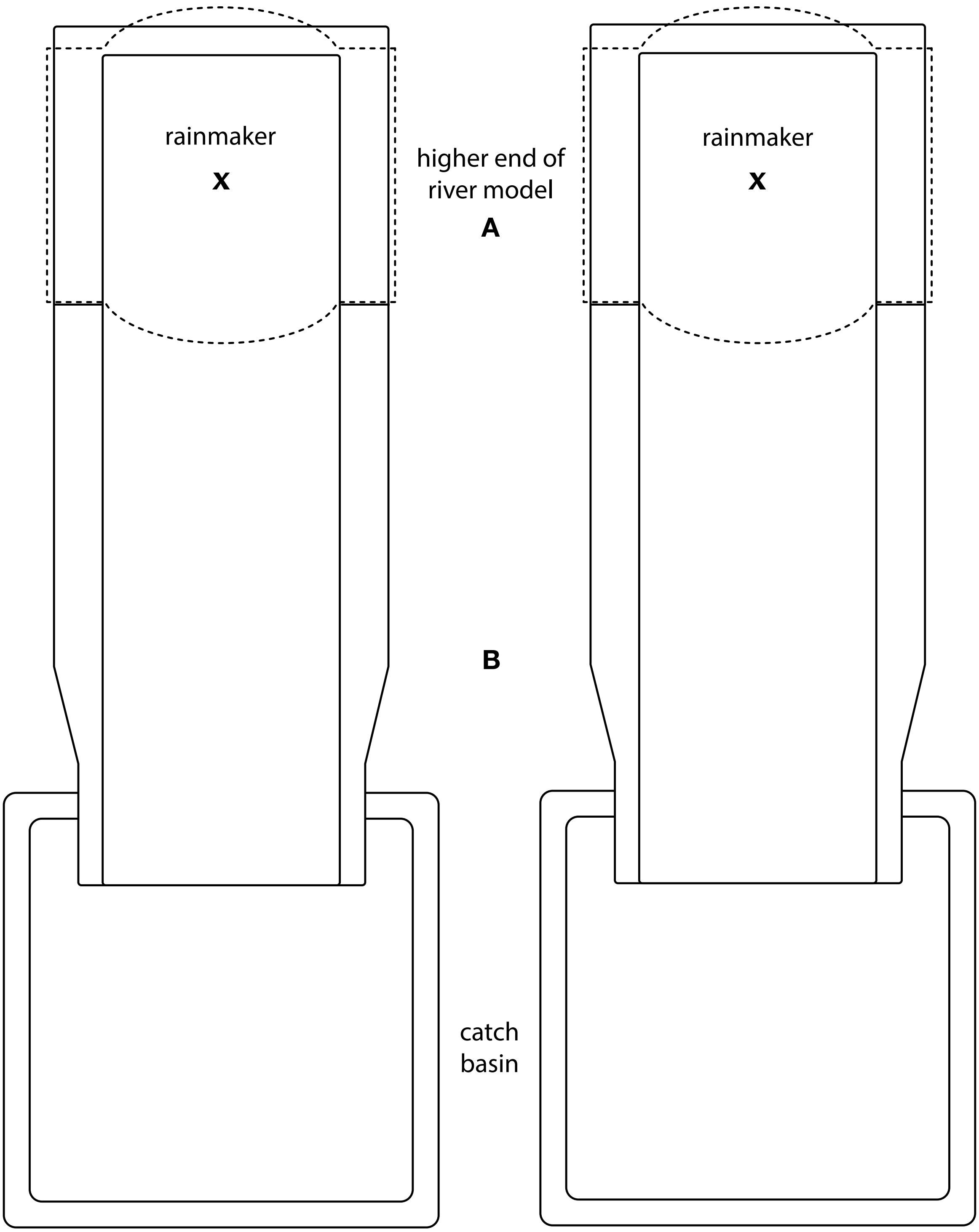
RIVER MODEL DRAWINGS

PREDICTION

Draw what you think will happen to the sand and water after it “rains” at Point X.

OBSERVATIONS

Draw what actually happened to the sand and water after it “rained” at Point X.



