ISSUES AND
EARTH SCIENCE

Land, Water, and Human Interactions

THIRD EDITION

REDESIGNED FOR THE NGSS

Issue-Oriented Science

ISSUES AND EARTH SCIENCE

Land, Water, and Human Interactions

THIRD EDITION

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THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

This book is part of SEPUP's *Issues and Science* course sequence. For more information about this sequence, see the SEPUP and Lab-Aids websites.

ISSUES AND EARTH SCIENCE

ISSUES AND LIFE SCIENCE

ISSUES AND PHYSICAL SCIENCE

Additional SEPUP instructional materials include
SEPUP Modules: Grades 6–12
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A Letter to *Issues and Earth Science* Students

As you examine the activities in this book, you may wonder, "Why does this book look so different from other science books I've seen?" The reason is simple: it is a different kind of science program, and only some of what you will learn can be seen by leafing through this book!

Issues and Earth Science uses several kinds of activities to teach science. As you conduct these activities, you will engage in the same practices used by scientists to understand the natural world and by engineers to solve problems. For example, you will plan and carry out an experiment to investigate how water and sand heat up differently. You will analyze and interpret data on ocean temperatures and worldwide winds. And you will examine evidence for links between climate change, global warming, and human activity. A combination of laboratories, investigations, readings, models, scientific debates, role plays, and projects will help you develop your understanding of science and the relevance of earth science to your interests.

You will find that important scientific ideas come up again and again in different activities throughout the program. You will be expected to do more than just memorize these concepts: you will be asked to develop explanations and apply them to solve problems. In particular, you will improve your decision-making skills by using evidence to weigh outcomes and to decide what you think should be done about the scientific issues facing our society.

How do we know that this is a good way for you to learn? In general, research on science education supports it. In particular, many of the activities in this book were tested by hundreds of students and their teachers, and then modified on the basis of their feedback. New activities are based on what we learned in classrooms using the materials and on new research on science learning. In a sense, this entire book is the result of an investigation: we had people test our ideas, we interpreted the results, and we then revised our ideas! We believe the result will show you that learning more about science is important, enjoyable, and relevant to your life.

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FIELD TEST CENTERS

The classroom is SEPUP's laboratory for development. We are extremely appreciative of the following center directors and teachers who taught the program during the 2003–04 and 2004–05 school years. These teachers and their students contributed significantly to improving the first edition of the course. Since then, *Issues and Earth Science* has been used in thousands of classrooms across the United States. This third edition is based on what we have learned from teachers and students in those classrooms. It also includes new data and information, so the issues included in the course remain fresh and up-to-date.

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Contents

Land, Water, and Human Interactions

Land, Water, and Human Interactions

When Leah was *getting ready for school, she saw an article about roads and parks flooding in a nearby area due to a lot of rain. She ate her breakfast while her mother looked at the forecast. "It says here the rain is finally going to let up," her mom said. "That's a good thing because the river has risen, and any more water might flood the whole area."*

On the way to school, Leah and her mom had to slow down several times where dark water had flooded the road. The water ran fast over the pavement and then cut a gully in the land next to the street. Leah noticed that in the parts of the road that were no longer flooded, there was a lot of mud and debris left behind.

"I wonder why the water looks cloudy. Where did that mud come from?" she asked.

"I don't know," said her mother, "but a couple of days ago, I remember seeing people working on the school's lawns and playing fields, spreading something over them. Maybe that had something to do with all this mud."

• • •

Where did the mud come from? How was it transported to the road? Can water change the land? What kind of things can be in the water? How does water move around the planet?

To investigate these questions, you will construct explanations based on evidence for how geoscience processes have changed Earth's surface. In this unit, you will model how water cycles over and under the surface and through the air. You will have opportunities to apply scientific principles to design systems that can reduce the human impact on land and water.

1 Where Should We Build?

INVESTIGATION

OVER THE PAST 20 years, the population of Boomtown has grown sharply, which has caused school overcrowding. Now the Boomtown City Council is trying to decide where to build a new school building. The Council is planning on including additional sports fields at the school for use by the whole community. Three possible locations for the new school and fields are being considered.

As more people live in and use the resources of an area, the natural characteristics of that area can change. More homes and businesses are built, more farms and gardens need fertilizer and water, and industries make more products to meet the population's needs. All of these activities use resources and create waste products. In this way, the effect on the environment caused by population growth can be significant. The effect on living organisms and their nonliving environment due to human activity is called **human impact.**

GUIDING QUESTION

What is the human impact of constructing buildings?

MATERIALS

For each student

Student Sheet 1.1, "Observations Before and After Construction"

PROCEDURE

1. Each set of photographs on the next page shows places before and after the construction of buildings. Examine the photographs, one location at a time. Observe changes—before and after construction—in
   - the land.
   - the water.
   - the plants and animals.
2. Discuss the changes you observed with your partner. Then record your observations on Student Sheet 1.1, "Observations Before and After Construction."
3. After observing the photographs of all three kinds of places, discuss your ideas with the other pair in your group of four. Review the information in your table on Student Sheet 1.1 together, and then add any new observations of the three kinds of places.
4. The observations you made provide a type of **evidence**, or information that supports or refutes a claim. With your group, use the evidence you gathered to make a claim about the human impact of building in Boomtown.

ANALYSIS

1. Explain how each of the following kind of places could be changed by the construction of buildings due to increased population:

   a. wetlands

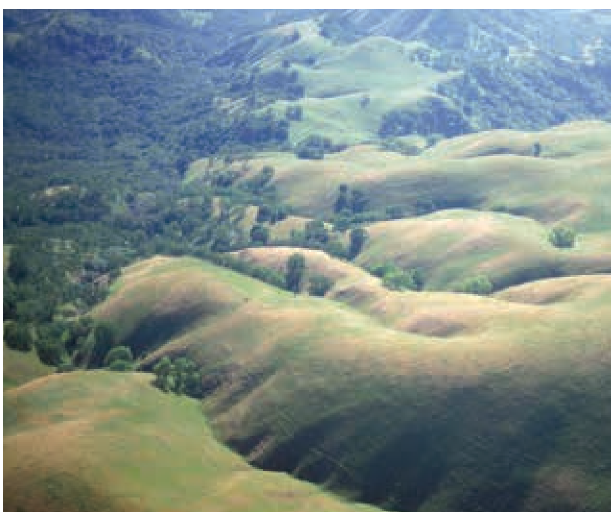
   b. hillside

   c. cliff

Building Sites Before and After Construction

Cliff before

Cliff after



Hillside before

Hillside after

Wetlands before

Wetlands after

2. A **trade-off** is a desirable outcome given up to gain another desirable outcome. What are some of the trade-offs involving the human impacts of building a new school and fields?
3. Examine the map of Boomtown on the next page. Find each of the three sites being considered for the new school and fields:
   - Delta Wetlands
   - Green Hill
   - Seaside Cliff

   Based on what you know so far, on which site do you think Boomtown should build the new school? Use the map and observations from this activity to form your opinion.
4. Provide the questions you might have about the following, which could help the City Council decide where to build the new school:
   a. animals in the area
   b. plants in the area
   c. shape of the land
   d. health of nearby water
5. **Reflection:** Compare Boomtown to where you live. How is it similar or different?

Boomtown Map

2 Does It Dissolve?

LABORATORY

IN THE PREVIOUS activity, you observed how construction can change the shape of land and its interaction with water. For example, filling in a wetland to build on it moves water from one place to another. When water moves, it sometimes picks up material such as soil, rocks, or substances in the soil. These substances can then be carried along by the water. Sometimes substances in moving water will **dissolve,** which is a phenomenon that occurs when the particles of one substance mix evenly into the particles of another substance. The ability of one substance to dissolve in another depends on the properties of the two substances. Dissolved substances can be helpful or harmful, depending on the nature and amount of what is dissolved.

In this activity, you will investigate what happens when salts, such as those that can occur in earth materials, are mixed into various liquids. Although you are focusing in this activity on solids dissolving in liquid, liquids and gases can also dissolve in liquids. An example of a gas dissolving in a liquid is when oxygen from the air dissolves into lake water that fish then use to breathe.

In the Middle East, the Dead Sea is so salty that you can see areas of dried salt on the shoreline.

GUIDING QUESTION

Which liquid best dissolves salts?

MATERIALS

For each group of four students

1 container of sodium chloride
1 container of calcium chloride
1 dropper bottle of water
1 dropper bottle of ethanol
1 dropper bottle of mineral oil
1 cup of water

For each pair of students

1 SEPUP tray
1 stir stick

For each student

1 pair of chemical splash goggles

SAFETY

Wear chemical splash goggles while working with chemicals. Do not touch the mixture or bring it into contact with your eyes or mouth. Wash your hands after completing the Procedure.

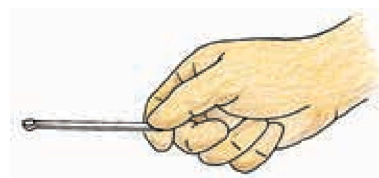
PROCEDURE

1. Carefully read the table below to review the different liquids and solids you will investigate in this activity.

Dissolving Salts

CUP	LIQUID	SOLID
1	15 drops of water	2 level scoops of sodium chloride
2	15 drops of ethanol	2 level scoops of sodium chloride
3	15 drops of mineral oil	2 level scoops of sodium chloride
4	None	2 level scoops of sodium chloride
5	15 drops of water	2 level scoops of calcium chloride
6	15 drops of ethanol	2 level scoops of calcium chloride
7	15 drops of mineral oil	2 level scoops of calcium chloride
8	None	2 level scoops of calcium chloride

2. Create a data table in your science notebook to record
   a. your observations of the liquids in Cups 1–8.
   b. your observations of each liquid and solid mixed together.
   c. the amount of solid dissolved in each liquid.
3. Work with your partner to add the correct amounts of liquids to your SEPUP tray as shown in the "Dissolving Salts" table on the previous page.
4. Observe the color, transparency, and odor of each liquid, and record your observations of Cups 1–3 and 5–7 in your data table.



5. Use the scoop end of your stir stick, as shown here, to add 2 level scoops of solids to Cups 1–8 as shown in the "Dissolving Salts" table.
6. Stir the mixture in each cup for exactly 1 min, making sure to rinse the stir stick before placing it in the next cup.
7. Compare the amount of solid remaining in the cups to the amount of solid in Cups 4 and 8. Estimate the amount of solid that dissolved (all, some, or none), and record your observations in your data table.

EXTENSION

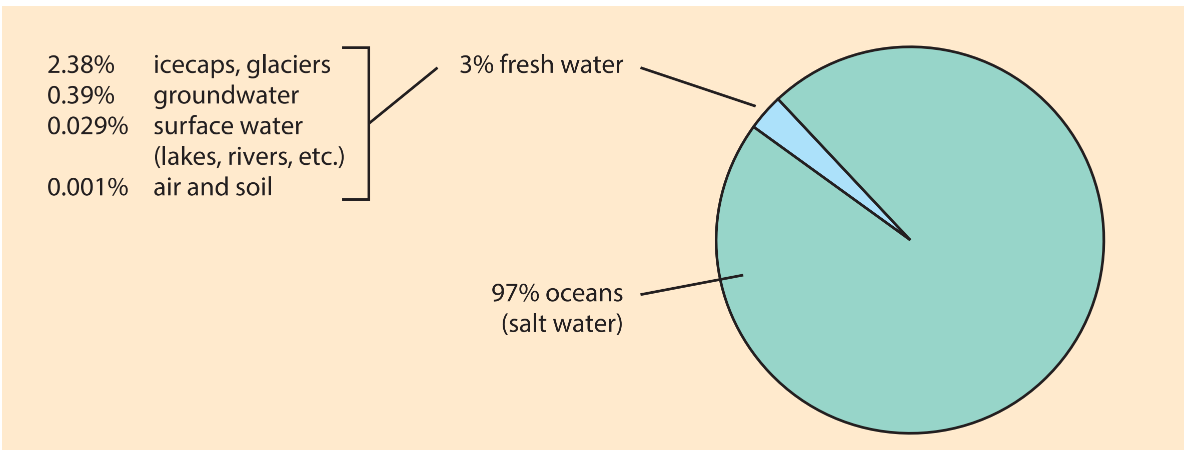
A *solvent* is a substance that dissolves other substances. How good a solvent is water? Design an experiment to find out. Consider investigating how much of a particular solid can dissolve in water, or test other solids to see if they dissolve in water. Then present your results to the class.

ANALYSIS

1. Answer the following questions, and then for each mixture, describe the evidence you observed.

   In this investigation, which mixtures
   a. did not seem to dissolve at all?
   b. dissolved partially?
   c. dissolved completely?

2. All water on Earth contains some dissolved materials, usually salts. Ocean water is about 3.5% salt, with sodium chloride (table salt) being the most common dissolved salt. Calcium chloride is also found on Earth's surface. Would you expect to find calcium chloride in ocean water? Explain.
3. The water on Earth is 97% saltwater found in oceans, seas, and salt lakes, as shown below. Given that salt is common on Earth, explain why you think that most of Earth's oceans contain salts.



4. In the natural world, water dissolves more substances than any other liquid.
   a. How does this property affect living things?
   b. Why should this property be considered when thinking about the human impact on the environment?

3 *Water Quality*

INVESTIGATION

WATER IS ONE part of the environment affected by human activities such as building. All the plants and animals on the planet depend on water. **Water quality** is a measure of the condition of the water based on its characteristics. Some human impacts on the environment, such as changes in water quality, can be directly observed or measured with indicator tests. An **indicator** is any visible sign that shows the condition of the system being studied. There are several indicators commonly used to determine the health of a water source.

In this activity, you will investigate water-quality indicators in Boomtown. You will also consider the cause-and-effect relationships between human activity and water quality.

GUIDING QUESTION

What can water-quality indicators show?

A contractor for the U.S. Army Corps of Engineers collects a water sample for testing.

MATERIALS

For each student

1–2 pieces of graph paper

1 ruler

PROCEDURE

Part A: Graph the Data

1. Scientists in Boomtown have been recording water-quality data from Boomtown River over the past 100 years. With your group, review the following definitions of population and of three water-quality indicators measured in the river:

   Population: the number of adults and children living within the city limits.

   Dissolved oxygen: the amount of oxygen dissolved in the water that is available for aquatic life.

   Total dissolved solids: the total amount of matter dissolved in the water from natural geologic sources or from mining, sewage, urban runoff, industrial wastewater, or agricultural discharges.

   Turbidity: the cloudiness of the water caused by suspended dirt, inorganic and organic matter, and microscopic organisms.

2. Assign each student in your group one of the tables of information below. Make a line graph from your table with "Years Ago" on the x-axis. Label the graph and describe what the data set shows.

3. Share your graph and description with your group.

Population

YEARS AGO	POPULATION
0	80,000
25	40,000
50	20,000
75	10,000
100	5,000

Dissolved Oxygen

YEARS AGO	DISSOLVED O_2 (mg/L)
0	8.3
25	9.0
50	9.7
75	10.5
100	11.3

Dissolved Solids

YEARS AGO	DISSOLVED SOLIDS (mg/L)
0	75.4
25	63.5
50	52.0
75	46.2
100	42.1

Turbidity

YEARS AGO	TURBIDITY (NTU)
0	3.7
25	1.5
50	1.1
75	0.5
100	0.7

Part B: Analyze the Data

4. In your group, determine whether each graph shows that the three water indicators over time have increased, decreased, or remained the same.

   Record what you found in your science notebook.

5. In your group, compare each of the three water indicators to the population graph and determine if each has the same trend, the opposite trend, or an unrelated trend.

   Record what you found in your science notebook.

6. With your group, review the definitions below and then discuss the question that follows.

   A **correlation** is a measure of how well one set of data relates to another. Looking at data sets on a graph can help make correlations more obvious.

   A **causal relationship** is one in which one factor causes an effect on the other factor. The first event is the cause and the result is the effect.

   Is there enough evidence in the graphs to determine that the population increase in Boomtown caused a decline in the water quality? Explain.

7. Share what you have found with your classmates.

ANALYSIS

1. For each of the three water-quality indicators in Boomtown River, explain

   a. how it has changed over the past 100 years.

   b. what could possibly cause it to change the way that it did.

2. What are some of the possible sources of increased pollution in water?

3. Do you think building the school and fields in Boomtown are likely to help, hurt, or make no difference to the water quality in the Boomtown River? Explain.

4. Provide an example of two
   a. correlated events.
   b. causal events.
5. Use Interpreting Graphs in Appendix C, "Science Skills," to determine if each of the four graphs made in this activity show a linear or nonlinear relationship, or if it is not clear what kind of relationship is shown.

EXTENSION

What is the water quality of your local water? Use a water monitoring kit to test a nearby river, stream, or lake.

A water quality testing kit for drinking water

4 Living Indicators

INVESTIGATION

*J*AYDEN AND HIS *grandmother, who grew up in Boomtown, took a special day to go fishing together in the park. Grandma was especially excited because she has not been to Boomtown River for several years. However, once there, she noticed that the water was no longer clear but murky. She also remarked that she remembered a lot fewer weeds and a lot more insects and frogs in the water. Jayden couldn't help but notice how strongly the water smelled. The biggest disappointment of the day, however, was that they brought home only one small catfish instead of the large and tasty trout they had anticipated catching.*

Good water quality is important to both humans and other living organisms in the environment. The organisms that live in the water are indicators of the health of the water. In this activity, you will determine water quality by examining a model of organisms from the river at three different times in Boomtown history. A scientific **model** is any representation of a system (or its components) used to help one understand and communicate how it works. The model in this activity is of macroinvertebrate samples from the river. **Macroinvertebrates** are animals without backbones that are large enough to see without magnification. Some macroinvertebrates are able to survive in water that has high levels of pollution whereas others cannot. The macroinvertebrate populations can indicate if there is a cause-and-effect relationship between human activity and water quality.

A group of students check their net for macroinvertabrates.

GUIDING QUESTION

How can organisms living in a stream indicate water quality?

MATERIALS

For each group of four students

3 sets of macroinvertebrate model samples

For each student

1 Student Sheet 4.1, "Macroinvertebrate Data"

PROCEDURE

1. Look at the images of macroinvertebrates below. There are two possible categories of macroinvertebrates shown:

Pollution Intolerant (abbreviated MSC)

mayfly larva

stonefly larva

caddisfly larva

Pollution Tolerant

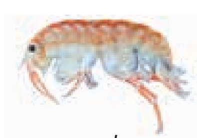
backswimmer

black fly larva

bloodworm larva

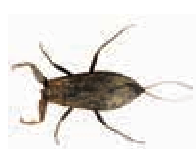
giant waterbug

leech

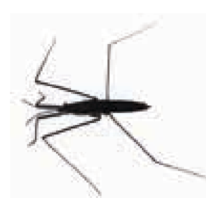


scud

snail



water scorpion



water strider

whirligig beetle

2. Obtain Student Sheet 4.1, "Macroinvertebrate Data," to record the data from your samples.
3. On the table, spread out the macroinvertebrate disks from the sample caught one month ago. Sort them into groups of pollution tolerant and pollution intolerant. Note that some groups may contain only one macroinvertebrate.

4. Record the data from the sample in the data table on Student Sheet 4.1.
5. Calculate the MSC indicator using the following equation:

$$\% \text{ MSC organisms} = \frac{(\text{number of MSC organisms})}{(\text{total number of organisms})} \times 100$$

   Record the result in the data table.
6. Interpret your results using the following indicator key, and record them in your data table:

MSC Indicator Key

PERCENT MSC ORGANISMS	WATER QUALITY
< 25%	Poor
Between 25% and 49%	Moderate
≥ 50%	Good

7. Repeat Procedure Steps 3–6 for the two other samples collected at different times.
8. Share your results with your class.

ANALYSIS

1. Look at the data from all three samples.
   a. What patterns do you see when comparing them? Be sure to consider the
      - total number of all organisms.
      - total number of MSC organisms.
      - MSC indicator.
      - number of different types of organisms.
   b. What do you think might be causing any patterns that you found?
2. How would you explain what has happened to the river in Boomtown between now and the last time Jayden's grandmother visited it several years ago?

3. List at least two other types of observations or measurements that would make you more certain of the trend you saw in the data.

   Hint: Think back to the last activity.

4. Imagine that you obtained samples collected from a different river in a different part of the country. Below are the data for the number of MSC organisms and the total number of organisms.

   a. Calculate the MSC indicator, and determine the water quality for each site.

   b. Describe any patterns in the data.

   c. If you see a pattern, describe a possible cause-and-effect relationship. If you don't see a pattern, provide an explanation for this result.

When sample was collected	Number of MSC organisms	Total number of organisms	MSC indicator	Water quality
1 month ago	16	27		
5 years ago	17	48		
25 years ago	14	60		

5 Nutrients as Contaminants

LABORATORY

GRANDMA TOOK JAYDEN *to another fishing spot outside of town. They didn't catch any trout at that location, either! The area was very different than Boomtown because it was less wooded and had a lot of farmland. There were miles of crops, chicken yards, and cows standing around. Jayden could not imagine that the farm could have anything to do with the poor water quality.*

All organisms need water and certain substances, called nutrients, to grow and stay healthy. **Nutrients** are chemicals that an organism takes in from its environment to use as a source of energy or as building blocks for growth. To help growing plants, mixtures rich in plant nutrients, called fertilizers, are often added to soil. The increased use of fertilizers over the years has increased crop yields that feed our growing population.

Fertilizers readily dissolve in water. When the force of gravity causes water to seep down through soil treated with fertilizers, the water dissolves excess fertilizer and carries it to where water is stored underground. **Groundwater** is water found underground in spaces and cracks in the earth. Gravity also causes water to flow downhill on the ground surface. Excess rainfall, melted snow, or irrigation water that flows across the ground surface is called **runoff**. Runoff can pick up substances like fertilizers from the air or the land as the water moves. Runoff flows downward until it joins water in streams, lakes, and oceans.

Excess plant nutrients in water, such as dissolved nitrogen, can cause harm to the environment. Nutrients in water are a type of **contaminant,** which is any physical, chemical, or biological substance in water. Drinking water usually contains at least small amounts of some contaminants. Once a certain level is reached in the water supply, however, contaminants can negatively affect water.

GUIDING QUESTION

Can using fertilizers have harmful effects on the environment?

MATERIALS

For each group of four students

1 bottle of nitrate extraction solution
1 bottle of fertilizer solution
1 dropper bottle of water
1 vial of nitrate testing powder
2 vials with caps
1 SEPUP tray
1 SEPUP filter funnel
1 white scoop
1 stir stick
1 filter-paper circle
1 pipet
1 graduated cup (30 mL)
1 nitrogen color chart
1 timer
supply of local soil

For each student

1 pair of chemical splash goggles

Nutrients used on farms may run off into nearby rivers.

