Discover FLOODS


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Educators Guide

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Weather • Climate • Water

Project WET™

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The World Meteorological Organization (WMO) is a specialized agency of the United Nations. It is the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources. The vision of WMO is to provide world leadership in expertise and international cooperation in weather, climate, hydrology and water resources and related environmental issues and thereby contribute to the safety and well-being of people throughout the world and to the economic benefit of all nations.

www.wmo.int

The Associated Programme on Flood Management (APFM) is a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP). The mission of the APFM is to support countries in the integrated management of floods within the overall framework of integrated water resources management. The programme has been financially supported by the Governments of Japan and Switzerland.

www.apfm.info

To reach children, parents, educators and communities of the world with water education. Project WET's Kids in Discovery series (KIDs) is designed to help kids discover the scientific, natural, cultural and historical wonders of their world.

www.projectwet.org

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Educators Guide

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Oosterschelde storm surge barrier, Netherlands

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Discover FLOODS Educators Guide

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A flooded street with a danger sign

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A tsunami warning sign on Ko Lanta Island, Krabi, Thailand

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Flooded river rushes past a home in southern France

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Heavy autumn rains cause river to overflow its banks, Limoges, France

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A road that collapsed due to flood damage

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Paraty, Brazil

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Pedestrians try to find their way through the flooded streets after a monsoon in the city of Fatehpur, Rajasthan, India.

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Home on stilts in the flooding Amazon River, Peru

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Sand bags aren't stopping the river from inundating the nearby walkway

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Looking southeast down the flooded Canal Street in New Orleans, Louisiana, USA

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Spring flood in Budapest, Hungary

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Beach pole almost flooded by a storm/high tide, North Sea, near the Dutch coast

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Spring flood in Spokane, Washington, USA

Discover FLOODS
Educators Guide

Dear Educators:

None of us will ever forget the heart-wrenching scenes of the 2004 Tsunami that devastated coastal communities in Indonesia, the Maldives, Sri Lanka, India and Thailand or the following year, of Hurricane Katrina in the United States. Flooding from these events, and countless smaller, yet devastating floods occurring in urban centers and in remote areas, caused loss of life and property and threw these communities into financial crisis that affected millions well beyond their borders.

In 2006, these disasters were top-of-mind for world water leaders at the 4th World Water Forum in Mexico City. Balancing development and flood risk, in addition to maximizing floodplain benefits to help alleviate poverty while protecting the environment, were priority topics. But the question dominating these discussions was, "How can we protect people in flood-prone areas?"

Project WET played a major role in education at the 4th World Water Forum and invited organizations from around the world to share their water education efforts at the Global Water Education Village™. During this venue, Project WET was approached by members of the World Meteorological Organization, Associated Programme on Flood Management. Immediately, planning began to create publications to help educate teachers, students and families in flood-prone communities about risk, flood management and preparedness.


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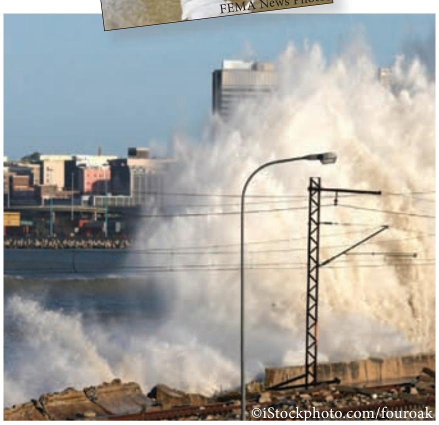
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Project WET, with support from United States Agency for International Development (USAID) Office of US Foreign Disaster Assistance (OFDA) and the World Meteorological Organization (WMO) produced companion publications: the *Educators Guide* and *KIDs (Kids in Discovery) Activity Booklet*, both entitled ***Discover Floods***. Using Project WET's proven methodology of presenting information through diverse, hands-on and interactive lessons and activities, these materials educate teachers, students, families and communities worldwide about risk assessment, flood management and preparedness. Learners assess their risk by creating a community hazard map, and prepare by assembling an emergency Action Pack and developing a family Action Plan.

These publications respect traditional knowledge and recognize that floodplains represent some of the most productive farmland in the world. The *Educators Guide* and *KIDs Activity Booklet* acknowledge the importance of floods and inundation to both natural and human communities including: floodplain enrichment, nutrient exchange between natural communities (e.g., Amazon flooded forests), refreshing wetlands, and water provision for irrigation.

Although we cannot control extreme weather events, through education we can reduce our vulnerability by assessing our risk, whether at home or traveling, and preparing a plan. Through ActionEducation™, we can prepare not only our families, but also our communities. As we seek to improve the quality of life for all people, through flood awareness education, risk assessment, management and planning, we can benefit from floodplains and help keep communities safe.

Dennis Nelson, CEO and President, Project WET Foundation

Avinash C. Tyagi, Director, Climate and Water Department, World Meteorological Organization

Discover FLOODS
Educators Guide

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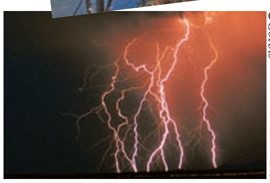
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Introduction


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About Project WET

Since 1984, Project WET has dedicated itself to the mission of reaching children, parents, teachers and community members of the world with water education. Project WET achieves its mission of worldwide water education by: publishing water resource materials in several languages; providing training workshops on diverse water topics (i.e., watersheds, water quality, water conservation); organizing community water events, such as Make a Splash with Project WET water festivals and the Global Water Education Village™; and building a worldwide network of educators, water resource professionals and scientists.

Project WET Core Beliefs

Project WET is grounded in the following beliefs:

- Water moves through living and nonliving systems and binds them together in a complex web of life.
- Water of sufficient quality and quantity is vital for all water users (energy producers, farmers and ranchers, fish and wildlife, manufacturers, recreationists, rural and urban dwellers).
- Water resources management is crucial for providing tomorrow's children with social and economic stability in a healthy and sustainable environment.
- Awareness of and respect for water resources can encourage a personal, lifelong commitment of responsibility and positive community participation.

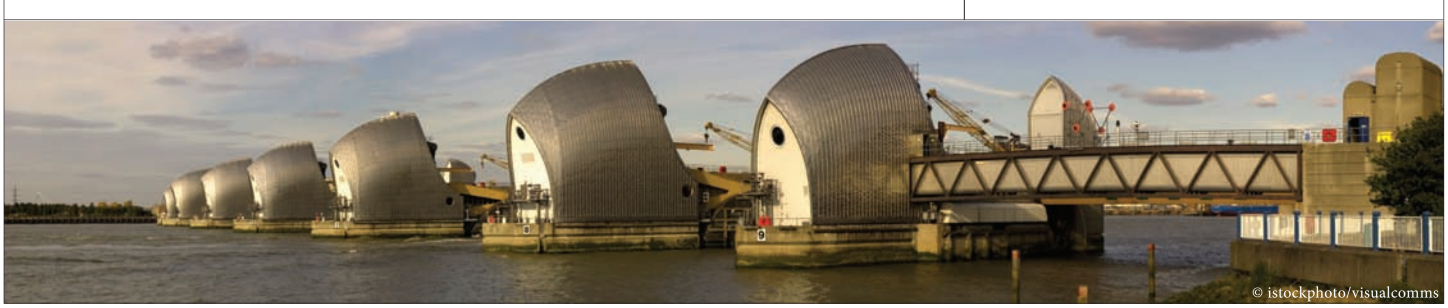
Project WET: Meeting 21st Century Water Resource Challenges

Over the past quarter-century, global water problems have continued to escalate. Every day, the quality and quantity of water resources affect the health and well-being of nearly seven billion people on our planet, and yet one in eight do not have access to clean and abundant water.

Floods affect every country and according to a UNESCO report, "Floods are among the most frequent and deadly of natural phenomena..." With a growing world population and many seeking to secure their livelihood by living and working in productive floodplains, since 1950 economic losses from flooding have continued to increase. (WMO, 2006)

Many water resource leaders are challenged to find solutions that allow countries to benefit from productive floodplains and help people living and working in flood-prone communities to be safe while preserving the environment. The Director-General of UNESCO, Mr. Koïchiro Matsuura, spoke to the critical role of education in 2005 in helping communities assess and reduce their risk, "anticipating, educating and informing are the keys to reducing the deadly effect of such natural disasters."

Thames Barrier, London, England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To help students, their teachers, parents and community leaders meet 21st century water challenges, Project WET believes that water resource education has never been more important.

Project WET Activities

Within educational systems, Project WET materials complement existing curricula and are localized to meet community goals. In the United States, Project WET activities have been correlated with the educational standards of most states.

The cornerstone of Project WET is its methodology of teaching about water resources through hands-on, investigative, easy-to-use activities. Skills such as teamwork, decision-making and problem-solving that students develop through these activities help prepare them for the water resource challenges of this century.

What are the qualities of Project WET materials that appeal to the natural curiosity of learners and will help prepare them for the water challenges of the 21st century?

- **Interactive**: Learners participating in Project WET activities are not passive observers. Engaging students through questioning and other inquiry-based strategies, educators become facilitators involving students in hands-on lessons and encouraging them to take responsibility for their own learning. For example, students design investigations to seek answers to real-world problems; play games to explore scientific concepts; reflect; debate, seek common ground to resolve conflicts, and creatively share their findings through songs, stories and dramas.

- **Accurate and Science-based**: Project WET activities are reviewed by scientists and other content-experts and are field tested to ensure that activities accurately represent concepts. To this end, Project WET was awarded the 2008 Universities Council on Water Resources Education and Outreach Award. Recognition by this membership of over 90 worldwide universities and organizations reflects Project WET's commitment to scientific and technical accuracy.

- **Multi-sensory**: Activities engage as many of the learner's senses as possible. Research has shown that stimulation of multiple senses enhances learning.

- **Adaptable**: While adaptable for any environment, many Project WET activities are ideal for outdoor settings and encourage children to be physically active.

- **Contemporary (21st Century Skills)**: Project WET activities help students develop skills necessary for success in the 21st century. In most activities students work in small, collaborative groups; many activities engage students in higher level thinking skills requiring them to analyze, interpret, apply learned information (including problem-solving, decision-making and planning), evaluate and present. Project WET is aggressively incorporating technology education into its activities and offering cross-cultural materials to prepare learners for participation in a global economy, in which an understanding of water resources will be critical.

- **Relevant**: Information is not delivered in isolation; educators are encouraged to localize activities to give them relevance.

- **Solution-oriented** (ActionEducation™): Through education, Project WET empowers students, teachers, parents and leaders to take action and find solutions in local communities. In this context, Project WET and local education and water partners seek to incorporate educational materials and training with on the ground action and solutions.

- **Measurable**: Project WET activities provide simple assessment tools to measure student learning.

Project WET Around the Globe

Project WET is currently active in over 40 countries on five continents. Its materials have been translated into several languages, including Arabic, French, Hungarian, Japanese and Spanish. Students, teachers and community members of diverse cultures, often with different learning styles, use Project WET.

An Invitation

We invite you to join Project WET in its mission to reach children, educators, parents and communities of the world with water education. We hope ***Discover Floods*** will offer ideas and insight about these events to help keep you, your family and community safer.

Storm surge barrier in Zeeland, Holland

ActionEducation™

Project WET: Expanding Its Mission

A few years back, a researcher from a prominent philanthropic foundation asked, "What can a water education program like Project WET do to reduce the number of deaths caused by water-borne diseases?" This was a watershed moment for Project WET; this inquiry stimulated considerable discussion and reflection and served to help Project WET better define its vision and role for worldwide water education. Eventually, it led to a decision to add ActionEducation to the Project WET Foundation's core work. Through ActionEducation, Project WET's mission worldwide has evolved from learner awareness to empowering students to take action leading to sustainable solutions for community water resource issues.

In simple terms, education that empowers learners to take positive and appropriate action to solve a local water resource issue is ActionEducation. In each new Project WET activity, projects are recommended for individuals, classrooms, schools and businesses. These projects offer opportunities for participants to apply the knowledge acquired in Project WET activities to effect positive change in their communities by either educating members or helping solve a local water resource issue.

In both the *Educators Guide* and *KIDs Student Activity Booklet* of ***Discover Floods***, you will see many examples of ActionEducation. In the activity, "Take Action!," students work with their families to prepare for a flood by creating an Action Pack (emergency kit) and an Action Plan. Students are encouraged to develop an Action Pack and Plan for their school and to extend their sense of responsibility to include their community. One aspect of developing an Action Plan is to identify vulnerable populations (e.g., elderly family members or neighbors) and to plan for their safe evacuation in the event of a flood. In the activity, "My Hazard Map," students are prompted to talk with community leaders to plant cover vegetation on bare hillsides and free streams from debris.

In the activity, "8-4-1, One for All," students are challenged to broaden their focus to include the needs of their community. They are asked, "What strategies help community members work together before, during and after a flood or other natural disaster?" Students discuss: responsibility, respect, communication, negotiation, listening, compromise and teamwork. Students learn their water address to stay safe at home, on vacation and when playing with friends and how to educate family and community members.

Examples of ActionEducation in other recent Project WET publications are found in the *Educators Guide* and *KIDs Student Activity Booklet*, ***Healthy Water, Healthy Habits, Healthy People.*** Teachers work with students to help them understand the relationship between effective hand washing and the prevention of disease. What is the ActionEducation component? Students are encouraged to make a Tippy Tap to provide a hand-washing station for their school or home. Project WET has distributed ***Healthy Water, Healthy Habits, Healthy People*** student activity booklets to 1,000 African schools to encourage healthy habits such as hand washing, one of the simplest and most effective methods to help prevent the spread of disease.

What can a water education program like Project WET do to reduce the number of deaths caused by water-borne diseases—or from natural disasters like a flood? Project WET has found its answer through ActionEducation—educating students about water resources and empowering them to take responsibility and appropriate action, not only for their personal health and wellbeing, but also for that of their families, community and local environment.

Project WET Foundation

Activity Format


FEMA News Photos

A snappy, thought-provoking teaser introduces the activity. This can be presented as an ice breaker.

▼ **Summary**
A brief description of the concepts, skills, and affective dimensions of the activity.


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■ **Subject Areas:**
Disciplines to which the activity applies.

■ **Duration:**
Preparation time: The approximate time needed to prepare for the activity. NOTE: Estimates are based on first-time use. Preparation times for subsequent uses should be less.

Activity time: The approximate time needed to complete the activity.

■ **Setting:**
Suggested site.

■ **Skills:**
Skills applied in the activity.

■ **Vocabulary:**
Significant terms defined in the activity.

Objectives

The qualities or skills students should possess after participating in the activity. NOTE: Learning objectives, rather than behavioral objectives, were established for Project WET activities. To measure student achievement, see **Assessment**.

Materials

- *Supplies needed to conduct the activity.* Describes how to prepare materials prior to engaging in the activity.

Making Connections

Describes the relevance of the activity to students and presents the rationale for the activity.

Background

Relevant information about activity concepts or teaching strategies.

Procedure

▼ *Warm Up*

Prepares everyone for the activity and introduces concepts to be addressed. Provides the instructor with pre-assessment strategies.

▼ *The Activity*

Provides step-by-step directions to address concepts. The primary component of each step is presented in bold-faced type. NOTE: Some activities are organized into "parts." This divides extensive activities into logical segments. All or some of the parts may be used, depending on the objectives of instruction. In addition, a few activities provide Options. These consist of alternative methods for conducting the activity.

▼ *Wrap Up*

Brings closure to the lesson and includes questions and activities to assess student learning. NOTE: Many Project WET activities include an "action" component ***Wrap Up and ActionEducation***™. ActionEducation moves learners beyond the classroom and involves friends, family, community, state, national, and/or international audiences.

Assessment

Presents diverse assessment strategies that relate to the objectives of the activity, noting the part of the activity during which each assessment occurs. Ideas for assessment opportunities that follow the activity are often suggested.

Extensions

Provides additional activities for continued investigation into concepts addressed in the activity. Extensions can also be used for further assessment.

Resources

Lists references providing additional background information. Resources for direct use by students are marked with an 🍎. NOTE: This is a limited list. Several titles are suggested, but many other resources on similar topics will serve equally well.

e-Links

Lists online references providing additional background information.

Incredible Journey

Where will the water in the river and floodplain be tomorrow?

Summary

With a roll of the die, students simulate the movement of water within the water cycle.

©iStockphoto.com/andrewashtree

- **Subject Areas:**
  Earth Science
- **Duration:**
  Preparation time: 50 minutes
  Activity time: two 50-minute periods
- **Setting:**
  A large room or playing field
- **Skills:**
  Organizing (mapping); Analyzing (identifying components and relationships); Interpreting (describing)
- **Vocabulary:**
  condensation, evaporation, electromagnetic forces

Objectives

Students will:

- describe the movement of water within the water cycle.
- identify the states of water as it moves through the water cycle.

Materials

- *9 large pieces of paper*
- *Copies of* ***Water Cycle Table*** (optional)
- *Marking pens*
- *9 boxes, about 6 inches (15 cm) on a side* Boxes are used to make dice for the game. Gift boxes used for coffee mugs are a good size or inquire at your local mailing outlet. There will be one die [or box] per station of the water cycle. [To increase the pace of the game, use more boxes at each station, especially at the clouds and ocean stations.] The labels for the sides of the die are located in the *Water Cycle Table*. These labels represent the options for pathways that water can follow. Explanations for the labels are provided. For younger students, use pictures.
- *A bell, whistle, buzzer, or some sound maker*

Making Connections

When children think of the water cycle, they often imagine a circle of water, flowing from a stream to an ocean, evaporating to the clouds, raining down on a mountaintop, and flowing back into a stream. Role-playing a water molecule helps students to conceptualize the water cycle as more than a predictable two-dimensional path.

Background

While water does circulate from one point or state to another in the water cycle, the paths it can take are variable.

Heat energy directly influences the rate of motion of water molecules. When the motion of the molecule increases because of an increase in heat energy, water will change from solid to liquid to gas. With each change in state, physical movement from one location to another usually follows. Glaciers melt to pools which overflow to streams, where water may evaporate into the atmosphere.

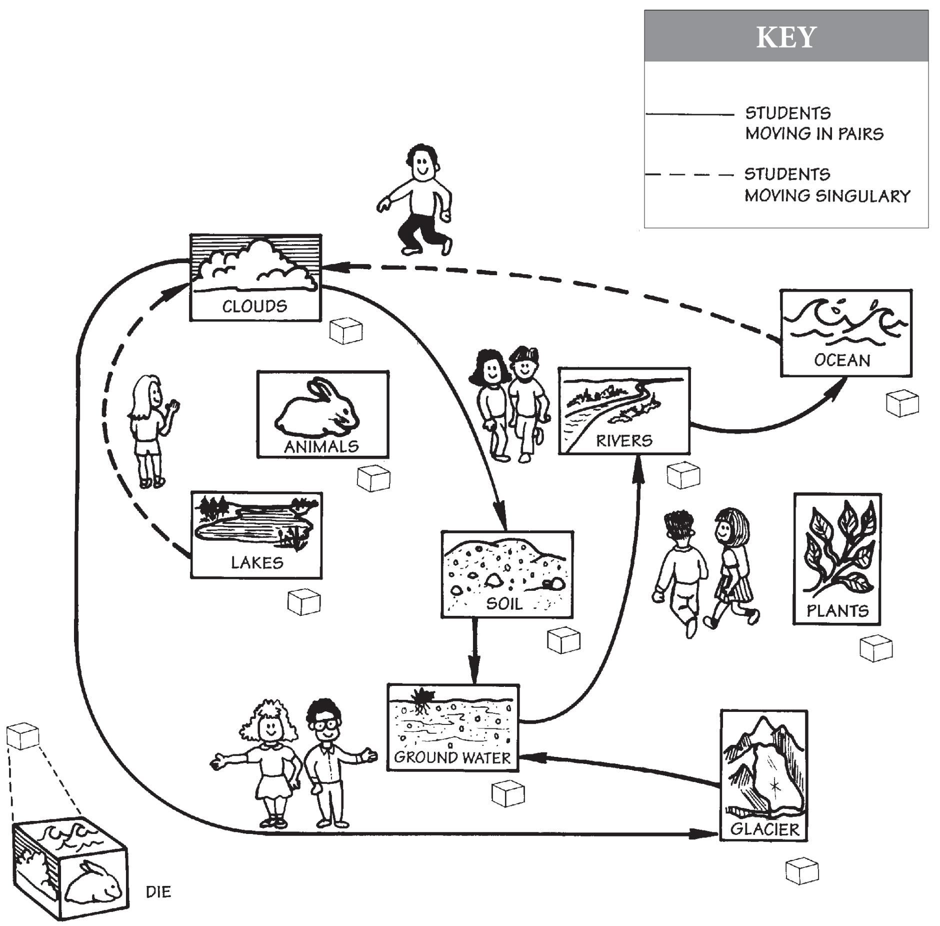
Gravity further influences the ability of water to travel over, under, and above Earth's surface. Water as a solid, liquid, or gas has mass and is subject to gravitational force. Snow on mountaintops melts and descends through watersheds to the oceans of the world.