NAME ______________________________ DATE ______________

KWL

What I know	What I want to know	What I learned

ENGINEERING DESIGN SOLUTIONS (ENG)

When to use this Scoring Guide:
This Scoring Guide is used when students design, evaluate, and refine solutions.

What to look for:

- Response includes a complete design relevant to the problem to be solved.
- Response includes evidence of how well the design meets criteria within the defined constraints.
- Response indicates how scientific disciplinary core ideas and crosscutting concepts relate to the successful design.

Level	Description
Level 4 Complete and correct	The student's design • meets all of the criteria within the defined constraints, AND • has further improved on the design, AND • uses relevant scientific concepts to explain why any revisions were made to optimize the design.
Level 3 Almost there	The student's design • meets all of the criteria within the defined constraints, AND • explains the relevant scientific concepts.
Level 2 On the way	The student's design • meets all of the criteria but exceeds the defined constraints OR • meets some of the criteria within the defined constraints.
Level 1 Getting started	The student's design does not meet any of the criteria.
Level 0	The student proposes no design or an irrelevant design.
x	The student had no opportunity to respond.

NGSS UNIT OVERVIEW

LAND, WATER, AND HUMAN INTERACTIONS

Performance Expectation MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

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

Performance Expectation MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Performance Expectation MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Performance Expectation MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: Where Should We Build?** Students are introduced to the human impact on land and water use with a scenario that engages them in the issues in the context of a community's building project. When considering the impact of development, they apply the crosscutting concept of the influence of science, engineering, and technology on the natural world.	MS-ESS3.C	Asking Questions and Defining Problems	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World	
2. **Laboratory: Does It Dissolve?** Students carry out a laboratory experiment that helps them develop a conceptual model for the phenomenon of dissolving salts in water. They apply what they have learned in the investigation to explain how the natural world is affected by the physical properties of water. The movement of dissolved substances into water is related to the crosscutting concept of energy and matter.	MS-ESS2.C MS-PS1.A	Constructing Explanations and Designing Solutions Planning and Carrying out Investigations	Energy and Matter	ELA/Literacy: RST.6-8.3
3. **Investigation: Water Quality** Students conduct a data analysis of water-quality indicators that monitor the human impact on waterways. They compare graphical displays of data that show changes to Earth's surface water at varying times in relation to increases in population. The crosscutting concept of cause and effect is explored through the introduction of a correlation and a causal relationship.	MS-ESS3.C	Connection to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence Analyzing and Interpreting Data	Cause and Effect Patterns Influence of Science, Engineering, and Technology on Society and the Natural World	Mathematics: 6.SP.B.5 MP.4

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Investigation: Living Indicators** Students identify patterns in data from simulated catches of aquatic invertebrates and construct arguments for possible cause-and-effect relationships to human activities. The crosscutting concept of cause and effect is applied to the phenomenon seen in the effect that human activity has on the types and number of aquatic invertebrates found over time.	MS-ESS2.A MS-ESS3.C MS-LS2.A MS-LS2.C	Analyzing and Interpreting Data Engaging in Argument from Evidence Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns Cause and Effect Scale, Proportion, and Quantity Influence of Science, Engineering, and Technology on Society and the Natural World	Mathematics: 6.SP.B.5 6.RP.A.1 ELA/Literacy: RST.6-8.3
5. **Laboratory: Nutrients as Contaminants** Students use a model to gather evidence about the interaction of soil, water, and fertilizers in a laboratory investigation to understand how human activities have altered the environment. They apply the crosscutting concept of cause and effect to human activity and environmental impacts.	MS-ESS3.C MS-ESS2.C	Developing and Using Models Constructing Explanations and Designing Solutions Planning and Carrying Out Investigations	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: RST.6-8.3
6. **Reading: Gulf of Mexico Dead Zone** Students read about the phenomena of dead zones—their formation, causes, and effects on the environment. They apply the crosscutting concept of scale, proportion, and quantity when they draw a model diagram to explain how human impact on natural resources in one place can have large-scale impacts in another, distant part of the ecosystem.	MS-ESS3.C MS-ESS2.A	Developing and Using Models Obtaining, Evaluating, and Communicating Information Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Cause and Effect Scale, Proportion, and Quantity Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: RST.6-8.1
7. **Modeling: Cutting Canyons and Building Deltas** Students model the phenomenon of sediment movement in a river to provide evidence for how geoscience processes change Earth's surface. They demonstrate how water's movements under the force of gravity contribute to the formation of landforms. Students then apply the scientific and engineering practice of asking questions and defining problems as they use criteria and constraints to design a system to hold sediments in place in the stream.	MS-ESS2.A MS-ESS2.C MS-ETS1.A	Asking Questions and Defining Problems Constructing Explanations and Designing Solutions Developing and Using Models	Scale, Proportion, and Quantity Energy and Matter Influence of Science, Engineering, and Technology on Society and the Natural World Stability and Change	ELA/Literacy: RST.6-8.3