SAFETY

Always wear chemical splash goggles and use caution when handling solutions. The chemicals used in this activity can cause skin irritation and damage clothing. Thoroughly rinse any area that comes into direct contact with laboratory chemicals.

PROCEDURE

Part A: Testing Unfertilized Soil and Water for Nitrogen

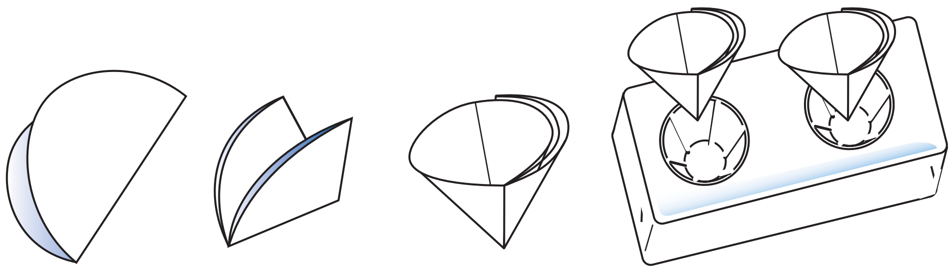
1. Use the white scoop to place 2 scoopfuls of soil into your vial.
2. Use the graduated cup to add 5 mL of nitrate extraction solution to the vial, and then cap the vial and shake it for 1 min.
3. Set the vial aside until most of the solids settle and the liquid is clear enough to see through.
4. Use the graduated cup to add 1 mL of water and 1 mL of nitrate extraction solution to Cup A on the upper row of your SEPUP tray.
5. Use the pipet to transfer 2 mL of the liquid from your vial to Cup B of your SEPUP tray.
6. Use the small scoop on one end of the clear stir stick to add 2 scoops of nitrate testing powder to Cup A, and then stir the mixture.
7. Rinse and dry the stir stick, and then repeat Step 6 for Cup B.
8. While these mixtures stand for at least 3 min, make a table in your science notebook just like the one below.

Material tested	***Cup***	***Color after at least 3 min***	***Estimated nitrogen content (mg/L)***
Water	*A*		
Unfertilized soil runoff	*B*		
Fertilized soil	*D*		
Fertilized soil runoff	*E*		

9. After at least 3 min have elapsed, record the color of each mixture in your data table.
10. Use the nitrogen color chart to estimate the nitrogen content of each mixture, and record this in your data table.
11. Clean up your dirty labware so that it is ready for use in Part B.

Part B: Testing Fertilized Soil and its Runoff for Nitrogen

12. Use the funnel and the filter paper to prepare a filtering setup that will drip into Cup C on the upper row of your SEPUP tray.



Step 1
Fold filter paper in half.

Step 2
Fold filter paper in half again.

Step 3
Open with three thicknesses of paper on one side of the cone and one thickness on the other.

Step 4
Place in funnel and add 3–5 drops of water from the dropper bottle to hold it in place.

13. Fill the filter-paper cone with soil, and slowly pour 5 mL of fertilizer solution over the soil. Allow the fertilizer solution to percolate through the soil and drip into Cup C.

14. Use the pipet to transfer 2 mL of the runoff liquid that collects in Cup C to one of your vials, and then use the white scoop to transfer 1 scoopful of the fertilized soil in the filter cone to the other vial.

15. Add 5 mL of nitrate extraction solution to each vial, cap both vials, and shake each one for 1 min.

16. Set both vials aside until the liquid in each vial is clear enough to see through.

17. Use the pipet to transfer 2 mL of liquid from the soil mixture vial to Cup D.

18. Rinse the pipet, and then use it to transfer 2 mL of liquid from the runoff mixture vial to Cup E.

19. Add 2 stir-stick scoops of nitrate testing powder to Cup D, and stir.

20. Rinse the stir stick, add 2 stir-stick scoops of nitrate testing powder to Cup E, and stir.

21. While these mixtures stand for at least 3 min, clean up all your dirty labware. After at least 3 min have elapsed, record the color of each mixture in your data table.
22. Use the nitrogen color chart to estimate the nitrogen content of each mixture, and record this in your data table.
23. With your group, discuss what your data tell you. Add a title to your table that clearly describes what the data set represents.

ANALYSIS

1. Rank the samples tested in order of highest to lowest nitrogen content. Explain how you determined your ranking.
2. What evidence do you have that adding fertilizer to soil increases
   a. the amount of nutrients available to plants?
   b. the amount of contaminants in the water supply?
3. What are some of the possible negative outcomes to having too much nitrogen in the water?
4. How could a farm miles away from the center of Boomtown affect the water quality of the river in town?
5. Fertilizers are important to farmers and are also used on lawns, gardens, sports fields, and golf courses. They are used regularly because they increase the amount and quality of food or plants that are grown. Do you think fertilizer use should be banned or otherwise restricted? Describe any evidence you used to make your choice and the trade-offs involved.

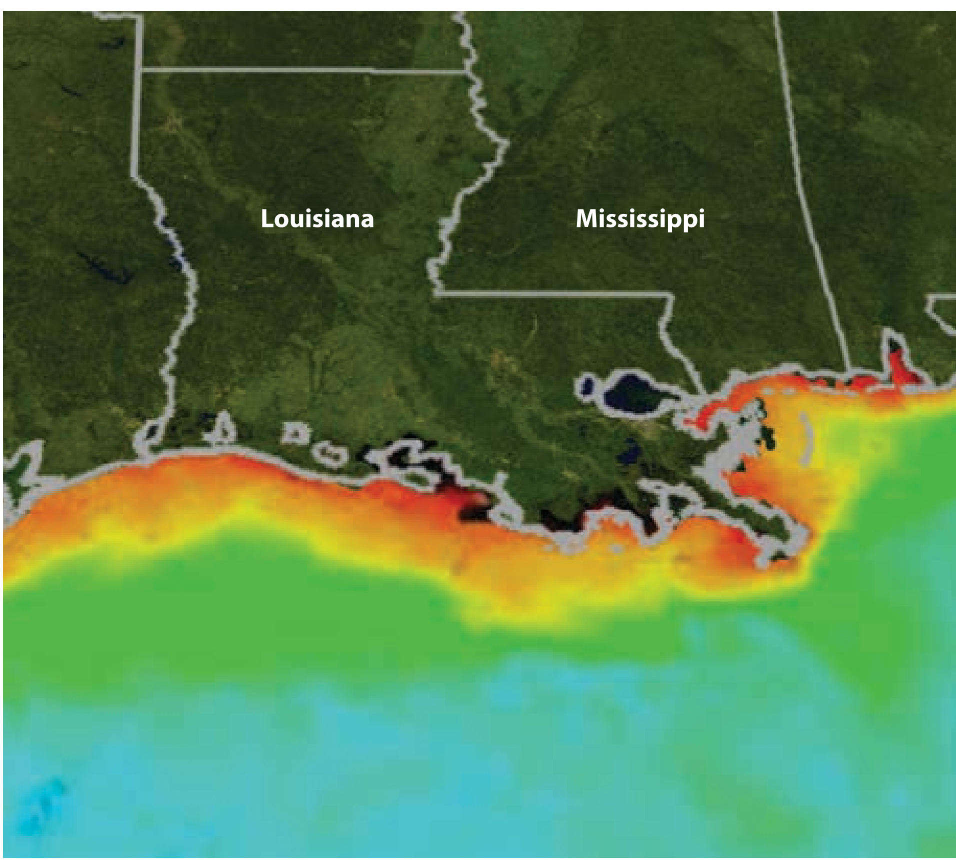
Most fertilizers are a combination of nitrogen (N), phosphorous (P), and potassium (K), commonly called "NPK" fertilizers.

6 Gulf of Mexico Dead Zone

READING

WATER PROBLEMS LIKE those found in fictional Boomtown River are common in real communities all around the world. Although many countries have laws designed to reduce contamination and require regular monitoring of water quality, nutrient pollution is still one of the leading global water quality problems.

When water contains too may nutrients, such as nitrogen, a phenomenon called a dead zone can form. A **dead zone** is a near-shore area of water with little or no dissolved oxygen and, therefore, very few organisms. Worldwide, there are over 500 dead zones. The largest dead zone ever recorded in the world is located where the Mississippi River meets the Gulf of Mexico. In this activity, you will explore the causes and effects of dead zones.



The Gulf of Mexico contains a dead zone that has reached an area over 22,000 km², or almost 9,000 miles². The colors indicate the level of oxygen in the water from lowest (red) to highest (blue).

GUIDING QUESTION

How does nutrient runoff affect the environment?

MATERIALS

For each student

1 Student Sheet 6.1, "Anticipation Guide: Gulf of Mexico Dead Zone"

PROCEDURE

Complete the "Before" column on Student Sheet 6.1, "Anticipation Guide: Gulf of Mexico Dead Zone," to prepare for the following reading.

READING

How Do Dead Zones Form?

Dead zones are a result of excess nutrients in the water. Once in the water, nutrients help small plant-like organisms called phytoplankton to grow. Excess nutrients cause phytoplankton populations to increase quickly. While these organisms are a very important part of the ecosystem, too many of them can cause problems. As the phytoplankton die and sink, they feed the bacteria on the bottom of the ocean. Bacteria, like most organisms, use oxygen. When the phytoplankton population increases, the bacteria population also increases. If the bacteria population gets big enough, there is little or no oxygen left for other organisms.

Dead zones were first noticed in the early 1900s. Starting in 1985, researchers began gathering samples in the area where water flows out of the Mississippi River into the Gulf of Mexico (called the Mississippi Delta). This gave convincing evidence that the Gulf of Mexico contained very high amounts of nutrients.

The data collected by scientists studying the area showed that the excess nutrients in the Gulf of Mexico came from human activities, such as the use of fertilizer and fuel. Fertilizer contains nutrients like nitrogen and phosphorus, which plants need to grow. Farmers apply fertilizer to crops to help them grow. The fertilizer not absorbed by plants remains in the soil. When it rains, the nutrients are carried away by the water into nearby lakes, rivers, and oceans. This effect is increased if the fertilized soil is also washed away. Dead zones form where nutrient-rich river water enters a lake or ocean and slows down.

When the faster-flowing water slows down, the nutrients tend to drop out of the water and become concentrated near shore.

Where Do the Nutrients Come From?

The Mississippi River has a huge river basin, which is area of land where water drains downhill on the surface or through the ground into a river or series of rivers. The Mississippi drains water from 41% of the land in the United States. The waterways in the basin are all connected. This means that fertilizer put on fields in Minnesota can travel all the way to the Mississippi Delta. This also means that there is no single source of pollution causing the Gulf of Mexico dead zone. As water runs downhill towards the ocean, it picks up nutrients from the soil along the way. The nutrients in the Mississippi Delta can come from 31 different states!

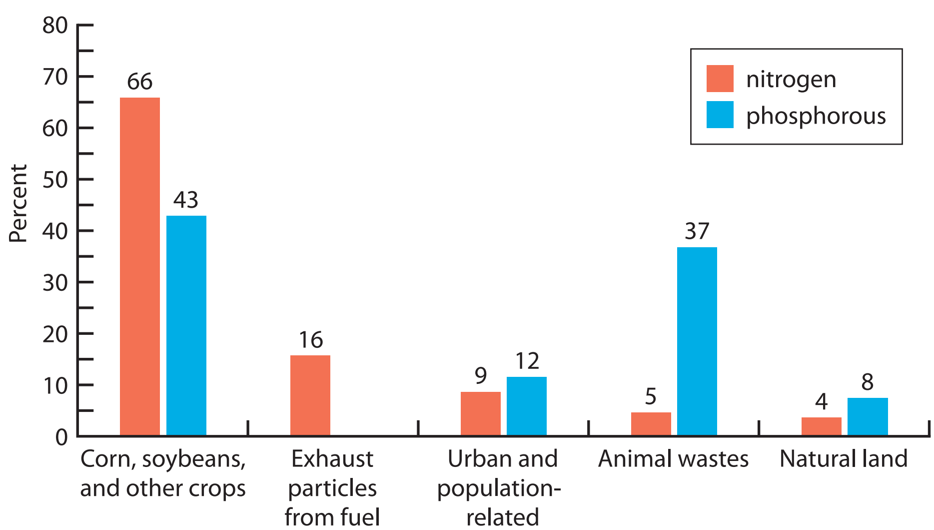
Mississippi Watershed Regions

The river basins shown above (labeled in all capitals) all drain into the Mississippi River and the Gulf of Mexico.

Given the vast size of the basin, it is not surprising that the dead zone at the mouth of the Mississippi can also be vast. It has been as large as 22,730 km^2 (8,776 $miles^2$). This dead zone is seasonal, growing in size during the warmer months of the year when bacteria can grow rapidly. The recent average size is about 14,150 km^2 (5,500 $miles^2$), about the size of the state of Connecticut. The size of the dead zone has grown over the years. This correlates with an increase in the amount of nitrogen in streams that drain into the Mississippi Basin. This amount has nearly tripled since the late 1950s.

Since agriculture covers nearly one-half of the continental United States, it is not surprising that much of the nitrogen in the Gulf of Mexico comes from farmland. However, there are other sources, such as the burning of fossil fuels, storm water, runoff, wastewater, and some home products. This graph shows the sources of two kinds of nutrient pollution: nitrogen and phosphorous.

Source of Nutrients in the Gulf of Mexico

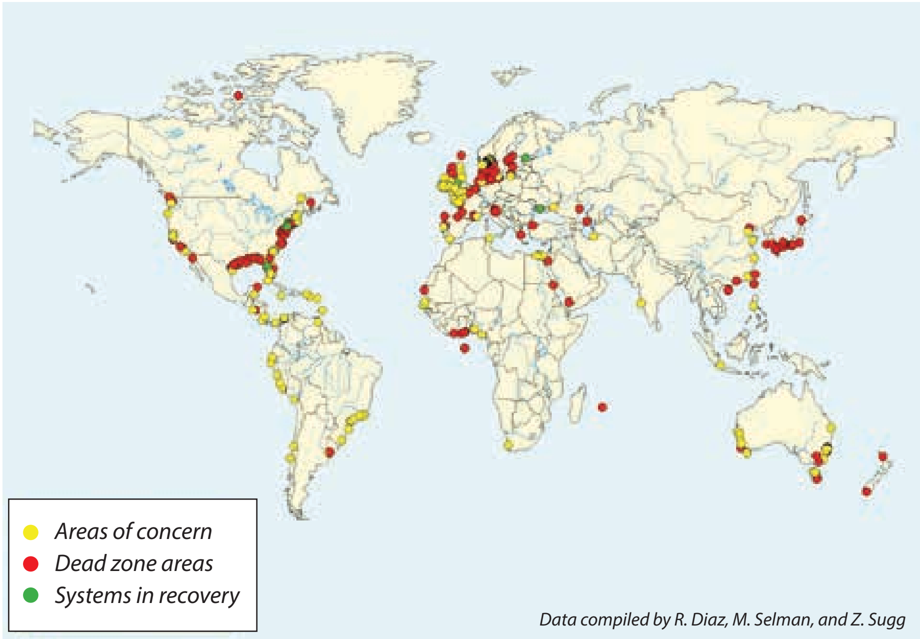


United States Geological Survey (USGS), 2014

Dead zones have occurred naturally in certain environments throughout time. Any condition that results in lower oxygen levels can result in a dead zone. For example, the dead zone in the lower part of the Black Sea in northern Europe is due to a natural lack of mixing of water rich in oxygen with water poor in oxygen. This area of the Black Sea is a permanent dead zone.

However, over the past several decades, the number of dead zones throughout the world has increased in size and number. Currently there are over 500 dead zones in the world. The recent increase is a direct result of human activities. Rising populations coupled with advances in science and technology have resulted in a large increase in the release of nitrogen and phosphorous into the environment. These nutrients have

World Dead Zone Areas



entered our air, soil, and water mainly through agricultural and industrial activities. Human activities add almost twice as much nitrogen and three times as much phosphorus as natural emissions.

What is the Impact?

Drinking or swimming in nutrient-rich water can cause serious health problems for animals and humans. Aquatic ecosystems have changed as a result of dead zones. Areas with dead zones have a lower diversity of organisms, smaller populations, and smaller-sized organisms compared with well-oxygenated water. Some organisms that have been heavily impacted are shrimp, eels, and crabs. Ecologists still do not fully understand the consequences of a dead zone over a long time period.

Nutrient pollution also has an impact on people's jobs. Because of many factors, including nutrient pollution, some fisheries are already overfished or in danger of becoming overfished. The commercial fishing industry in the Gulf of Mexico provides millions of jobs and catches billions of pounds of finfish and shellfish each year. The economic gain of this industry has been negatively impacted by steady and significant declines in the aquatic population that has led to smaller fishing catches.

What Can We Do?

There is evidence that dead zones can be reversed. After decades of nutrient inflow from commercial farming, the northwestern Black Sea developed a large dead zone. In the late 1980s, the economy of the area collapsed, commercial farming decreased, and nutrient runoff dropped by 50 percent. Over the next several years, the water quality improved. Since then, careful management and continued reductions in emissions has helped the Black Sea recover. Fish populations have now increased to high enough levels that fishing has again become part of the region's economy.

While commercial practices cause the most nutrient pollution, our everyday actions can make a difference. We can help by reducing our use of fertilizers and detergents and properly disposing of yard and pet waste. Other ways to help combat nutrient pollution is to reduce our consumption of fossil fuels by using public transportation, using more energy-efficient vehicles, and reducing home energy use through more efficient heating, cooling, and lighting systems.

Broader things that communities can do are to manage land and water sensibly. This could include encouraging development that allows people to walk or take public transportation to jobs and shopping. Better engineering and landscape design can also help. When water runs off across hard surfaces, like parking lots, rooftops, sidewalks, and roads, it often carries pollutants down storm drains and into local waterways. Making sure the runoff gets properly treated and replacing paved surfaces with materials that allow water to drain (such as small stones) or absorb the water (such as plants) can help keep nutrients out of our streams, lakes, and oceans. Restoration of wetlands can also help. Wetlands are a natural filter that can remove contaminants from water, but as populations have grown around the world, many wetlands have been neglected or destroyed.

ANALYSIS

1. Describe the roles of phytoplankton and bacteria in the formation of dead zones.
2. Look at the graph in the "Where Do the Nutrients Come From" portion of the reading.
   a. Choose two strategies that can reduce the amount of nutrients flowing into streams and rivers.
   b. Explain why you chose these two strategies and how they can help the problem.
3. What evidence do you have from this reading that dead zones can be reversed?
4. Draw a diagram that models and explains the cause-and-effect relationships that led to the creation of the dead zone in the Gulf of Mexico.

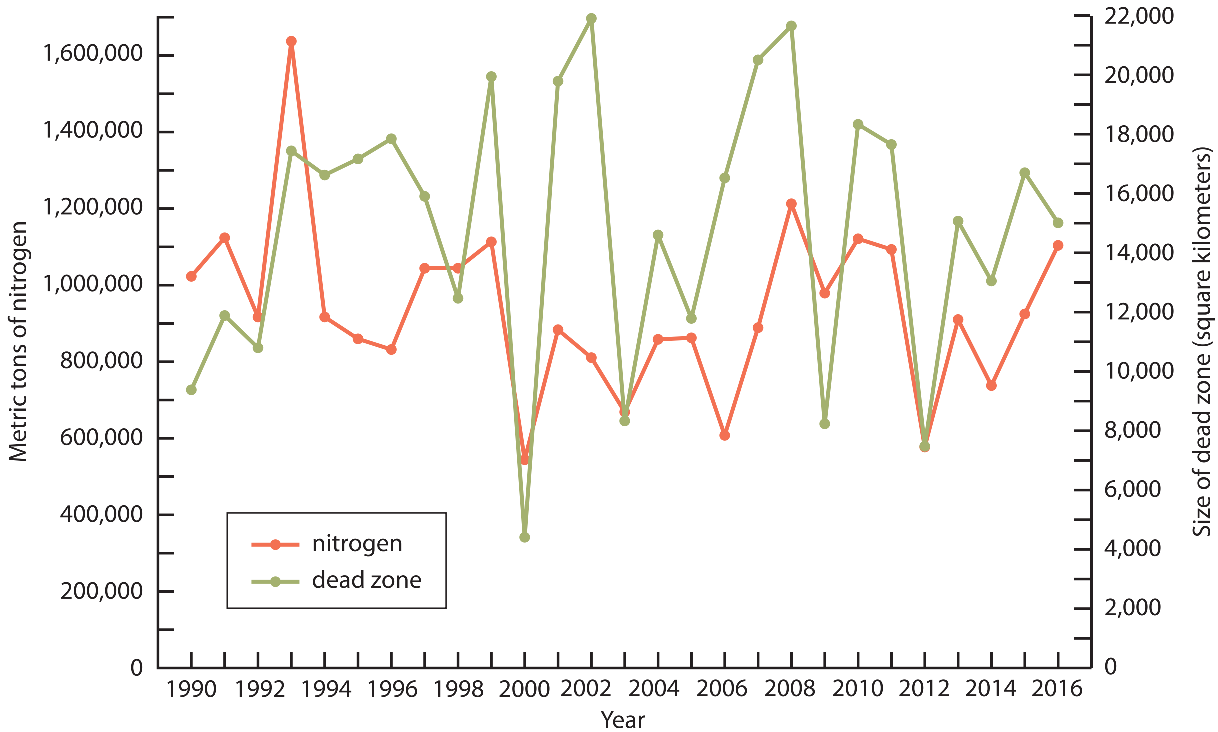
   Hint: Be sure to include all components, from the source to the outcome.

Water drains down hill on the surface or through the ground into a rivers and lakes.

EXTENSION

Look at the graph below of the nitrogen input in wastewater into the Mississippi River and the dead zone area in the Gulf of Mexico. Do these data show that nitrogen is likely to be the only cause of dead zones? Use this graph to explain why or why not.

Nitrogen Input and Dead Zone Area in the Gulf of Mexico



7 Cutting Canyons and Building Deltas

MODELING

Gravity causes water to flow downhill from higher elevations to lower elevations. As you have learned, water can pick up contaminants as it moves on the surface of and through earth materials. Moving water can also pick up and carry away **sediments.** Sediments are small pieces of earth, such as rocks, shells, and other debris. Faster moving water transfers more energy and can carry larger sediments than slower moving water. As flowing water slows down, any sediments it can no longer carry are dropped to the ground. If enough sediments get dropped in the same area, these deposits can form new landforms, such as deltas. In this activity, you will investigate the effects of moving water with a model.