One of the most visible states in which water moves is the liquid form. Water is seen flowing in streams and rivers and tumbling in ocean waves. Water travels slowly underground, seeping and filtering through particles of soil and pores within rocks.

Although unseen, water's most dramatic movements take place during its gaseous phase. Water is constantly evaporating, changing from a liquid to a gas. As a vapor, it can travel through the atmosphere over Earth's surface. In fact, water vapor surrounds us all the time. Where it condenses and returns to Earth depends upon loss of heat energy, gravity, and the structure of Earth's surface.

Water condensation can be seen as dew on plants or water droplets on the outside of a glass of cold water. In clouds, water molecules collect on tiny dust particles. Eventually, the water droplets become too heavy and gravity pulls the water to Earth.

Using station illustrations, create a one page graphic on which students record their movements during the Incredible Journey.



Living organisms also help move water. Humans and other animals carry water within their bodies, transporting it from one location to another. Water is either directly consumed by animals or is removed from foods during digestion. Water is excreted as a liquid or leaves as a gas, usually through respiration. When water is present on the skin of an animal (for example, as perspiration), evaporation may occur.

The greatest movers of water among living organisms are plants. The roots of plants absorb water. Some of this water is used within the body of the plant, but most of it travels up through the plant to the leaf surface. When water reaches the leaves, it is exposed to the air and the sun's energy and is easily evaporated. This process is called transpiration.

All these processes work together to move water around, through, and over Earth.

Procedure

Warm Up

Ask students to identify the different places water can go as it moves through and around Earth. Write their responses on the board.

The Activity

1. **Tell students that they are going to become water molecules moving through the water cycle**.

2. **Categorize the places water can move through into nine stations: Clouds, Plants, Animals, Rivers, Oceans, Lakes, Ground Water, Soil, and Glaciers. Write these names on large pieces of paper and put them in locations around the room or yard. (Students may illustrate station labels.)**

3. **Assign an even number of students to each station. (The cloud station can have an uneven number.) Have students identify the different places water can go from their station in the water cycle. Discuss the conditions that cause the water to move**. Explain that water movement depends on energy from the sun, electromagnetic energy, and gravity. Sometimes water will not go anywhere. After students have come up with lists, have each group share their work. The die for each station can be handed to that group and they can check to see if they covered all the places water can go. The *Water Cycle Table* provides an explanation of water movements from each station.

4. **Students should discuss the form in which water moves from one location to another**. Most of the movement from one station to another will take place when water is in its liquid form. However, any time water moves to the clouds, it is in the form of water vapor, with molecules moving rapidly and apart from each other.

5. **Tell students they will be demonstrating water's movement from one location to another**. When they move as liquid water, they will move in pairs, representing many water molecules together in a water drop. When they move to the clouds (evaporate), they will separate from their partners and move alone as individual water molecules. When water rains from the clouds (condenses), the students will grab a partner and move to the next location.

6. **In this game, a roll of the die determines where water will go**. Students line up behind the die at their station. (At the cloud station they will line up in single file; at the rest of the stations they should line up in pairs.) Students roll the die and go to the location indicated by the label facing up. If they roll *stay*, they move to the back of the line.

When students arrive at the next station, they get in line. When they reach the front of the line, they roll the die and move to the next station (or proceed to the back of the line if they roll *stay*).

In the clouds, students roll the die individually, but if they leave the clouds they grab a partner (the person immediately behind them) and move to the next station; the partner does not roll the die.

7. **Students should keep track of their movements**. This can be done by having them keep a journal or notepad to record each move they make, including stays. Students may record their journeys by leaving behind personalized stickers at each station. Another approach has half the class play the game while the other half watches. Onlookers can be assigned to track the movements of their classmates. In the next round the onlookers will play the game, and the other half of the class can record their movements.

8. **Tell students the game will begin and end with the sound of a bell (or buzzer or whistle). Begin the game!**

Wrap Up

Have students use their travel records to write stories about the places water has been. They should include a description of what conditions were necessary for water to move to each location and the state water was in as it moved. Discuss any *cycling* that took place (that is, if any students returned to the same station).

Provide students with a location (e.g., parking lot, stream, glacier, or one from the human body—bladder) and have them identify ways water can move to and from that site. Have them identify the states of the water.

Have older students teach the "Incredible Journey" to younger students.

Assessment

Have students:

- role-play water as it moves through the water cycle (step 8).
- identify the states water is in while moving through the water cycle (step 4 and ***Wrap Up***).
- write a story describing the movement of water (***Wrap Up***).

Extensions

Have students compare the movement of water during different seasons and at different locations around the globe. They can adapt the game (change the faces of the die, add alternative stations, etc.) to represent these different conditions or locations.

Have students investigate how water becomes polluted and is cleaned as it moves through the water cycle. For instance, it might pick up contaminants as it travels through the soil, which are then left behind as water evaporates at the surface. Challenge students to adapt "Incredible Journey" to include these processes. For example, rolled-up pieces of masking tape can represent pollutants and be stuck to students as they travel to the soil station. Some materials will be filtered out as the water moves to the lake. Show this by having students rub their arms to slough off some tape. If they roll *clouds*, they remove all the tape; when water evaporates it leaves pollutants behind.

Resources

Alexander, Gretchen. 1989. *Water Cycle Teacher's Guide*. Hudson, N.H.: Delta Education, Inc.

Mayes, Susan. 1989. *What Makes It Rain?* London, England: Usborne Publications.

Schmid, Eleonore. 1990. *The Water's Journey*. New York, N.Y.: North-South Books.

Photo Resources

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Water Cycle Table

STATION	DIE SIDE LABELS	EXPLANATION
Soil	one side *plant*	Water is absorbed by plant roots.
	one side *river*	The soil is saturated, so water runs off into a river.
	one side *ground water*	Water is pulled by gravity; it filters into the soil.
	two sides *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	one side *stay*	Water remains on the surface (perhaps in a puddle, or adhering to a soil particle).
Plant	four sides *clouds*	Water leaves the plant through the process of transpiration.
	two sides *stay*	Water is used by the plant and stays in the cells.
River	one side *lake*	Water flows into a lake.
	one side *ground water*	Water is pulled by gravity; it filters into the soil.
	one side *ocean*	Water flows into the ocean.
	one side *animal*	An animal drinks water.
	one side *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	one side *stay*	Water remains in the current of the river.
Clouds	one side *soil*	Water condenses and falls on soil.
	one side *glacier*	Water condenses and falls as snow onto a glacier.
	one side *lake*	Water condenses and falls into a lake.
	two sides *ocean*	Water condenses and falls into the ocean.
	one side *stay*	Water remains as a water droplet clinging to a dust particle.

Water Cycle Table, continued

STATION	DIE SIDE LABELS	EXPLANATION
Ocean	two sides *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	four sides *stay*	Water remains in the ocean.
Lake	one side *ground water*	Water is pulled by gravity; it filters into the soil.
	one side *animal*	An animal drinks water.
	one side *river*	Water flows into a river.
	one side *clouds*	Heat energy is added to the water, so the water evaporates and goes to the clouds.
	two sides *stay*	Water remains within the lake or estuary.
Animal	two sides *soil*	Water is excreted through feces and urine.
	three sides *clouds*	Water is respired or evaporated from the body.
	one side *stay*	Water is incorporated into the body.
Ground Water	one side *river*	Water filters into a river.
	two sides *lake*	Water filters into a lake.
	three sides *stay*	Water stays underground.
Glacier	one side *ground water*	Ice melts and water filters into the ground.
	one side *clouds*	Ice evaporates and water goes to the clouds (sublimation).
	one side *river*	Ice melts and water flows into a river.
	three sides *stay*	Ice stays frozen in the glacier.

Thunderstorm

What rumbles but is never hungry, and crashes but never gets hurt?

Summary

Students simulate the sounds of a thunderstorm through an aerobic activity and generate precipitation maps through a mock monitoring network.


©Corbis

- **Subject Areas:**
  Earth Science, Language Arts
- **Duration:**
  Preparation time:
  Part I: none needed
  Part II: 30 minutes
  Activity time:
  Part I: 30 minutes
  Part II: 50 minutes
- **Setting:**
  Classroom
- **Skills:**
  Gathering information (calculating); Organizing (plotting data, mapping); Analyzing
- **Vocabulary:**
  precipitation, isohyetal line

Objectives

Students will:

- work cooperatively to mimic the sounds of a thunderstorm.
- become more aware of the various sounds of a thunderstorm.
- monitor and record "precipitation."

Materials

- *Hundreds of small pieces of paper* (half-inch [1 cm] squares)
- *Paper and pencils*
- *Containers with lids* (Ask students to collect containers of the same size, one per student.)
- *Rulers*
- *Local map*

Making Connections

Discussing thunderstorms will evoke diverse student reactions. Most will have experienced the sights and sounds of a storm. Some will be aware of thunderstorms' effects through reading newspapers, watching television or researching the internet.

Students should learn how thunderstorms can affect their lives and how meteorologists study thunderstorms.

Background

Thunderstorms are one of nature's most spectacular phenomena. They occur throughout the world. What distinguishes a thunderstorm from other types of storms? Thunder and lightning.

Electrical charges build up and move about within certain types of clouds (for example, a cumulonimbus cloud that contains large amounts of moisture).

When these charges jump from one area of the cloud to another, to another cloud or to the ground, lightning occurs. The electric current in the lightning heats the air through which it passes. This heat expands the air along its path and creates a shock wave of sound—thunder.

If you count five seconds from the time you see lightning until you hear thunder, the storm is about one mile (1.6 km) away. Why? The lightning you see is traveling at the speed of light (186,282 miles [299,792 km] per second); whereas the thunder you hear is traveling much slower, at the speed of sound (1,100 feet [335 m] per second).

The sights and sounds accompanying a thunderstorm are impressive—lightning flashes illuminate the sky; thunder rumbles and shakes houses; rain falls on roofs; the wind sways tree branches; and sometimes hailstones rattle windows.

In watching a thunderhead grow in the distance on a warm summer evening, we witness a spectacle of great beauty. When we are caught in a thunderstorm, however, safety becomes a priority.

Rain can be a benefit of thunderstorms. They also can generate flash floods, which are very dangerous to humans, wildlife and human-made structures. Flash floods form when too much precipitation falls in a relatively short time.

Flash floods are more likely in narrow, steep catchments or where soil and vegetation cover cannot retain the rain water from running off the land surface.

It is important to monitor the amount of precipitation released in an area by a thunderstorm. For example, 10 inches (25 cm) of rainfall in a 24-hour period in a limited area may cause extensive flooding. On the other hand, if the same area receives 10 inches (25 cm) of precipitation over several months, flooding may not occur.

©Cobis

An extensive record of rainfall and streamflow measurements over a long time period can help watershed and emergency managers assess the possible impact of precipitation a thunderstorm creates. By studying these records for specific areas—and how precipitation and streamflow can affect these areas—land-use planners can make educated decisions about locating buildings, roads and bridges.

Precipitation can be monitored through a network of recording stations, ground radar or through instruments on satellites. Each station collects data transmitted to scientists of the National Meteorological and Hydrological Services and in the United States, the National Weather Service. The quality of the data generated by a network is related to the size of the area monitored; number of data collection stations; duration of the monitoring; accuracy of measurement devices; and skill of the observer.

Scientists use graphs to illustrate their measurements. Graphs and maps make data easier to visualize and understand.

Procedure

Warm Up

Have students describe how they would feel if they heard this report on their car radios:

> A large thunderstorm with lightning, heavy rain, small hail and gusty winds is moving toward (your town's name) at 25 miles (40 km) per hour. People in the storm's path should take precautions.

Have students outline the precautions they should take when they are at home, in a car or in an open field. Discuss precautions and compare them to the official recommendations of the National Meteorological and Hydrological Services or similar organization that issues safety guidelines.

Ask students to create a mental picture of the approaching thunderstorm. Have them list some of its sights and sounds. What do they think causes the sound of thunder? Provide a brief explanation. Explain that they are going to create the sounds of a thunderstorm and then calculate how much "rain" fell as the storm passed through the classroom.

The Activity

Part I

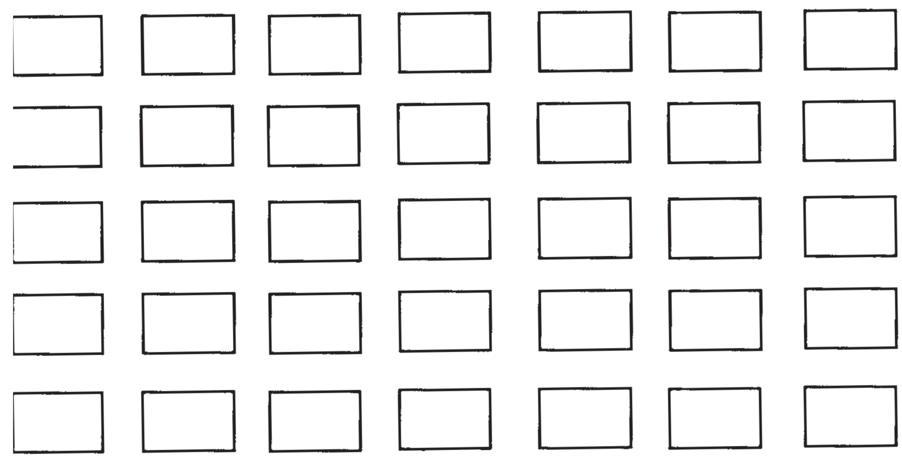
1. **Ask students to stand in a semicircle in front of you. Explain that when you make eye contact with or point to a student, he or she should imitate your motion. The student should continue making the motion until you make eye contact again and then make a new motion.**

Start with a student on one end of the semicircle and begin the first motion. Continue the motion as you make eye contact with each student. Return to the first student and start the second motion. This will create a crescendo as the sounds produced move from one end of the semicircle to the other. Using this strategy, lead students through the following motions:

- Rub your hands together.
- Snap your fingers.
- Clap your hands in an irregular cadence.
- Slap your hands on your legs. (Optional: At this time, a student flicks a light switch on and off to represent lightning, while another beats a drum to symbolize thunder.)
- Stomp your feet.
- Slap your hands on your legs and stomp your feet (represents height of the storm).
- Stomp your feet.
- Slap your hands on your legs.
- Clap your hands in an irregular rhythm.
- Snap your fingers.
- Rub your hands together.
- Open palms (quiet).

2. **When all students are standing with open palms, have them remain silent for a minute to think about the exercise and catch their breath.** Ask students to be seated. Discuss each motion and the effect it mimics in a real thunderstorm.

3. **Have students write stories or draw pictures about thunderstorms they have experienced**. Create a collection, "Tales of Thunderstorms," and place it in the school library for everyone to read.



Part II

1. Have students arrange their chairs or desks in rows to form a grid and stand behind them.

2. Give one student a container filled with pieces of paper. Tell the student that when you say "Now!" he or she should toss the paper into the air.

3. Repeat the thunderstorm activity. At the height of the storm, when students are stomping their feet and slapping their hands on their legs, say "Now!"

4. After the last sounds fade, ask students to be seated. Explain that the pieces of paper represent the amount of rainfall from the thunderstorm.

5. Discuss the importance of monitoring rainfall. Tell students they each represent one data point in the monitoring network. Have students gather as many pieces of paper as possible without leaving their seats.

6. Calculate the amount of precipitation by counting each piece of paper collected as one millimeter of rain. Ten pieces equal 1 cm of rain, five pieces equal 0.5 cm, 23 pieces equal 2.3 cm and so on. In standard measurement, 10 pieces equal one inch of rain, five pieces equal half an inch and 23 pieces equal 2.3 inches. Numbers can be rounded for younger students.

7. Draw the grid of the "student monitoring stations" on the board. Record the number of pieces of paper collected by each student in the corresponding square on the grid. Have students locate the area that received the most precipitation and mark it with an "X."

8. Divide the class into groups. Have each group copy the grid and rainfall measurements.

9. Have each group make a precipitation map. The purpose is to identify areas with similar amounts of precipitation. Ask students how they would categorize or group the stations.

Suggest that they refer to the number of inches or centimeters of rainfall. For example, if the area with the heaviest rainfall received 12.8 cm, have them locate all other sites that received 12 cm or more. They should draw a line connecting all those stations.

The end result will be a polygon—make sure the polygon does not enclose any stations that received less than 12 cm. The same should be done with the 10-, eight- and six-centimeter rainfall measurements. The eight-centimeter polygon will encompass or surround the 12-cm polygon, the six-cm polygon will surround the eight-cm polygon and so on. The lines should not cross.

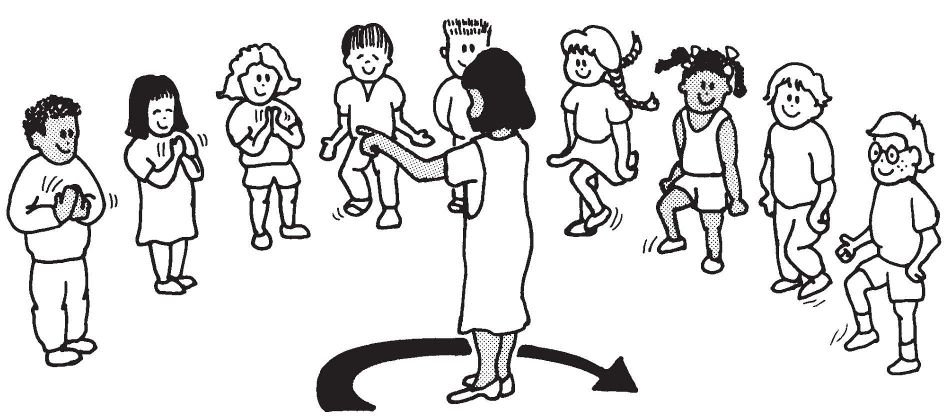
10. The polygons are called isohyetal lines. Theoretically, they indicate that every point along the line is of equal value. Ask students how a hydrologist might use the data from this map (flood predictions; storm-water drainage system design; irrigation; bridge design; culverts beneath highways; soil erosion; and so forth).

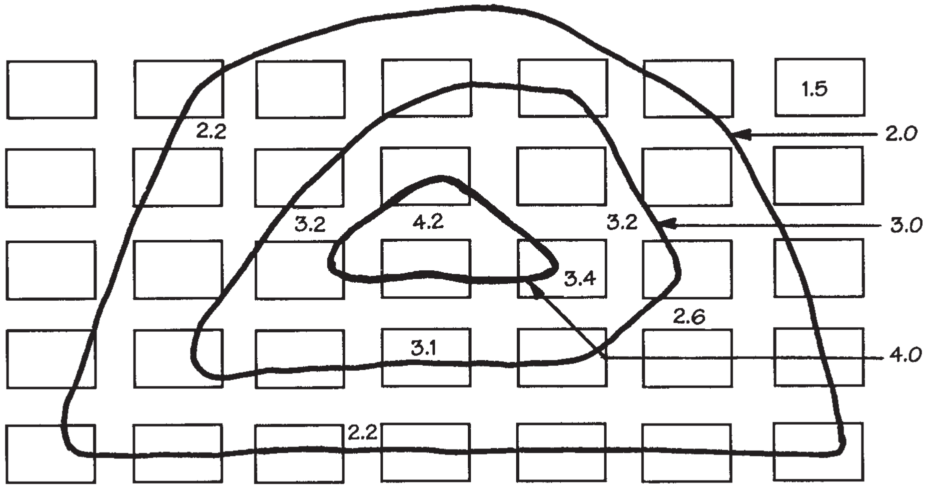
11. For example, imagine a river flowing from the upper left-hand corner of the grid diagram (page 17) diagonally to the lower right-hand corner. How would the upstream portion of the river (upper left-hand corner) be affected by this rain event? (It would likely not be affected.) The river passes through an area of high precipitation. How might this affect the downstream area? (Some flooding may occur.)