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
8. **Investigation: Traveling with the Water Cycle** Students model the phenomenon of global water movement as driven by the sun and gravity. Students construct an explanation on the water cycle and the cycling of matter. They consider how the planet's systems interact over various time and spatial scales. They use the crosscutting concept of scale, proportion, and quantity to discuss how water movement can be studied using a model of a system too large to observe all at once.	MS-ESS2.A MS-ESS2.C	Developing and Using Models Constructing Explanations and Designing Solutions	Scale, Proportion and Quantity Energy and Matter	ELA/Literacy: WHST.6-8.2
9. **Reading: Human Impacts on Earth's Water** Students read about human impacts on Earth's water. Scientific principles are applied to discuss methods for monitoring and minimizing human impacts on Earth's water. The crosscutting concept of the influence of science, engineering, and technology on society and the natural world is developed as students consider the health of people and the natural environment. Students are formally assessed on Performance Expectation MS-ESS2-4.	MS-ESS2.C MS-ESS3.C	Constructing Explanations and Designing Solutions Obtaining, Evaluating, and Communicating Information Developing and Using Models	Energy and Matter Influence of Science, Engineering, and Technology on Society and the Natural World Stability and Change	ELA/Literacy: RST.6-8.1 RST.6-8.9
10. **Investigation: Making Topographic Maps** Students conduct a hands-on investigation to model Earth's landforms using topographic maps. They create a map of a landform and then apply their understanding to interpret other maps. The consider how the maps reflect evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.	MS-ESS2.A	Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data	Patterns Scale, Proportion, and Quantity	Mathematics: MP.2 MP.4 ELA/Literacy: RST.6-8.3
11. **Problem Solving: Boomtown's Topography** Students analyze data from topographic maps that display temporal and spatial information about a particular area. They construct explanations based on this evidence for how geoscience processes have changed Earth's surface over time. They consider how water's movements on the land and underground have changed the land's form. The crosscutting concept of stability and change is applied to the scenario as students use evidence from the past to make predictions of what future changes are likely in Boomtown.	MS-ESS2.A MS-ESS2.C	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Cause and Effect Scale Proportion and Quantity Stability and Change	Mathematics: MP.2 MP.4

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
12. **Modeling: Modeling Cliff Erosion** Students apply what they have learned about the phenomena of erosion and deposition to a model of cliff erosion. They use the model to design an erosion-mitigation structure for the cliff using relevant scientific principles that might limit solutions. They use design criteria to develop a solution that is evaluated by others using a systematic process to determine how well they meet the criteria and constraints of the problem. Students are formally assessed on Performance Expectation MS-ETS1-1.	MS-ESS2.C MS-ETS1.A MS-ETS1.B	Constructing Explanation and Designing Solutions Asking Questions and Defining Problems Developing a Model Engaging in Argument from Evidence	Influence of Science, Engineering, and Technology on Society and the Natural World Scale, Proportion, and Quantity Energy and Matter Stability and Change	ELA/Literacy: RST.6-8.3
13. **Reading: Weathering, Erosion, and Deposition** Students read about the phenomena of geologic processes and how they work on Earth's surface over varying time and spatial scales. They investigate how changes in the soil and water change the landscape either by sudden events or gradual changes that accumulate over time. Students construct an explanation about changes they observe due to erosion and deposition based on information in this and previous hands-on activities. The crosscutting concept of energy and matter is used to examine how the transfer of energy drives the motion and/or cycling of matter in geologic processes.	MS-ESS2.A MS-ESS2.C	Constructing Explanations and Designing Solutions	Energy and Matter Stability and Change Scale, Proportion, and Quantity Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: RST.6-8.9 WHST.6-8.9
14. **Role Play: Building on the Mississippi** Students apply what they have learned about geologic phenomena and the monitoring and mitigation of human impact to the Mississippi River and Delta. They use the crosscutting concepts of cause and effect, and stability and change to investigate how New Orleans has coexisted with the river. The use of unprecedented engineering in this area was driven by the needs of the city and its people. Students are formally assessed on Performance Expectation MS-ESS2-2.	MS-ESS2.A MS-ESS2.C MS-ESS3.C	Constructing Explanations and Designing Solutions Obtaining, Evaluating, and Communicating Information	Scale, Proportion, and Quantity Energy and Matter Influence of Science, Engineering, and Technology on Society and the Natural World Stability and Change	ELA/Literacy: RST.6-8.1