After using the model to observe the effects of flowing water on a land surface, you will design a structure to reduce river erosion. All engineering projects have minimum requirements, called **criteria** (singular **criterion**), for how the design must function. Projects also have **constraints,** things that limit or restrict the design. For example, a criterion for an electronic device could be that it must operate continuously while a constraint could be that it must run on batteries.

GUIDING QUESTION

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

Mud is a mixture of sediment and water.

MATERIALS

For each group of four students

Parts A and B

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)
supply of sand
supply of water
paper towels and/or newspapers

Additional Materials for Part B

1 channel maker
9 building bricks
2 mesh sleeves
supply of small rocks

For each student

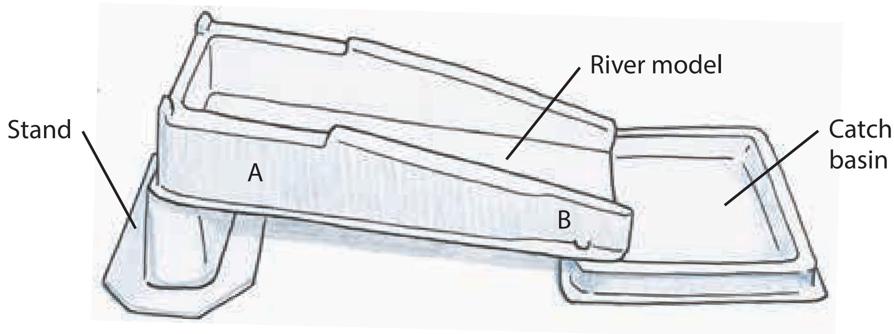
1 Student Sheet 7.1, "River Model Drawings"

The water in rivers and streams carries sediment downriver.

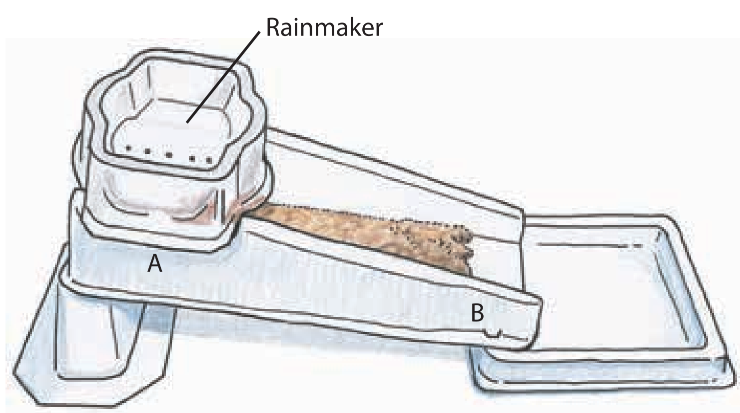
PROCEDURE

Part A: Modeling Erosion and Deposition

1. Set up the river model as shown below.



2. Using the 30-mL graduated cup, put 3 full cups of sand into the river model between Point A and Point B.
3. Use your fingers or the spoon to pack the sand into a uniform layer that covers the bottom of the river model between Point A and Point B. If the sand is too wet, mix in a little dry sand until it is the consistency of cookie dough.
4. Place the rainmaker over Point A of the river model, as shown below.



5. Use the left-side diagram labeled "Predictions" on Student Sheet 7.1, "River Model Drawings," to sketch a picture showing where you think the sand and water will end up after water is poured into the rainmaker and allowed to "rain" on the model.

6. Add 50 mL of water to the rainmaker.
7. Carefully observe what happens. Don't forget to watch what happens in the catch basin. Sketch or write down what you see.
8. Repeat Steps 6 and 7 two more times.
9. Use the right-side diagram labeled "Observations" on Student Sheet 7.1 to draw the position of the water and sand in the model. Label the diagram as completely as you can.
10. Read the following description of some geological processes and landforms. Then write a complete description of what happened in your river model using the bolded terms.

    The removal of sediments from an area is called **erosion** (e-ROW-zhun). Common causes of erosion are gravity and moving water, wind, and ice. Erosion leads to **deposition** (de-puh-ZI-shun), which happens when the current slows down and the sediments settle out of the flowing water, ice, or wind and drop to the ground. A **delta** is a fan-shaped landform that develops where sediments are deposited in one area as a result of flowing water (such as a stream or river) entering still water (such as a lake or ocean).

Part B: Engineering an Erosion-Control Structure

11. Read the following criteria and constraints for designing a system that will reduce erosion in the model. As a class, clarify or add any relevant criteria or constraints to the design challenge.

    Design Criteria

    The design must

    - provide less erosion over the length of the river model than if there was no erosion-control system in place.
    - result in less deposition in the catch basin.

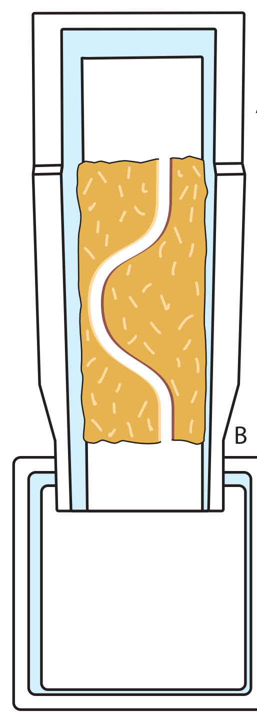
    Design constraints

    The design is limited by

    - using the channel maker to begin the design.
    - using the materials provided.

The retaining wall along the side of this stream is designed to reduce erosion due to water in the river channel.

12. Get the additional engineering materials from your teacher.
13. Set up the river model as you did in Steps 1–4.
14. Press the channel maker into the sand layer and then remove it. This forms a shallow channel like the one shown to the right. Make a sketch of the channel in your science notebook.
15. Add 50 mL of water to the rainmaker, and carefully observe what happens. Add information to your sketch showing and describing the erosion patterns.



16. Talk among your group about how to use the materials provided to prevent erosion along the river channel. Choose a design to test in the river model.
17. Repeat Steps 13 and 14, and then add your erosion-control structure. Make sure to include your structure in your sketch.
18. Test your design, making sure to record any information that indicates how effective your structure was at reducing erosion.
19. Based on your results, redesign your erosion-control structure to optimize erosion control. Sketch and describe your design, and then write a brief explanation using scientific concepts about how your revisions will improve the design.
20. Retest your design and record the results.

EXTENSION 1

Investigate how the steepness of the land affects the movement of sediments. Model a steeper river by placing a book under the base of the river model, and then repeat Part A. Compare the results from the steeper slope with those from Part A.

EXTENSION 2

Investigate how the type of earth material that the river flows through affects the movement of sediments.

ANALYSIS

1. Thinking about the river model in this activity, answer the following:
   a. How is the model like a real river?
   b. How is it different from a real river?
2. What were the biggest changes that occurred
   a. at the higher elevations? Explain why you think this happened.
   b. at the lower elevations? Explain why you think this happened.
3. How well did your redesigned erosion-control structure work compare with your original? Use evidence from your tests to explain why your design changes did or did not make a difference.
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.
5. How could the movement of sediments cause a problem if someone builds on
   a. Delta Wetlands?
   b. Green Hill?
   c. Seaside 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.
   b. Explain what happened to the rock that once filled up the canyon.

A canyon cut by the Daning River in China

8 Traveling with the Water Cycle

INVESTIGATION

*I*N BOOMTOWN, JAYDEN *watched the rain fall from the sky and then flow down the street and into a drain. He wonders where all the water goes. He knows that lakes and oceans have lots of water and thinks that maybe it ends up there. Then he imagines what it would be like to shrink himself all the way down to the size of a raindrop to follow the water on its path.*

Water constantly moves and changes form as it has been doing for billions of years. This movement of water through the air and land is called the **water cycle**. The sun's energy and Earth's gravity drive the water cycle. Solar energy keeps the water cycle in motion. The sun's rays heat the water until it changes state, such as evaporating water from oceans, lakes, rivers, and even the soil. Gravity keeps water moving by forcing it to fall from the clouds as precipitation, seep down into the ground, and flow downstream from higher elevations to lower elevations.

In this activity, you will model what happens when water travels and changes as it moves throughout the planet. You will also model what happens when water picks up harmful contaminants along its journey.

What parts of the water cycle do you see in this photograph, and how might the water become contaminated?

GUIDING QUESTION

How does water move around the planet?

MATERIALS

For each pair of students

1 set of 6 Contaminants and the Water Cycle Cards

1 white number cube

1 blue number cube

colored pencils

For each student

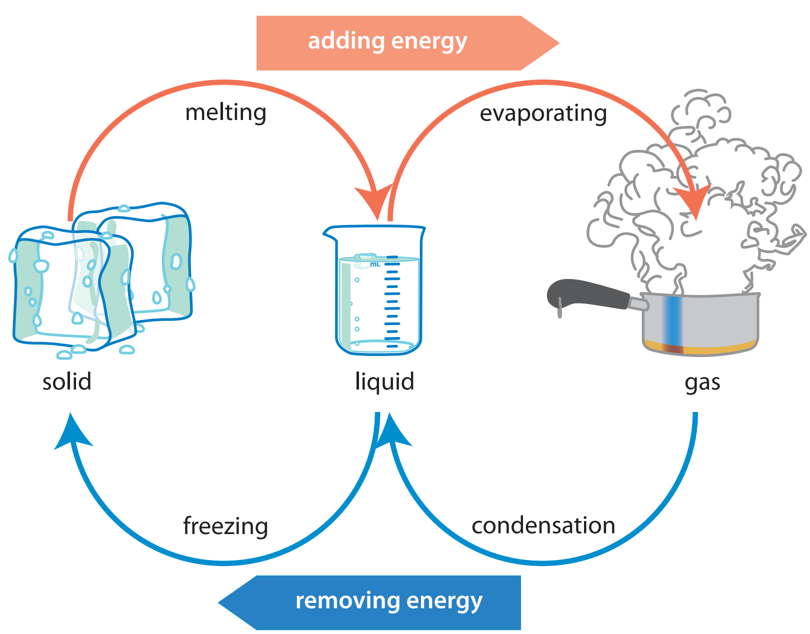
1 Student Sheet 8.1, "Talking Drawing: The Water Cycle"

1 Student Sheet 8.2, "My Water Cycle Story"

PROCEDURE

Use Student Sheet 8.1, "Talking Drawing: The Water Cycle," to help prepare you for this activity.

1. With your class, review water's changes of state in the diagram and text below and on the following page.



melting The process of a solid (such as ice) gaining heat energy to become a liquid (such as water).

evaporating The process of a liquid (such as water) gaining heat energy to become a gas (such as water vapor).

condensing The process of a gas (such as water vapor) losing heat energy to become a liquid (such as water).

freezing The process of a liquid (such as water) losing heat energy to become a solid (such as ice).

2. With your partner, review the six Contaminants and the Water Cycle Cards.
3. Find the Precipitation Card. Your water travels will begin with this card.
4. Record the card title, "Precipitation," in the first column of the top row on Student Sheet 8.2, "My Water Cycle Story."
5. With your partner, look at your card to see where your water can be located. Make a choice, and record it in the second column of Student Sheet 8.2. In the third column, identify the state of your water (solid, liquid, or water vapor).
6. Roll the blue number cube. Look for the number you rolled on the Contaminants and the Water Cycle Card to determine which, if any, contaminant the water picks up. Record the contaminant in the fourth column of Student Sheet 8.2. If no contaminant was picked up, write "none" in the fourth column.
7. Roll the white number cube. Look for the number you rolled on the Contaminants and the Water Cycle Card to find out where your water will go next. Record this location in the first column of the next row on Student Sheet 8.2 and find its card.

   Note: Water can cycle back to the same place, so you might not use all six cards. When you get to one you have had before, choose another state for the water.
8. Using the card for your new location, repeat Steps 5–7 until you have filled in all but the last column of Student Sheet 8.2.

9. Each row of Student Sheet 8.2 is one part of the story of your water. With your partner, discuss where your water is in each part of your story. Remember, your water first started as precipitation with almost no contaminants. Describe what happened to your water from one part of the story to the next. Be sure to explain what contaminants the water picked up and exactly how your water changed.

   Hint: Did it move? If so, how? Or did something else happen, like a temperature change? Did it pick up contaminants? If so, which ones? from where?

10. Based on your discussion, complete the final column, "How it happened," of Student Sheet 8.2.

ANALYSIS

1. On Student Sheet 8.1, you recorded your initial ideas about the water cycle. Do you think, after completing the Procedure, that your original diagram is a good summary of the water cycle? Explain why or why not.

2. Based on what you learned during the activity, use a different colored pencil to revise and complete Student Sheet 8.1.

   a. Use the following words to identify where water can be found in the picture.

      atmosphere — groundwater
      land — ocean
      organisms — precipitation

   b. Draw at least six arrows showing the movement of water from one place to another.

   c. Label places where each of the following changes in state is occurring.

      condensation — evaporation
      freezing — melting

   d. Label places where the sun's energy and the force of gravity help drive the water cycle.

3. Do you think that your *revised* diagram on Student Sheet 8.1 is a good summary of the water cycle? Why or why not?

The rainbow is the result of a diesel spill on the road.

4. In this activity, you used cards and number cubes to model the water cycle and contaminants that water picks up.
   a. In what ways did this activity model the water cycle well?
   b. What parts of the water cycle were not included?
5. Expand your notes from Student Sheet 8.2 into a story that describes your water's journey. Your story should follow your water through at least five places. Be as creative and scientifically accurate as you can. Be sure to
   - describe or draw how your water moves from one place to another.
   - identify any changes in state (solid, liquid, gas) that occur.
   - describe the role of gravity and the sun.
   - describe any contaminants the water picks up as it travels and how the contaminants got there.

9 Human Impacts on Earth's Water

READING

HUMANS INTERACT WITH water every day. Some interactions improve water quality while others have negative impacts. Unfortunately, the water people want to use is not always in the right place or of the right quality. And, although the water cycle has been active since billions of years before humans even existed, human activities can affect how the water cycle redistributes Earth's water.

Hydrologists (hi-DRAH-luh–jists) are scientists that study how water moves around the Earth. They help us find new sources of water, monitor water quality, and determine best practices for water use and restoration. Hydrologists and engineers also work together to determine how to **monitor**, or measure and keep track of, contaminant levels in the water and **mitigate**, or lessen the impact of, contaminants.

This hydrologist heats up a water-testing device that identifies toxic contaminants in the water.

GUIDING QUESTION

How can we mitigate modern society's harmful effects on Earth's water?

MATERIALS

For each group of four students

1 sheet of chart paper
markers

For each student

1 Student Sheet 9.1, "Three-level Reading Guide: Human Impacts on Earth's Water"

READING

The Water Cycle

Water is one of Earth's most important natural resources. Humans rely on and use a lot of water in many ways. Our activities can also impact Earth's water in several ways. We can make water cleaner, we can pollute it, and we can affect its natural travels through the water cycle.

Imagine water moving through the water cycle. Every second, across the planet, water is changing its state and moving. Evaporation of water from the lakes and oceans adds water vapor to the air. When water evaporates from plant leaves, it is called transpiration. Condensation turns water vapor in the air into tiny solid and liquid particles that form clouds and fog. These droplets of water and ice can then fall back to Earth's surface as precipitation in the form of dew, rain, snow, or hail.

Energy from the sun plays a major role in the water cycle. The sun's energy causes wind to blow and ocean currents to flow. Both of these processes move water around the globe. More heat from the sun causes more ice to melt and more water to evaporate. Less heat from the sun causes more water vapor to condense and more water to freeze. Solid ice melts into liquid water that flows into rivers and oceans. Gravity also plays a major role in the movement of matter in the water cycle by pulling water downwards.

Contaminants, such as excess nutrients from runoff, can be picked up in nearly all parts of the water cycle. The process of evaporation is one exception because the liquid water changes to vapor, but typically the contaminants do not also change to gas. The water is evaporated into the air, but the contaminants are left behind. This process cleans the water that moves into the atmosphere but also concentrates the remaining contaminates. The result is more potent contamination at that location.

Human Impact on the Water Cycle

People impact these earth processes because human activities use a lot of water. Sometimes when we use water, we alter the local balance of the water cycle. For instance, when we dam a river, it forms a lake and reduces water flow in the river downstream. In the lake, water evaporates more rapidly, and in the smaller river, less water is available. When we remove lots of water from lakes or rivers, the areas around the lakes and rivers have less water available and are more likely to experience drought. This can have devastating consequences for the organisms that live there. We also extract groundwater stored deep below the surface to use for a variety of purposes. Once on the surface, that water can evaporate more easily.

As you have probably read or heard about on the news, measurements from across the globe indicate that the average temperature at Earth's surface is increasing. Evidence also indicates that various "greenhouse gases" added to the atmosphere by human activities, in particular carbon dioxide (CO_2), are a cause of this global warming trend. This rise in average temperature has already affected the natural balance of the water cycle.

Increased melting of glaciers and ice sheets has increased the amount of water and decreased the amount of ice. Human activities that affect the amount of evaporation or condensation that occurs can also affect the amount of clouds that form. Clouds both cool and warm Earth. Clouds can reflect the sun's rays back into space, causing surface temperatures to be cooler. Clouds can also act as a blanket, keeping surface temperatures warmer. While we don't know exactly what changes will occur,

Changes in the surface of Earth, such as this artificial lake formed behind a dam, can change storage and pathways of water in the water cycle.

evidence makes it clear that human activities are causing changes. These changes are considered a major factor in the increase in severe weather events, such as storms, hurricanes, floods, droughts, and wildfires. In other words, our activities are changing the climate.

Human Impact on Water Quality

Human activities release contaminants such as nitrogen, salts, pesticides, metals, harmful organisms, and even medicines into the water. Even everyday activities such as cleaning can add washed-off dirt, oil, sewage, and cooking scraps as well as chemicals found in soap, detergent, and other cleaning products.

When the human population was lower and there were no densely populated areas, natural processes and filters were able to remove the contaminants that we added. Ever since large numbers of humans started living close together in towns and cities, the amount of contaminated water produced in these areas began to overwhelm the areas' natural abilities to remove contaminants. Initially, the contaminants were mostly from human and animal waste. But as human society began to include large-scale agricultural and industrial processes, many more and different contaminants began to enter the water supply. These contaminants can make the local environment unfit for life and can cause populations of some species to decline, and possibly even go extinct.

Personal water use is not society's biggest use of water. The two biggest uses of water are for agriculture and industry. Common agricultural water pollutants are nitrates, phosphates, disease-causing organisms, and sediments. Common industrial water pollutants are various toxic metals (mining), acids (chemical and manufacturing), petroleum products (oil and gas), asbestos (textiles), and cleaning solvents (electronics). Another large human impact on our water supply is land use—the clearing, leveling, digging, draining, and otherwise changing of the landscape that occurs whenever we build something.

Scientists have shown how much this Canadian glacier has receded by marking its position over time.

These activities tend to both decrease the solidity of soil and rock and increase precipitation runoff. These combine to produce more erosion and sediment pollution. The loss of the natural environment, particularly wetlands, reduces Earth's natural abilities to reduce pollution and maintain a balance. And even if what is being built is replanted, such as a farm field, park, playground, or sports field, the use and upkeep of these areas often require additional water use and add contaminants to water.

A dairy farm in Pennsylvania (top) uses a sustainable practice of processing cow manure into liquid fertilizers and methane gas that fuels electrical power. The construction site (bottom) shows a newly cut building pad that caused soil erosion and gullies next to the site.

To continue to have clean, good-quality water for our own use and for use by the other organisms living on our planet, humans have had to take action. We have come up with new methods for obtaining naturally clean water and for cleaning the water we have contaminated. We have dug (then later drilled) wells to obtain water stored beneath the surface, built dams and aqueducts to trap and transport water from rivers and lakes, and engineered processes and machines to trap and remove contaminants before they get into the environment. Humans have successfully engineered solutions to control water, but it has not kept pace with the impact of land use.

Monitoring Earth's Water

Even though water continually cycles between land, ocean, and atmosphere, monitoring water quality is a fairly straightforward process. This is accomplished by collecting samples at key locations over time. The U.S. government, as well as many state governments, set limits for allowable levels of contaminants. Some of these contaminants are shown in the table below.

Some Common Contaminants

CONTAMINANT	POTENTIAL HEALTH EFFECTS	SOURCES
Aluminum	Kidney damage	Rock and soil runoff
Glyphosate (weed killer)	Kidney problems; reproductive difficulties	Runoff from herbicide use
Lindane	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Mercury	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate	Infants can have symptoms including shortness of breath, blue-baby syndrome, and death; major cause of algal blooms, which can lower dissolved oxygen and cause dead zones	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Turbidity	Associated with higher levels of disease-causing microorganisms such as viruses, parasites, and bacteria that can cause symptoms such as nausea, cramps, and diarrhea	Soil runoff
Solvents, (such as trichloro-ethylene, vinyl chloride, and xylenes)	Liver problems; nervous system damage; increased risk of cancer	Discharge from chemical factories; metal cleaning sites; petroleum manufacturing; leaching from PVC pipes

Monitoring effects on the water cycle is not as straightforward as measuring water quality. This is in large part due to the long time frame required. The water cycle is a complex process. Natural fluctuations in water levels, sizes of glaciers and ice sheets, global temperature, and other phenomena need to be monitored. Because of this, it often takes many years to notice any changes in overall trends, such as global warming.

Mitigating Human Impacts on Water

Mitigation of human impacts on water quality is even more challenging than monitoring. Once contaminants enter the water supply, it is difficult to remove them. They are constantly moving as they travel through the water cycle. The most effective method to improve water quality is to stop using all potentially harmful chemicals. This, however, is unrealistic. Many chemicals that can become contaminants are also useful. For example, nitrates help crops grow faster and produce more food. The next most effective method for reducing contamination is to limit the amount of contaminants that enter the water supply. This can be done by reducing the amount of chemicals used to the bare minimum needed. The wastewater and runoff should

A municipal water treatment plant treats millions of gallons of water each day.

be thoroughly treated so contaminants are removed before the water goes back into the environment. Big spills can usually be discovered and cleaned up, but smaller everyday spills, such as a small oil leak from your car, often end up getting into the water supply. Another way to limit contamination is by choosing appropriate land areas for development and by designing buildings to minimize erosion and runoff.