Wrap Up

Check student maps to ensure they were drawn correctly. Have students discuss the following questions:

- What change could have been made to the monitoring network to get better results?





- Would the results have been better if there had been more collection-points?

Repeat the activity several times to generate different maps.

Post a map of your community and have each student mark the location of his or her house. Have students place containers in open areas near their homes.

Instruct them to measure the amount of rain collected after the next storm and bring the results to class. Tell students to record the measurements on the community map. Have them use the results to produce a precipitation map of the storm event.

Assessment

Have students:

- mimic the sounds of a thunderstorm (***Part I***, step 1).
- relate the sounds to actual thunderstorm events (***Part I***, step 2).
- recount experiences of thunderstorms (***Part I***, step 3).
- draw and interpret a precipitation map (***Part II***, step 9 and ***Wrap Up***).

Extensions

Introduce the process of estimating the distance of a thunderclap. Challenge students to incorporate this into the thunderstorm activity (i.e., ask them to simulate a storm that is five seconds away).

Have students suggest ways to vary the intensity of the thunderstorm or to mimic different intensities of rain. Make an audio recording of each type of storm or rain sound produced by the students. Play the recordings and have students match the recording to the type of storm or rain intensity they tried to mimic.

Convert the precipitation amounts on the map to snow depth. For example, 1 cm of rain generally equals 10 cm of snow. If you collected 24 pieces of paper you would have 2.4 cm of rain or 24 cm of snow.

In standard measurement, one inch of precipitation equals 10 inches of snow. So, if you collected 24 pieces of paper, you would have 2.4 inches of rain or 24 inches of snow.

This type of data is important in areas that receive snow. Snowfall affects spring runoff, avalanche (snow slide) conditions, wildlife migrations to winter feeding areas and river-basin planning. Ask students if snow falls where they live? What other regional storms affect precipitation events where they live?

Use blue pieces of paper to represent rain and white to represent hail. Conduct the activity the same way. This time, count the total pieces of paper for each color. This will allow you to draw isohyetal lines for rain and hail on the same map.

Create a wild weather report. To stimulate creative thinking, have students write a weather report from the perspective of a gopher, robin, fox, trout or a tree. What would they experience from a thunderstorm? What would they tell their wild friends to do?

Discuss why, under certain circumstances, hardtop vehicles or planes can be struck by lightning, but the passengers inside remain unharmed. The idea that a hollow metal conductor will protect the interior from electric fields can be demonstrated using Faraday screens, cans or cages.

An aircraft being struck by lightning is a demonstration of the Faraday cage effect. Neither the plane nor the passengers are harmed because the metal body of the airplane protects the interior.

Discuss what can still make a person vulnerable inside a vehicle during a thunderstorm, such as open windows or doors, contact with metal objects of the car, highly flammable gasoline (petrol) in the tank, or other hazards, such as falling trees or electrical wires, or being carried away by floodwaters.

Resources

Branley, Franklyn M. 1985. *Flash, Crash, Rumble and Roll*. New York: Harper.

Graf, Mike. 1998. *Weather Channel Lightning and Thunderstorms*. New York: Simon Spotlight.

Lambert, David, and Ralph Hardy. 1984. *The World of Science: Weather and Its Work*. New York: Facts on File.

Polacco, Patricia. 1990. *Thunder Cake*. New York: Philomel Books.

e-Links

National Oceanic and Atmospheric Association
NOAA Lightning Safety Information: http://www.lightningsafety.noaa.gov/

Photo Resources

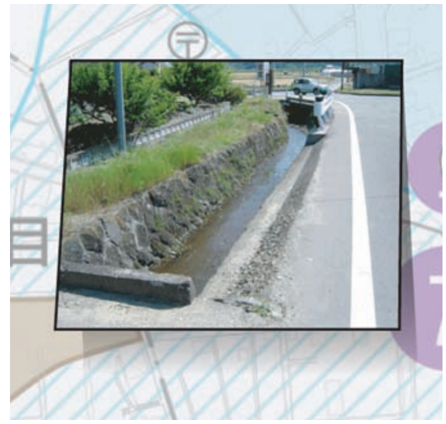
Non-credited photos contained in this activity are courtesy FEMA News Photos.

My Hazard Map

It is important to know if you live in a flood-prone region and how to respond—before disaster strikes.

Summary

Students gather information about floods and create a hazard map to increase awareness of floods in their community.



- **Subject Areas:**
  Earth Science, Environmental Science

- **Duration:**
  Preparation time:
  10 minutes
  Activity time:
  Interview/Survey: 60 minutes
  Map: 50 minutes

- **Settings:**
  Outside/Classroom

- **Skills:**
  Gathering (interviewing); Organizing (mapping); Interpreting (relating, defining problems); Applying (planning)

- **Vocabulary:**
  floodplain, vulnerabilities, hazard

Objectives

Students will:

- map their community, indicating aid facilities and those with vulnerable populations, dangerous structures, and evacuation routes and points.
- identify surrounding hazards, and how to evacuate and stay safe during a flood.
- relate vulnerabilities to floods and the importance of community participation.
- increase flood awareness in their families and other community members.

Materials

- *Hazard information* (hazard map if available)
- *Local history books, survey reports about past floods*
- *Photocopy of local map* (large, one per group)
- *Colored pencils* (about five colors)
- *Camera, drawing board, clipboard*
- *Photos of region*
- *Notebook*
- *Scissors, glue, repositionable sticky paper*

Making Connections

Students may know they live in a flood-prone community, but a flood or other disaster may not have occurred in their lifetime. Interviewing elders and neighbors, and surveying their community to assess its strengths and vulnerabilities, will help them prepare for a potential flood.

Background

Societies, communities and households seek the best use of available natural resources and assets to improve their quality of life. A floodplain offers enormous advantages for communities, although living in a floodplain exposes its occupants to flooding. The deep, fertile alluvial soil of floodplains—resulting from eons of flooding—is ideal for higher crop yields. Floodplains contribute substantially to food production and provision in most countries. As such, floodplains typically support very high densities of human settlement. But, a balance must be struck between reducing losses from floods and maximizing efficient use of floodplains.

History shows that absolute protection from flooding is neither technically feasible nor economically (or environmentally) viable. This is because a risk-reduction strategy—aimed at reducing flood damages through structural measures (such as flood embankments)—provides only partial protection for people inhabiting floodplains. Such measures, too often, offer a false sense of security. In these locations, an extreme flood can inflict serious—and sometimes deadly—consequences.

When flood protection measures fail, damage can be severe due to extensive development in the floodplain. For many societies, the cost of reducing the incidence of flooding is too high or the side effects are unacceptable. In such cases, disaster preparedness and flood emergency responses may provide an alternative. Everyone living in a floodplain must be aware of the risks and be prepared for flood. Flood-hazard maps are one tool to help achieve this.

Procedure

Warm Up

Show students pictures of flooding in urban and natural areas, like those below, or have them search the Internet for similar photos. Tell them that flood risk consists of the magnitude (size) of the flood, the duration of the flood, the exposure of human structures and activities, and the vulnerability of the elements at risk (i.e., people, structures, environment). Ask students if they believe there is greater damage to people and property in urban or natural areas after a flood. Why?

Direct students to form groups based on the neighborhoods in which they live. Show them a community map and have students lightly color the map by land-use practices, (e.g., orange for housing, pink for farms, green for woods, blue for rivers).

Ask students to discuss the types of facilities or buildings susceptible to flood damage.

Tell students a story about a past local or regional flood, and ask them to discuss their expectations related to future flooding. If flood hazard information is available, ask students to imagine what could happen if a flood occurred in their community.

If students have concerns about a potential flood, ask them what they can do. Can they prevent a natural disaster like a flood? (No, that is not within their control.) What is within their control? (They can plan and prepare for what they, their families and friends would do in case of a flood.)

Divide students into two investigation teams—Interview and Field Survey teams. Direct each investigation team to prepare for outside activity.

The Activity

1. **Direct the Interview Team to make a list of people who have lived in neighborhoods that have experienced flooding.** Have students make an appointment for an interview by phone or in person if their parents can accompany them.

2. **Direct the Interview Team to develop questions and prepare an interview sheet such as:**

What flood events have you experienced?

In what years did they occur?

What community areas experienced the most flooding?

Did the community receive warnings before the events? How?

Did you take shelter in your home?

If not, where were the emergency shelters?

How did you prepare, and what did you do during and after flooding?

What is your most vivid memory of a flood?

What advice would you offer?

3. Direct students to record necessary information on the interview sheet and note locations of floods discussed by interviewees to be placed on the community map.

Right: Yellow River, China

Below: River in northern Canada

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4. **Direct the Field Survey Team to plan for the survey (date, location).**

5. **Direct the Field Survey Team to determine facilities to be identified.** This includes important locations such as police and fire stations, schools, hospitals, nursery and daycare facilities, and homes for the elderly. They should also include dangerous structures such as dams and facilities, like power plants and chemical factories. Note buildings in poor repair. Identify the community water supply, wastewater treatment, waste disposal area, major rivers, roads and power lines.

6. **Ask students to survey the environment to determine if there are bare hillsides that put the community at risk for landslides during rain and floods. Also, check for streams choked with debris—another potential flooding hazard.**

7. **Inform the Field Survey Team of potential dangers during evacuation (i.e., deep, rapidly moving water, floating objects) and the need for an appropriate evacuation route.**

8. **Direct students to identify physical impacts of past area floods, and safe and hazardous zones.**

9. **Based on the questions above, and others that students create, have them develop a field survey sheet.**

10. **Direct the Field Survey Team to survey the selected area and record information on the field survey sheet. Also, have students take photographs.**

Wrap Up

Have students put all information from the field survey on the map. Have them develop their own legend with symbols color-coded for aid facilities (hospitals, police and fire stations, flood shelters); dangerous structures and industries (dams, power plants, factories for production of chemicals and other toxic substances); and vulnerable facilities (schools, nursery and daycare facilities, homes for the elderly). Have them indicate environmental hazards, such as denuded hillsides at risk for landslides or debris-choked streams with the potential for flooding. Have them outline the floodplain in their community. Direct students to note all areas of greatest flood risk in a particular color.

Example of hazard map produced in Japan (MLIT 2007).

Signs are reminders of flood events, Toyooka, Japan.

Photo by MLIT

Have them clearly mark all evacuation routes to safe areas, either to higher, stable ground or areas beyond the reach of flood water, or evacuation centers. Have them note evacuation points on their maps, such as schools where people may shelter during a flood, and also sites to temporarily store farm equipment, bicycles and cars, and house livestock. Be sure each student understands the evacuation route in relation to his or her own home.

Have the interview group place their information on the large community map. Identify each student's house and evacuation shelter, and have students describe how to evacuate to that location during flooding.

Discuss with students how to reduce community flood risk. (Discuss with community leaders planting cover vegetation on bare hillsides and freeing streams from debris.) What other things could the community do to make people safer? (Establish an early warning system in their community [i.e., community sirens, home telephone notification, local radio station messages, police broadcasting warnings via megaphone, visits by volunteer fire brigade].) What can help the community recognize the flood risk even though flooding events are rare? (Standardized flooding marks or signs are a possible solution. See flood event signs left.) Prepare a community evacuation plan to ensure vulnerable populations are moved to safety.

Have students discuss with their families the hazard map and plans for possible evacuation.

Assessment

Have students :

- describe characteristics of the local area flooded in the past (steps 1-3).
- relate the importance or necessity of mapping before and after flooding (steps 5-9).
- draw and interpret a hazard map for proper flood response (***Wrap Up***).
- describe the evacuation route from their home to a safe place (***Wrap Up***).
- describe what their communities can do to prepare for floods (***Wrap Up***).
- describe how they can help elderly or vulnerable people (***Wrap Up***).

Extensions

Compare results of the mapping exercise with hazard maps published by government or technical experts. If such a map is available, it will show precise information for students' reference. This also can also help students imagine local area flooding.

Have students role-play a hypothetical flood to have them check their hazard map for practical aspects. In role-playing, some students can be elderly people or others at risk to understand their vulnerability.

Share with students the activity, "High Water History" from the *Kids in Discovery Student Activity Booklet*, ***Discover Floods***.

Acknowledgement

This activity is based on and re-organized from the *Disaster Management Education Manual* in Japan (MLIT, 2007). Photos from the *Disaster Management Education Manua*l.

Resources

Ministry of Land, Infrastructure and Transport (MLIT), Booklet for Mapping by Children *Oh! My Hazard Map*, 2007

Ministry of Land, Infrastructure and Transport, Disaster Management Education Manual, *Bousai Gakushu Manual,* (Japanese), 2007

e-Links

Ministry of Land, Infrastructure and Transport, 2006.
Marugoto-Machigoto Hazard map no suishin, (Japanese)
http://www.mlit.go.jp/kisha/kisha06/05/050703_.html

World Meteorological Organization, 2004.
Integrated Flood Management Concept Paper,
http://www.apfm.info/pdf/concept_paper_e.pdf

Photo Resources

Non-credited photos contained in this activity are courtesy FEMA News Photos.

Color Me A Watershed

What might make a watershed blue . . . or brown . . . or green?

▼ **Summary**

Through interpretation of maps, students observe how land use and development can affect a watershed.

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■ **Subject Areas:**

Environmental Science, Mathematics, History

■ **Duration:**

Preparation time:

Option 1: 10 minutes

Option 2: 10 minutes

Option 3: 10 minutes

Activity time:

Option 1: 40 minutes

Option 2: 50 minutes

Option 3: 40 minutes

■ **Setting:**

Classroom

■ **Skills:**

Gathering information (calculating); Analyzing (comparing); Interpreting (identifying cause and effect)

■ **Vocabulary::**

discharge, watershed, runoff

Objectives

Students will:

- recognize that population growth and settlement cause land-use changes.
- analyze how land-use variations in a watershed can affect surface-water runoff.

Materials

- *Maps and photographs of local community, past and present* (optional)
- *Copies of* ***Maps A, B*** *and* ***C***

For Option 1

- *Colored pencils*

For Options 2 and 3

- *Calculator*
- *Copies of the* ***Area of Land Coverage*** *chart*
- *Copies of the* ***Volume of Rain and Volume of Runoff*** *chart*

Making Connections

Learning about the past refines our current perspectives and helps us plan for the future. Historical, sequential maps can provide graphic interpretations of watershed history. By comparing past and current land-use practices, students can recognize development trends. This knowledge can help them appreciate the importance of watershed management.

Background

Resource managers and policy-makers use maps to monitor land-use changes that could contribute to increased surface water runoff into a river, pond, lake or wetland. Monitored land uses include, but are not limited to: urban (e.g., residential, parks and businesses); agriculture (e.g., pastures and corn, soybean, wheat, sugar cane, rice, pineapple and lettuce production); industry; transportation systems (e.g., roads, railroads and trails); and public lands (e.g., refuges, parks and monuments).

Land-use changes can significantly impact a region's water resources. Streams, lakes, wetlands and other bodies of water collect surface water from the surrounding land, called a watershed, drainage basin or catchment. After periods of precipitation or during snowmelt, some surface water is captured by the soil and vegetation, stored in ground water and plants, and may be slowly released into a collection site (e.g., a stream). Some evaporates or remains as ground water.

Resource managers use Geographic Information Systems (GIS) to store data and generate land-use maps electronically. Although the data collection process can be tedious, the ease of generating usable maps and map overlays is significant.

For example, water managers generate maps that show a river's watershed and major tributaries, its floodplains, and the location of urban dwellings (homes, businesses and factories) likely to be

©iStockphoto.com/_arh0n

impacted by floods. This information is valuable to local governments, planners, homeowners, insurers and others. This map also could be compared to land-use maps from 10, 20, or 30 years ago.

One way water managers study drainage basins is by measuring streamflow. Determining how much water is discharged in a watershed involves measuring the amount of water (volume) that flows past a certain point over time. Streamflow is measured in cubic meters per second (m^3/s) or cubic feet per second (cfs).

Scientists calculate average streamflow by measuring the amount of water flowing through a stream channel over years. When streamflow changes significantly from its normal quantities, water managers investigate reasons for this anomaly.

The amount of water discharged in a watershed is influenced by a complex set of factors. Those include upstream human releases of water from reservoirs; availability of snow and ice cover in the upper reaches of the watershed; development of river engineering works, such as dams and levees; rainfall and soil conditions; vegetative coverings; and human settlement patterns.

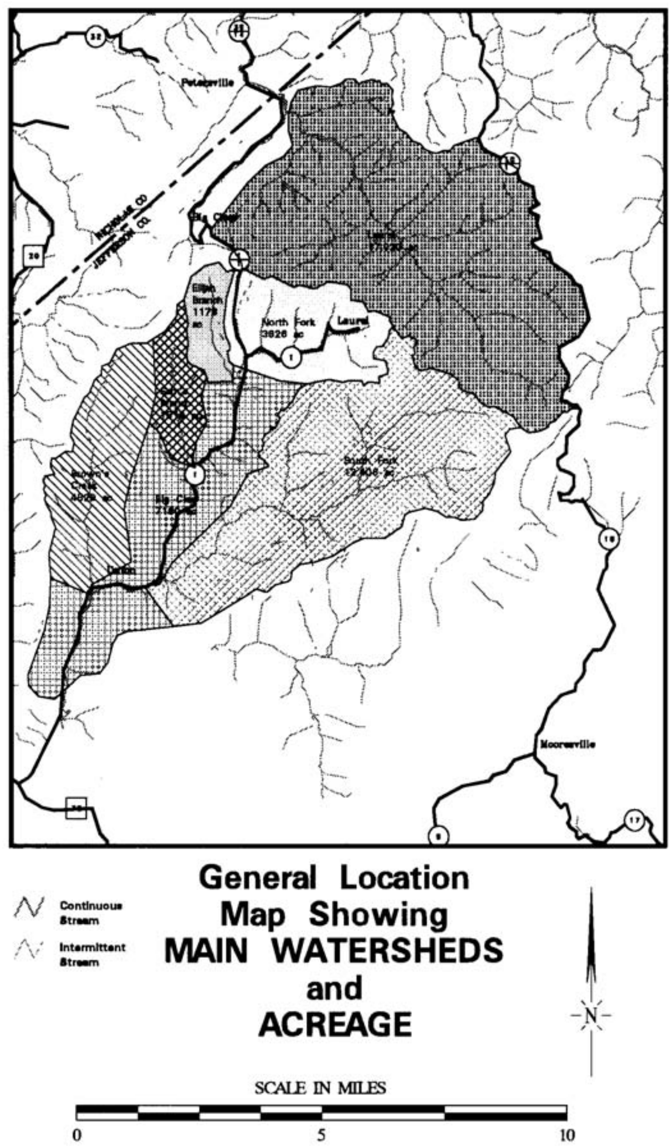
Wetlands, forests, and prairies capture and store more water than paved roads and parking lots. So, urban areas will have more runoff than areas covered with vegetation.

Floodplain managers seek to manage the natural resources there to maximize society's benefits from their long-term use. Floodplain maps from different areas can show development of flood defenses. This may include transportation infrastructure and power plants, agricultural and residential development, and nature reserves benefiting society. Comparing floodplain maps over time can be valuable to community development planners designing strategies for safe, healthy growth of towns and cities.