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
15. **Investigation: Building in Boomtown** Students use criteria and constraints for building and the information provided in the unit to choose a building site. They identify the consequences of their choices on the health of the people and environment. Then they compare and critique others' choices and determine whether they emphasize similar or different interpretations of evidence.	MS-ESS2.A MS-ESS2.C MS-ESS3.C	Constructing Explanation and Designing Solutions	Influence of Science, Engineering, and Technology Connections to the Nature of Science: Science Is a Way of Knowing Cause and Effect	ELA/Literacy: WHST.6-8.9 WHST.6-8.2
16. **Investigation: Building Site Plan** In this final activity, students apply scientific principles and knowledge of geologic phenomena to design the school and fields at one of the sites. Students then evaluate the solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Students are formally assessed on Performance Expectations MS-ESS3-3 and MS-ETS1-2.	MS-ESS3.C MS-ESS2.C MS-ETS1.B	Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Analyzing and Interpreting Data	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: WHST.6-8.2 SL.8.4

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

LAND, WATER, AND HUMAN INTERACTIONS

This unit explores the anchoring phenomenon: The landscape is constantly changing due to natural processes and human activity. Examples include formation and destruction of beaches and impacts of homes on cliff erosion. Students generate and answer questions such as: How do earth processes, like wind and flowing water, change Earth's surface? How do human activities change Earth's surface?

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Land development by humans has an impact on the environment.	How can people mitigate the negative impact on the land and water when building new construction?	What is the human impact of building construction? (Activity 1) What location is best for a new school and fields? (Activity 15) How can you design the new school and fields to mitigate the human impact on the environment? (Activity 16)	1, 15, 16	MS-ESS3-3	Human population growth leads to the need for more use of land and water resources and more impact on these resources. Responsible development reduces this impact where possible.
Human activities disrupt water quality.	How do human activities on land negatively impact water quality?	Which liquid best dissolves salts? (Activity 2) What can water-quality indicators show? (Activity 3) How can organisms living in a stream indicate water quality? (Activity 4) Can using fertilizers have harmful effects on the environment? (Activity 5) How does nutrient runoff effect the environment? (Activity 6)	2, 3, 4. 5, 6	MS-ESS3-3	Substances dissolved in the earth's water affect water quality and animal habitats. Water movement is driven by gravity though and on top of soil. As it moves, it can pick up and dissolve contaminants such as excess nutrients from fertilizers. These contaminants reduce water quality.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
As water moves through the water cycle, it can dissolve and carry substances from one location to another.	How does the water movement through the water cycle move energy and matter?	Which liquid best dissolves salts? (Activity 2) How does moving water affect the areas through which it flows? (Activity 7) How does water move around the planet? (Activity 8) How can we mitigate modern society's harmful effects on Earth's water? (Activity 9)	2, 7, 8, 9	MS-ESS2-4	Water moving through the soil and on top the surface is part of a greater system of water movement. This global system is the water cycle and it moves water and contaminants around the planet.
Humans disrupt geologic processes.	How do human activities interact with the processes of erosion and deposition?	How does a topographic map show landforms? (Activity 10) How can topographic maps help you evaluate potential building sites? (Activity 11) How can we reduce the effects of ocean waves on coastal areas? (Activity 12) What happens when earth processes move soil and rocks from one place to another? (Activity 13) What has been the human impact on geologic processes of the Mississippi River Delta? (Activity 14)	10, 11, 12, 13, 14	MS-ES2-2	Water running through the land can move sediments from one location to another. The geologic processes of erosion and deposition have been occurring for millions of years but humans have disrupted this natural movement of materials and have changed land formations. Building on the land accelerates the movement of sediments. The outcome of theses geologic processes are altered when wetlands are filled in, farms are created, vegetation is removed, and/or the hard surfaces of buildings are installed.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Engineering can help mitigate the problem of habitat destruction and land mismanagement.	How can we engineer structures to mitigate environmental impact?	How does moving water affect the areas it flows through? (Activity 7) How can we reduce the effects of waves on coastal areas? (Activity 12) What has been the human impact on geologic processes of the Mississippi River Delta? (Activity 14) How can you design the new school to mitigate the human impact on the environment? (Activity 16)	7, 12, 14, 16	MS-ETS1-1 MS-ETS1-2	Changes in the land and water can be monitored to help in the effort to mitigate impact. People can develop design solutions while building to reduce negative outcomes on the environment. Humans controlling water flow does not always reduce the impact, but thoughtful designs can be beneficial. Building designs can be evaluated to determine how well they meet specific design criteria and constraints in an effort to reduce impact on the environment.