Mitigating human impact on the water cycle involves large-scale societal changes. Efforts to do this include reducing water use and limiting the amount of contaminants, including greenhouse gases, that are released into the water and air. This can best be done by making some sacrifices to reduce our consumption of resources and by investing in cleaner technologies that create less pollution.

ANALYSIS

1. Describe an effect on the environment that could be caused by
   a. changes to the water cycle.
   b. addition of contaminants to the water supply.
2. Describe the major human impacts on
   a. the water cycle.
   b. water quality.
3. Draw a diagram of the water cycle that includes
   - 6 places where water can be found.
   - 6 or more arrows showing how water moves.
   - 3 labels where changes in states of matter can be found.
   - 1 representation of sunlight.
   - 1 or more representations of gravity.
   - 3 representations of how human behavior causes changes in the cycle.
4. Why is it challenging to monitor contaminants as they travel through the water cycle?
5. What are some ways humans are attempting to mitigate their impact on Earth's water?

6. Do you think humans have more of a positive or a negative impact on Earth's water? Support your argument with evidence.

EXTENSION

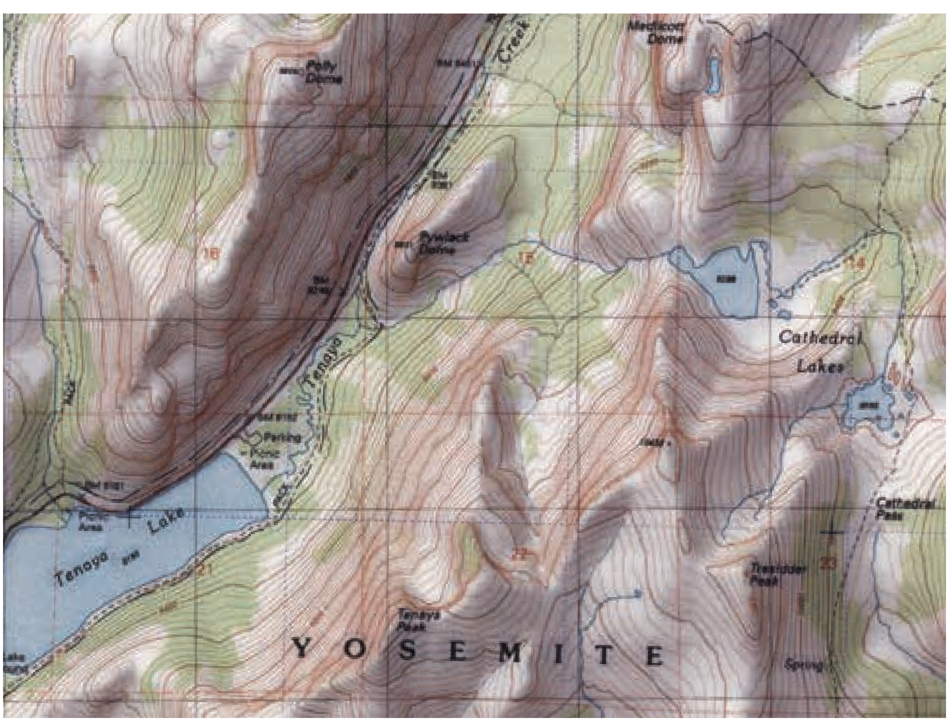
Research the water quality in your community. Investigate the major contaminants, their sources, and what mitigation strategies have been used to reduce the contaminants.

10 Making Topographic Maps

INVESTIGATION

EVERYWHERE ON EARTH, water moving within the water cycle shapes the land. The collection of landforms in an area is called its **topography** (tuh-PAH-gruh-fee). Topography includes features such as a hill, river, delta, cliff, and beach. On typical maps, landforms can be shown with labels, but the information about the landform is limited. A **topographic** (toe-pah-GRAF-ik) **map** is a flat, two-dimensional map that is a model of the actual three-dimensional shape of a land surface.

Topographic maps can be confusing for those not familiar with them. Topographic maps are covered with a series of **contour lines**, each representing a specific elevation (el-a-VAY-shun) relative to sea level. Adjacent lines always differ from each other by the same amount of elevation. This is called contour interval. For example, if one line on a topographic map represents an elevation of 100 m, the lines on either side of it might represent elevations of 90 m and 110 m. The contour interval here is 10 m. This activity will help you understand how contour lines represent the shape of the land.



In addition to its contour lines that represent elevation, this topographic map also shows roads, trails, creeks, and lakes.

GUIDING QUESTION

How does a topographic map show landforms?

MATERIALS

For each group of four students

- 1 landform model
- 1 transparent plastic lid
- 1 dry erase marker
- 1 bottle of blue food coloring
- 1 large container of water

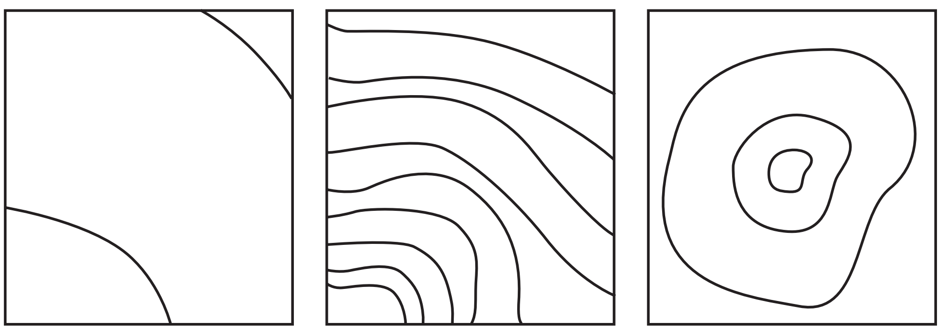
PROCEDURE

1. Place 20 drops of food coloring in your container of water.
2. Place the lid on the box of the landform model, and then stand up and look down through the lid from directly above the landform. Use the marker to draw a dashed line on the lid that outlines the outside edge of the landform.

   Hint: It may help to close one eye when you're viewing the box from above. Make sure to keep your head in one place while you're drawing the line.
3. Being careful not to smudge your line, remove the lid and fill the box with water until it reaches the first step on the side of the box.
4. Place the lid on the box and, looking down from above, use the marker to draw at least one line that shows everywhere the water touches the side of the landform.
5. Label any line you drew with a "1."
6. Remove the lid and add water until it reaches the next step.
7. Repeat Steps 4–5. Label the line(s) drawn with water filled to the second step with a "2."
8. Add water to the levels of the third, fourth, and fifth steps of the box, repeating Steps 4–5 each time. Label the lines "3," "4," and "5."
9. Watch carefully as you add just enough water to cover the top of the landform. Use your observations to place an "X" on the lid above the highest point.

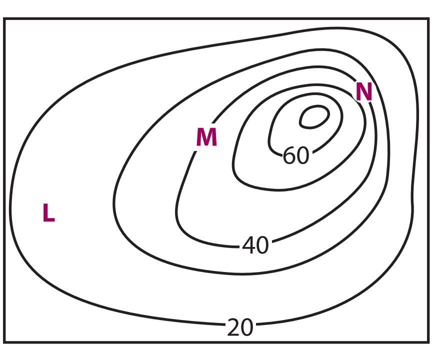
ANALYSIS

1. A contour interval is the change in elevation between adjacent lines. If the distance between each step in your landform model represents 25 m, what is
   a. the contour interval for your topographic map?
   b. an estimated height of the top of the hill?
2. Look at your topographic map.
   a. What does it show you about the land?
   b. What doesn't it show you about the land?
3. Each of the three topographic maps below was drawn with the same contour interval and scale.



x y z

   a. Describe the main difference between the contour lines in Map x and Map y.
   b. Based on your answer to 3a, how does the shape of the land shown in Map x compare with the shape of the land shown in Map y?
   c. What landform do the contour lines on Map z represent? *Hint*: There are two possibilities.
4. Look at the topographic map below, and answer the questions that follow.



a. What landform does the map represent?
b. At which of the locations (L, M, or N) marked on the map would you expect the most erosion to take place? Explain your reasoning.
c. At which of the locations (L, M, or N) marked on the map would you expect the most deposition to take place? Explain your reasoning.
d. At which of the locations (L, M, or N) marked on the map would you choose as the best building site? Explain your reasoning.

5. Create a fully labeled topographic map similar to the ones in item 4, and then describe what it shows. The map should show a long slope that has

- 10 horizontal contour lines.
- contour lines that are 20 m apart.
- a gentle slope on the top third of the diagram.
- a steep slope in the center of the diagram.
- a gentle slope in the bottom third of the diagram.

11 Boomtown's Topography

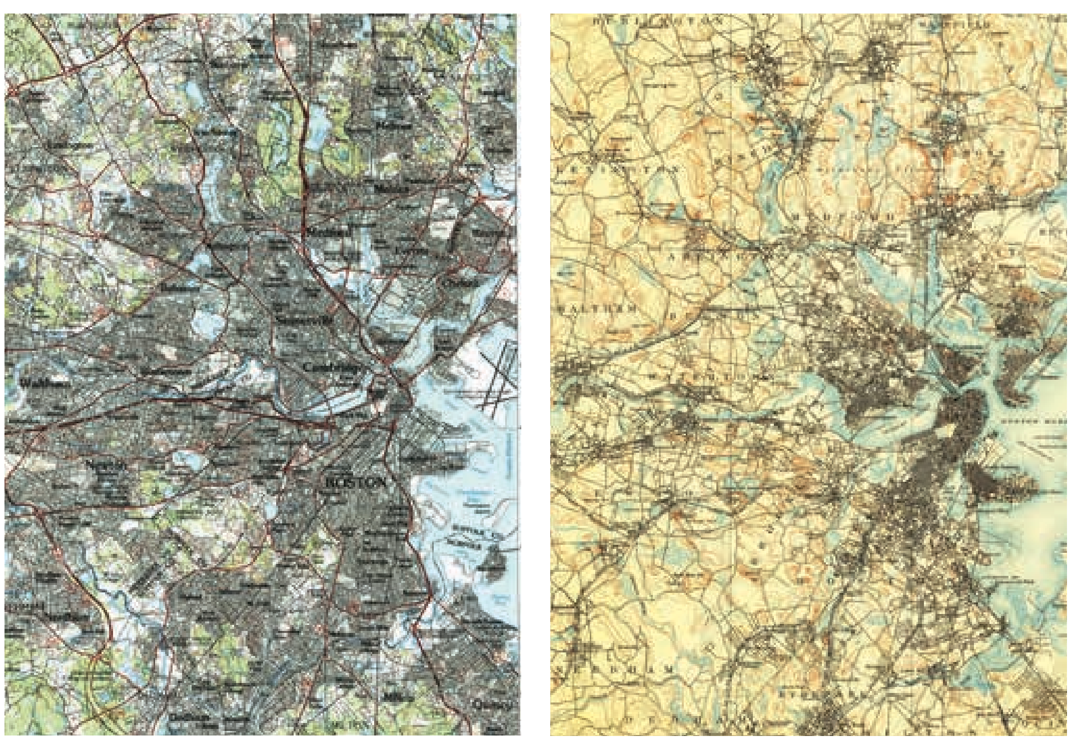
INVESTIGATION

BOOMTOWN HAS GROWN *quickly in the past 20 years. One hundred years ago, it was only a small town. One day Jayden was in the Boomtown Library, and he noticed that they had maps that show the topography of Boomtown at different times in its history. He decided to investigate how the land has changed over that time.*

Earth processes, including the movement of water in the water cycle, can cause landforms to change over time. Comparing an area's present-day topography with its topography in the past can provide evidence about past landform changes. Knowing this can help predict changes that might occur in that area in the future. An important part of evaluating a building site is determining what landform changes, if any, are likely to occur over time.

GUIDING QUESTION

How can topographic maps help you evaluate potential building sites?



Compare the street maps of Boston from 1989 (left) and 1893 (right). What evidence of changes to the land and water over time do you observe?

MATERIALS

For each pair of students

1 Student Sheet 11.1a, "Street Map of Boomtown Today"
1 Student Sheet 11.1b, "Topographic Map of Boomtown Today"
1 Student Sheet 11.2a, "Street Map of Boomtown 25 Years Ago"
1 Student Sheet 11.2b, "Topographic Map of Boomtown 25 Years Ago"
1 Student Sheet 11.3a, "Street Map of Boomtown 100 Years Ago"
1 Student Sheet 11.3b, "Topographic Map of Boomtown 100 Years Ago"

PROCEDURE

1. Layout the three sets of Student Sheets next to each other on the table. Compare them and make a list of
   - similarities between the kind of information shown on the street maps and the topographic maps.
   - differences between the kind of information shown on the street maps and topographic maps.
2. In your science notebook, make a table like the one below:

Comparisons of Boomtown Today with the Past

Location	*25 years ago*	*100 years ago*
Seaside Cliff		
Delta Wetlands		
Green Hill		

3. For each site, examine the maps and compare today's maps to those of the past. Record changes in the table that have occurred to
   - roads and buildings.
   - waterways.
   - landforms.
4. Compare the changes you noticed with the ones your partner observed. Record any new observations in your table.
5. Compare your observations with those of the other pair in your group of four. Discuss your findings, and add any new observations of the three building sites.

ANALYSIS

1. Compare the information provided by a street map with what is shown on a topographic map. Which map would be better to use for finding the
   a. quickest way to ride a bike to a friend's house? Explain why you chose this type of map.
   b. easiest route for hiking to the top of a high hill? Explain why you chose this type of map.
2. What major changes did you observe
   a. between 100 years ago and 25 years ago?
   b. between 25 years ago and today?
3. Have more changes occurred in the past 25 years than in the 75 years before that? Provide evidence to support your answer.
4. Look at the maps of the three locations in Boomtown.
   a. Which of the three locations shows the least change?
   b. Which of the three locations shows the most change?
   c. What caused these changes?

5. Describe what you think the cause was for the major changes you saw on the maps.
6. Do the maps indicate any potential stability problems in the future for building a school at any of the three possible locations? Explain the evidence that supports your answer.

12 Modeling Cliff Erosion

MODELING

Jayden visits his friend who lives on Seaside Cliff. As he walks toward the cliff to see the ocean, he notices some gullies. He thinks the gullies must have been caused by runoff that eroded the top edge of the cliff near the parking lot. He then remembers seeing topographic maps showing how the cliffs have eroded more rapidly in the past 25 years. When he looks out at the ocean, he thinks that those big powerful waves must also be causing erosion on the face of the cliff.

Water flowing down a slope due to gravity is not the only way water can cause erosion and deposition. For example, in a coastal area, ocean waves hitting the shore can move earth materials from one place to another. In this activity, you will use a model to investigate what happens when a large system of ocean waves hitting sea cliffs, such as those in Boomtown. You will then be given a set of engineering criteria and constraints to use as you build, test, and redesign erosion-control model structures to mitigate the effect of waves on sea cliffs.

Ocean waves eroded the cliff base of these houses until the support columns were revealed.

GUIDING QUESTION

How can we reduce the effects of ocean waves on coastal areas?

MATERIALS

For each group of four students

Parts A and B

1 plastic box with line
1 plastic cliffmaker
1 wavemaker holder (with slot)
1 wavemaker paddle
1 river model catch basin
1 graduated cup (30-mL)
1 spoon
1 plastic cup (9-ounce)
supply of moist sand
supply of water

Additional Materials for Part B

2 mesh sleeves of small rocks
9 building bricks

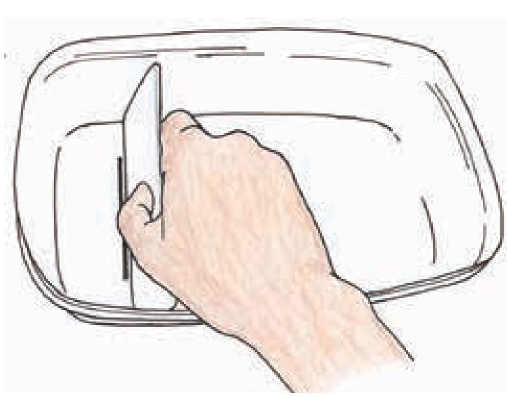
For each student

1 Student Sheet 12.1, "Evaluating Designs: Cliff Erosion"

PROCEDURE

Part A: Modeling Cliff Erosion

1. Place the plastic cliffmaker in the plastic box at the line marked on the box. Hold it so that it makes a vertical wall in the box, as shown below:



2. Use the 30-mL graduated cup to fill the smaller portion of the box with 150 mL of moist sand. Level the top of the sand with the spoon.
3. Slide the catch basin from the river model under the sand-filled end of the box. This will create a gentle slope.
4. While holding the cliffmaker in place, gently pour water into the edge of the box opposite the sand until it just touches the bottom of the cliffmaker, as shown below:

5. Complete the model cliff by carefully removing the cliffmaker. Do this by slowly lifting the wall straight up out of the box. Sketch the model cliff in your science notebook.
6. Place the wavemaker holder on the side opposite the model cliff. Insert the wavemaker paddle into the slot, as shown below:

7. At the rate of 1 wave per 3 s, move the wavemaker paddle back and forth along the bottom of the box 5 times. Sketch and record your observations in your science notebook. Don't forget to record what is happening at the bottom of the box.

8. Make 5 more waves, and record your observations in your science notebook. Make 2 more sets of 5 waves. Sketch and record your observations.

9. Summarize your observations by answering the following:
   - What happened to the cliff?
   - What happened at the bottom of the model?
   - What earth processes did you observe in action?

10. Use the cliffmaker to push the sand back up into the upper end of the box. Carefully drain out any remaining water in the box.

Part B: Mitigating Cliff Erosion

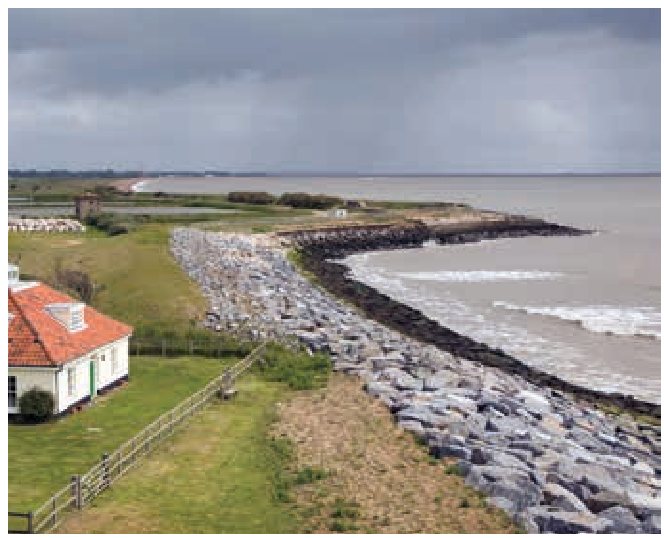
11. Read the following criteria and constraints for designing a system that will reduce erosion in the model. As a class, clarify or add any relevant criteria or constraints to the design challenge.

    Design Criteria

    The design must
    - cause less erosion to the cliff than if there was no erosion-control system in place.
    - have maximum effectiveness when subjected to 5 waves at the rate of 1 wave per 3 s.

    Design constraints

    The design is limited by using the materials provided.



The hard surfaces of the large rocks mitigate the erosion of the land between the house and the water.

12. Obtain the erosion-control materials from your teacher. Talk among your group about the different ways you could use the materials provided to prevent erosion along the cliff. Choose what you think is the best design to test using the cliff model.

13. Rebuild the cliff as in Steps 1–5. If the sand is too wet to form the cliff, mix a little dry sand into it until it is the right consistency. Once the sand cliff is packed so that it can stand on its own, carefully remove the cliffmaker.

14. Build and properly position your prototype erosion-control structure.
15. Gently pour water into the edge of the box opposite the sand until it just touches the bottom of your structure. Make a clearly labeled "before waves" sketch of the model cliff with your structure in place.
16. Repeat Steps 6–9, and make a clearly labeled "after waves" sketch of the model.
17. Discuss with your group how effective your structure was at reducing erosion. What were its strong points? What were its weak points?
18. Based on your results, work with your group to redesign your erosion-control structure to optimize erosion control.
19. Prepare a new cliff, and then repeat Steps 14–17.
20. Compare the effectiveness of your re-engineered structure with your original structure, and make suggestions for further improvements.
21. Follow your teacher's instructions for presenting your final design to the class. Complete Student Sheet 12.1, "Evaluating Designs: Cliff Erosion" to compare erosion-control designs.

ANALYSIS

1. In Part A, what did the waves do to the cliff model? Explain in terms of energy, erosion, and deposition.
2. Think about the different designs for reducing cliff erosion.
   a. Explain how they reduce erosion.
   b. Are there any drawbacks to building structures to protect cliffs? Explain your reasoning.
3. Do you think you could improve your cliff-erosion structure if you had
   a. more of the materials provided? Explain using evidence from your investigations.
   b. different materials than those provided? Explain using evidence from your investigations.

4. Imagine two identical cliffs, one next to an ocean and one far away from any water. Compare the erosion at these two locations if both locations receive the same amount of rainfall and
   a. both cliffs are made from the same type of rock. Explain your reasoning.
   b. the rocks on the inland cliffs are made of a softer type of rock than the coastal cliff. Explain your reasoning.
5. Imagine two identical cliffs, one with stores and a parking lot built close to its edge and the other undeveloped. Compare the erosion at these two locations if both receive the same amount of rainfall. Explain your reasoning.
6. What other design criteria or constraints do you think should apply for the building of the new school and fields on the cliff?
7. Consider a real city that wants to build a new school. The city is located in a hot, urban climate in an area prone to hurricanes.
   a. What additional criteria and constraints might the city have in building their new school?
   b. How could the additional criteria and constraints you described help ensure a successful building design?
   c. What determines which technology is used in the design?
   d. What are the consequences for the people and the environment in using natural resources for the building?

13 *Weathering, Erosion, and Deposition*

READING

ANY EARTH PROCESS that breaks down earth material, such as water eroding a hillside, is called a **destructive process**. Processes that build up earth material, such as the deposition of sediments in a delta, is called a **constructive process**. In both of these processes, energy transfer drives the motion and/or cycling of matter on Earth's surface. Both processes cause problems for builders and engineers. The potential effects of destructive and constructive processes need to be carefully evaluated when choosing a building site.

GUIDING QUESTION

What happens when earth processes move soil and rocks from one place to another?