Water managers assess land-use changes and encourage corresponding development policy. Water managers also seek to cooperate with land-use planners and other local government officials to coordinate planning between land and water development.

For example, in areas susceptible to erosion, soil conservation measures (e.g., planting cover crops on farmland and establishing grassed waterways) can significantly reduce erosion and stream sediment load. Managers may designate lands so susceptible to erosion that landowners are required to plant vegetation. In urban areas, local governments may set aside natural areas as filters for storm-water runoff, based on runoff data and stream-water quality problems. In each situation, water managers can use maps to understand past and present land use to better predict future problems.

Sample GIS map



Procedure

Warm Up

What did your community's land and water resources look like 50 or 100 years ago? How has growth changed your community?

Ask students to imagine their community 100 years ago. They may want to refer to photographs or news stories. Did the school exist? What happened when precipitation fell then, compared to now? What happened when the floodplain was inundated and what would happen now? If a body of water is near the school, have the years altered its appearance and condition?

Tell students that maps can teach us about the past and possibly answer questions such as these.

The Activity

Provide students with copies of *Maps A*, *B* and *C*. Explain that they represent aerial views of a watershed taken at different times. To simplify map interpretation, watershed borders coincide with edges of the grid. Also, outlines of land areas (e.g., wetlands, forests) align with grid lines.

Following are three options for interpreting changes in the watershed presented on the maps. The first option may be more appropriate for younger students, but can help all students complete ***Options 2*** and ***3***. Students should be able to multiply and calculate percentages to complete the second and third options.

Option 1

1. **Tell students to look at *Maps A*, *B* and *C*.** Explain that they represent changes in land use over a 100-year period. Have students review each map key. Instruct them to designate each land area with a different color (e.g., color all forest areas green). Use the same color scheme for all maps.

2. **When students finish coloring, have them compare the sizes of the different areas on each map and among maps**. Ask them to compare plant cover and land-use practices during the 100-year period. They may note changes in crop lands, forests, grasslands, wetlands, urban land uses, etc.

3. **Discuss one or more of the following questions:**

- What happens to the amount of forested land as you go from ***Map A*** to ***Map C***?
- Which map has the most land for human settlements?
- Where are most human settlements located? What benefits or risks do you see in placing those settlements there?
- What effect might these human settlements have on the watershed?
- Would you have directed development differently?

Option 2

1. **Have students determine each map's land area**. Each unit in the grid represents one square kilometer; there are 360 square kilometers (or 360,000,000 m^2) on each map.

2. **For each map, have students determine how much area is occupied by each type of land coverage (e.g., forest, wetland and farmland).** Responses can be guesses or exact calculations. For example, for ***Map A***, 17 of the grid units are occupied by wetlands. By dividing 17 by the total number of units (360), students should calculate that 4.7% of the land area is wetlands.

The land allotted to wetlands, forests, etc. will change for each map, but the stream coverage (111 squares or 30.8%) will remain constant. Students should record their answers in the ***Area of Land Coverage*** chart.

3. **Tell students that the watershed has received 5 cm (0.05 m) of rain.** (Although rain does not normally fall evenly over a large area, assume that the 5 cm of rain fell evenly over the entire watershed.) By converting both the rainfall and the land area to meters, students can calculate the amount of water (m^3) which fell on the land.

About 18,000,000 m^3 of rain fell on the watershed (0.05 m x 360,000,000 m^2 = 18,000,000 m^3). Of this, 5,550,000 m^3 landed on the stream (111,000,000 m^2 x 0.05 m = 5,550,000 m^3). This might seem like a large quantity, but if 5 cm of rain fell evenly on a watershed of this size, the stream would receive this volume of water. (**Note:** 100 cm = 1 m; 1,000,000 m^2 = 1 km^2.)

4. **Ask students to estimate the amount of water that would be drained from the land into the stream**. Tell students that for the watershed represented by ***Map A***, 2,767,500 m^3 of rain was runoff (i.e., the water flowed into the stream and did not soak into the ground, did not evaporate and was not used by plants or animals). Runoff volumes are provided in the *Answer Key*. In ***Option 3***, students can calculate runoff for each land area.

5. **Discuss land coverage changes represented in *Maps A* through *C*.** Ask students if they think the amount of runoff would increase or decrease?

6. **Tell students that when 12,450,000 m^3 of rain fell on the land represented by *Map A*, 2,767,500 m^3 was runoff. For *Map B*, 3,102,500 m^3 was runoff. For *Map C*, 4,797,500 m^3 was runoff.** Discuss the following questions in addition to those listed in ***Option 1***.

- Which absorbs more water, concrete or forest?
- Which map represents the watershed capable of capturing and storing the most water?
- What problems could result if water runs quickly over surface material, rather than moving slowly or soaking in?
- Look at Map C and note Community A and Community B toward the bottom of the map. What could happen if, due to increased runoff and river discharge, Community A decides to build a levee on its side of the river to reduce the likelihood of flooding? What would happen to Community B that does not have a levee? (People along the Mississippi River in the U.S. had this problem in the 1800s. Each levee district tried to build their levee a little bit higher than the levee on the other side of the river. They would even cross the river in a boat, very quietly at night, and use dynamite to make a hole in the levee across the river. That would relieve the flood water pressure on their levee as floodwaters pored through the hole on the other side of the river. Levee board members on both sides of the river often stayed on their levee all night to protect it from midnight attacks.)
- What solutions may work for the benefit of both communities? (Cooperation and teamwork are required to protect both communities. As long as Community A tries to keep its levee at a higher elevation than Community B, flood disasters will occur on one side of the river or the other. This is unacceptable. Communities must work together, and agree to an equal elevation mark for the top of both levees. This will make the two communities equal partners to protect themselves against flood disasters. On the Mississippi River, the U.S. Army Corps of Engineers eventually took over construction of the levees, and made sure they were the same elevation on both sides of the river.)
- How might the stream's water quality be affected by watershed land-use changes?

Option 3

Have students determine how the figures in *Option 2* were obtained. In the chart ***Volume of Rain*** and ***Volume of Runoff***, each land area has been assigned a proportion of the water not absorbed or that runs off its land surface. Using information from this chart and from the *Area of Land Coverage* chart, have students calculate the amount of water each land area does not absorb.

For example, for the forested land in ***Map A***, 189 km^2 x 1,000,000 m^2/km^2 = 189,000,000 m^2 of land. Multiply this by the amount of rainfall (189,000,000 m^2 x 0.05 m = 9,450,000 m^3). Since 20% of the rainfall was runoff, 1,890,000 m^3 of water drained into the stream from the forested land (9,450,000 m^3 x .20).

Note: Percent runoff figures are based on hypothetical data. To determine how much water is absorbed by surface material requires knowing soil type and texture, slope, vegetation, intensity of rainfall, etc. In addition, many farms and urban areas practice water conservation measures that help retain water and prevent it from streaming over the surface. The information in the chart is intended only for practice and comparisons.

ANSWER KEY: AREA OF LAND COVERAGE

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Forest	189	52.5	162	45	111	30.8
Grassland	20	5.6	14	3.9	6	1.7
Wetland	17	4.7	13	3.6	5	1.4
Residential	13	3.6	33	9.2	58	16.1
Agriculture	10	2.8	27	7.5	69	19.2
Stream	111	30.8	111	30.8	111	30.8

Wrap Up

Have students summarize how land-use changes affect a watershed's quantity and quality of surface-water runoff. Discuss community land-use practices and how they may affect water discharge in the watershed.

Take students on a walking tour of the school and community, and note areas that contribute to or reduce storm runoff. For example, parking lots, paved roads and sidewalks promote runoff; parks, wetlands and trees capture water.

Students could attend a public meeting where community land-use changes are being discussed.

If students were to draw a fourth map of the same area 100 years from now, how would it appear? Have students plan a city that contributes to a watershed's health. They should contact city planners or conduct library research to support their projections.

Assessment

Have students:

- compare land area occupied by farms, towns, and natural areas in a watershed during different time periods (***Options 1*** and ***2***).
- describe how surface-water runoff is influenced by changes in land use (***Option 2***).
- calculate quantities of runoff from different land areas in a watershed (***Option 3***).

Extensions

NOTE: The exercise including the answer key are simplified examples that do not necessarily reflect all physical processes in the catchment. For example, in semi-arid areas the losses from evapotranspiration may increase with increasing forest cover. This can reduce streamflows in the lean season. Similarly the role of wetlands can be very different depending on how much water they already took up from previous rainfall events.

Some caution may also be due concerning the role of forests on flood peaks. For extreme flood events and larger catchments the influence of forest cover on reducing flood peaks may be minimal. One issue that is, however, fairly well established is that deforestation can lead to larger sediment yields in the river. This can cause massive problems for flood managers and river engineers, especially where those sediments are deposited. In those places the flood protection levels may become insufficient over time as the riverbed rises in relation to the adjacent land, or the river takes a different course.

Such questions could be raised and discussed with older students.

Provide discharge values for a specific point on the stream corresponding to

ANSWER KEY: VOLUME OF RAIN AND VOLUME OF RUNOFF

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage and % runoff	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**
Forest 20% runoff	(9.45×10^6) 9,450,000	(1.89×10^6) 1,890,000	(5.55×10^6) 5,550,000	(1.11×10^6) 1,110,000	(5.55×10^6) 5,550,000	(1.11×10^6) 1,110,000
Grassland 10% runoff	(1.0×10^6) 1,000,000	($.1 \times 10^6$) 100,000	($.7 \times 10^6$) 700,000	($.07 \times 10^6$) 70,000	($.3 \times 10^6$) 300,000	($.03 \times 10^6$) 30,000
Wetland 5% runoff	($.85 \times 10^6$) 850,000	($.425 \times 10^6$) 42,500	($.65 \times 10^6$) 650,000	($.0325 \times 10^6$) 32,500	($.25 \times 10^6$) 250,000	($.0125 \times 10^6$) 12,500
Residential 90% runoff	($.65 \times 10^6$) 650,000	($.585 \times 10^6$) 585,000	(1.65×10^6) 1,650,000	(1.485×10^6) 1,485,000	(2.9×10^6) 2,900,000	(2.61×10^6) 2,610,000
Agriculture 30% runoff	($.5 \times 10^6$) 500,000	($.15 \times 10^6$) 150,000	(1.35×10^6) 1,350,000	($.405 \times 10^6$) 405,000	(3.45×10^6) 3,450,000	(1.035×10^6) 1,035,000
Total runoff		**2,767,500**		**3,102,500**		**4,797,500**
Total runoff plus stream discharge (5,550,000 m^3)		(8.32×10^6) 8,317,500		(8.652×10^6) 8,652,500		(10.347×10^6) 10,347,500

the three runoff values provided under point 6. Have students indicate flood-hazard areas corresponding to those discharge values, (i.e., possible extent of flooding should discharge occur). Discuss the consequence of a levee that could safely discharge the amount of water provided under scenario B (50 years ago) for scenario C (the present).

With land-use changes and resulting streamflow increases, the old levee may not be sufficient to protect the community. If the levee is overtopped under scenario C, a larger area will be covered by water than under scenario B. In addition, constructing a levee provides incentive for increased investment and development of the protected area. Due to increased investment in the community because of the levee's assumed protection, more value is concentrated in the flooded area and damage potential is higher.

Have students explore changes in their community. Usually, maps are available at local, state and federal land and water agencies. Libraries have historical, hand-drawn maps. Employees there also will have information about past, present and future water use.

Students may want to conduct a more accurate analysis of the degree to which different surface areas are permeable to water. Contact community conservation agencies to learn how different soil types affect runoff.

Students can use Geographic Information Systems (GIS) computer technology to better understand geographic features.

Resources

Baker, Jeannie. 1991. *Window*. New York: Greenwillow Books.

Guling, Cynthia L., and Kenneth I. Helphand. 1994. *Yard Street Park*. New York: John Wiley & Sons.

Huff, Barbara A. 1990. *Greening the City Streets: The Story of Community Gardens*. St. Louis, MO.: Clarion.

Leopold, Luna B. 1974. *Water: A Primer*. San Francisco, CA: W. H. Freeman.

Patterson, Mark, and Ron Mahoney. 1993. *Environmental Education Software and Multimedia Source Book*. Moscow, ID: University of Idaho Agricultural Publications.

Hellmund. 1993. *Ecology of Greenways*. Minneapolis: University of Minnesota Press.

e-Links

World Meteorlogical Organization, 2004, Integrated Flood Management Concept Paper, Geneva, available at http://www.apfm.info/pdf/concept_paper_e.pdf

Photo Resources

Non-credited photos contained in this activity are courtesy FEMA News Photos.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Name: ______________________ Date: ______________

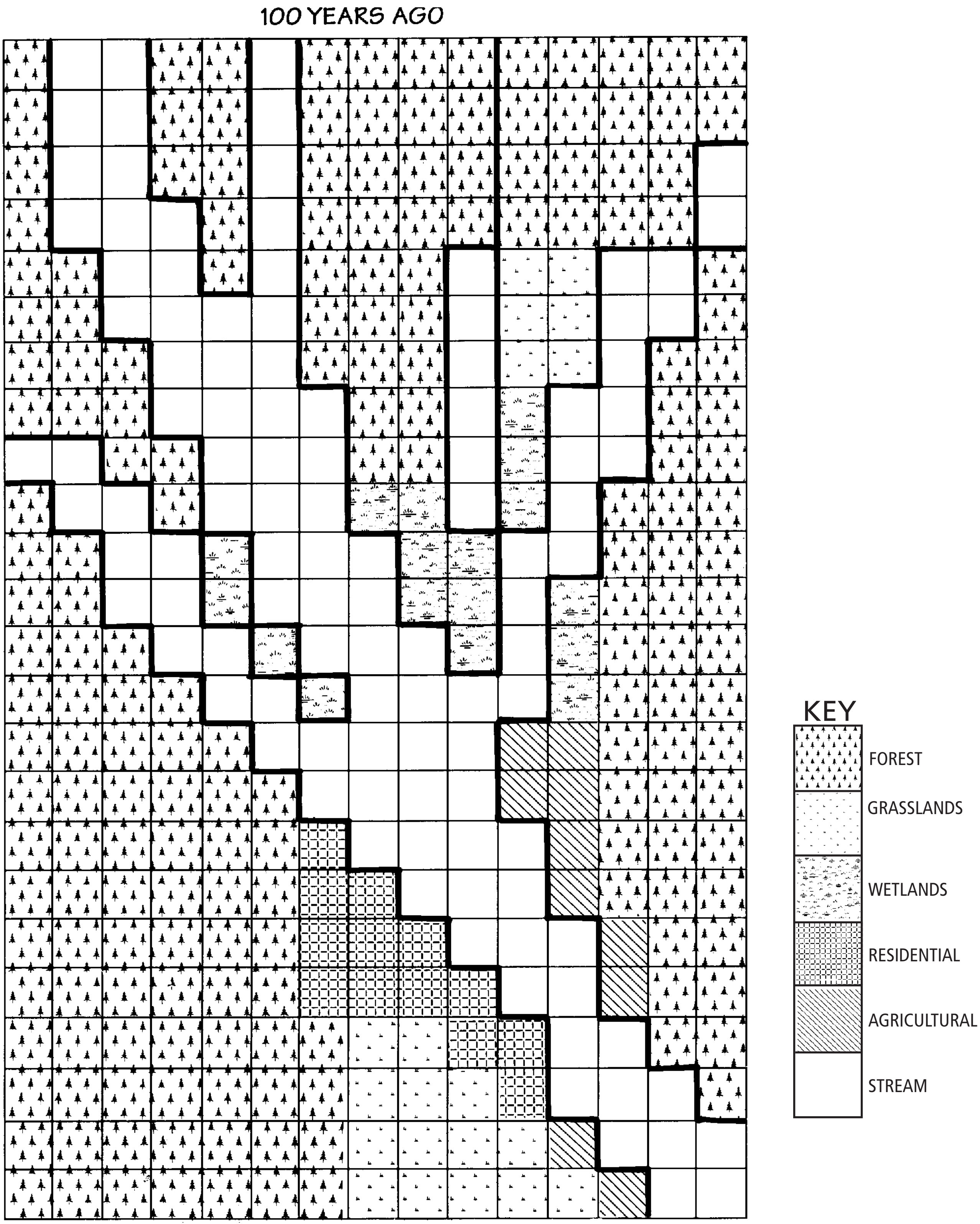
Chart for Option 2 AREA OF LAND COVERAGE

	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Forest						
Grasslands						
Wetlands						
Residential						
Agricultural						
Stream						

Chart for Option 3 VOLUME OF RAIN AND VOLUME OF RUNOFF

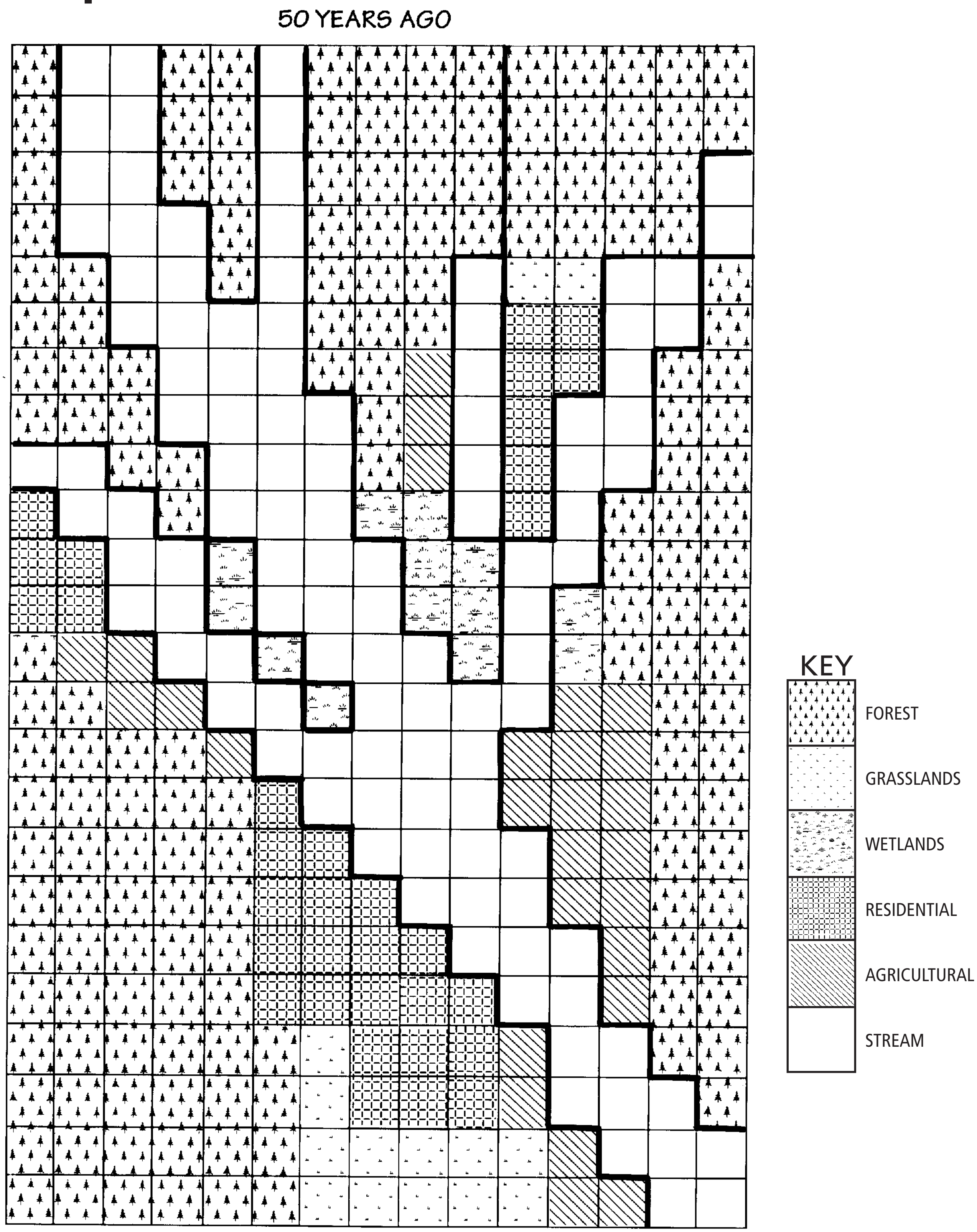
	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage and % runoff	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**
Forest 20% runoff						
Grasslands 10% runoff						
Wetlands 5% runoff						
Residential 90% runoff						
Agricultural 30% runoff						
Total runoff						
Total runoff plus stream discharge (5,550,000 m^3)						