UNIT OVERVIEW

LAND, WATER, AND HUMAN INTERACTIONS

This unit explores the issue of how geoscience processes and human activities change Earth's surface. Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 19-34 periods of approximately 45 to 50 minutes (approximately 5-7 weeks).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **Investigation: Where Should We Build?** Students examine photographs of undeveloped and developed hillsides, wetlands, and clifftop areas. Students make observations about changes that have happened to the land and water in these areas.	evidence human impact trade-offs LITERACY	Prepare Student Sheet.		1
2. **Laboratory: Does It Dissolve?** Students compare the solubility of solids in three different liquids. They compare the ability of the liquids to dissolve salts and apply the results to the natural world.	dissolve evidence human impact LITERACY	Set up containers.	ODA Proc.	1–2
3. **Investigation: Water Quality** Students construct graphs of three common water quality indicators and compare them to a graph of Boomtown population. Students then consider whether the increase in population is a correlation or causal relationship between the population and the decline in water quality.	causal relationship correlation dissolve evidence human impact indicator water quality LITERACY MATHEMATICS	Prepare glasses of water; gather local water quality report.	AID Proc. Part B	1–2
4. **Investigation: Living Indicators** Students analyze and interpret data collected from simulated catches of aquatic invertebrates collected at three different points in time corresponding with different levels of human impact. They identify patterns in the data and construct arguments for possible cause-and-effect relationships.	causal relationship correlation human impact indicators macroinvertebrates model pattern water quality LITERACY MATHEMATICS	Prepare Student Sheet.	AID A1 ARG QUICK CHECK A2	1–2
5. **Laboratory: Nutrients as Contaminants** Students explore one of the major routes for contaminants to enter the water supply by investigating water that passes through soil. They first test unfertilized soil and fresh water for the presence of nitrates then add fertilizer to the soil and test both the fertilized soil and the runoff water for nitrates.	contaminants evidence groundwater indicator nutrients runoff trade-offs	Gather and prepare local soil.	OAD Proc. E&T QUICK CHECK A5	1–2