PROCEDURE

1. Read the text below.
2. Follow your teacher's instructions for how to use the Stop to Think questions.

READING

Weathering

An important earth process that breaks down rocks into smaller pieces is called **weathering**. Over time, rocks crack, crumble, and are broken apart by water and wind. You have seen evidence of this phenomenon if you have ever observed cracked rocks or grains of sand on a beach. Water can dissolve chemicals in some rocks, creating small holes and cracks in the rocks. When water in the

The cracks in this boulder are due to the process of weathering.

holes and cracks of a rock freezes, the solid ice that forms can push the rock apart. Gravity causes loosened rocks to fall and roll, and this can break the rocks apart. Microscopic organisms, animals, and the roots of plants also help break down rocks.

Erosion

Weathering forms smaller sediments and soil that can be more easily moved by wind and water. Erosion happens when moving water or air carries away pieces of sediment. Cuts in the ground, called channels, form in areas where more material is removed. These channels often start as tiny scratches in Earth's surface. As time passes and more water flows through them, channels get bigger. Some even become huge canyons, such as the Grand Canyon. Erosion over long periods of time has created many features of Earth's landscape, such as rivers, hills, canyons, and caves. Large areas of snow and ice called glaciers also cause erosion. Glaciers move very slowly and as these massive chunks of ice move, they scrape and gouge the surface of land. Glaciers have helped form many valleys and lakes.

Glaciers caused these landforms in Yosemite National Park.

The projections from the roof and floor of this cave were formed when carbon dioxide evaporated from the cave.

STOP TO THINK 1

What are four agents that can break down and/or move earth material?

Erosion is often a slow, gradual process that changes the landscape over thousands of years. However, a single natural event, such as a flood, mudslide, or tsunami, can cause dramatic erosion in a matter of minutes. Shorelines have shifted and rivers have abruptly changed their courses as a result of these events. The rate of erosion depends not only on the speed and amount of water involved, but also on the earth material across which it flows. For example, most soil will erode quicker than most rocks. And some rocks, such as limestone, will erode more easily than other rocks, like granite. When certain chemicals, such as carbon dioxide and nitrogen oxides, dissolve in water, the water becomes an acid. This acid dissolves limestone, forming caves and sinkholes underground. Differences in materials can make a dramatic difference in how fast erosion takes place.

STOP TO THINK 2

What are some natural formations made by erosion?

The rock layers shown above are made of limestone and shale. Notice how the two kinds of rock erode differently.

Human Impacts on Erosion

Weathering and erosion are natural and continuous earth processes that have been going on for billions of years. It is part of Earth's natural cycle of energy and matter. Humans cannot stop or start these processes, but our activities can affect them, such as causing the extinction of organisms by depositing sediments loaded with nutrients into a water habitat. Activities like farming, animal grazing, mining, or building speed up the process. Building structures such as retaining walls and levees protect areas from erosion. Planting and maintaining vegetation help protect against erosion because roots help keep soil in place, and the plant parts that are above ground protect the soil from wind and rain. When forests are cut down or grasses and shrubs are removed, the bare soil is more easily washed and blown away. When vegetation is replaced by building materials, such as concrete, metal, and asphalt, less water soaks into the ground and more becomes runoff. Increased runoff often causes faster, and more, erosion.

In this suburban neighborhood, sediments were washed into the street by the rain because the soil was not protected during house construction.

On this farm, rains have damaged crops by eroding soil from one place and depositing it in another location.

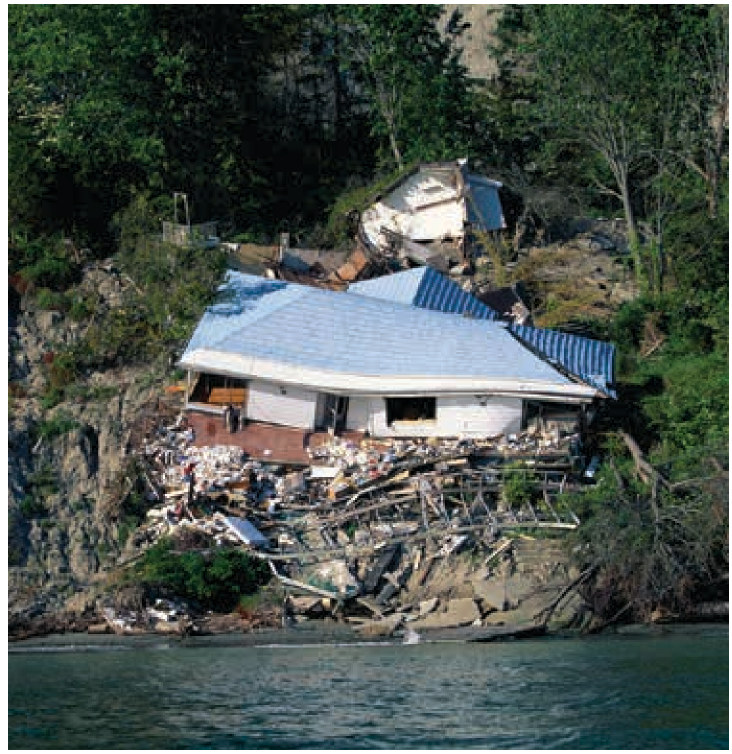
Erosion can cause damage to roads and buildings. A hillside that erodes over many years can cause structures built on it to crack, tilt, or even topple over. Erosion above a road can cause debris to cover the road. Erosion below a road can cause the road to collapse. Larger, faster erosion events can cause serious problems when land quickly collapses, as shown on the next page.

STOP TO THINK 3

What are some ways that people speed up the process of erosion?

Deposition

Deposition, the counterpart of erosion, is the adding of sediments to an area. When erosion carries sediments away from one place, the sediments are left, or deposited, somewhere else. Sediments are often deposited far away from their source. For example, sediments formed on a Canadian mountain peak can be carried thousands of miles to the Gulf of Mexico. A delta at the mouth of a river is an example of a landform formed by deposition.



This house was destroyed when the land under it collapsed.

The driving force for deposition is gravity, which pulls the sediments down and out of the water, air, or ice. Most deposition occurs when flowing water or wind slows down and is no longer powerful enough to overcome gravity and carry the sediments. Glaciers deposit sediments when they melt and get smaller. It is the natural process of deposition that lets sediments fill in rivers, lakes, wetlands, bays, and even parts of the ocean.

If deposition in an area continues for a very long time, the accumulated thickness of the sediments can reach thousands of meters. The pressure near the bottom of these immense piles of sediments due to gravity can compact the sediments back into solid rocks, such as sandstone.

Constructive earth processes build up a delta where this river meets a lake.

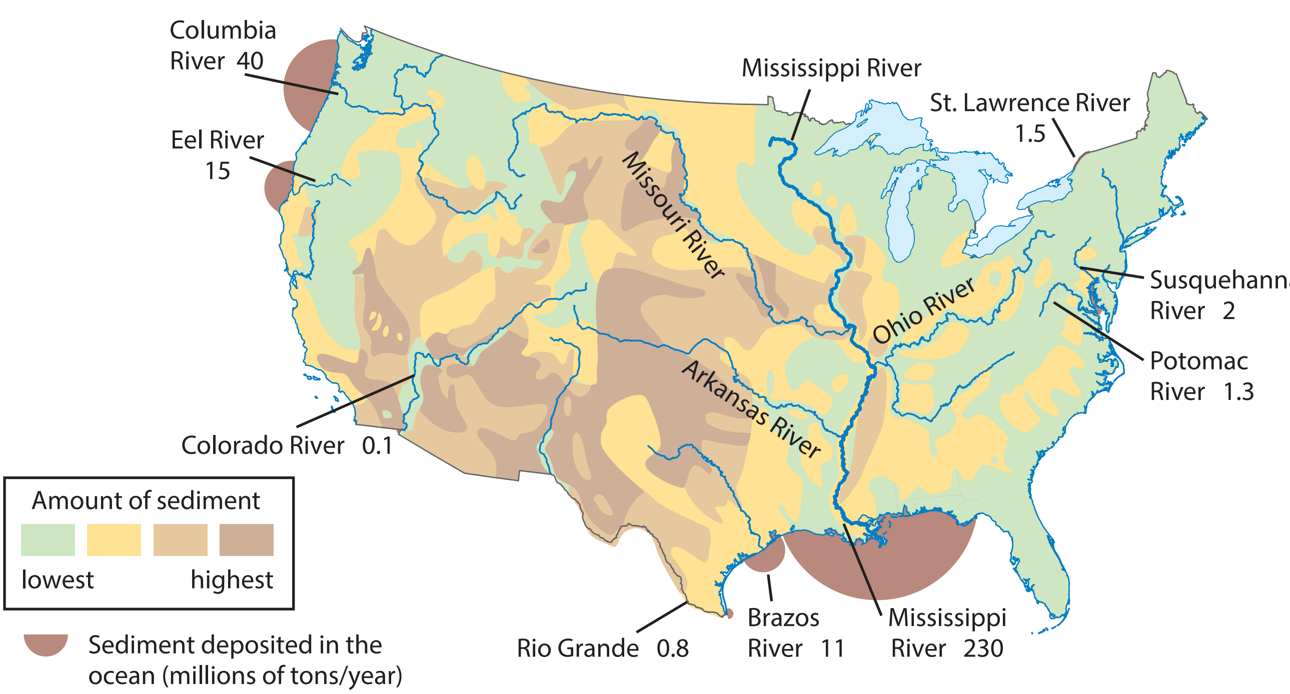
The processes of weathering, erosion, and deposition occur on the surface of Earth, often as a result of water movement. This surface water movement is part of the larger water cycle that moves water globally. The cycling of water through Earth's systems is driven by energy from the sun and the force of gravity.

STOP TO THINK 4

What is the driving force of erosion? of deposition? Explain

Deposition can be helpful. For example, deposited sediments add important nutrients to the soil. When a river floods, nutrient-rich sediments get deposited in the areas on either side of the riverbank. These areas, called floodplains, are often excellent for growing plants. Some of the best cropland is found on floodplains. Deposition can also change water-filled areas into usable land. The image below shows the amount of sediment at the mouths of rivers in different areas of the United States. Notice the large amount of sediment where the Mississippi River empties into the Gulf of Mexico.

Sediment Deposition in the United States



The size of each brown semicircle indicates the amount of sediment deposited by a river when it empties into the ocean. Colors on the land indicate how much eroded sediment is moved by rivers.

Sediments have filled up the opening of this drainage pipe.

Deposited sediments can also be harmful. Sediments can cover the habitat areas needed by fish and other animals. For humans, deposition in the wrong place can bury houses and roads, make the water too shallow for boats, and clog pipes that provide water to towns and cities. Perhaps one of the biggest impacts of deposition occurs when sediments contain an excess of chemical contaminants. These sediments can carry excess nutrients or toxic substances that come from runoff or that are already present in the soil. In time, this negatively impacts natural environments, which can lead to plant and animal extinctions.

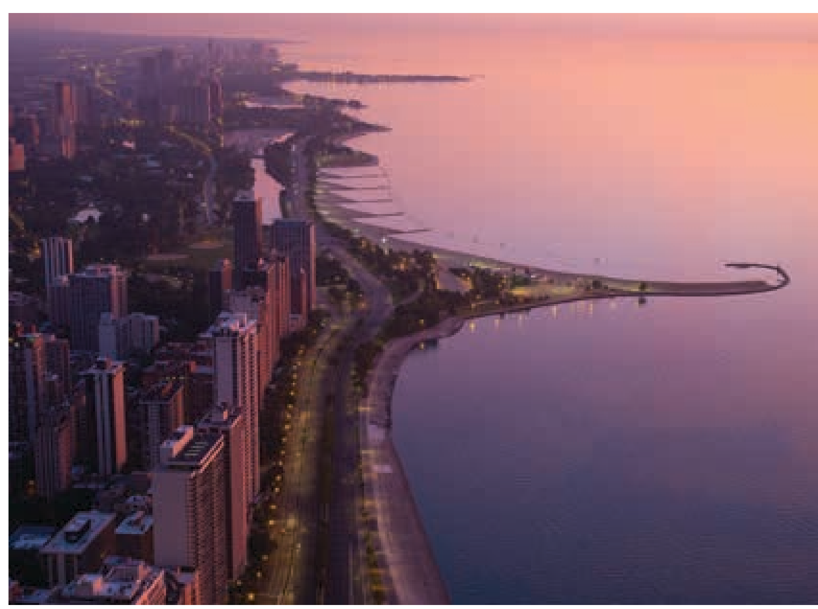
When human activity adds contaminants and accelerates erosion, it causes more deposits with higher levels of contaminants. An example of this is the increased formation and growth of dead zones near the mouths of rivers.

STOP TO THINK 5

Is the relationship between erosion and deposition causal or just correlational? Explain your answer.

Monitoring and Mitigating Human Impact

Erosion control on the shores of Lake Michigan, Chicago.



Cutting down the natural landscape for construction, farming, and livestock grazing are human activities that cause significant erosion and deposition. Some other activities such as mining and wildfires caused by humans are also sources of accelerated erosion. To prevent making the environmental problems worse, people can try to mitigate, or reduce, the effects of their activities.

Measuring and monitoring are used to determine whether mitigation efforts are working. Visual inspection is one approach to monitoring erosion. Regular observations are made on the location, type, and stability of soil and bedrock and on water movement. Measurements include the percentage of vegetation coverage in the area, which is often measured with overhead photographs or images. Because plants protect the ground from eroding, the higher the percentage of plant coverage, the less likely the soil will erode.

For deposition, monitoring is done by observation and by measuring the width, depth, or shape of the deposit. Other methods to monitor the area of deposition include photographs, GPS, and/or remote sensing. Total dissolved solids, turbidity, and species populations are also indicators of sediment load.

Generally, data need to be recorded over at least a 3-year period before conclusions can be made about the extent of erosion and deposition. Once enough data have been collected, computer models can analyze the data to predict patterns and rates of future erosion and deposition. Computer analysis and modeling are especially useful for investigating phenomena that can only be observed at very large or small scales.

STOP TO THINK 6

Why is it important to monitor changes in erosion and deposition?

There are many ways to minimize human-induced erosion and deposition. The most effective mitigation depends on the topography of the site. The lists below summarize some common mitigation strategies:

For hillside locations where accelerated erosion and runoff are major concerns, strategies include

- maximizing vegetation and ground covers.
- building terraces.
- keeping soils high in organic content by adding mulch.
- minimizing the building area to reduce additional runoff.

For shoreline locations where erosion from wave action is a major concern, strategies include

- installing tall grasses and aquatic vegetation to create a buffering marsh at the shoreline.

- adding vegetation on dunes.
- installation of appropriately engineered structures.

At delta locations where accelerated deposition and wetland disruption is a major concern, strategies include

- reducing erosion and runoff upstream.
- increasing the area and health of the wetland.
- restoring wetlands that were previously filled in.
- leaving plenty of space for land formation.

A small organic farm uses terraces to reduce soil erosion.

With increased awareness of the geological processes at work, people can design and engineer structures with the goal of minimizing the negative environmental and biological impacts.

ANALYSIS

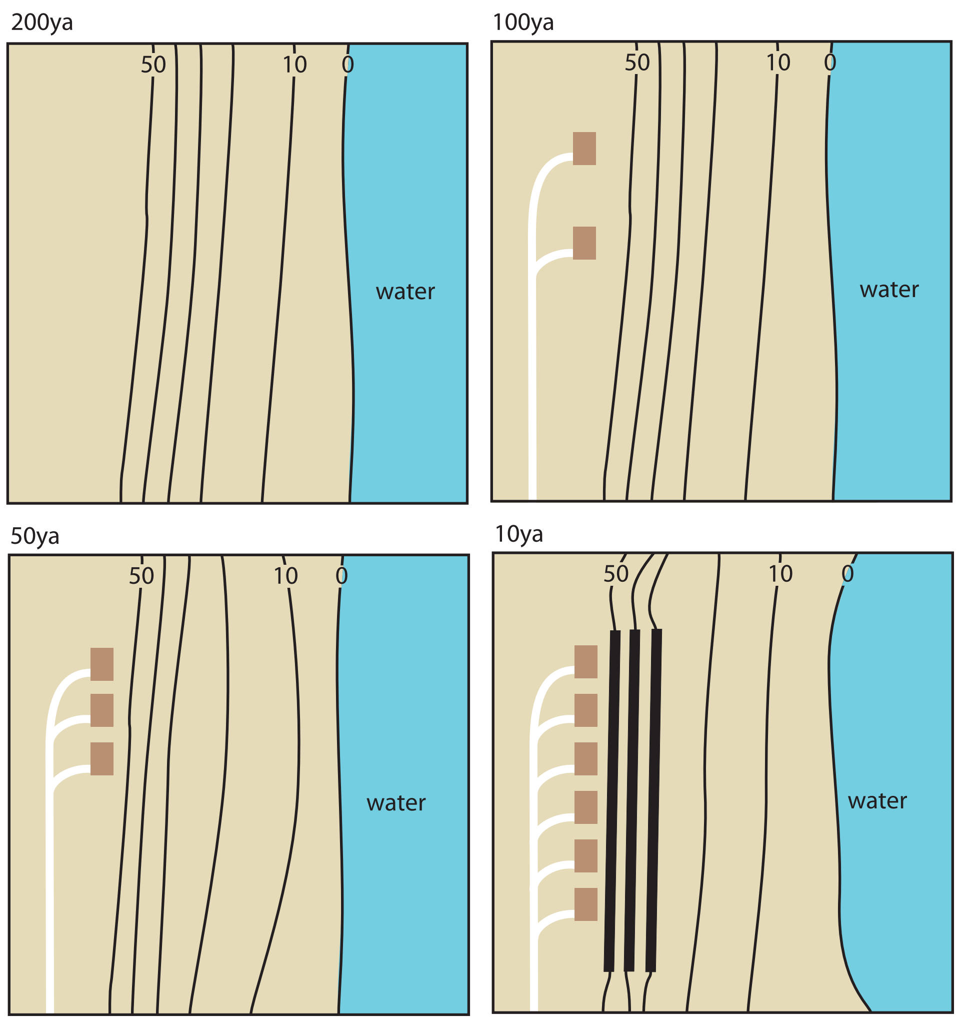
1. Why is weathering important to the process of erosion?
2. How does erosion lead to deposition?
   a. Explain why these two changes are related.
   b. Model how erosion and deposition work in a drawing.
   c. Predict what would happen if erosion increased in your model.
3. Prepare a concept map for weathering, erosion, and deposition. Be sure to use the following terms, but you may also add your own:

earth processes	population	engineering
erosion	sediments	gravity
deposition	vegetation	human impact
water sediments	water	mitigate
delta	weathering	monitor
nutrients	wetlands	pollution

4. Look back at the topographical maps on the Student Sheets from the activity "Boomtown's Topography." Choose one major topographic change in Boomtown. Describe the change and the earth process(es) that may have caused the change.

5. At which of the three building sites—Delta Wetlands, Green Hill, and Seaside Cliff—would you expect
   a. erosion to have the most effect on the land?
   b. deposition to have the most effect on the land?

6. Look at the following map of a cliff 10, 50, 100, and 200 years ago.



a. Describe what processes have changed the shape of the cliff and explain how.

b. What human activities have likely had an impact on the cliff?

c. What mitigation was attempted on the cliff?

d. What do you predict the cliff will look like in another 100 years?

EXTENSION

Earth processes such as weathering, erosion, and deposition help make the landforms that are all around you. Some landforms are formed quickly; others take millions of years. Visit the *SEPUP Third Edition Land, Water, and Human Interactions* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* to find more information about specific landforms found in the United States.

14 Building on the Mississippi

ROLE PLAY

After school one day, Jayden heard a talk show about the Mississippi River. As he listened, he was surprised that it did not mention the problem of nutrient runoff and the Gulf of Mexico Dead Zone. Instead, the show focused on the interactions between people and the processes of erosion and deposition in the river. When it was over, he wondered how the problems in and around the Mississippi River relate to the Boomtown River.

The Mississippi River is 3,730 km (2,320 miles) long and runs from north to south. The river and its tributaries either border or move through 10 states and drain water from 31 states. The river has been a historically important route for trade and travel, which has resulted in the growth of cities and ports along the riverbanks. Since the beginning of the 20th century, massive engineering works, such as levees, locks and dams, were built along the river. Many of these structures impact the Mississippi Delta, where the river drops over 300 metric tons of sediment per year over an area of 3 million km^2.

The Port of New Orleans, located on the Mississippi River, is the sixth largest port in the United States.

GUIDING QUESTION

What has been the human impact on geological processes of the Mississippi River Delta?

MATERIALS

For each student

1 Student Sheet 14.1, "Intra-act: Building on the Mississippi"

PROCEDURE

1. Assign one of the following roles to each person in your group:
   - Teresa Corelli, interviewer for the Student Science Hour
   - Natalie Ludlow, ecologist
   - Dr. K. C. Sandoval, geology professor at Boomtown University
   - Ethan Porter, engineer from Builders, Inc.
2. In your group, read the role play aloud. As you read, think about what each character is saying.

Locator Map: Mississippi River and New Orleans

3. Discuss what you think the people of New Orleans can do about the problems they face due to their location.
4. Mark whether you agree or disagree with the statements on Student Sheet 14.1, "Intra-act: Building on the Mississippi." Predict what you think other members of your group will say.
5. Discuss the statements with your group. Have each person share their opinion about each statement and explain why they agreed or disagreed.

NEW ORLEANS: AN UNCERTAIN FUTURE

Teresa: Welcome to the Student Science Hour. Today we have brought together a panel of experts who will help us explore some of the challenges facing the city of New Orleans because of its location on the Mississippi. Panelists, please introduce yourselves and describe your background.

Dr. Sandoval: Hello, my name is K. C. Sandoval. I am a geology professor at Boomtown University. I study earth processes, such as erosion and deposition, in the Mississippi River Delta.

Ms. Ludlow: My name is Natalie Ludlow. I studied ecology when I was in college. Ecology looks at the relationships between organisms (including humans) and their environment. I use my ecology background to help politicians preserve the environment for the future.

Mr. Porter: And I'm Ethan Porter. I'm an engineer for a large construction company. My company works with the cities along the Mississippi River, building many of the large buildings, roads, and bridges in the area. My expertise is in flood control and in constructing safe structures on soft, wet ground.

Teresa: I'm glad that you could take the time to join us today. Now let's talk about New Orleans and the Mississippi. Dr. Sandoval, I understand that even before such disasters as Hurricane Katrina, which hit New Orleans in 2005, many people knew that the city was in danger.

Dr. Sandoval: Yes, that's right. Its location on the river puts it at great risk. Over thousands of years, sediments built up at the Gulf of Mexico until they rose slightly above the level of the water. New Orleans was built on the loose soil of the delta. The powerful Mississippi River continues to carve the land and deposit over 300 metric tons of sediment per year as it flows downhill. New Orleans is, essentially, in its way.