Map A

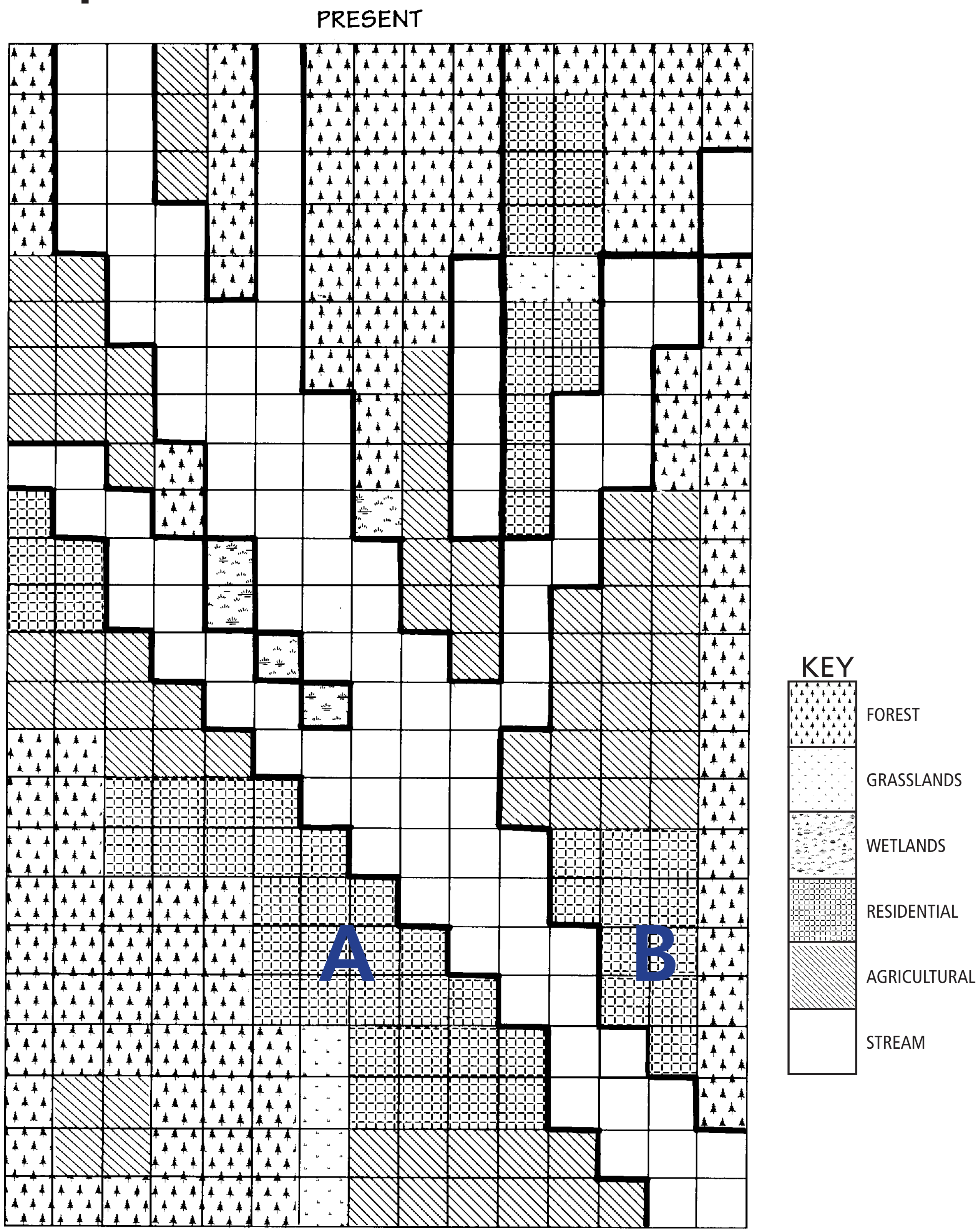


100 YEARS AGO
KEY
FOREST
GRASSLANDS
WETLANDS
RESIDENTIAL
AGRICULTURAL
STREAM

Map B


50 YEARS AGO
KEY
FOREST
GRASSLANDS
WETLANDS
RESIDENTIAL
AGRICULTURAL
STREAM

Map C


PRESENT
A
B
KEY
FOREST
GRASSLANDS
WETLANDS
RESIDENTIAL
AGRICULTURAL
STREAM

Back to the Future

Did you know the future is often hidden in our past? Where can we look to find it?

Summary

Students analyze streamflow monitoring data to determine safe and beneficial locations for a growing community.

- Earth Science, Environmental Science, Mathematics, Government

- **Duration:**
  Preparation time:
  Part I: 30 minutes
  Part II: 10 minutes
  Activity time:
  Part I: 30 minutes
  Part II: 50 minutes

- **Setting:**
  Classroom

- **Skills:**
  Organizing (graphing); Interpreting

- **Vocabulary:**
  discharge, floodplain, hydrograph, inundate

Objectives

Students will:

- analyze and interpret streamflow data.
- identify the risks and benefits of development in a floodplain.

Materials

- *News reports of floods (in a local or international river basin) or of water shortages (optional)*
- *Copies of* ***Streamflow Discharge Data*** *(****Part I*** *and* ***Part II****)*
- *A cube 30 centimeters (12 inches) on a side*
- *Graph paper*
- *Copies of a* ***Community Planning Map,*** *or similar map, indicating existing and future land uses*

Making Connections

Floods and drought frequently make the news. While some events occur unexpectedly, people often prepare for events by looking to the past. Understanding and interpreting historical streamflow data helps students understand how water managers predict and prepare for water excess or shortage.

Background

Data collection is a critical component of most scientific investigations. Water experts calculate the amount of water flowing in a river and analyze streamflow data to assess water availability, allocate water supplies and document historic high water levels to predict flooding issues.

River Thames flood marks, United Kingdom

Streamflow data are collected by many government agencies worldwide, such as the National Hydrological Services, U.S. Geological Survey, navigation groups, irrigation organizations, hydropower operators, and many others. Streamflow (or discharge) data are a measure of water volume (in cubic meters per second or cubic feet per second) passing a given location over a period of time. To determine streamflow, water managers must know the streambed profile, the height (or stage) of a river, and its velocity. This information tells water managers how much water is flowing in a river at a given time and location.

Streamflow information is collected manually or with electronic gages. Electronic gages, typically located near dams or bridges, generally record flows 24 hours a day, 365 days a year. Manual sites are monitored daily, weekly, or monthly as needed, or after large rainfall events. To take a manual reading, a hydrographer wades into the stream or stands on a bridge or cable system, with a current meter and gaging stick, to record velocity and river depth.

Streamflow data are used to develop hydrographs, which show the amount of water flowing or discharged over time at a given location. For example, the average monthly discharge may be plotted at a site over a one-year period (12 monthly readings or data entries) to create the historical hydrograph.

Hydrologists learn about stream fluctuation patterns by monitoring it over many years. For example, depending on the prevailing climate, rivers may have low flows in the fall and winter, increased levels in the spring, and peak flows in early summer. Hydrologists use this data to create computer models to help predict streamflow during and after rainfall, snowmelt, and drought.

Watershed precipitation amounts, and snowpack levels, also help forecast possible streamflow levels. The amount of snowpack in a local mountain range directly affects the amount of water discharged by a river in late spring or summer. Once hydrologists know streamflow patterns, they inform water resource management agencies, city planners, extension agencies, farmers and others of future estimated streamflow discharges.

Streamflow predictions, even when using scientific methods, might not be fully reliable. Significant changes in a river's watershed, like construction of dams, levees, or water diversions, can cause flows to vary from historical patterns. But, knowing historical patterns can help people predict streamflows and better prepare for possible flood disasters.

Knowledge of river slope (a river's change in elevation—for example, a high mountain stream with steep slope as opposed to a prairie stream that is relatively flat), as well as availability of water, land use, soil type, vegetation and flooding potential are essential for community planning. Water managers may recommend that people not live in a certain location because of frequent floods. Such an area is called a floodplain (any area that can be inundated when water levels exceed stream banks).

One option is to limit development in these areas or require that flood-prone areas remain in their natural state. However, such sites are often desirable for human settlement; they are fertile, level and scenic. In countries with largely agricultural economies, floodplains play a key role in the livelihood and food security of many people.

Dams, levees, detention basins and bypass channels are built to protect areas from inundation, up to a certain elevation. In other locations, flood waters are diverted to areas where less harm is caused, or where it can be stored for later use. These flood control projects are relatively costly, but even costlier measures are usually necessary to deal with large floods. Flood forecasting and warning systems, flood insurance programs, land use regulations, emergency preparedness and response plans, in addition to public awareness programs, comprise methods that can minimize the costs and impact of urban-area floods.

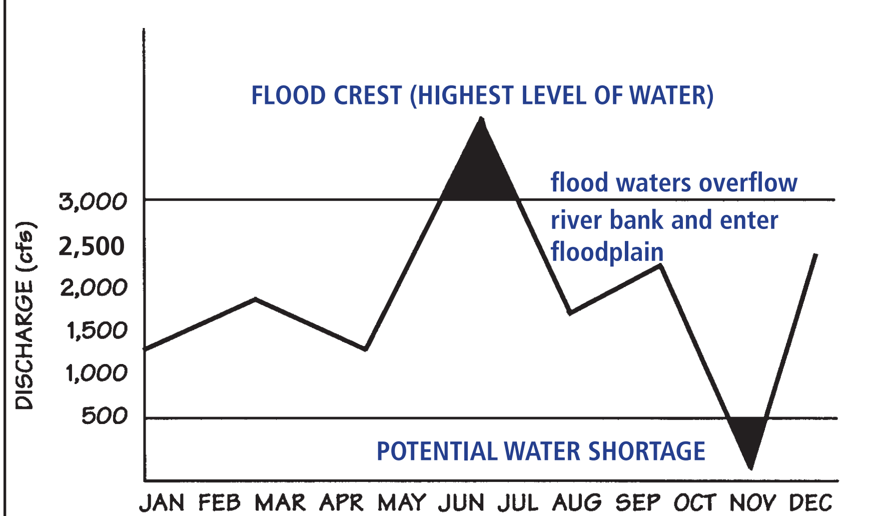
Throughout the world, floodplain areas can extend dozens of kilometers (miles) on each side of the river. This can force residents of entire communities to relocate on a regular basis—to temporary housing on higher ground—during the flood season.

Despite how devastating floods can be for human communities, they play a vital role in natural systems. River corridor ecosystems are accustomed to, and in many cases dependent on, variations in streamflow. For example, many fish species depend on floodplains temporarily covered by floodwaters. Wetlands may depend on water circulation and nutrient recycling during floods.

Floods are designated by their probability of occurrence—such as 500-, 100-, or 10-year floods. Past flood records must be studied to make this analysis. A 10-year flood means that in any particular year, there is a 1 in 10 chance of a flood of that magnitude or discharge occurring in a given location (based on historical data). A 100-year flood has a 1 in 100 chance of occurring at a given location in any given year. It's important to note that a 100-year flood can occur two consecutive years at a given location. Hydrologists can only say that, according to historical flood records and other statistical analysis, a flood of a particular magnitude has a given probability of occurring in any particular year.

The concept of a 10-, 100- or 500-year flood is often misunderstood. Many people think that if they have experienced a 500-year flood, it will

STREAM HYDROGRAPH FOR A HYPOTHETICAL RIVER



not occur again for another 499 years. That is not true. A 500-year flood is the discharge of water in a river that has a 1 in 500 chance of happening in any one year. This is based on the laws of probability. For example, the U.S. Geological Survey (USGS) takes annual peak flow discharge values from USGS stream gages and uses a probability model to determine discharge values for a 10-, a 100-, or a 500-year flood. Designations of 10-, 100-, or 500-year floods can be thought of as big, bigger, and biggest floods. Scientists create maps to show the water levels and potential inundated areas of 10-, 100-, and 500-year floods. These are extremely useful for public safety and flood insurance purposes.

Of course, the more data hydrologists have available the more reliable their calculations. That is why the USGS and other organizations strive to keep their gaging stations active as long as possible. If a probability model uses data from a gaging station with a 25-year record, that mathematical model will not be as reliable as a gaging station that has 100 years of data.

Lack of streamflow data, incomplete or inconsistent data makes flood analysis in many countries very difficult. Lack of information can have major implications for planning new flood protection works or drainage infrastructure, as well as the location of settlements, roads and bridges.

Although living on a floodplain may expose its occupants to flooding, it also offers enormous advantages. The deep, fertile alluvial soil of floodplains—resulting from eons of flooding—is ideal for crop production. In addition, floodplains typically support very high density human settlements. It is not coincidental that population densities are high in the Netherlands and Bangladesh since they are comprised mostly of floodplains.

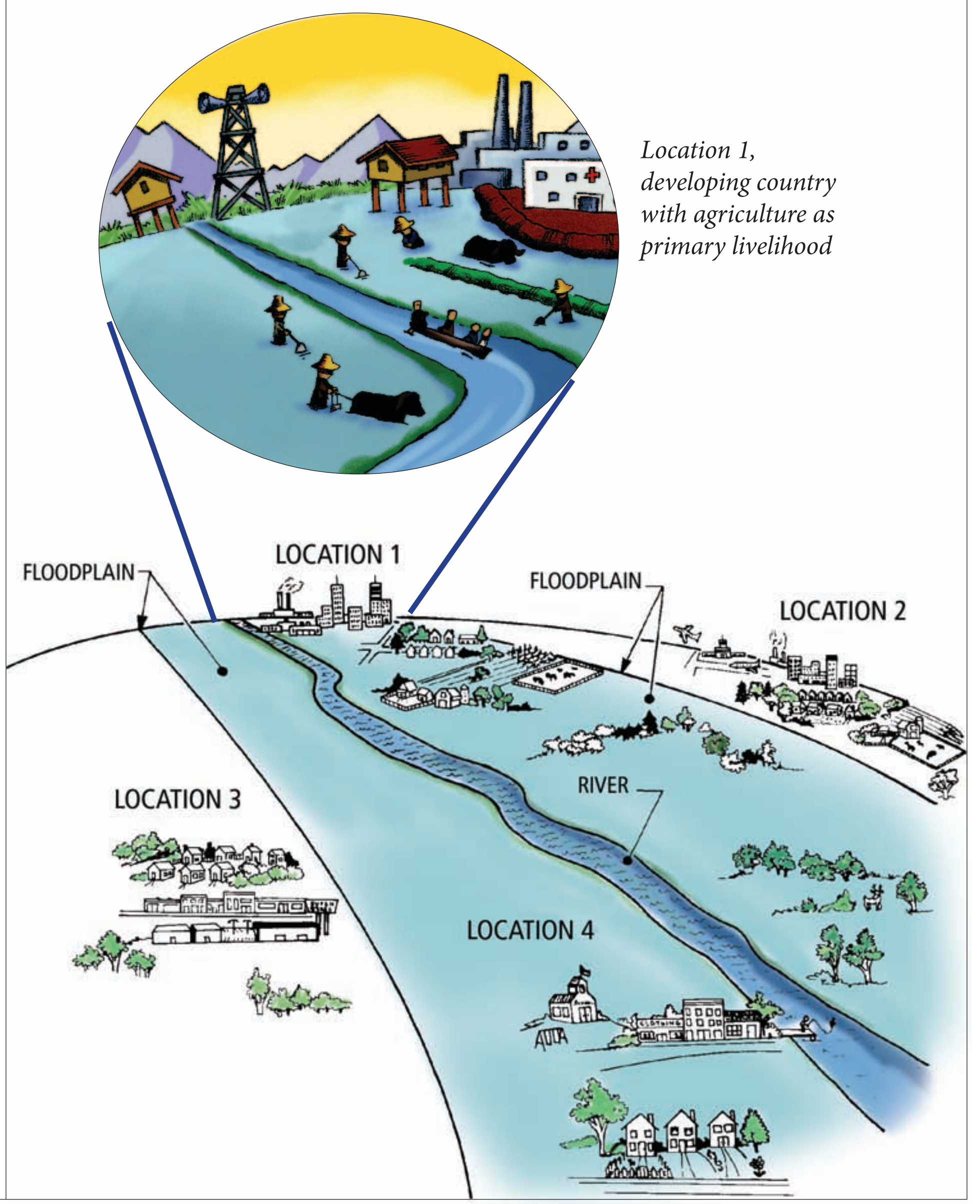
Floodplain managers depend on accurate, long-term streamflow records to make decisions about water management. One of the most important aspects is the "net-benefits" of a proposed plan. Net-benefits can be determined by calculating the overall benefits of a particular proposal and then deducting the expected losses from flooding. Maximizing these net-benefits is a primary goal of flood managers and community planners.

Procedure

Warm Up

Ask students to describe the effects streamflow variations can have on people, property, and ecosystems. Have them describe events they have heard or read about regarding floods. Share news articles about these events. Have students scan the reports to discover what conditions might have led to severe flooding (for example, large amounts of rainfall in a brief period, or inadequate flood control structures).

COMMUNITY PLANNING MAP



The Activity

Part I

1. **Show students the Streamflow Discharge Data (Part I). Explain that these measure the quantity of river water flowing past a certain point within a certain timeframe.**

2. **Explain that streamflow measurements are typically in cubic meters per second (cms) or cubic feet per second (cfs). Show students a one cubic meter or cubic foot box.** If a river discharges 300 cubic meters or cubic feet per second, that means that 300 "boxes of water" pass by a certain point of the river within one second!

3. **Have students work in groups to plot the monthly averages from *Streamflow Discharge Data* (*Part I*). There are 39 years of data. Divide the number of years by the number of groups, and assign each group a set of data to graph. All data can be plotted on one graph, or, for clarity, each group can plot their data on a separate graph.** Hydrologists refer to this as a hydrograph.

4. **Discuss the following questions: During which month(s) does the greatest amount of water flow in the river? In which month(s) is the streamflow lowest?**

5. **Have students locate months when the streamflow exceeds 3,000 units.** Tell them this is when river discharge is at flood stage. How many years are there between floods? Indicate time periods when discharge is less than 600 units in June or July; these may be times of critical water shortage.

VIEWS

LOCATION 1:

I think we should build at Location 1. The property values are low and we won't have to pay high prices to get water into our homes. The soil is great for farming and the views of the river are wonderful! I also think we should allow industries to build their factories here. There is plenty of water for their production needs, and they will provide jobs for community members. There hasn't been a flood here in over 10 years, so it's nothing to fret about. In addition, floodplain management program funds or subsidies are available for structural and non-structural flood management measures.

LOCATION 2:

Well, just because a flood hasn't happened in 10 years doesn't mean it won't. I say let's build above the floodplain. We'll have to pay more in property taxes and for water, but homes will be less expensive because we won't have to floodproof them. If we invite industries to locate here, people will have secure jobs and the city will prosper.

LOCATION 3:

Even though we'll have to pay more, I think we should build above the floodplain. Location 3 is a good distance from the floodplain, and the land is not too steep. I don't think we should allow industry to settle here; it will use too much water and could create pollution problems. Instead, we should promote small businesses.

LOCATION 4:

I agree that we should plan for a small community and promote small businesses instead of industry. More people will place more demands on our water supply . . . and what happens during times of drought? However, if we build in the floodplain, at Location 4, we'll have flat, fertile land, which is easier to farm and better for constructing houses. I don't think a flood will happen in our lifetime, so that shouldn't stop us from building.