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
6. **Reading: Gulf of Mexico Dead Zone** Students read about the large-scale impact of human activity on aquatic systems. Students use an Anticipation Guide before, during, and after the reading to make predictions based on prior knowledge and then examine how their understanding has changed at the end of the activity. Students draw a model diagram to explain the chain of events leading to the formation of dead zones. They also discuss ways to minimize the size and impact of dead zones.	causal relationship contaminant correlation dead zone evidence indicator model nutrients runoff trade-offs LITERACY	Prepare Student Sheet.	MOD A4	1–2
7. **Modeling: Cutting Canyons and Building Deltas** Students use a river model to investigate how flowing water erodes and deposits sediments to create common landforms. They then design erosion-control structures and use the river model to test them. Based on the results of their initial testing, students redesign and retest their structures.	constraint criterion, criteria delta deposition erosion model sediments LITERACY	Gather large containers for sand and water; gather newspapers; confirm level work surfaces; prepare Student Sheet.	ENG QUICK CHECK Proc. Part B	2–3
8. **Investigation: Traveling with the Water Cycle** After reviewing the three most common phases of matter and the phase changes of water, students use a card-based simulation to follow water as it travels through the water cycle. Each pair of students writes a story that describes and demonstrates their understanding of the water cycle's major processes and reservoirs, and the types and sources of contaminants that can be picked up along the way.	condensing contaminant energy evaporation freezing gravity melting water cycle LITERACY	Set up stations around room (optional); prepare Student Sheets.	MOD A4 COM A5	1–2
9. **Reading: Human Impacts on Earth's Water** Students complete a Three-level Reading Guide as a means to increase their comprehension of a reading that describes some ways in which human activities affect Earth's water. The reading focuses on how humans impact water quality and the water cycle, and on how these effects can be mitigated.	condensation contaminants evaporation freezing human impact melting mitigate monitor water cycle water quality LITERACY	Prepare Student Sheet.	MOD A3 (Assessment of PE MS-ESS2-4) ARG A6	1–2

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
10. **Investigation: Making Topographic Maps** Students use a small-scale plastic model to construct a topographic map of a land formation. This experience provides students with a better understanding of topographic maps and how to interpret them. In the next activity, they apply this understanding to compare topographic maps of Boomtown made at different times.	contour line topographic map topography		MOD QUICK CHECK A5	1–2
11. **Problem Solving: Boomtown's Topography** Students compare the street maps and topographic maps of Boomtown in the present with topographic maps of Boomtown from 25 and 100 years ago. They identify changes that have taken place in the landforms at the building locations. They consider how evidence from the topographic maps might suggest potential problems for the three possible building locations.	contour interval contour line landform scale topographic map topography LITERACY	Prepare Student Sheets.	QUICK CHECK ENG Proc. Part B	1–2
12. **Modeling: Modeling Cliff Erosion** Students model the effect of ocean waves on a cliff. They then design, test, and redesign structures to prevent cliff erosion. They use their observations and understanding of erosion to compare the likely rate of erosion on a hillside and a shoreline cliff.	causal relationship constraint correlation criterion, criteria deposition erosion mitigation model	Gather large containers for sand and water; prepare Student Sheet.	ENG A7 (Assessment of PE MS-ETS1-1)	1–2
13. **Reading: Weathering, Erosion, and Deposition** Students read about geoscience processes that include those they investigated in the last activity—erosion and deposition—and the related earth process of weathering. The impact of human activity on these earth processes is presented with information on how to monitor and mitigate changes caused by development.	deposition earth processes erosion human impact sediment weathering mitigation monitor LITERACY		MOD A2 EXP A6	1–2
14. **Role Play: Building on the Mississippi** Through a role-playing exercise, students explore the history of New Orleans' location on the Mississippi River and the interaction of the city and the river. Students focus on the impact of human activities that have prevented natural cycles of erosion and deposition in the Louisiana Delta region	dead zone deposition erosion evidence mitigation monitoring trade-offs LITERACY	Prepare Student Sheet.	EXP QUICK CHECK E&T A4 EXP A5 (Assessment of PE MS-ESS2-2)	1–2

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
15. **Investigation: Building in Boomtown** Students use the information they have gathered throughout the unit to create a report about the geology at each of the building locations in Boomtown. Then they use their reports and information from the Boomtown City Council to make their decision.	causal relationship constraint criterion, criteria deposition erosion evidence nutrient runoff sediments topographic map trade-off LITERACY	Prepare Student Sheets.	COM Proc. E&T A1	2–3
16. **Investigation: Building Site Plan** Students play the role of a building team that generates a site plan for the school and fields. They also design a plan for monitoring and minimizing soil erosion, increase nutrient run off, or reduce the water quality of Boomtown River.	causal relationship constraint criterion, criteria deposition erosion evidence mitigation monitor nutrient runoff sediments trade-off water quality LITERACY	Prepare Student Sheets.	COM PROC. (Assessment of PEs MS-ESS3-3 and MS-ETS1-2) ENG QUICK CHECK Proc.	2–3