Teresa: Mr. Porter, why was the city built on such an unstable place?

Mr. Porter: New Orleans was built on the banks of the Mississippi River because the river was used to ship products between the central United States and the Gulf of Mexico. It has not always been located below sea level. Until 100 years ago, construction was limited to a more stable area on the naturally higher ground along the river. Much of the rest of the delta at that time was a marshy floodplain that was wet and frequently flooded.

Teresa: How can parts of New Orleans be located below sea level but not be under water?

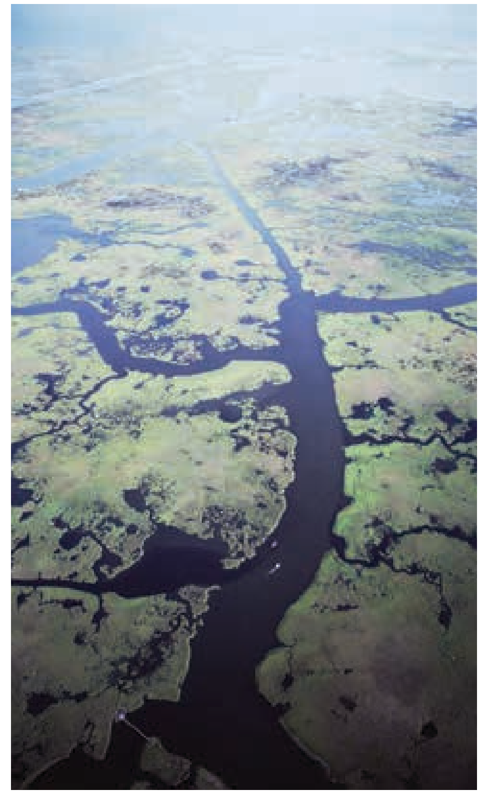
Mr. Porter: As the population in New Orleans grew and the city expanded, a system made up of levees, canals, and pumps was built to control the water. This system was built to hold back the river and drain the surrounding marsh, so New Orleans could grow. Because of this engineering, parts of the city were built 1–6 m below sea level. The system keeps the land dry by controlling the path of the Mississippi and by removing extra water.

After Hurricane Katrina passed through New Orleans in 2005, flood waters caused even more destruction and forced a complete evacuation of the city.

Teresa: Is that why Hurricane Katrina caused such a severe flood?

Mr. Porter: That is part of it. The levees that held the water back and the pumps used to remove water failed in the storm, partially due to flawed engineering and partially because Katrina was stronger than the "100-year storm" for which the system was designed. Water quickly flooded the city and destroyed houses, roads, and the pump system itself.

Teresa: Ms. Ludlow, can you tell us how building a city on the delta can affect the environment?



Part of the Mississippi Delta seen from the air.

Ms. Ludlow: When New Orleans expanded, the surrounding marshy wetland was drained to provide more land for the city. It may be good for the city in the short term, but removing a wetland can be a disaster for the environment. It damages plants and animals that can only live in that kind of environment, including many fish, shellfish, and birds. Wetlands also buffer the effects of flooding by absorbing large amounts of water before it hits the land. Also important is that the marshy environment filters and cleans some toxins in the water. By removing the wetlands, we increase pollution in addition to adding to the risk of flooding.

Teresa: Dr. Sandoval, I understand that the levee system has been rebuilt to better protect New Orleans in the event of another hurricane. Isn't this the end to the problems the city will face in the future?

Dr. Sandoval: There is no doubt the new water control system is far superior to the old one in terms of protecting residents from another storm. However, there are additional problems that are the result of efforts to control the Mississippi River.

Teresa: You mean there is more to the story than just holding the water back from the city?

Dr. Sandoval: That's right. The natural processes in the area are disrupted by the city. This is because the sediments that would usually be deposited in the New Orleans area are not allowed to be deposited there. Instead, the river water is forced through a 2,000-km man-made river channel that carries the sediments farther downstream. They are deposited beyond the natural mouth of the river. The land in the New Orleans area is not built back up with fresh sediment deposits.

Teresa: Is this related to the sinking land in New Orleans?

Dr. Sandoval: Absolutely. The city has been sinking for quite a while. The land below the city compresses as the water is pumped away, which causes it to slowly sink. Even before the flood, it was not uncommon to see large gaps and cracks under buildings in New Orleans.

Teresa: Mr. Porter, is the water control system in New Orleans making the delta smaller?

Mr. Porter: Yes, it is. An unfortunate result of the water control system that moves water away from the city is that it prevents the water from depositing sediments. It's successful in keeping the city dry, but Dr. Sandoval is right in that controlling the river flow disrupts the natural balance of erosion and deposition in the area. All of the sediments are sent downstream to another location, while erosion continues to wash away the delta. It has also resulted in the land sinking in the city.

Teresa: Ms. Ludlow, is the area near New Orleans the only place where the Mississippi Delta is sinking?

Ms. Ludlow: No, the entire southern part of Louisiana is losing wetlands at an accelerated rate. It is not just due to the human impact from New Orleans but in other areas as well, such as parts of the delta that have been drained for agriculture. As a result, the delta is sinking and being washed away faster than it is being replaced. These wetlands took thousands of years to develop, but at this rate, this crucial habitat will be gone in about 200 years. Monitoring species in the delta over time tells us that many species in the Gulf are in danger of extinction as a result of the wetland loss. This problem was only made worse by an environmental disaster in 2010, when an offshore oil rig exploded and spilled more than 100 million gallons of crude oil into the northern Gulf of Mexico, which killed marsh plants and accelerated wetland erosion.

Teresa: Dr. Sandoval, I heard that the Mississippi River is trying to change its course. Is this true?

Dr. Sandoval: Yes, that is true. Over time, the channel of any river will change as the processes of erosion and deposition continue to cycle matter around Earth. The Mississippi River is no exception. For the past 50 years, the river has been trying to travel a shorter path to the sea. This would take it away from the city of New Orleans.

Teresa: Dr. Porter, it seems like letting the Mississippi River change its channel would reduce the risk to the people of New Orleans. Isn't it a good idea to let nature win this battle?

Mr. Porter: You're right that a change in the river channel would reduce the risk of flooding in the city of New Orleans. But it would destroy homes, roads, and other structures as it created its new channel. It would also be the end of the port of New Orleans. The economic impact of closing this port is tremendous, since it is one of the largest in the United States.

The powerful 17th Street Canal pumping station was built after Hurricane Katrina.

Teresa: I have one last question for each of you. What do you think should be done to return the health of the lower Mississippi while respecting the needs of those who live there?

Ms. Ludlow: I believe we should continue to find ways to restore the wetlands habitat and better balance the rate of land loss. Not only will this help protect the wildlife, but it will also protect the built-up areas from the next storm. One solution I support is being done in Nashville after massive floods along the Cumberland River. There, the government has a buyout program for houses near the river. Houses damaged in the flood are bought, torn down, and the land is converted back to a more natural park space.

Mr. Porter: We must continue to focus on maintaining the safety of the large population of New Orleans. We have the technology to protect ourselves from even the worst disasters. It is a question of maintaining what has been built to keep people safe. I believe that the answer is to do a better job of controlling the water in the future through engineering. We have so much invested in this state-of-the-art system that it would be a shame to waste it.

Dr. Sandoval: Having studied the effects of natural processes over long time periods, I do not believe that controlling the river is good for the people of New Orleans in the long run. I believe that we should allow the river to change its course and that people should learn to work around nature instead of bending nature to our needs. In the end, I think that nature will win anyway.

Teresa: Unfortunately, we have run out of time for the Student Science Hour. Thank you all for joining us today.

ANALYSIS

1. Name three problems that the city of New Orleans faces as a result of its location on the banks of the Mississippi River.
2. How are the phenomena of erosion and deposition related to the problems that New Orleans has experienced?
3. How has the channeling of the Mississippi contributed to the dead zone?

4. Imagine you are given the money to build a profitable business in New Orleans, but the offer was not good anywhere else. Would you build the business? Describe the evidence you used to make your decision and the trade-offs of your choice.
5. Based on the evidence presented in this activity and previous ones, which geological processes along the Mississippi
   a. changed the land's surface features? Identify the process(es) and the evidence.
   b. worked over millions of years? Identify the process(es) and the evidence.
   c. work over a short period of time? Identify the process(es) and the evidence.
   d. will continue in the future?
   e. can be observed in a model? Explain how.
6. Compare the situation of the Mississippi River in New Orleans to the Boomtown River in Boomtown.
   a. List the similarities.
   b. List the differences.
7. How has your understanding of building on the Mississippi influenced your thinking about what site you select for the school and fields in Boomtown?

EXTENSION

Investigate various careers in earth science. Start by visiting the *SEPUP Third Edition Land, Water, and Human Interactions* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition*, and go to the career page.

15 *Building in Boomtown*

INVESTIGATION

IT IS TIME for the Boomtown City Council to decide where to build the new school and fields. There are many things to consider—the cost, the current and future needs of the community, citizen opinions, and the impact on the local geology and wildlife. The Council has committed to choosing a site that will have the smallest environmental impact on the nearby land and water. Each site will carefully be considered before one is chosen to be the site of the building design.

GUIDING QUESTION

Which site is the best choice for the school and fields?

MATERIALS

For each student

1 Student Sheet 15.1, "Evidence for the Geologist's Report"
1 Student Sheet 15.2, "Discussion Web: Our Building Site"
Student Sheets, observations, and notes from previous activities

PROCEDURE

Part A: Compare the Three Sites

1. Read the Green Hill Geologist's Report on the next page.
2. Assume the role of a geologist. With your group, review the report by identifying the following information:
   - the general and geologic description of the site
   - the topographical changes at the site that have happened over time and an explanation of the processes that caused the changes
   - the ways in which geological processes at the site may have contributed to the water-quality changes in Boomtown that have happened over time
   - the potential geologic challenges for construction
3. Write a report with a partner on one of the two remaining sites. To prepare for writing your report, do each of the following steps with your partner:
   a. Gather information about the geology and water quality at the Delta Wetlands and/or Seaside Cliff. Use what you have learned from other activities in the unit.
   b. Complete Student Sheet 15.1, "Evidence for the Geologist's Report," by filling in the columns for your location(s). As an example, the Green Hill column is filled in already.
4. Share your report with the other two members of your group and then with the class.

Green Hill Geologist's Report

Site Description

Green Hill is a smooth hill located next to the Boomtown River in the western part of Boomtown. The east and south sides are covered with roads and homes that were built 20 years ago. There are clusters of exposed houses with large lawns. Green Hill is 150 m high at its peak. The hill is steeper on the west and south sides of the peak and has a gentler slope on the east and north sides. Building on the hill would mean moving a lot of earth and flattening the area to make fields.

Topographical Changes

Erosion from rain is the main earth process that has changed Green Hill over the years. The topographic maps of Boomtown show that the hill has been mostly stable over the past 100 years, except for the area with houses. On that slope of the hill, there has been more erosion in the 20 years since the houses and roads were built. Green Hill is made up of a soil that is firmer than the Delta Wetlands but not as hard as that at Seaside Cliff.

Water Quality

The sediments removed from Green Hill are carried down the Boomtown River and deposited in the Delta Wetlands. Since there are many large lawns on the hill, the sediments carry fertilizers to the delta. Also, farther uphill behind Green Hill are farms, so some agricultural runoff is likely to be on the hill and carried into the water.

Building Challenges

The biggest potential geologic problem at Green Hill is erosion due to more building. Although the hill is eroded by rain instead of powerful ocean waves, the composition of the hill is less resistant to erosion than the Seaside Cliffs. Erosion can be a problem because water will stream around buildings, roads, and lots that cannot absorb water. The school needs a lot of parking so a big lot could accelerate erosion and runoff. Another big challenge is preventing more nutrient runoff when adding large sports fields that must be maintained with fertilizers. This could mean loss of soil and soil fertility on the hill and excess soil and nutrients farther downstream at the wetlands. Lastly, the large size of the site will significantly impact the trees, plants, and animals due to removal of natural habitat.

Part B: Choose a Site

5. Assume the role of a community member. Review the City Council Report for each of the three sites, below.
6. With your group, use the Geologist's Reports and the City Council Report to choose the location you would like to put the school and fields.
7. With your group, complete Student Sheet 15.2, "Discussion Web: Our Building Site." This will help you identify the evidence you used, and the advantages and disadvantages of your chosen location.

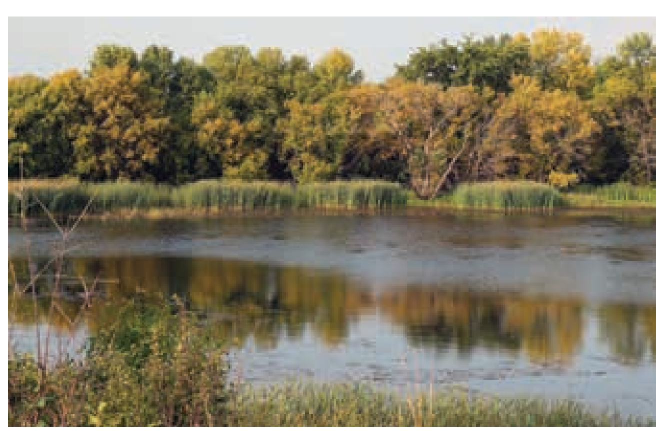
   Remember to listen to and consider the ideas of the other members of your group. If you disagree with others in your group, explain why you disagree.

City Council Report

Green Hill

People who already own houses on the hill are concerned about the new buildings. Some are upset that the habitat of the animals on the hill will be disturbed and that some species will be prevented from moving between areas. Others think that large buildings and fields will make the area too crowded. The expected traffic for a school would increase on the small neighborhood streets. The Green Hill Neighborhood Organization is sending around a petition trying to block any new buildings on the hill. People in town are concerned that the water running off the hill could cause flooding or landslides that would damage their own houses and affect the neighborhoods below the hill.

Delta Wetlands



The city next to Boomtown filled in a wetland area 10 years ago and has not yet experienced any disasters, such as flooding. If Boomtown decides to fill in the wetlands, the plans must be evaluated by the Wetlands Protection Agency in order to determine the impact on the habitat. Their evaluation will take at least 12 months. It is likely that Boomtown will be required to preserve part of the wetlands. The Boomtown Wetland Preservation Society is campaigning against any kind of building on the delta of the Boomtown River. They claim the wetland is a unique habitat for shellfish, fish, and birds who cannot survive if the wetlands are destroyed.

Seaside Cliff

Some homes built on cliffs in other towns have been damaged when severe erosion has caused the cliffs to collapse. Because of this, insuring any new buildings at Seaside Cliff will cost twice as much as in other areas. The school would have great access to the ocean, though, and there has been interest in a marine science program at the school. People from Boomtown have expressed concern that the school and fields will take away from the natural environment of the beach, since it will be so close to the water. The beachgoers of Boomtown are also worried that any engineered erosion-prevention structures put in place will have negative effects on the coastline. There are also concerns about weakening the soil on the cliff by removing plants and vegetation to build on it.

ANALYSIS

1. What location did you choose for Boomtown to build its new school and fields? Describe the evidence that you used from the Geologist's Reports and the City Council Report to make your decision. Explain how you weighed the advantages and disadvantages of each location and why you did not make another choice.

2. Look in your science notebook, and review how you answered Analysis item 3 in the activity "Where Should We Build?"

   a. Have you changed your mind since then?

   b. What new information did you use to make your decision this time?

16 Building Site Plan

DESIGN

NOW THAT A site has been selected, the City Council is requesting builders and architects to submit designs for approval. In addition to the building design, they are required to develop a detailed plan for how they will mitigate the human impact on the environment. Also required is a plan for monitoring the land and water in Boomtown so they can respond to changes in the future.

In this activity, you will play the role of a builder and present your plans for the school and fields at one of the sites. You need to make sure that the process of building, using, and maintaining the new school doesn't accelerate soil erosion, increase nutrient runoff, or reduce the water quality of Boomtown River. Then you will have an opportunity to compare competing designs at each site and determine which ones meet the criteria and constraints of the problem.

An architectural drawing of a new school site

MATERIALS

For each group of four students

1 Student Sheet 16.1, "Building Ideas"
1 piece of chart paper
ruler
colored pens/pencils
graph paper

For each student

1 completed Student Sheet 15.1, "Evidence for the Geologist's Report"
1 completed set of Geologist's Reports from the activity "Building in Boomtown"
1 Student Sheet 16.2, "Evaluating Designs: Building Site Plan"
Boomtown street and topographic maps

GUIDING QUESTION

How can you design the new school to mitigate the human impact on the environment?

PROCEDURE

1. Read the following design criteria and constraints for the building project. As a class, clarify or add any relevant criteria or constraints to the design challenge.

   Design Criteria

   The design must

   - minimize potential environmental impacts.
   - monitor erosion, deposition, runoff, and river water quality, with a minimum of four measurements per year.
   - include a minimum of one sports field, one building containing 30 classrooms, and parking for 100 cars.

   Design Constraints

   The design

   - is limited to one of the three sites under consideration.
   - is limited to a total building size no larger than 100,000 square feet.
   - may have no more than two additional features added to the basic project.

2. With your group, brainstorm and come up with a list of four preliminary ideas for the building and fields. List them on Student Sheet 16.1, "Building Ideas."
3. With your group, identify at least two ways to measure with indicators and two ways to mitigate the following impacts for each preliminary building idea. Record them on Student Sheet 16.1.
   - accelerated erosion
   - nutrient runoff
   - displaced sediment deposits
   - reduced water quality
4. Discuss the four design options with your group, and come up with one design you all like best. It could be one of the four preliminary designs or a new one that combines the best features of the preliminary designs.
5. Prepare a report and poster that shows your building plans. Be sure your presentation will appeal to a geologist, an engineer, an ecologist, and a City Council member. Your poster should include the following:
   - a sketch of the site, including the size and location of buildings, playing fields, parking lots, and structures
   - design elements for mitigating the impacts identified in Step 3.
   - a monitoring plan for water quality, erosion, and runoff that includes
     - a description of each indicator and why it was chosen.
     - what the indicator shows. Describe any causal relationships related to the measurement.
     - when and where samples will be taken.
     - an action plan in case monitoring indicates a problem.
     - uses and limitations of technology for monitoring indicators at the site.
     - approximate annual cost to run monitoring project (assume $200 per sample).
6. Present your building plan to the class.

7. As a class, evaluate the designs using Student Sheet 16.2, "Evaluating Designs: Building Site Plan." Add on columns for criteria that you identified in Step 1 of the Procedure. Establish a scoring method for each criterion.
8. Compare the designs by completing the table for each display.
9. Identify the strengths and weaknesses of each group's design.

ANALYSIS

1. What were the most important aspects of your site design that reduced the human impact? Describe how it contributed to the design.
2. Which one of the class's designs
   a. best met the design requirements? Explain your reasoning.
   b. had the most promise to be developed into a real school? Explain your reasoning.
3. How did the process of developing four different preliminary building ideas contribute to your final design?
4. What other criteria and constraints would be necessary for a real school design to be approved?
5. What other human activities related to the school and fields
   a. have an impact on the environment?
   b. could be mitigated using engineering and technology?

EXTENSION

Investigate the issues in your community that involve human impact on geological processes.

Construction site of a new school

Land, Water, and Human Interactions

UNIT SUMMARY

Human Impact of Building

Humans have impacted the environment in many ways, some of which are the result of using land to build and to farm. Looking at water quality and the movement of sediments provides evidence that the environment has been changed by human activities. There are ways that engineers can design man-made structures to reduce negative impacts from runoff, sediment erosion, and deposition. Some of the ways that changes can be monitored is testing water quality, measuring erosion depth, and imaging the ground cover. Strategies that can be implemented is the reduction of fertilizer use, increase of groundcover and vegetation, terracing the land, and reducing the area of hard surfaces.

Nutrient Pollution

Land is eroded by rainwater when the water picks up sediments as it flows. These sediments can have excess nutrients, especially if coming from farmland rich in fertilizers, which are carried with the water. Dissolved nutrients such as nitrogen and phosphorus are carried until they are deposited in a delta. Nutrient overloading in a delta can create a dead zone, or an area in the water with reduced oxygen. As a result, aquatic animals cannot survive in the habitat.

The Water Cycle

Sunlight and gravity drive the water cycle, where water moves around the planet in a complex but predictable manner. Evaporation of water from the lakes and oceans adds water vapor to the air. Condensation turns water vapor in the air into tiny solid and liquid particles that form clouds and fog. These droplets of water and ice can then fall back to Earth's surface as precipitation in the form of dew, rain, snow, or hail. Surface water is constantly changing its state and moving in global patterns.

Contaminants that are picked up by surface water when it is moving around, such as when it erodes sediments loaded with nutrients, continue to be carried throughout the water cycle. The contaminants may relocate, but they are maintained within Earth's geological systems.

Erosion and Deposition

The surfaces of rocks and soil are weathered by wind, water, or ice. Once broken down, small particles are eroded. The wind, water, or ice will move the small particles and soil to other locations. When the wind, water, or ice slows down, the particles or sediments are deposited, or dropped, in a new location. The process of erosion and deposition over time will change the landscape by cutting rivers and canyons and building up deltas and hills. These geoscience processes have been going on for millions of years and will continue into the future.

Essential Scientific Terms

causal relationship
constraint
correlation
criterion, criteria
dead zone
delta
deposition
erosion
evidence
geologic processes
human impact
indicators
mitigate
monitor
nutrients
sediments
trade-off
topographic map
topography
water cycle
water quality
weathering

APPENDIX

A Science and Engineering

THE NATURE OF SCIENCE AND ENGINEERING

IF SOMEONE ASKED you the question, "What is science?" how would you answer?

You might reply that it is knowledge of such subjects as biology, chemistry, Earth science, and physics. That would be only partly correct. Although science is certainly related to the accumulation and advancement of knowledge, it is much more than that. Science is a way of exploring and understanding the natural world.

According to the American Association for the Advancement of Science (AAAS), two of the most fundamental aspects of science are that the world is understandable and that scientific ideas are subject to change.

Scientists believe that the world is understandable because things happen in consistent patterns that we can eventually understand through careful study. Observations must be made and data collected for us to discover the patterns that exist in the universe. At times scientists have to invent the instruments that allow them to collect this data. Eventually, they develop theories to explain the observations and patterns. The principles on which a theory is based apply throughout the universe.