BUILDING IN THE FLOODPLAIN

PRO	CON
flat building surface	chance of flooding
scenic views	economic and emotional impacts
easy access to river	temporary or permanent:
fertile soil	- loss of home and contents
ease of transporting water	- business closure with loss of income
livelihood opportunities in fisheries and agriculture	- sense of property violation
	- fear
	- injury or death

Part II

1. **Show groups the *Community Planning Map*.** Normally, river discharge is low enough that no inundation occurs. But, when a river floods, surface water flows into the floodplain area. Explain to students that a community plans to expand into a new area along this river. Four sites—Locations 1, 2, 3, and 4—have been proposed.

2. **Provide students with the following information.** The land in the floodplain is flat and fertile, and provides attractive views of the river. In addition, the land on the floodplain provides great opportunities for farming. Because the area is known to become inundated, land values in the floodplain are lower than land away from it. In addition, certain industries want to build factories in the area so they can have access to river water for manufacturing. Towns that support industry are more likely to have larger populations because factories provide job opportunities. At Location 1, floodplain management program funds or subsidies are available for structural and non-structural flood management measures. At Location 4, no such program is available (Note: This information pertains to this activity's scenario and may differ in actual situations.)

3. **Have students listen to the views of four people—proponents of Locations 1, 2, 3, and 4—on where to expand the community.** Students may wish to role-play the different views. In addition to discussing where to build, consider the issue of allowing certain industries to locate their factories in the community.

4. **Ask students to list the pros and cons for building on a floodplain. Discuss the benefits and drawbacks of establishing industries in a community.** The chart *Building in the Floodplain*—presenting pros and cons—is an example of a decision-making strategy.

OUTCOMES

The outcome for Locations 1 and 2 is the same, except that 1 is in the floodplain and 2 is not. If you choose 1 or 2, the end result is a large community including three factories and several farms. The farms in Location 1 need less fertilizer and have easy access to irrigation water. During winter, the community needs about 60 million gallons (228 million liters) per day. In summer, because of agriculture and additional water requirements in energy production, water needs increase to nearly 500 million gallons (1.9 billion liters) per day.

Based on the argument that floodplains can provide opportunities, but also potential flood losses, Location 1 is the best selection for a rapidly growing population (e.g., developing countries with agriculture as the main source of livelihood). In addition, it may be the only viable option for placing settlements even though it's in a floodplain. Many small farms prosper on the floodplain, but small agricultural levees are required to protect crops from frequent/smaller floods. Houses are built on stilts to avoid flood waters or they are elevated. An effective flood warning system is also necessary. Industries, key infrastructure and other vulnerable buildings (power stations, hospitals, etc.) are located at the outer end of the floodplain, and are protected by small ring levees. Emergency shelters are made available in nearby towns outside the floodplain in case of a major flood.

The outcomes for Locations 3 and 4 are the same, except that 4 is in the floodplain and 3 is not. It is likely that Location 4 has no funding from a floodplain management program, and cannot develop adequate safeguards to protect human life and property from flooding. If you choose Locations 3 or 4, the end result is a medium-sized community, including one small factory, a number of small businesses, and several farms. During winter, the community needs approximately 50 million gallons (190 million liters) of water per day. In summer, water needs increase to nearly 350 million gallons (1.33 billion liters) per day because of agriculture and additional water requirements in energy production.

5. **Ask students to predict outcomes for each location (1, 2, 3, or 4). Have each group select one site for expansion and discuss the reasons for their choice.**

6. **After groups have made their selections, read the Outcomes in the sidebar.**

7. **Provide students with the *Streamflow Discharge Data* (*Part II*).** This table represents the six-year period following the community's expansion. Have students look for times when the river flooded (> 3,000 units). Have them identify times when the community might have experienced times of water shortage (<600 units in June or July). To confirm whether or not there is enough water for community needs, have students use the conversion of 1 unit per second = 0.646 million gallons (2.4 million liters) per day. They can then calculate how many gallons (or liters) of water the river supplies (i.e., 922 units per second x 0.646 = 595.61 million gallons (2.3 trillion liters) per day.

8. Instruct students choosing Location 3, that they should find that their community avoided inundation. Students may be interested in checking how other sites fared. Locations 1 and 4 would have flooded. Location 2 would not have flooded.

9. Ask students if they think their choices of locations would have been different if the annual probability of flooding was 1 in 50 (2%) in any given year. What about a 1 in 100 chance? Or 1 in 500? Provide students with information about an extreme flood in their area. Ask students if they think homes destroyed by a flood should be rebuilt on a floodplain. If they answer yes, what conditions would they require to allow for rebuilding in a floodplain? The answers could include: mandatory flood insurance, flood proofing houses, flood forecasting and warning systems, flood defenses, mandatory flood emergency response plans for the community, etc.

Wrap Up and ActionEducation

Have students summarize how past records can help plan for the future. They could contact community planners and state government agencies to study their local floodplain laws and flood management plans.

Ask students to survey friends and family to determine if they would build their homes in a location that had reasonable property rates, attractive views, or a friendly community, even if the site was located in a 100-year floodplain. Have students tally the responses and draw conclusions from the results.

Assessment

Have students:

- graph streamflow data (***Part I***, step 3).
- interpret streamflow data to identify fluctuations in discharge (***Part I***, step 5).
- analyze the risks and benefits of living in a floodplain (***Part II***, step 9, and ***WrapUp***).

Extensions

Students may be interested in entering data into a spreadsheet software program that will plot the data.

Have an insurance representative visit the class to discuss floodplain insurance. Ask students how flood insurance premiums would affect the outcomes of their decisions.

Contact city planners to learn if local rivers flood or if water shortages occur. Take a field trip to a stream and observe development of the surrounding area.

Resources

Leopold, Luna B. 1974. *Water: A Primer*. San Francisco, Calif.: W. H. Freeman & Co.

Patterson, Mark, and Ron Mahoney. 1993. *Environmental Education Software and Multimedia Source Book*. Moscow, Idaho: University of Idaho Agricultural Publications.

e-Links

World Meteorological Organization, 2004. *Integrated Flood Management Concept Paper*, http://www.apfm.info/pdf/concept_paper_e.pdf

United States Geological Survey Fact Sheet 229-96 http://pubs.usgs.gov/fs/FS-229-96/

United States Geological Survey CoreCast, June 2008 *Two 500-Year Floods Within 15 Years?* http://www.usgs.gov/corecast/details.asp?ID=81

United States Geological Survey The National Streamflow Statistics Program: A Computer Program for Estimating Streamflow Statistics for Ungaged Sites

http://pubs.usgs.gov/tm/2006/tm4a6/

Photo Resources

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Streamflow Discharge Data (Part I)

Monthly average discharge in units

Students should plot data until present date. After they decide on a location for the community, they should use Part II of this table to plot the rest of the data.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
19—	147	144	150	306	802	1043	581	184	118	46	58	44
19—	43	47	61	861	1430	1158	437	159	145	207	112	85
19—	74	82	184	609	1411	937	462	150	82	113	108	75
19—	70	63	60	265	991	1648	502	168	108	144	142	157
19—	162	144	138	536	1194	863	235	54	85	86	97	81
19—	124	122	123	382	1055	1361	706	256	222	217	204	137
19—	152	172	172	910	1790	1453	820	374	203	207	169	154
19—	156	145	140	926	2708	3079	859	351	260	218	185	190
19—	199	164	200	585	755	1507	927	276	176	187	169	142
19—	149	149	157	549	1287	908	617	191	143	150	133	110
19—	108	105	99	137	694	1174	489	193	124	121	156	202
19—	178	138	180	941	2288	2132	747	291	215	227	190	163
19—	143	147	161	336	1600	1900	683	256	184	189	169	159
19—	144	146	145	386	2862	1950	692	326	240	191	183	163
19—	148	147	146	371	520	938	308	135	207	220	166	129
19—	125	115	169	545	659	751	213	101	101	107	105	92
19—	97	94	100	248	515	751	207	126	138	134	121	96
19—	99	119	117	703	952	2121	566	245	180	201	162	137
19—	120	159	146	214	1180	3608	670	257	215	206	209	158
19—	145	149	143	391	942	1437	707	259	173	169	158	197
19—	219	179	206	852	2057	2916	1759	666	438	312	247	184
19—	197	172	179	507	805	562	202	118	105	121	127	112
19—	113	113	141	269	1876	2778	1194	351	249	269	234	188
19—	172	166	216	347	516	974	355	276	229	212	185	151
19—	156	156	163	1312	2031	2010	741	314	250	243	189	168
19—	157	147	169	297	914	687	283	208	154	152	140	132
19—	146	142	154	642	1726	1662	1049	363	310	259	215	186
19—	177	170	216	568	1198	3353	449	205	152	201	194	158
19—	150	162	216	492	2393	2877	1426	500	326	304	256	220
19—	212	198	273	494	2189	2272	1550	683	426	427	430	324
19—	289	275	288	641	1755	1985	1112	469	329	283	259	224
19—	216	189	213	712	1003	749	330	219	383	265	214	196
19—	189	194	475	1178	1815	2410	694	344	290	278	226	167
19—	155	152	213	375	725	520	284	172	128	125	131	121
19—	119	119	153	343	621	715	217	133	116	120	125	115
19—	120	114	149	644	994	954	351	174	156	165	156	131
19—	126	121	157	439	464	831	359	185	152	150	146	122
19—	167	150	177	288	1107	1661	832	277	240	241	254	204
Present	212	208	334	439	1263	2550	660	315	257	266	226	161

Streamflow Discharge Data (Part II)

Monthly average discharge in units

For six-year period following the community's expansion

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
First	159	159	155	324	861	743	632	380	160	169	210	166
Second	181	168	279	1089	2199	3161	953	378	246	244	223	171
Third	168	158	162	209	1083	2227	1517	392	253	256	233	202
Fourth	181	181	179	492	1486	1114	615	349	312	238	183	152
Fifth	143	132	134	151	201	574	550	153	141	148	134	136
Sixth	132	131	198	623	1319	1783	955	347	346	230	196	160

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AfterMath

After damage is calculated, what are the real losses associated with a natural disaster like a flood?

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■ **Subject Areas:**
Mathematics, Environmental Science, Language Arts, Government

■ **Duration:**
Preparation time: 30 minutes
Activity time: 50 minutes

■ **Setting:**
Classroom

■ **Skills:**
Gathering information (calculating); Organizing (mapping); Analyzing (comparing); Interpreting (discovering conclusions)

■ **Vocabulary:**
water-related disaster

▼ Summary
By calculating economic loss resulting from flooding in a specific area, students investigate how people are affected by floods and other natural disasters.

Objectives

Students will:

- interpret how economic damage reports present individual and community losses from a natural disaster.
- differentiate between emotional and economic loss from a natural disaster.
- recognize why some natural events are classified as disasters.

Materials

- *Mail-order catalogues of household items*
- *Classified ads for real estate and advertisements for new and used automobiles*
- *Paper and pencils*
- *About 300 small pieces of paper* (half-inch [1 cm] squares) *in a bag*
- *A collection of state and national newspapers and magazines with water-related disaster stories*

Making Connections

Some students may have experienced a water-related natural event, such as a flood, drought, mudflow, hailstorm, hurricane, typhoon, snowstorm, ice storm or tsunami. They may have heard or read about the economic losses from major local, national and world water disasters. The international press reports water-related natural hazards (floods and droughts) as top stories almost every year. Learning about the events' impact helps students understand how it is possible to recognize and reduce risks associated with these events.

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Background

When does a natural event become a disaster? While snowstorms, heavy rains and minor flooding may be inconveniences, most people do not consider them tragedies.

Weather events, such as floods, hurricanes and hailstorms, are characterized as disasters only when they negatively affect people through loss of life, property or income. This perspective is human-centered and also based on economic principles.

If a flood had occurred on a river before human habitation, it would not have been classified as a disaster. Instead of sweeping away the accomplishments of generations, the flood waters would have nourished the river's floodplain.

Economic losses caused by water-related natural disasters can be staggering. Billions of dollars in damages are caused worldwide by hailstorms, floods, droughts, hurricanes, ice storms, heavy snows and large waves in coastal areas.

An estimate of loss follows every disaster. "Aftermath" literally means the result of some major event (e.g., number of houses inundated by flood waters or number of automobiles damaged by a hailstorm).

Calculating the economic loss caused by a hurricane, typhoon, flood or other such event is complicated. From an analytical approach, losses can be calculated at the micro level (city block or single house) and macro level (county, state or regional).

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Losses can include not only damage to homes and buildings, infrastructure, cars and crops, but also loss of business and income through interruptions in production or market access. Estimates of economic losses help policymakers (city councils, county commissions, state legislative groups and federal government) determine actions needed to balance the benefits of floodplain use (during flood-free times) and potential loss from future floods.

Damage reports establish the magnitude of losses that must be weighed against the cost of preventing these losses. Floods are good examples of this rationale.

Consider an area along a stream inundated year after year. The last flood may have resulted in (US)$20 million dollars in damages to homes, businesses and the agricultural sector. Frequent flooding can lead to less investment in a flood-prone area, regardless of whether it lies in an urban or agricultural region.

Cost of a structural solution (e.g., dike, dam, channel or flood-proofing homes and businesses) or nonstructural solution (e.g., improved forecasting and warning systems, education and flood awareness, planning, zoning codes and insurance) may not be economically feasible. Decision-makers face difficult choices when managing development in settled floodplains.

Natural disasters require major resources to restore damaged areas, including funds from multiple sources, such as private resources of those affected; governmental disaster funds; insurance payments; and foreign aid. Many things cannot be restored with money, such as lost memorabilia (family photos, etc.), personal health (trauma, etc.), and a sense of security.

Weather events, like severe rainstorms and drought, are less predictable and thus harder to manage. A farmer in a hail-prone area must weigh the cost of crop insurance against the economic impact of a lost crop. Farming in areas with high levels of hail damage is "risky business."

Procedure

Warm Up

Ask students to generate a list of water-related weather events. Discuss the role of each event from an ecological perspective. What determines whether a natural event, like a flood or hurricane, is a disaster? Who makes that determination? Ask students why news reporters often cover stories like disasters and whether they think this reporting is justified.

Ask students to think of their own bedrooms. Imagine their rooms are on the first floor of their homes. A flood occurs in their community; the water is rising in their rooms. It is now a foot (0.3 meter) deep.

Tell students the water will not recede for two to three days. How will their personal possessions be affected? (The longer water remains in a house, the greater the likelihood of structural damage.)

Rescue workers tell students they can take five items. Which personal possessions would they select? Have students discuss the "value" of these possessions. Do these items reflect an emotional or economic worth?

The Activity

1. **Inform students they will be part of a flood simulation and will calculate economic losses. Have students arrange their chairs or desks in rows to form a grid.**

2. **Assign each student to a square on the grid. Tell students the square represents their home and property. Have students determine "property values" for their squares.** Distribute mail-order catalogues, magazines and newspapers with ads for houses and automobiles. Tell each student to clip pictures of a house and two cars. Have students select furnishings and appliances for their home. Students should record all items and associated costs, and determine the value of their assets.

3. **Ask students to stand at their desks. Give a bag of paper squares to one student. Inform the student that when you say "Now," he or she should move diagonally from the upper right-hand corner of the grid to the lower left-hand corner.**

The student will weave among the desks and toss paper above his or her head and from side to side. Lead students through the motions described in "The

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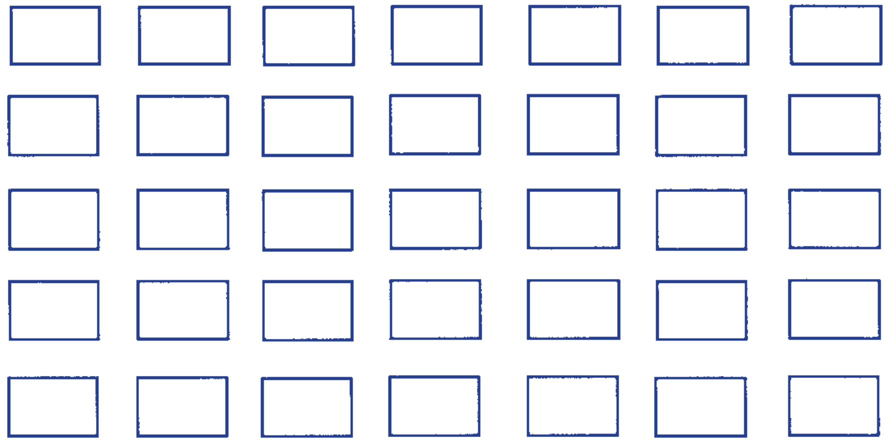
Thunderstorm" activity. When you initiate the motion "stomp your feet," say "Now" to the student holding the bag of paper.

4. **When all students are standing with open palms (last movement in "The Thunderstorm"), ask them to be seated. Have students gather as many pieces of paper (representing flood damage) as they can without leaving their seats.** Tell students it has been an unusually wet spring. Melting snow and heavy spring rains have raised river levels above their banks. With the last torrential rain, the river in some areas has now overflowed the levee (a barrier constructed to hold back seasonally high water). Because of land variations and differences in elevation, the amount of flooding varies.



5. **Calculate losses as follows:** Each piece of paper collected represents a $1,000 loss from flood waters. Have students determine their individual losses. Compare their losses to their calculated assets.

6. **Draw the grid on the board. Write the economic loss for each student in the grid squares. Have students connect areas of similar property loss.** These are called isolines and connect points of equal value. Have them calculate the community's total loss. (Add all student losses.)

7. **Ask how they will replace or repair their homes and possessions.** Discuss what role their livelihoods and sources of local income for their families play in the recovery process. On what do they base those incomes (agriculture, local manufacturing and services, etc.)?

8. **Can they "buy back" all items lost in a flood? What about photos, letters, family heirlooms, diaries, etc.? Have students recall the five items they said they would remove from their bedrooms in a flood. Have them differentiate between economic and emotional losses.**

Wrap Up and ActionEducation

Have students compare property losses to their locations on the grid. Discuss how people living in heavily damaged areas would feel compared to those who missed the brunt of the flood.

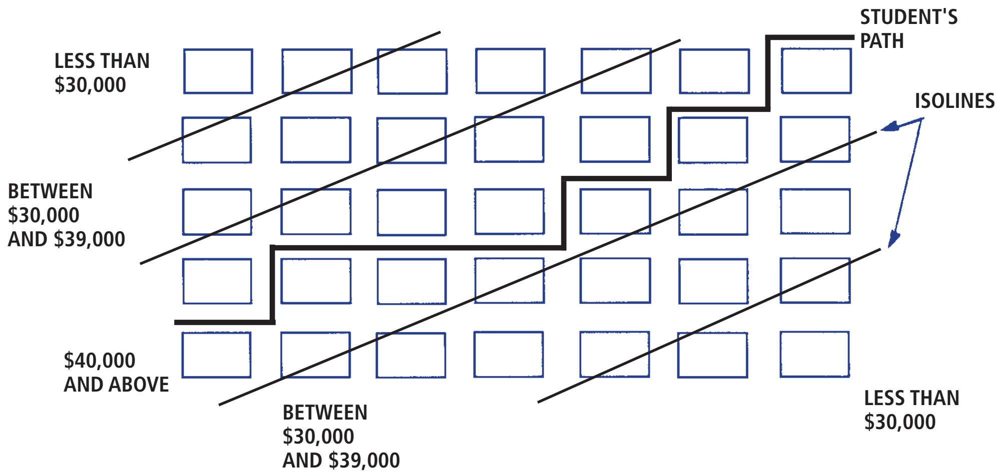
Have each student locate a news article describing a water-related natural disaster. Encourage students to collect both recent and historical accounts. Have them research the nature of each disaster; how much rain, snow, or hail fell; and how much damage was caused. Students should present their reports to the class.

Ask students if they think the damage estimates reported in the articles are accurate. Discuss the difficulty of getting exact numbers and the need to estimate. Do these estimates include family heir–looms, old photos or a prized flower garden washed away?

Ask students why they live at their current location. Their ancestors may have lived there for decades or longer. Why did their ancestors settle there? Their parents may have moved there because of job or business opportunities. Perhaps the land or house was affordable.

It is usually the opportunities (benefits) which drive decision-making rather than risks. With flooding, perhaps the last event occurred decades ago. Maybe

EXAMPLE OF DISTRIBUTION OF ECONOMIC LOSS



their current location is less risky than other areas where other natural hazards are prevalent (forest fires, landslides, tornados, etc.).

Divide students into small groups. Then have them develop and deliver a 60-second news report on a simulated flood. They might focus on personal property and community damage. What was the total amount lost? What area was hit worst? What area was not hit? Record their presentations and have groups critique each other's newscasts.

Have students review water-related disasters occurring in their community during the past 25 years. Collect headlines and construct community water-disaster posters.

Assessment

Have students:

- explain why natural events, like floods, droughts and hailstorms, are sometimes classified as disasters (***Warm Up***).
- calculate individual and community losses to create a damage report (steps 5 and 6).
- assess the impact of a simulated water-related natural disaster (***Wrap Up***).
- develop and deliver a news report on a simulated flood (***Wrap Up***).
- discuss the "value" we place on our possessions (***Warm Up*** and ***Wrap Up***).

Extensions

What would your students do if you told them to expect a similar flood once every five years? Every 10? Every 100? Every 500 years? Which interval would cause them to take action? What action would they take?

Explain to students that many communities are not arranged in grid-like patterns. Keep the desks in order, but have students alter their positions.

For example, have four students per desk in one area, while another area has no students. Each student owns a house and two cars. Repeat the thunderstorm and the flood activities.

The flood waters may not crest where most students (representing population) are located. How does economic loss correlate with the amount of flooding and population density?

What other disasters occur?

Obtain newspapers from a community different from your own (i.e., if you live in a rural area, obtain papers from an urban community). Repeat the "AfterMath" activity using the new information from the newspapers. Compare this estimated damage to your own community's. Which received the most damage? Why?

Resources

Lyon, George Ella. 1990. *Come a Tide*. New York /Richard Jackson.

e-Links

Intergovernmental Panel on Climate Change.
www.ipcc.ch

Federal Emergency Management Agency. *Disaster education for children.*
www.fema.gov/kids/dizarea.htm

World Meterological Organization.
www.wmo.ch/apfm

http://www.apfm.info/pdf/concept_paper_e.pdf

http://www.apfm.info/pdf/ifm_tools/Tools_Flood_Loss_Assessment.pdf

Photo Resources

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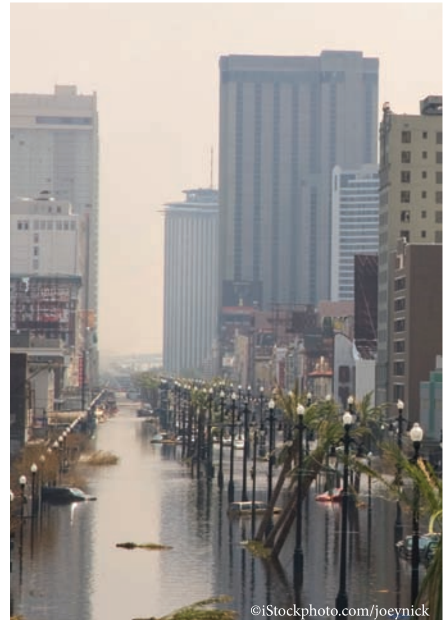
8-4-1, One for All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Sharing river waters also means sharing responsibility during natural disasters.

▼ Summary

Using simulated water-management challenges, eight students, representing eight different water users, must safely carry a water container "downstream" to the next community of water users on the "river." During a flood event, students identify individuals and organizations that must cooperate within their community.


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- **Subject Areas:**
  Social Science, Natural Science
- **Duration:**
  Preparation time:
  Part I: 60 minutes
  Part II: 60 minutes (20 minutes if you have materials from Part I)
  Activity time:
  Part 1: 45 minutes
  Part II: 45 minutes
- **Setting:**
  Classroom or open area
- **Skills:**
  Gathering information; Organizing, Analyzing, Interpreting
- **Vocabulary:**
  indirect water use, direct water use, water user, 4Rs

Objectives

Students will:

- demonstrate the interconnection of a community's water users and a watershed.
- demonstrate the complexity of sharing water.
- negotiate how to adapt to the river's water-management challenges.
- identify individuals and organizations that must work together before, during, and after a flood or other natural disaster.

Materials

- *Soup can or small coffee can* (three-quarters full of water)
- *Eight pieces of string* (equal length, about five feet [1.5 meters] each)
- *Two or three rubber bands large enough to securely hold the can* (You only need one; the extras are in case one breaks.)
- *Three pieces of rope, string or poles* (each at least six feet [1.8 meters] long)
- *At least four chairs*
- *Ten pieces of string* (various lengths with pieces of paper, any size, tied to one end)
- *Several small sticks*
- *Masking tape or chalk*
- *Nametags that hang around students' necks*
- *Marker*

Making Connections

Students may be unaware that water needs to be shared among users, or about the relationship between products they use and the water needed to produce them. Although students probably have seen floods on television or the Internet, or have heard stories, they may be unaware of the organizations or individuals needed before, during and after a flood to warn, evacuate, clean up and prepare for a possible recurrence.

Background

We cannot manage a watershed well until we know who the water and land users are, the 4Rs of water use, and how to collectively deal with common water-management challenges (e.g., flooding, drought, pollution, and endangered species).

These challenges affect all of us, and any decisions to solve a water dilemma must consider everyone in a watershed. Water is critical for all water users including fish and wildlife, recreation, energy, earth systems, business and industry, urban, rural, agriculture and navigation.

Each water user group uses water in a specific way. Some uses are direct, such as when an irrigator applies water to crops to grow food or when individuals wash, bathe, or cook. Indirect water uses are not immediately obvious. For example, a person indirectly uses water when driving a car or riding a bike, because water was used in the production of steel and other parts of the vehicle or bike.

In addition to human uses, fish and wildlife have critical water needs, too, that must be met for species survival. Human alterations in a watershed can have serious impact on fish and wildlife. For example, upstream land-use changes can drastically alter characteristics of a flood and associated water quality, including sediment transport characteristics that affect fish and wildlife habitat.

A shared goal of watershed managers is to meet the water needs of individuals and groups not just some of the time, but all of the time. This goal presents a major challenge to the watershed manager. To satisfy the water needs of any water user, the 4Rs must be considered.

They are:

The right **quantity (not too little but not too much).**

The right **cost.**

The right **time.**

The right **quality**.

With only one river to support eight water users, communication and teamwork are essential to meet the basic water needs for sustainability for all people, plants, animals, and ecosystems in a watershed.

The **right quantity** or **amount** means enough water to sustain life. For humans, this is about eight glasses of water per day. Navigation needs enough water in the channel to support boat traffic; agricultural needs vary according to region and crops. Recreationists want enough water to raft, kayak, canoe or fish. Growing cities need approximately 300 gallons (1,140 liters) per household per day, but this varies greatly on a global scale. Manufactured goods, from paper to cars, require large amounts of water to produce. Energy producers require a steady flow to operate turbines and cool motors. Although the quantity needed by each water user may vary substantially, the interconnections between different users bind us all.

The **right cost** is the expenditure of energy and/or financial resources for a water user to secure and consume water. For an industry it may involve elaborate purification methods to clean and return water to the common allotment. A water-stressed plant closes down the stomata to conserve water; carbon dioxide intake is reduced which limits photosynthesis and stunts growth. For animals the cost might be migration to a new watering hole or a dying off of the weaker animals. All water users have some cost associated with the water they use directly or indirectly.

The **right time** means water must be available when it is needed. Humans are unable to store excess water and dehydration can take place in a few hours during exercise. Salmon need sufficient water to migrate and lay eggs in the fall. Energy demands require a steady availability of water, meaning holding tanks must store seasonal precipitation or energy production will fluctuate throughout the year. Even a small seed demands the right amount of water at the right time: enough to germinate and not so much to wash it away.

The **right quality** of water has different meanings for different water users. Navigation, industry, and energy can often make use of water other users cannot. Humans are well aware of the need for drinking water free of bacteria, viruses, and toxins, but not everyone can turn on the tap and know the water is safe. On the other hand, plants and animals can generally use the water directly available in their environment. If this water contains a healthy balance of dissolved oxygen and nutrients—and few contaminants—it can support abundant and diverse aquatic life including algae, microscopic organisms, and macroinvertebrates. These organisms form the cornerstone of the aquatic food chain that leads to the larger food chain. All life depends on enough clean water at the right time and price.

What about when there is too much water for all water users? Another important aspect of water management occurs during natural disasters, such as floods. How do individuals and community organizations—such as police and fire departments—coordinate efforts to protect property and human life during floods? Public-safety officials rely on cooperation and teamwork to respond to floods, but how is this accomplished?

Command and control centers are established to handle issues, such as reverse 911 calls to warn residents of flooding. They also coordinate fire protection; traffic control; public information to the media; sandbagging operations; medical care; and many other public-safety issues.

Procedure

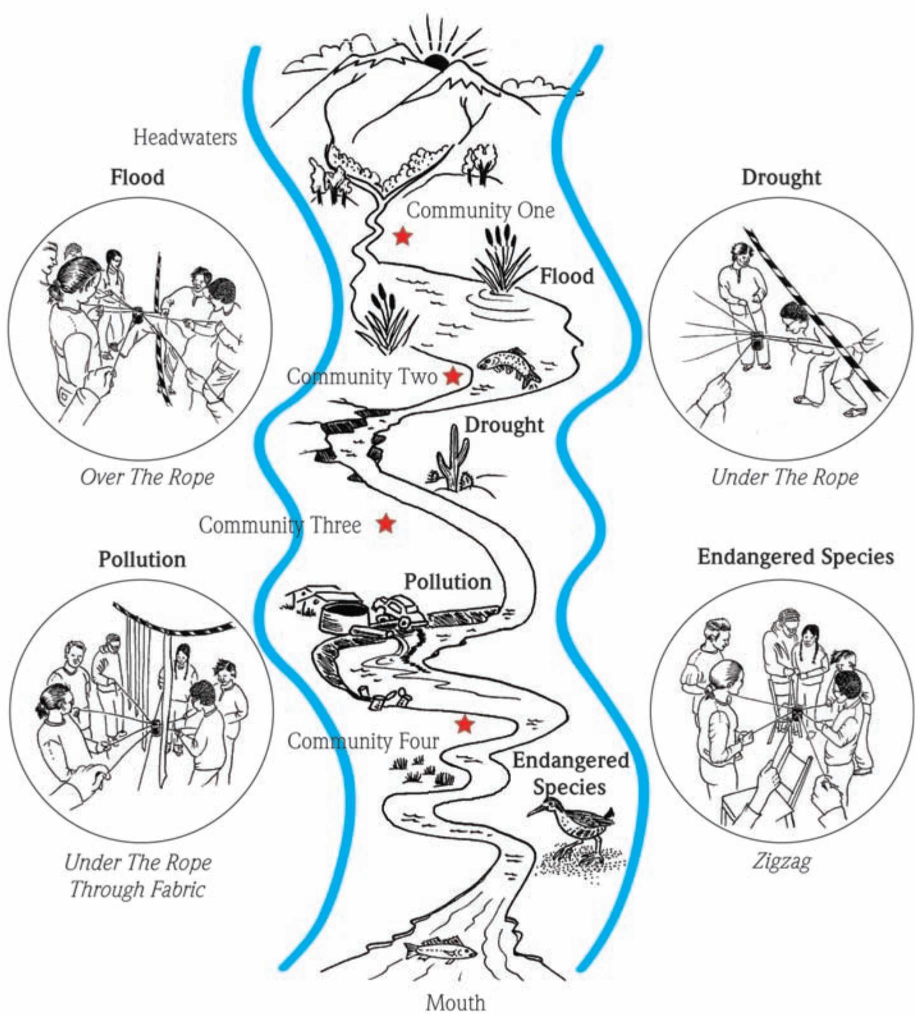
Preparation

1. **Make eight nametags representing water users.** Label the nametags: urban use, recreation, earth systems, business and industry, navigation, fish and wildlife, agriculture, and energy production.

2. **Tie eight strings to one rubber band.** Water users will place the rubber band with strings around the can. They then will carry the can by holding the strings and gently lifting together. Test the rubber band to ensure it is the proper tension—too loose and it will not hold the can, too tight and the can will fall, or the rubber band will break.

3. **Lay out a "river" on the floor or ground using a rope, tape or chalk.** Label communities along the river's path. Students exchange the can at each community.

Make water management challenges. The four obstacles are drought, flood, endangered species and pollution.



Set up for "8-4-1, One for All" activity

- Drought is represented by a rope the water users will pass under.
- Flood is a rope they must travel over.
- Endangered species is a zigzag path between chairs they must pass through.
- Pollution is a rope above their heads holding strings with attached paper they must pass through.

Students whose community is waiting can hold the obstacles.

Warm Up

Give students three minutes to list all the ways they know of using water. Ask several students to share their answers, then discuss similarities and differences. Ask students how they think riding in a car, reading a newspaper and turning on a light are connected to water. Discuss uses of water, including direct (e.g., drinking) and indirect (e.g., riding a bike).

Ask students to guess how much water is required to make each item listed in the column above. Do not provide the answers until the activity is completed.

Jeans made from cotton	1,800 gal. (6,840 l)
Loaf of bread	1,000 gal. (3,800 l)
Finished steel for car (one ton)	32,000 gal. (121,000 l)
40 sheets of paper	100 gal. (380 l)

List the eight water-user groups on the board (business and industry; earth systems; energy; fish and wildlife; navigation; recreation; agriculture; urban). Brainstorm specific water users for each category (e.g., coal mine; wetland ecosystem; hydroelectric plant; fish; rafting company; rice farm; city swimming pool). Brainstorm examples of how products in each category relate to students' lives.

Ask students if they know what communities are upstream and downstream from them. How is water and land use in one community connected to another?

The Activity

Part I

1. Briefly discuss the 4Rs—right quantity, right cost, right time, right quality. With one river supporting all eight water users' needs, teamwork and cooperation are essential. Notify students that in the ***Wrap Up,*** they will be asked to consider the 4Rs and how they relate to the river challenges.

2. Explain the significance of the river and obstacles you have made.

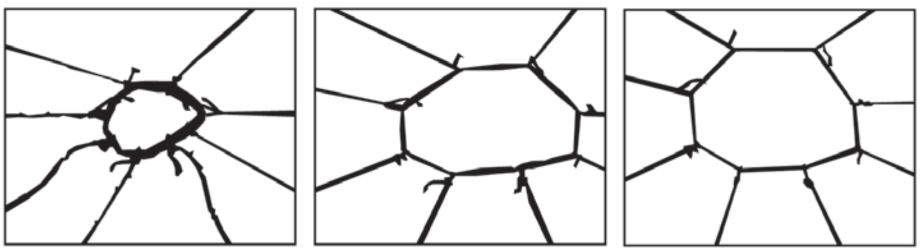
3. Divide the class into four groups of eight. Each group represents a river community. Assign the remaining students roles as obstacle helpers. Give each group a name. You may number the communities one through four or you may name them according to communities in your area. If you have too few students, reduce the number of communities or have one student represent several water users.

4. **In the first community, have each student select one of the eight water-user categories he or she will represent (urban use, recreation, earth systems, business and industry, navigation, fish and wildlife, agriculture, energy production).** Give students their water-user nametags and show them where to stand. As the communities carry water down the "river," each water user will give his or her nametag to the next water user.

5. **Place Community One before the first obstacle, Community Two between the first and second obstacle, Community Three between the second and third, and Community Four between the third and fourth.**

6. **Direct Community One to stand in a circle.** Place the can three-quarters full of water on the floor in the middle of the circle, with the strings tied to the rubber band next to the can. There should be eight strings, one end in front of each water user.

1. Loose *2. Pull to expand opening* *3. Group maneuvers stretched band over can*

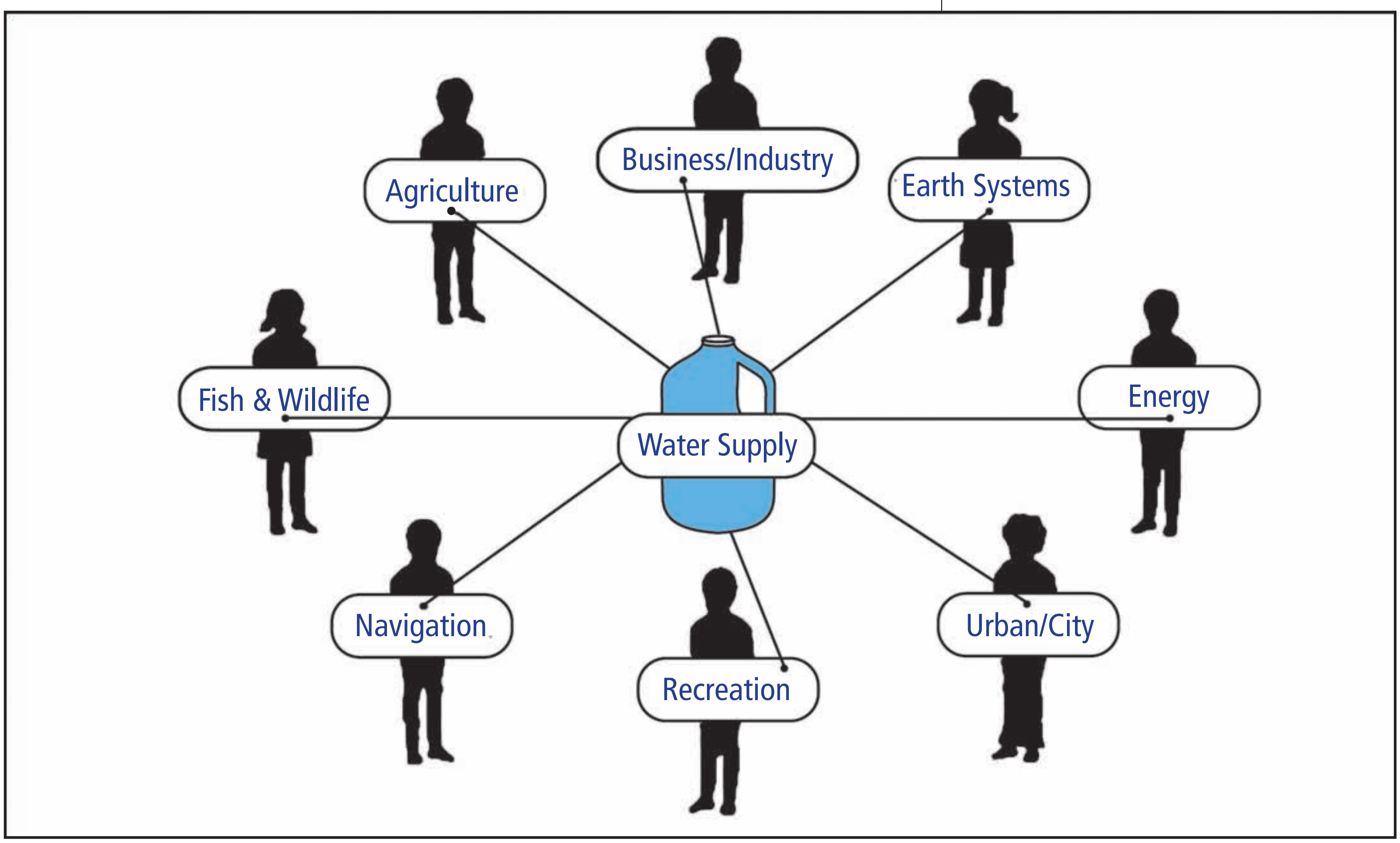


Direct the students to carefully pick up the strings and use teamwork to stretch the rubber band, fit it over the can, slowly release tension on their strings to tighten the rubber band around the can and work together to lift the can. Remind them that if any water user pulls too hard, the can will fall out of its loop.

Starting at the headwaters, they must work as a team to pass through the flood (over the rope) and hand off the water to the next community downstream.

7. **Have students from Community One hand off their ropes and nametags to Community Two as the water moves downstream through the drought obstacle.** Do not allow the can to touch the floor. Repeat this process for Community Three and Four, in turn, for pollution and endangered species.