When new knowledge becomes available, it is sometimes necessary to change theories. This most often means making small adjustments, but on rare occasions it means completely revising a theory. Although scientists can never be 100% certain about a theory, as knowledge about the universe becomes more sophisticated most theories become more refined and more widely accepted. You will see examples of this process as you study the history of scientists' understanding of such topics as elements and the periodic table, the cellular basis of life, genetics, plate tectonics, the solar system, and the universe in this middle school science program.

While the main goal of science is to understand phenomena, the main goal of engineering is to solve problems. Like science, engineering involves both knowledge and a set of practices common across a range of engineering problems. Just as scientists start by asking questions, engineers start by defining problems. Just as scientists search for explanations for phenomena, engineers search for solutions to problems.

Science and engineering often build on each other. For example, scientists use instruments developed by engineers to study the natural world. And engineers use scientific principles when designing solutions to problems.

Scientific Inquiry

Inquiry is at the heart of science, and an important component of inquiry is scientific investigation, including experimentation. Although scientists do not necessarily follow a series of fixed steps when conducting investigations, they share common understandings about the characteristics of a scientifically valid investigation. For example, scientists obtain evidence from observations and measurements. They repeat and confirm observations and ask other scientists to review their results. It is important for scientists to avoid bias in designing, conducting, and reporting their investigations and to have other unbiased scientists duplicate their results. Some types of investigations allow scientists to set up controls and vary just one condition at a time. They formulate and test hypotheses, sometimes collecting data that lead them to develop theories.

When scientists develop theories they are constructing models and explanations of the patterns and relationships they observe in natural phenomena. These explanations must be logically consistent with the evidence they have gathered and with evidence other scientists have gathered. Hypotheses and theories allow scientists to make predictions. If testing turns out to not support a prediction, scientists may have to look at revising the hypothesis or theory on which the prediction was based.

Engineering Design

An engineer uses science and technology to build a product or design a process that solves a problem or makes the world better. Engineering design refers to the process engineers use to design, test, and improve solutions to problems. Like scientists, engineers design investigations to test their ideas, use mathematics, analyze their data, and develop models.

Since most solutions in the real world are not perfect, engineers work to develop the best solutions they can, while balancing such factors as the function, cost, safety, and usability of their solutions. The factors engineers identify as important for solutions to a problem are called criteria and constraints. Most engineering solutions have one or more trade-offs—desired features that must be given up in order to gain other more desirable features.

References

American Association for the Advancement of Science (AAAS). (1990). *Project 2061: Science for all Americans*. New York, NY: Oxford University Press.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K–12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

APPENDIX

B Science Safety

SCIENCE SAFETY GUIDELINES

YOU ARE RESPONSIBLE for your own safety and for the safety of others. Be sure you understand the following guidelines and follow your teacher's instructions for all laboratory and field activities.

Before the Investigation

- Listen carefully to your teacher's instructions, and follow any steps recommended when preparing for the activity.
- Know the location and proper use of emergency safety equipment, such as the safety eye-and-face wash, fire blanket, and fire extinguisher.
- Know the location of exits and the procedures for an emergency.
- Dress appropriately for lab work. Tie back long hair and avoid wearing dangling or bulky jewelry or clothing. Do not wear open-toed shoes. Avoid wearing synthetic fingernails—they are a fire hazard and can tear protective gloves.
- Tell your teacher if you wear contact lenses, have allergies to latex, food, or other items, or have any medical condition that may affect your ability to perform the lab safely.
- Make sure the worksurface and floor in your work area are clear of books, backpacks, purses, or other unnecessary materials.
- Ask questions if you do not understand the procedure or safety recommendations for an activity.
- Review, understand, and sign the Safety Agreement, and obtain the signature of a parent or guardian.

During the Investigation

- Carefully read and follow the activity procedure and safety recommendations.
- Follow any additional written and spoken instructions provided by your teacher.
- Use only those activities and materials approved by your teacher and needed for the investigation.
- Don't eat, drink, chew gum, or apply cosmetics in the lab area.
- Wear personal protective equipment (chemical splash goggles, lab aprons, and protective gloves) appropriate for the activity.
- Do not wear contact lenses when using chemicals. If your doctor says you must wear them, notify your teacher before conducting any activity that uses chemicals.
- Read all labels on chemicals, and be sure you are using the correct chemical.
- Keep chemical containers closed when not in use.
- Do not touch, taste, or smell any chemical unless you are instructed to do so by your teacher.
- Mix chemicals only as directed.
- Use caution when working with hot plates, hot liquids, electrical equipment, and glassware.
- Follow all directions when working with live organisms or microbial cultures.
- Be mature and cautious, and don't engage in horseplay.
- Report any unsafe situations, accidents, or chemical spills to your teacher immediately.
- If you spill chemicals on your skin, wash it for 15 minutes with large amounts of water. Remove any contaminated clothing and continue to rinse. Ask your teacher if you should take other steps, including seeking medical attention.
- Respect and take care of all equipment.

After the Investigation

- Dispose of all chemical and biological materials as instructed by your teacher.
- Clean up your work area, replace bottle caps securely, and follow any special instructions.
- Return equipment to its proper location.
- Wash your hands with soap and warm water for at least 20 seconds after any laboratory activity, even if you wore protective gloves.

Your teacher will give you an agreement similar to the one below to sign.

Science Safety Agreement

STUDENT

I, ________________________, have read the attached Science Safety Guidelines for students and have discussed them in my classroom. I understand my responsibilities for maintaining safety in the science classroom. I agree to follow these guidelines and any additional rules provided by the school district or my teacher.

Student Signature____

Date____________________

PARENT OR GUARDIAN

Please review with your student the attached Science Safety Guidelines, which include the safety responsibilities and expectations for all students. It is important that all students follow these guidelines in order to protect themselves, their classmates, and their teachers from accidents. Please contact the school if you have any questions about these guidelines.

I, ________________________, have read the attached guidelines and discussed them with my child. I understand that my student is responsible for following these guidelines and any additional instructions at all times.

Parent or Guardian Signature____

Date____________________

APPENDIX

C Science Skills

THE FOLLOWING PAGES include instructional sheets that you can use to review important science skills:

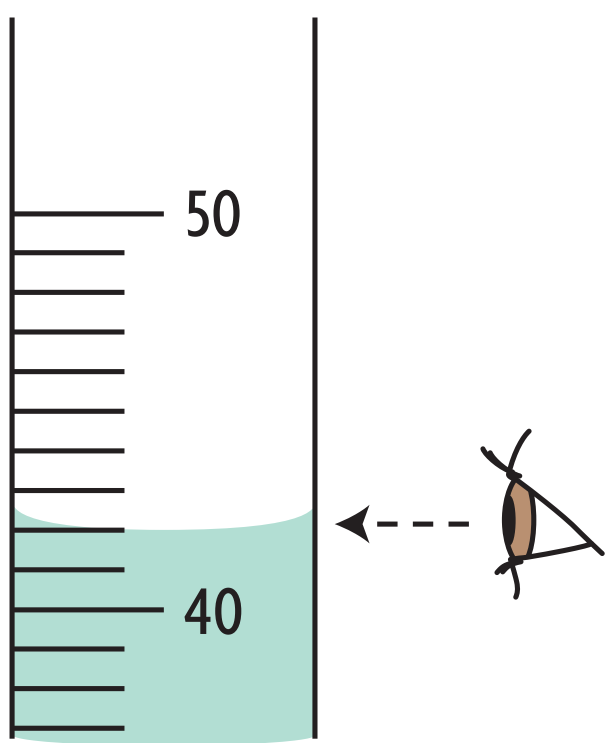
- Reading a Graduated Cylinder
- Using a Dropper Bottle
- Bar Graphing Checklist
- Scatterplot and Line Graphing Checklist
- Interpreting Graphs
- Elements of Good Experimental Design
- Using Microscopes

READING A GRADUATED CYLINDER

A graduated cylinder measures the volume of a liquid, usually in milliliters (mL). To measure correctly with a graduated cylinder:

1. Determine what measurement each unmarked line on the graduated cylinder represents.
2. Set the graduated cylinder on a flat surface and pour in the liquid to be measured.
3. Bring your eyes to the level of the fluid's surface. (You will need to bend down!)
4. Read the graduated cylinder at the lowest point of the liquid's curve (called the *meniscus*).
5. If the curve falls between marks, estimate the volume to the closest milliliter.

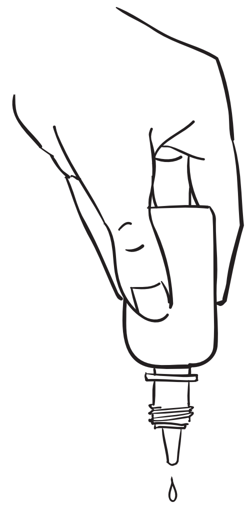
The example below shows a plastic graduated cylinder that contains 42 mL of liquid.



USING A DROPPER BOTTLE

Incorrect

Holding the dropper bottle at an angle creates drops that vary in size.



Correct

Holding the dropper bottle vertically creates drops that are more consistent in size.

BAR GRAPHING CHECKLIST

Sample Graph

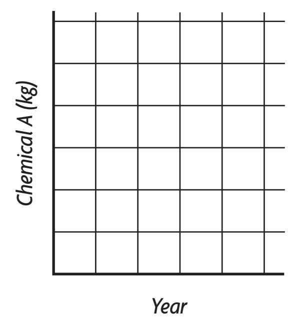
Follow the instructions below to make a sample bar graph.

- ☐ Start with a table of data. This table represents the amount of Chemical A that the Acme Company used each year from 2011 to 2015.

Year	*Chemical A used (kg)*
2011	*100*
2012	*80*
2013	*110*
2014	*90*
2015	*105*

- ☐ Determine whether a bar graph is the best way to represent the data.

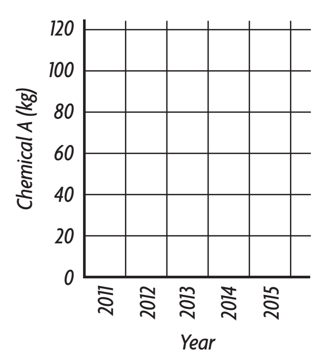
- ☐ If so, draw the axes. Label them with the names and units of the data.



- ☐ Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

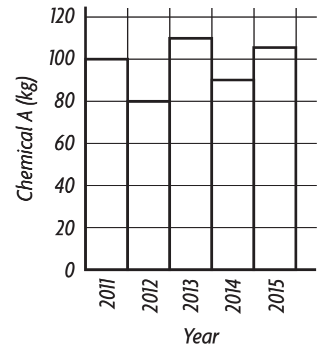
Year axis: 1 block = 1 year
Chemical A axis: 1 block = 20 kilograms

- ☐ Mark intervals on the graph, and label them clearly.

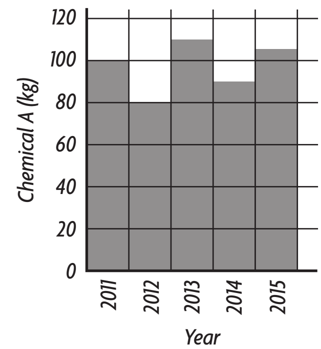


BAR GRAPHING CHECKLIST (continued)

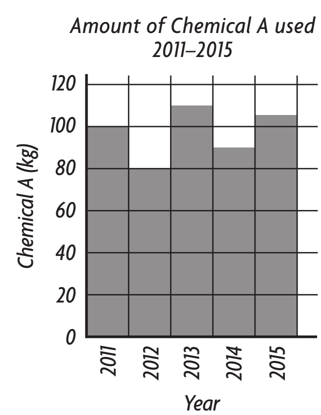
☐ Plot your data on the graph.



☐ Fill in the bars.



☐ Title your graph. The title should describe what the graph shows.



SCATTERPLOT AND LINE GRAPHING CHECKLIST

Sample Graph

Follow the instructions below to make a sample graph.

☐ Start with a table of data.

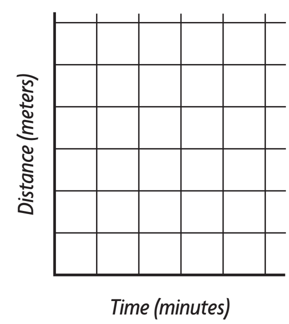
MOTION OF A BALL

Time (minutes)	Distance (meters)
0	0
1	5
2	9
3	16
4	20
5	27

☐ Determine whether a line graph or a scatterplot is the best way to represent the data.

LINE GRAPH

☐ Draw the axes. Label them with the names and units of the data.

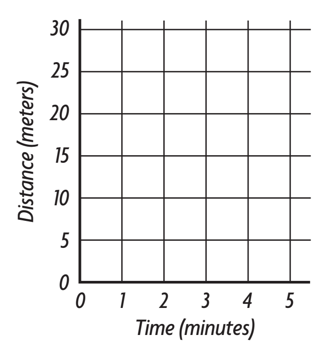


☐ Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

Time axis: 1 block = 1 minute

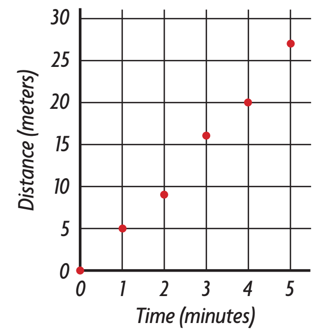
Distance axis: 1 block = 5 meters

☐ Draw intervals on the graph, and label them clearly.



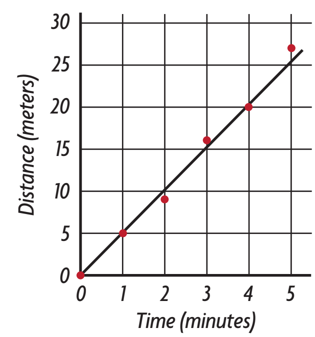
SCATTERPLOT AND LINE GRAPHING CHECKLIST (continued)

☐ Plot your data on the graph.

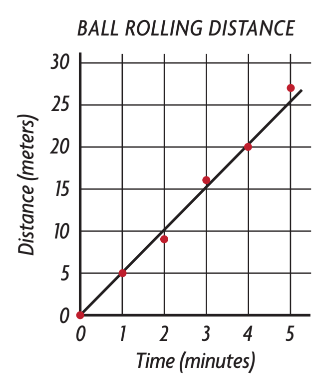


☐ For a scatterplot, leave the points unconnected.

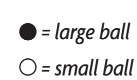
For a line graph, draw a smooth line or curve that follows the pattern indicated by the position of the points.



☐ Title your graph. The title should describe what the graph shows.

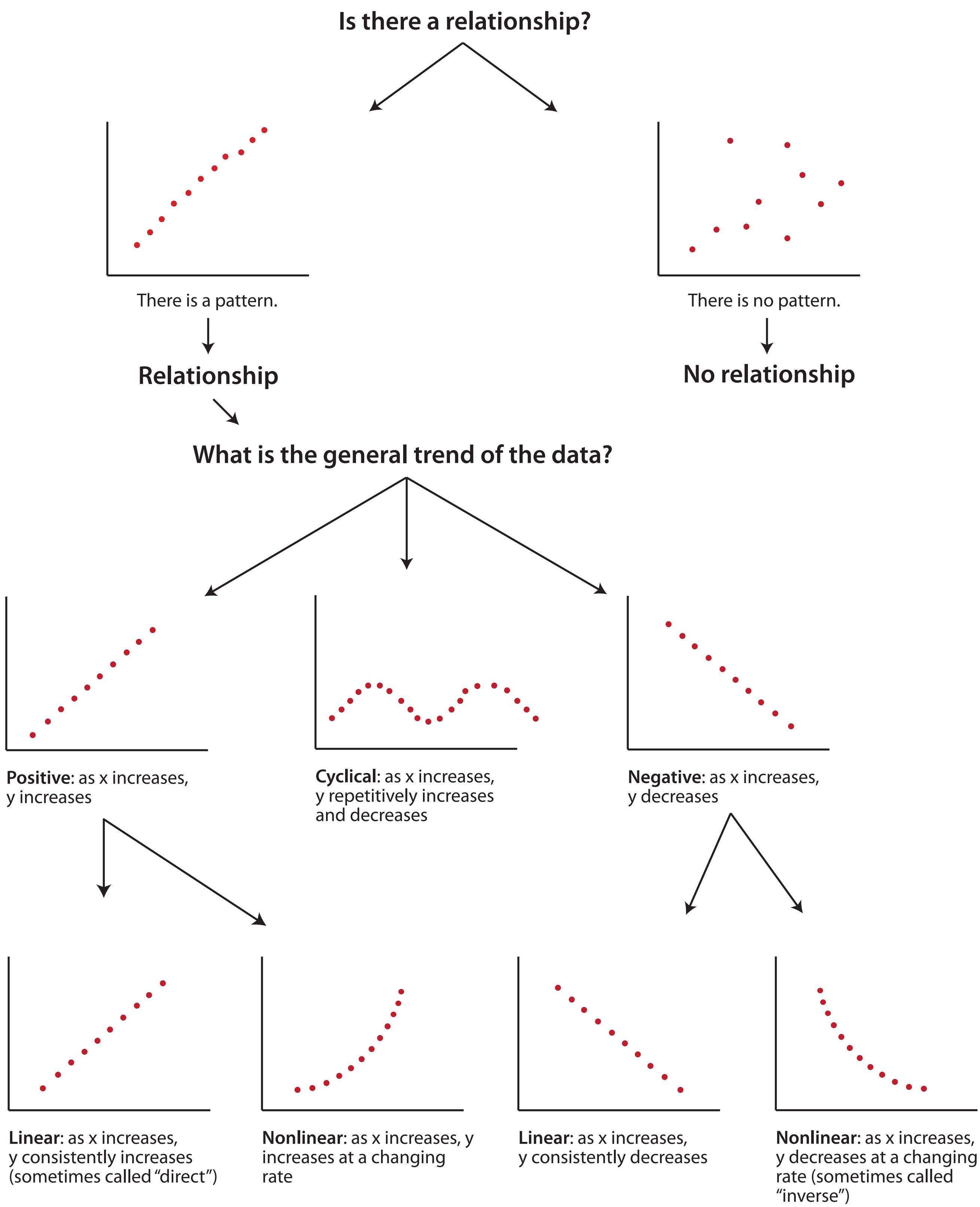


☐ If more than one data set has been plotted, include a key.



INTERPRETING GRAPHS

Determine the path that describes the data.



INTERPRETING GRAPHS (continued)

Define the components of the graph.

Things you can say:

"The title of the graph is …"

"The independent variable in this graph is …"

"The dependent variable in this graph is …"

"__________ is measured in ____________________"

Create a description of what the graph reveals.

Things you can say:

"This graph shows that …"

"As the __________ increases, the …"

"The ______ has the highest …"

"__________ is different from ____________ because …"

"The___________ peaked at …"

"The rate of _______ increased from …"

Describe how the graph relates to the topic.

Things you can say:

"This graph is important to understanding _________because …"

"This graph supports the claim that ______________ because …"

"This graph refutes the claim that ______________ because …"

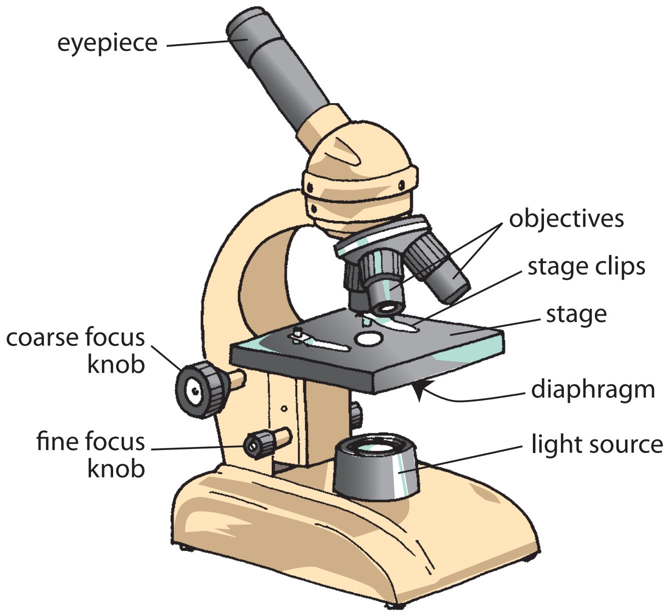
ELEMENTS OF GOOD EXPERIMENTAL DESIGN

An experiment that is well designed

- builds on previous research.
- is based on a question, observation, or hypothesis.
- describes all steps in a procedure clearly and completely.
- includes a control for comparison.
- keeps all variables—except the one being tested—the same.
- describes all data to be collected.
- includes precise measurements and all records of data collected during experiment.
- may require multiple trials.
- can be reproduced by other investigators.
- respects human and animal subjects.

Note: Elements may vary depending on the problem being studied.

USING MICROSCOPES



Focusing a Microscope

Be sure that your microscope is set on the lowest power before placing your slide onto the microscope stage. Place the slide on the microscope stage. Center the slide so that the sample is directly over the light opening, and adjust the microscope settings as necessary. If the microscope has stage clips, secure the slide in position so that it does not move.

- Observe the sample. Focus first with the coarse-focus knob, and then adjust the fine-focus knob.
- After switching to a higher power magnification, be careful to adjust the focus with the fine-focus knob only.
- Return to low power before removing the slide from the microscope stage.

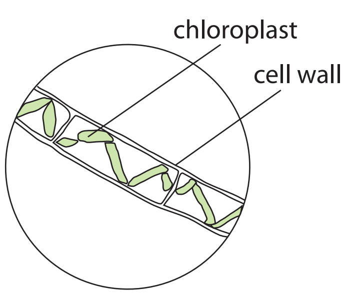
Safety

Always carry a microscope properly with both hands—one hand underneath and one holding the microscope arm. When you are working with live organisms, be sure to wash your hands thoroughly after you finish the laboratory.

Some Tips for Better Drawings

- Use a sharp pencil and have a good eraser available.
- Try to relax your eyes when looking through the eyepiece. You can cover one eye or learn to look with both eyes open. Try not to squint.
- Look through your microscope at the same time as you do your drawing. Look through the microscope more than you look at your paper.
- Don't draw every small thing on your slide. Just concentrate on one or two of the most common or interesting things.
- You can draw things larger than you actually see them. This helps you show all of the details you see.
- Keep written words outside the circle.
- Use a ruler to draw the lines for your labels. Keep lines parallel—do not cross one line over another.
- Remember to record the level of magnification next to your drawing.

Spirogyra (algae) x 400



APPENDIX

D The International System of Units

MEASUREMENTS THAT APPEAR in this program are expressed in metric units from the International System of Units, otherwise known as *SI units* (from Système Internationale d'Unités), which was established by international agreement. Virtually all countries in the world mandate use of the metric system exclusively. The United States does not use the metric system for many measurements, although it has been the standard for the scientific community in the United States for more than 200 years. A U.S. government effort to convert from the United States customary system to metric measurements in all realms of life has yet to extend far beyond governmental agencies, the military, and some industries.

The reason that many countries have replaced their traditional measurement systems with the metric system is its ease of use and to improve international trade. There are far fewer units to understand in comparison to the system commonly used in the United States. The metric system has only one base unit for each quantity and larger or smaller units are expressed by adding a prefix. The table below shows the base units in the International System of Units.

QUANTITY	BASE UNIT
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	ampere (A)
Luminous intensity	candela (cd)
Mole	mole (mol)

Other international units appearing in SEPUP's *Issues and Science* units are shown in the table below:

QUANTITY	UNIT	COMMON EXAMPLE
Temperature	Celsius (°C)	Room temperature is about 20° Celsius
Volume	liter (L)	A large soda bottle contains 2 liters.
Mass	gram (g)	A dollar bill has the mass of about 1 gram.
Wavelength	nanometer (nm)	Visible light is in the range of 400 to 780 nanometers

The International System's prefixes change the magnitude of the units by factors of 1,000. Prefixes indicate which multiple of a thousand is applied. For example, the prefix *kilo-* means 1,000. Therefore, a kilometer is 1,000 meters and a kilogram is 1,000 grams. To convert a quantity from one unit to another in the metric system, the quantity needs only to be multiplied or divided by multiples of 1,000. The chart below shows the prefixes for the metric system in relation to the base units. *Note*: Although it is not a multiple of 1,000 the prefix *centi-* is commonly used, for example, in the unit centimeter. Centi- represents a factor of one 100th.

METRIC PREFIX	FACTOR	FACTOR (NUMERICAL)
giga (G)	one billion	1,000,000,000
mega (M)	one million	1,000,000
kilo (k)	one thousand	1,000
[UNIT]	one	1
milli (m)	one one-thousandth	1/1,000
micro (μ)	one one-millionth	1/1,000,000
nano (n)	one one-billionth	1/1,000,000,000

APPENDIX

E Literacy Strategies

THE FOLLOWING PAGES include instructional sheets and templates for some of the literacy strategies that are used throughout this book. Use them for reference or to copy into your science notebook.

- Oral Presentations
- Reading Scientific Procedures
- Keeping a Science Notebook
- Writing a Formal Investigation Report
- Constructing a Concept Map
- Developing Communication Skills

ORAL PRESENTATIONS

- Your presentation time is short. Focus your presentation on the most important ideas you need to communicate.
- Communicate clearly by planning your words in advance. When speaking, talk slowly and loudly, and look at your audience.
- Group members should ask for and give each other support if they need help expressing a key word or concept.
- Include graphs and maps when possible. Make sure the type or handwriting and the images are large enough for everyone in the audience to see them.
- While you have your own opinions on a topic, it is important that you present unbiased and complete information. Your audience can then make their own conclusions.
- All the members of a group must participate.
- Since any group member may be asked to answer questions from the class, all group members should fully understand the presentation.
- In a group presentation, you could all play the role of different experts when presenting your information. The class would represent the community members who might be making a decision on the issue.

READING SCIENTIFIC PROCEDURES

The purpose of reading a scientific procedure is to find out exactly what to do, when to do it and with what materials, in order to complete all the steps of an investigation.

If you read a step and are not sure what to do, try these strategies:

- Re-read the previous step.
- Re-read the step that confuses you. Sometimes re-reading clarifies the information.
- Ask your partner if he or she understands what the step says to do.
- Ask your partner if there are words you don't understand.
- Ask your partner to explain what the step says to do.
- Ask your partner to read the step aloud as you listen and try to do what your partner is describing.
- Re-read the purpose (Guiding Question) of the investigation.
- Try to say the purpose of the step out loud in your own words.
- Look at the clues in the pictures of the activity.
- Peek at other groups and listen to see if they are doing the step that confuses you.
- Tell your teacher exactly what you are confused about and why it doesn't make sense.

KEEPING A SCIENCE NOTEBOOK

- Write in blue or black ink.
- Cross out mistakes or changes with a single line. Do not erase or use correction fluid.
- Write neatly.
- Record the date of each entry.
- For each new investigation, write down the following:

Title:

Purpose:
Re-write the Guiding Question in your own words.
Hint: What are you going to do? Why are you going to do it?

Materials:
Place a "√" here after you have collected the necessary materials.

Procedure:
Write down whether you understand the procedure.

Data:
Record observations, measurements, and other lab work.
Include data tables, charts, diagrams, and/or graphs when needed.
Be sure to label your work clearly.

- Sometimes, you may want to do the following:

Make inferences or draw conclusions based on the data.
I think my results mean . . .
I think that this happened because . . .

Reflect on how the activity worked in your group.
This is what went well . . This is what did not go well . . .
If I could do this activity again, I would . . .

Think about what questions you still have.
I wonder if . . .
I'm not sure about . . .

Keep track of new vocabulary and ideas.
A key word I learned is . . .
I would like to find out what happens when . . .
One interesting thing to do would be to . . .

KEEPING A SCIENCE NOTEBOOK

The following is a guide to help you conduct investigations. However, depending on the investigation, you may not always use all of steps below or use them in the same order each time.

Title: Choose a title that describes the investigation.

Purpose: What am I looking for? Write what you are trying to find out in the form of a question.

Background: What do I know about the topic? Write a summary of background information you have on the topic that led to the purpose for the investigation.

Hypothesis: Write a statement about what you predict you will see as data in the experiment to answer the question in the "Purpose" and why you are making that prediction.

Experimental Design: How will you answer the question?

Describe the methods you will use (what you will do) to answer the question.

Use short numbered steps that are easy to follow in the lab.

Make a list of the materials you will use to answer the question.

Outline the variables:

- Independent variable (what is being changed)
- Dependent variable (what is being measured)
- Control (what will be used as baseline comparison)

Data: What did you find?

Record observations and measurements.

Use a data table where appropriate to organize the data.

Don't forget to include proper units and clear labels.

At the end of your investigation, do the following:

Make inferences or draw conclusions about the data:

I think my results mean . . .

I think this happened because . . .

Think about any errors that occurred during the investigation:

What did not go as planned?

What steps were hard to follow while doing the investigation and why?

Think about questions you still have that could lead to new investigations:

I wonder if . . .

I'm not sure about . . .

Keep track of new vocabulary and new ideas that could lead to new investigations

I would like to find out what happens when . . .

One interesting thing to do would be to . . .

Reflect on how the activity worked in your group

This is what went well . . . This is what did not go well . . .

If I could do this investigation again, I would . . .

WRITING A FORMAL INVESTIGATION REPORT

Use the information from your science notebook to write a formal report on the investigation you performed.

Title:

Choose a title that describes the investigation.

Abstract: What were you looking for in this investigation, and what did you find?

Write a paragraph that summarizes what you already knew about the topic, your purpose, your hypothesis, and your results and conclusions.

Experimental Design:

Describe the materials and investigational methods you used to answer the question.

State what variables you worked with and any controls.

Data: What did you find?

Report observations and measurements. Include an organized data table if appropriate to help someone reviewing your report to easily see the results.

Don't forget to use proper units of measurement and write clear labels for your table columns.

Data Analysis: Represent the data in a way that can be easily interpreted.

Use graphs, diagrams, or charts where appropriate to help a reviewer interpret your data.

Conclusion: What do the data mean?

Summarize the data.

Discuss your conclusion based on the accuracy of your hypothesis and the data you collected.

Discuss any errors that occurred that may have interfered with the results.

Describe any changes that need to be made the next time the investigation is performed.

Describe any new questions to be investigated based on the results of this investigation.

CONSTRUCTING A CONCEPT MAP

1. Work with your group to create a list of 15–20 words related to the topic.
2. If you are uncertain of the meaning of a word, look it up in the book or your notes or discuss it with your group.
3. Discuss with your group how all of the words on your list are related, and sort your list of words into three to five categories based on these relationships.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain to the rest of the group why you disagree.
4. Identify words that can be used to describe each category.
5. Work with your group to create a concept map on this topic. Follow these steps:
   a. Write the topic in the center of your paper, and circle it.
   b. Place the words describing each category around the topic. Circle each word.
   c. Draw a line between the topic and each category. On each line, explain the relationship between the topic and the category.
   d. Repeat Steps 5b and 5c as you continue to add all of the words on your list to your concept map.
   e. Add lines to connect other related words. Explain the relationship between the words on the line.
6. View the concept maps of other groups. As you look at their concept maps, observe similarities and differences between their maps and yours. Discuss your observations with your group members.

DEVELOPING COMMUNICATION SKILLS

COMMUNICATION	SENTENCE STARTERS
To better understand	One point that was not clear to me was . . . Are you saying that . . . Can you please clarify . . .
To share an idea	Another idea is to . . . What if we tried . . . I have an idea. We could try . . .
To disagree	I see your point, but what about . . . Another way of looking at it is . . . I'm still not convinced that . . .
To challenge	How did you reach the conclusion that . . . What makes you think that . . . How does it explain . . .
To look for feedback	What would help me improve . . . Does it make sense, what I said about . . .
To provide positive feedback	One strength of your idea is . . . Your idea is good because . . . I have an idea. We coud try . . .
To provide constructive feedback	The argument would be stronger if . . . Another way to do it would be . . . What if you said it like this . . .
To discuss information presented in text and graphics	I'm not sure I completely understand this, but I think it may mean . . . I know something about this from . . . A question I have about this is . . . If we look at the graphic, it shows . . .

APPENDIX

F Media Literacy

IMAGINE YOURSELF READING a magazine. A feature article summarizes recent studies on the effectiveness of vitamin supplements and concludes that taking vitamin pills and liquids is a waste of money. A few pages later, an advertisement from a vitamin company claims that one of its products will protect you from all sorts of diseases. Such wide differences in claims that you will see in the popular media are common, but how can you tell which one is correct? "Media literacy" is the term that encompasses the skills we need to develop to effectively analyze and evaluate the barrage of information we encounter every day. Media literacy also includes the ability to use various media to create and communicate our own messages.

A strong background in the process of science helps you build two important skills of media literacy: being able to identify valid and adequate evidence behind a claim and evaluating if the claim is a logical conclusion based on the evidence. The skills share much in common with the process of scientific inquiry, in which you learn to seek out information, assess the information, and come to a conclusion based on your findings.

EVALUATING MEDIA MESSAGES

A "media message" is an electronic, digital, print, audible, or artistic visual message created to transmit information. Media messages can include newspaper articles, political advertisements, speeches, artwork, or even billboards. The following are some of the kinds of questions you might ask as you learn to critically analyze and evaluate messages from various kinds of media. On the next page are three examples of media messages, all related to a common theme. Use these three examples to analyze and evaluate the messages.

1. Who created this message?

Is this person an expert in the content of the message? What credentials does this person have that would make them an expert in this topic? Does this person have any conflicts of interest that may make him or her biased in any way? Who sponsored (or paid for) the message? Does the source of funding have any conflicts of interest?

2. **What creative techniques in the message attract a person's attention?**
   Are there any sensational or emotional words, images, or sounds that grab the viewer's attention? Do any of these words, images, or sounds try to stir up emotions and influence the viewer's ideas?

3. **Does the message cite or mention appropriate sources of factual information?**
   Does the author cite first-person sources when reporting facts? Are the author's sources from credible organizations?

4. **Does the presented evidence completely support the claim?**
   Might there be other information that could support or discredit the message? Does the author make logical inferences and conclusions from the evidence presented in the article?

5. **Who is the target audience of this message?**
   How is this message directed at this particular audience?

6. **Is the message promoting certain values, lifestyles, positions, or ideas either directly or indirectly?**
   Are there any positions or ideas that are being promoted that are not explicit in the message?

EVALUATING INTERNET SOURCES

Imagine that you want to search the Internet to find out about the effectiveness of vitamin supplements so that you can come to your own conclusion. When you are searching for information online, a search engine is searching from over one trillion websites.[1] Determining which websites and sources of information are reliable and which are biased is difficult. To make an informed decision about this topic, you will need to identify accurate and unbiased websites. Below is a suggested list of questions that will help you determine if a particular website is an accurate and unbiased source of information.

1. **Are the authors' names, contact information, and credentials clearly labeled on the website?**
   Accurate websites will usually contain information from knowledgeable authors who have their names, credentials, and contact information clearly labeled on the website. Some websites are managed by a collection of people or an organization, and information on the exact author may not be clearly stated. However,

1. Alpert, Jesse & Hajaj, Nissan. (July 25, 2008). We knew the Web was big. . . . *The Official Google Blog*. Retrieved August 2010 from http://googleblog.blogspot.om /2008/07/we-knew-web-was-big.html.

these organizations should state the names, contact information, and credentials somewhere on their website of the people who represent the organization.

2. **Is the information and the website up to date?**
   Some information that you may be seeking needs to be current. For example, if you were looking for the number of cars in the United States, you would want the most recent data. A study conducted in 1982 would not be helpful in this case. When seeking information that needs to be current, determine if the date the article or information was written is clearly indicated on the website so you can be sure you are accessing the most recent information. Credible websites will usually indicate the date the article or information was created or last updated. Also, the person or organization maintaining the website should be regularly updating the website, so that the majority of links to other websites work.

3. **Are sources of information clearly cited?**
   When factual information is stated in a website, is the source clearly cited so you can refer back to it?

4. **Are there links to more resources on this topic?**
   Authoritative websites will often provide links to further information from other sources that support their claim. Authors of websites that contain information that is biased or inaccurate usually do not provide additional information that supports their claims.

5. **What are other people saying about the author or the organization that produced this information?**
   If you come across information from an author or organization that you are unfamiliar with, perform a search for other information about the author or organization. What are experts writing about the author's or organization's other work?

6. **Why is this website on the Internet?**
   Was this information put on the Internet to inform or to persuade people? Is the author selling something? What is the author's motivation for providing this information?

Further Resources

Thier, M., & Daviss, B. (2002). The new science literacy. Portsmouth, NH: Heinemann.

Center for Media Literacy. http://www.medialit.org.

PBS Teachers. Media literacy. http://www.pbs.org/teachers/media_lit.

APPENDIX

G Crosscutting Concepts

PATTERNS	A pattern is a set of repeating things or events. Scientists observe patterns in their data. Patterns lead to questions about relationships and ideas about what causes these relationships.
CAUSE AND EFFECT	Events have causes. If "A" causes "B" to happen, they have a cause-and-effect relationship. A major activity of science is to explain how this happens. Sometime the causes are simple and sometimes they are complex. Sometimes both A and B occur, but one does not cause the other.
SCALE, PROPORTION, AND QUANTITY	Scientific phenomena occur at various scales of size, time, and energy. Phenomena observed at one scale may not be observable at another scale. Scientists use proportional relationships to compare measurements of objects and events. They often use mathematical expressions and equations to represent these relationships.
SYSTEM AND SYSTEM MODELS	A system is a group of interacting objects or processes. Describing a system, including its components, interactions and boundaries, and making models of that system helps scientists and engineers understand phenomena and test ideas.
ENERGY AND MATTER	Tracking changes of energy and matter into, out of, and within systems helps scientists understand the systems' possibilities and limitations. Many cause and effect relationships result from changes of energy and matter.
STRUCTURE AND FUNCTION	The structure (shape, composition, construction) of an object or living thing determines many of its properties and functions (what the structure can do).
STABILITY AND CHANGE	For natural and built systems alike, conditions are sometimes stable (the same or within a range), and sometimes they change. Scientists study what conditions lead to either stability or change.

Glossary

absorb To take in or soak up. *See* absorption.

absorption The process of absorbing or being absorbed. *See* absorb.

advantage A property that in your opinion, is favorable.

altitude The elevation of a location above (or below) sea level.

analysis (of experimental results) Making connections between the results of an experiment and the idea or question being investigated.

atmosphere The mixture of gases ("air") that surrounds a planet.

biodiversity The variety of life at every level, from genes to species to ecosystems.

carbon dioxide A waste produced from the breakdown of sugars during cellular respiration. Carbon dioxide gas in the atmosphere is essential for photosynthesis.

cardiovascular system *See* circulatory system.

causal relationship A relationship in which one factor causes an effect to the other factor. The first event is the cause and the result is the effect.

climate change The climate of an area can change over time. Scientists are studying climate change related to global warming.

climatologist A scientist who studies Earth's climates.

condensing The process of a gas (such as water vapor) losing heat energy to become a liquid (such as water).

constraint In engineering design, something that limits the solution to a problem.

contaminant Any physical, chemical, or biological substance in water.

contour interval The interval between lines on a topographic map that differ from each other by the same amount of elevation.

contour line A line on a topographic map that represent a specific elevation relative to sea level.

control A standard of comparison for checking or verifying the results of an experiment. The results of the experiment are compared with the control in order to see if the variable changed in the experiment caused any effect.

controlled variable A variable in an investigation or experiment that is held constant.

correlation A measure of how well one set of data relates to another.

criteria In engineering design, the goals and the desired features of the solution. Plural of criterion, *see* criterion.

criterion A minimum requirement for how the design must function, *see* criteria.

cytoplasm The material that fills much of the inside of cells.

data Information gathered from an experiment or observations.

dead zone A near-shore area of water with little or no dissolved oxygen and, therefore, very few organisms.

decibel (dB) A unit of measure that indicates the relative intensity of a sound.

decibel scale A common way of describing intensity of sound relative to the softest audible sound.

dependent variable The observed phenomenon that is being measured.

deposition Sediments that settle out of the flowing water, ice, or winds and drop to the ground due to slowing water.

delta A fan-shaped landform that develops where sediments are deposited in one area as a result of flowing water, such as a stream or river, entering still water, such as a lake or ocean.

design To develop a plan for a product or structure.

disadvantage A property that, in your opinion, is not favorable.

dissolve A phenomenon that occurs when the particles of one substance mix evenly into the particles of another substance.

ecologist A scientists who studies ecology.

ecology The study of the relationships of organisms to one another and to the physical environment.

ecosystem All of the living and nonliving components, and all of the interactions among them.

energy The ability to cause objects to change, move or work.

engineer Someone who uses science and tools to build a product that solves a practical problem.

engineering design process A series of steps that engineers follow to come up with a solution to a problem.

erosion The removal of sediments from an area. Common causes of erosion are gravity and moving water, wind, and ice.

evaporating The process of a liquid (such as water) gaining heat energy to become a gas (such as water vapor).

evidence Information that supports or refutes a claim.

freezing the process of a liquid (such as water) losing heat energy to become a solid (such a ice).

global warming The gradual warming of Earth's average surface temperature. Evidence indicates a relationship between human activity and the current global warming event. *See* greenhouse gas.

gram (g) A unit of mass in the metric system; 1 gram is equal to 1,000 milligrams.

greenhouse gas A gas that traps thermal energy in the atmosphere. Examples include carbon dioxide, water vapor, and methane. Evidence indicates that human activity has increased the concentration of greenhouse gases in Earth's atmosphere. *See* global warming.

groundwater Water that is found underground in spaces and cracks in the earth.

habitat A location in an environment where an organism lives.

human impact The effect on living organisms and their nonliving environment due to human activity is called.

hydrologist A scientist who studies the distribution and movement of Earth's water.

hypotheses Plural of hypothesis. *See* hypothesis.

hypothesis A possible explanation for observations, facts, or events that may be tested by further investigation. *See* hypotheses.

independent variable The controlled variable in an experiment.

indicator Any visible sign that shows the condition of the system being studied.

infer To conclude by reasoning from known facts. *See* inference.

inference A conclusion based on observations or what is already known. *See* infer.

interpret To explain or give an account of facts with regard to the explainer's conception of what the facts mean.

liter (L) A unit of volume in the metric system; 1 liter is equal to 1,000 milliliters.

macroinvertebrates Animals without backbones that are large enough to see without magnification.

mass The amount of matter in an object.

matter The stuff that makes up all living and nonliving objects. . *For biology units optionally add* Carbon dioxide, oxygen, and sugars are all example of matter.

melting The process of a solid (such as ice) gaining heat energy to become a liquid (such as water)

meteorologist A scientist who studies weather.

meter (m) A unit of length in the metric system; 1 meter is equal to 100 centimeters or 1,000 millimeters.

metric system The worldwide measuring system used by scientists. Also known as the International System of Units (SI).

mitigate To lessen the impact of something.

model Any representation of a system (or its components) used to help one understand and communicate how it works.

monitor To measure and keep track of something.

nutrients Chemicals that an organism takes in from its environment to use as a source of energy or as building blocks for growth.

observation Any description or measurement gathered by the senses or instruments.

optimize To make better or as good as you can.

pattern Something that happens in a repeated and predictable way.

population A group of organisms of the same species living in the same habitat.

precipitation Any form of water that falls to Earth, including rain, snow, sleet, and hail.

prototype An early sample of a product that provides information about how the device or system works.

risk assessment The breaking down of various events or actions to see the amount and type of risk involved. Sometimes called "risk analysis" or "risk comparison."

risk management A group or individual's change of behavior, lifestyle, or both to reduce the amount of risk involved in a situation, action, or event.

risk The chance that an action or event could result in something unfavorable happening, such as injury.

runoff Excess rainfall, melted snow, or irrigation water that flows across the ground.

scientific model Any representation of a system (or its components) used to help one understand and communicate how it works.

scientist Someone who pursues understanding of the natural world by using evidence to answer

sediments Small pieces of earth such as rocks, shells, and other debris.

solvent A substance that dissolves other substances.

technology Any product or process made by engineers and scientists.

topographic map A flat, two-dimensional map that is a model of the actual three-dimensional shape of a land surface.

topography The shape of the land with its various elevations in an area.

trade-off A desirable outcome given up to gain another desirable outcome.

transpiration The process of water evaporating from plant leaves.

volume The amount of space that an object or substance occupies.

water cycle The movement of water through the air and land.

water quality A measure of the condition of the water based on its characteristics.

weathering An earth process that breaks down rocks into smaller pieces. Rocks crack, crumble, and are broken apart by water and wind over time.

weight The vertical force exerted by a mass as a result of gravity.

Index

Bold page number indicates a definition. *Italic* page number indicates an illustration.

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E

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Credits

Abbreviations: t (top), m (middle), b (bottom), l (left), r (right), c (center)

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