Reinforce the concept that if the water needs of community members are to be consistently met, it will take teamwork, communication, and compromise.



Part II

1. **Briefly discuss with students the idea of teamwork and cooperation.** With a community to protect during a flood, teamwork and cooperation that includes respect for co-workers, listening and communication are essential for individuals and organizations.

2. **Explain the significance of public safety and re-label the obstacles:**

a. **Obstacle One: Have students walk a short distance between Community One and Two to represent evacuation.**

b. **Obstacle Two: Have students move under the rope to represent the flood between Community Two and Three.**

c. **Obstacle Three: Have students pick up sticks that have been scattered on the ground to represent cleaning up after a flood between Community Three and Four.**

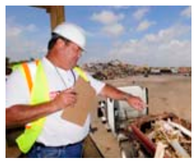
d. **Obstacle Four: Have students from Community Four wind their way through a maze created with three or four chairs to represent evaluating how they functioned during the flood event and better preparing for the next one.**

3. **Divide the class into four groups of eight.** Each group represents a community of individuals/professionals who must work together before, during and after a flood event. Assign the remaining students roles as helpers. Give each community a name.

4. **In the first community, have each student select one of eight public-safety categories he or she will represent (e.g., fire/police, military, medical, city workers, media, homeowner, FEMA [U.S.] or United Nations, volunteer relief worker [e.g., the American Red Cross]).** Give students their public-safety nametags and show them where to stand. As the professionals cooperate to protect the flooded community, each community will pass their nametags to the next community. Examples of professionals and agencies may include:

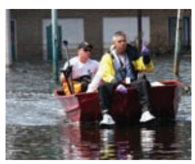
Scientists forecast the severity of flooding to warn people.

Local, state and federal government agencies, in addition to global organizations, work to coordinate emergency efforts (e.g., FEMA [U.S.], United Nations [global]).



Engineers look for ways to repair damage to levees and dams.

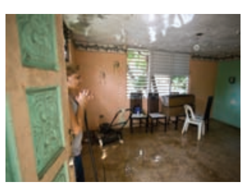
Media outlets, such as television and radio stations, broadcast public service announcements about ways to stay safe.



Emergency response personnel respond to life-threatening situations.

Disaster relief workers bring safe drinking water and food to flood victims.

Utility company crews work to restore power, gas and water.



Citizens clean their homes to prevent mold.

Military personnel support government agencies and assist relief organizations.

Medical professionals tend the injured and inoculate people against disease.

Contractors repair or rebuild buildings and roads destroyed by flooding.

5. **Direct Community One to stand in a circle.** Place the can three-quarters full of water on the floor in the middle of the circle, with the strings tied to the rubber band next to the can. There should be eight strings, one end in front of each organization or individual.

Direct students to carefully pick up the strings and use teamwork to stretch the rubber band, fit it over the can, slowly release tension on their string to tighten the rubber band around the can and work together to lift the can. Remind them that if anyone pulls too hard, the can will fall out of its loop.

They must work as a team to pass through the first obstacle (covering an established distance to represent evacuation) and hand off the water to the next community.

6. **Have students from Community One hand off their ropes and nametags to Community Two.** Do not allow the can to touch the floor. Repeat this process for Community Three and Four as groups clean up after the flood and then evaluate how they performed during the flood and how they will improve the next time.

Wrap Up and ActionEducation

Discuss the results of the activity. How much water was left in the can when it reached the last river community? Where did they experience the most trouble? What did they learn about the eight water users, four water needs (4Rs), and one river? How was communication important for delivering the water? What do they know about specific water users?

Did the concepts of cooperation, communication and teamwork apply to the activity with the public-safety individuals and organizations as well?

Inform students of the quantities of water used to produce the materials listed in the ***Warm Up***. Do any of the water users from this activity make or use these products? If community water supply and demand are out of balance, how will they resolve the issue? Would they reduce the supply of one water user or would they find another solution?

Have students analyze the challenges they faced as they moved the can of water downriver. As a class, discuss the specific challenges of each water user in overcoming each obstacle. Which of the 4Rs relates to each obstacle—right amount, right cost, right time or right quality?

Finish by having each student write a one- to two-page paper telling what "8-4-1, One for All," means. They should briefly define each water user, the 4Rs, and sharing one river. Ask them to add an epilogue discussing their feelings about how communities throughout a watershed can improve the ways they share water.

In addition, have students write a similar paper defining each public-safety individual or organization and the need for cooperation during a flood. Ask them to write about their feelings seeing these organizations in action from watching a flood on television, reading about it in a news article or the Internet.

Assessment

Have students:

- analyze their direct and indirect water uses (***Warm Up***).
- define eight water users and connect them to their lives (***Warm Up***).
- discuss the strategies used by community groups to allow eight water users to meet the 4Rs and share one river (***Part I,*** steps 2–7).
- discuss how challenges in one community affect another (***Wrap Up***).
- write about how the eight categories of water users must work together when using water (***Wrap Up***).
- write about how the many categories of public safety organizations or individuals must work together before, during and after a flood or other natural disaster (***Wrap Up***).

Extensions

Write the names of the eight water users on slips of paper. Have each group draw two to four slips of paper and eliminate those water users from their group. When they make it past the obstacle to the next community, ask them to discuss how carrying water was different with fewer water users. Then ask them to list what products or services the community loses along with the missing water users and discuss the impacts.

Change the length of the string to some water users, indicating a greater distance to the river or that they'll receive a smaller supply of water. Discuss the effect this creates when the team tries to carry the can.

Resources

Project WET. 2002. *Discover a Watershed: Watershed Manager*. Bozeman, MT: Project WET.

e-Links

World Meteorological Organization: http://www.apfm.info/pdf/concept_paper_e.pdf

http://www.apfm.info/pdf/ifm_social_aspects.pdf

http://www.apfm.info/pdf/pilot_projects/manual_india.pdf

Photo Resources

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Take Action!

During a natural disaster, such as a flood, knowing your water address could be lifesaving information.

▼ Summary

Students create an Action (Emergency) Pack and Family Action Plan to be prepared in case of a flood or other natural disaster.

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- **Subject Areas:**
  Environmental Science, Health
- **Duration:**
  Preparation time:
  Part I: 10 minutes
  Part II: 10 minutes
  Activity time:
  Part I: 50 minutes
  Part II: 50 minutes
- **Setting:**
  Classroom
- **Skills:**
  Gathering information; Organizing information; Applying learned information
- **Vocabulary:**
  water address, flash flood, riverine flood, coastal flood, urban flood, Action Pack, Action Plan

Objectives

Students will:

- identify their water address to determine the area's risk from flooding.
- identify and gather items to build an Action (Emergency) Pack for their home in case of a flood or other natural disaster.
- develop a Family Action Plan in case of a flood or other natural disaster.

Materials

- *Catalogues, magazines or newspapers that can be cut*
- *Paper*
- *Scissors*
- *Glue*
- *Poster board or paper for collage*
- *Computer and print capability,* or students can draw elements of Action Pack if they do not have computer access or collage materials

Making Connections

Students must know how to prepare for, and react during, a flood affecting their home or school. Floods cause enormous damage every year, including loss of life.

It is easy for a family to become separated during the confusion created by a flood or other natural disaster. Too often, drivers attempt to cross flooded streets and become trapped in their vehicles. Sometimes, people do not realize they live in, or have ventured into, a flood-prone area. It is important for students to know their water address to stay safe.


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Background

A water address includes the natural features of a specific location, such as topography/landscape, geology, hydrology (atmospheric, surface and ground water), soils and vegetation; weather and climate; and the human environment, including structures and utilities (e.g., roads, buildings, power lines, dams, dikes, levees). The features of a specific site may change over time.

Individuals should determine their water address to assess the likelihood of their location becoming inundated during a flood. The location could be a home, school, hiking trail, camping site or vacation destination.

Perhaps a home is not in danger during a flood disaster, but what if a school located in a low area is vulnerable to flooding? What about a road outside of town that crosses a river? A person's water address changes if she or he is on vacation, at school, in a car, camping or on a hike. If flood waters approach an individual's water address, it is important to be prepared.

Not all floods are the same. Some occur quickly, like a **flash flood** that fills a dry creek bed with raging waters during a summer thunderstorm. Or it may be a

riverine flood, which can be predicted by water managers several days ahead of time. Riverine floods occur along major rivers, such as the Nile or Mississippi.

Oral history, along with records of flood events on different rivers, have given many cultures worldwide the knowledge necessary to live with periodic floods and prepare for larger ones. For example, ancient Egyptians were concerned with riverine floods, so they built water-measurement gages carved into rocks along the banks of the Nile.

The king or queen of Egypt instructed runners to go far upstream and report the height of water in the Nile. Rising waters in Ethiopia could indicate future flooding in downstream Egypt.

Coastal floods are caused by huge storms, such as hurricanes or typhoons, in addition to tsunamis created by an earthquake. **Urban floods** occur when heavy precipitation overwhelms the ability of roads, ditches or storm drains to carry water away from a community.

A flash flood may be the most difficult to predict. A flash flood can occur along any small stream or dry wash in areas prone to heavy rainstorms. These storms release a great deal of precipitation in a short time, causing flash flooding miles from the storm. A small stream could suddenly swell with water and surge through an urban area, dry wash or tight canyon. Heavy rain can also trigger landslides, mud and debris flows especially in mountainous areas and their foothills.

Individuals need to know if their water address could be affected by a flash flood. They should look for signs that warn of flash floods, like high-water marks (visual evidence of past high water), study maps or check other information sources, such as the Internet. Weather patterns of a specific area (such as the rainy season in a desert) are key indicators for what time of year to expect a flash flood.

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An urban flood requires similar assessment. Is the student's water address near a stream? Is it in a low-lying area of the community prone to flood waters? Are there sufficient storm drains free of debris near the water address? Local maps and neighbors can provide additional information about a specific area.

A coastal flood requires different preparation. Is the region prone to hurricanes, monsoons or typhoons? Is it located where a tsunami could strike? In these locations, residents or visitors should check weather sources and talk to local residents for historical information.

Finally, riverine floods can generally be predicted several hours or even days in advance. But, when flood waters arrive, damage can be just as devastating as other types of floods. Inhabitants can check floodplain maps, historical records, listen to news and warnings about floods, search the Internet and visit neighbors to assess flood risks.

The following activity involves developing an Action (Emergency) Pack and a Family Action Plan.

An Action Pack could include:

- Containers of water—drinking water may be polluted.
- Flashlight with batteries—electrical power may be out.
- Battery-powered or hand-crank radio to hear flood warnings and updates.
- Batteries—to power the radio and flashlight.
- First Aid kit—for minor scratches/injuries.
- Rain gear—protection in a storm.
- Canned food—fresh food may be contaminated by flood waters.
- Can opener—to open canned food.
- Emergency cooking supplies—power to cook may be unavailable.
- Pet food, water—pets need basic essentials, too.
- Medicine/prescriptions—anything you need to stay healthy.
- Emergency phone numbers—to call for help if you become separated from your family.

- All important documents such as passports, birth certificates, valuables, insurance policies, money and stock certificates, papers related to your home and other holdings.

A Family Action Plan could include the following points:

- Prepare an Action Pack (or emergency supply kit).
- Put special treasures and memorabilia in a waterproof container.
- Plan how you will secure your home; moving furniture and appliances to the second floor, also any chemical agents, paints, etc. You must shut off electricity, gas and water, and if possible hermetically seal sewage installations.
- Know where to go and where your family will meet.
- Know evacuation routes to safety, either to higher, stable ground or away from the flood area.
- Know how to stay in contact with family if separated.
- Have pets and personal items ready, so you can evacuate immediately.
- Know where you will store farm machinery, cars, etc. and where you will keep livestock.
- Listen to flood watches and warnings on the radio, television and Internet. Follow instructions.
- Make those around you aware of a possible flood.
- When you are away on vacation, be aware of your surroundings.
- Pay attention to the weather and think about how a flood could affect you and your activities.
- Stay away from rushing water, storm drains and rising rivers.
- Stay out of flood water.
- Never drive through flood water in a vehicle.
- Understand weather patterns in your area.

Procedure

▼ *Warm Up*

Tell students, whether they are at home, school, or on vacation, their water address is the natural features (topography, landscape, geology, hydrology, soils and vegetation, weather and climate) and the human environment (buildings and utilities) of a specific location.

Ask students if they know their water address. Ask them to think about where they live. Is there a river, stream, dry wash or creek bed near their home? Is their home located at a lower elevation in the community? Is their home in a floodplain? (This can be determined by obtaining local or federal flood maps, online or through government agencies.) Do they live in a coastal area prone to hurricanes, typhoons, monsoons or tsunamis?

Have students answer the questions below. These help determine if their water address is at risk from floods. Have students record their answers and discuss.

How far is your home from a dry wash or creek bed, stream or river?

Has it ever flooded where you live?

Have long-time residents ever recounted floods?

Has land use in your community changed to affect where surface water flows?

If you live in hilly or mountainous country, are the hillsides stable or have trees and ground cover been removed?

If you live near a stream, is it free-flowing or clogged with refuse?

How does weather affect where you live?

Do you experience hurricanes, monsoons, typhoons or spring thaws?

What seasonal changes affect your water supplies?

Do you camp or hike along rivers or in narrow canyons?

Ask students if they are at risk from flooding? If their water address is safe from flooding, do they ever travel to locations that are at risk?

What could they do to be safe from floods or other natural disasters at their new water address? Could they listen for weather warnings?

If they are hiking in a narrow canyon and they hear thunder, should they quickly leave? What other locations or situations could put them at risk from floods?

Should anyone ever drive through a flooded street? Should they play in rapidly flowing streams or drainage pipes?

Other flood scenarios could be presented to students for their thoughts and comments.

Some locations may have never experienced a flood; therefore, this exercise is hypothetical. But, as an individual changes location (e.g., going on vacation, to school, the mall, hiking), he or she may arrive at a water address that is prone to flooding. That makes the information provided in this activity critically important for everyone.

The Activity

Part 1

1. **Inform students they are going to prepare an Action (Emergency) Pack in case a flood or other natural disaster affects their community.**

2. **Tell students they have one minute to write all the items they would gather from their home if they needed to evacuate quickly or shelter in their home because of a flood.** Stop all writing after one minute.

3. **Have students break into groups to compare their lists.** After a few minutes, ask groups to tell the class the common and different items listed by each person in the group (e.g., everyone listed their pets, but only one person listed rain gear).

4. **Ask students how complete their lists were when they were given only one minute?** Ask them to imagine being under pressure and making such difficult and important choices during a flood. Is it better to be prepared and plan ahead?

5. **Explain that preparing an Action Pack in advance is much better than making difficult choices during a flood.** Being prepared is smart!

6. **Divide students into groups and give each group appropriate magazines, catalogues or access to computers and printers to locate pictures of common items in a home.** Have students cut out appropriate items they would gather from their home in preparation for a flood. This creates the student's Action Pack.

7. **Direct students to create a collage by cutting out pictures and gluing them on a poster board or sheet of paper.**

8. **If materials are not available, students can draw items.**

9. **Direct students to discuss their Action Pack with their family that evening.**

10. **Ask students to report to the class the following day the results of the family Action Pack discussion. Did any students work with their families to assemble an Action Pack for emergencies?**

Part II

1. **Inform students they are going to prepare a Family Action Plan in case a flood or other natural disaster strikes their community.**

2. **Have students organize into small groups**.

3. **Ask students to develop a list of tasks that should be included in a Family Action Plan.**

4. **After 15 minutes, ask each group to report and record their suggestions on the board.**

5. **Provide each student with a copy of the Family Action Plan.**

6. **Compare the class list with the Family Action Plan. Add student items to the bottom of the student copy page.**

7. **Discuss the Family Action Plan. Ask students to begin completing it.**

8. **Instruct them to take the list home to finish with their families.**

9. **On the following day, discuss their lists and have them work in teams to complete.**

10. **Ask students why it is important to prepare the Family Action Plan well before a natural disaster, such as a flood.**

Wrap Up and ActionEducation

Have students discuss how their families reacted to the Action Pack and Family Action Plan. Ask students if they think the Action Pack and Family Action Plan will make them better prepared for a flood or other natural disaster.

Inquire why it is important to be prepared in advance of an emergency. Discuss the idea that an emergency situation may invoke fear and panic unless they are organized and have a plan. Ask students if there are other things they could do to be prepared.

So that they are not overly concerned, remind students that there are many agencies that collect and assess data, monitor weather and climate patterns, and recommend structural (e.g., levees, flood-proofing homes) and nonstructural (e.g., early warning systems) solutions to help protect people from floods.

Assessment

Have students:

- identify the nearest river, stream, dry wash or creek bed and assess the possibility of flooding at their water address (***Warm Up***).
- list five items to be included in their Action Pack (***Part I***, step 7).
- create a ***Family Action Plan*** (***Part II***, steps 1-8).

Extensions

Have students observe the landscape around their home or school. Is there a stream nearby? If so, is it choked with garbage or other debris?

Have students talk to families, school or other community officials to organize a clean-up effort to reduce or even prevent a flood.

Have students discuss what other efforts could reduce or mitigate flood impacts in their community or at another water address. This could include alerting community officials of plugged neighborhood storm drains.

Have students develop an Action Pack and Action Plan for a flood at school.

Have students research their community's natural disaster relief organizations and invite representatives to the classroom to discuss flood preparedness.

e-Links

Delaware River Basin Commission, *Flood Information for Kids*, http://www.state.nj.us/drbc/Flood_Website/kids.htm

Federal Emergency Management Agency, *FEMA for Kids*, http://www.fema.gov/kids/floods.htm

Scottish Environment Protection Agency (SEPA), *Floodline Kids*, http://apps.sepa.org.uk/floodlinekids/floods/plan.html

U.S. Geological Survey, *USGS Real Time Water Data for the Nation*, http://waterdata.usgs.gov/nwis/rt

World Meteorological Organization, *Flood Forecasting Initiative*, http://www.wmo.int/pages/prog/hwrp/FFI-index.html

Photo Resources

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Family Action Plan Student Copy Page

Be sure each family member has one copy of the Family Action Plan and post it in a prominent place in the home.
Review the plan every six months with family members.

1. Record your physical home address: ______________________________
____
____

2. Record addresses, land and cell telephone numbers for each family member and a responsible family friend or relative: ______________________________
____
____

3. Record emergency numbers and discuss when it is appropriate to call these numbers:

   Fire ______________________________

   Police ______________________________

   Doctor ______________________________

   Hospital ______________________________

4. Draw or describe community evacuation routes from your home to a known safe place. Practice driving or walking it once a year with family members. ______________________________
____
____
____

5. If family members become separated and they are not sheltering in their home, their meeting place will be:
____
____
____

6. List local radio and television channels to receive emergency information: ______________________________
____
____

7. List location of community safe shelters: ______________________________

____

____

8. Record location of nearest hospital: ______________________________

____

____

9. Keep your Action Pack ready to go!*

- ❒ Flashlight with plenty of extra batteries
- ❒ Battery-powered radio with extra batteries, or wind-up radio
- ❒ First aid kit
- ❒ Prescription medications in their original bottle, plus copies of the prescriptions
- ❒ Eyeglasses (with a copy of the prescription)
- ❒ Water (at least one gallon [3.8 l] per person is recommended; more is better)
- ❒ Foods that do not require refrigeration or cooking
- ❒ Items that infants and elderly household members may require
- ❒ Sanitation and personal hygiene supplies (e.g., hand sanitizer, toilet paper)
- ❒ Matches in a waterproof container
- ❒ Can opener
- ❒ Paper plates and eating utensils
- ❒ Small tool box (e.g., hammer, screw driver, small saw)
- ❒ Medical equipment and devices, such as dentures, crutches, prostheses, etc.
- ❒ Change of clothes for each household member
- ❒ Waterproof clothing, such as raincoats and especially rubber boots for each family member
- ❒ Sleeping bag or bedroll and pillow for each household member
- ❒ Checkbook, cash and credit cards
- ❒ Passports, birth certificates, insurance documents—place all important documents in a waterproof container
- ❒ Map of the area

10. Develop a plan for taking care of family members, such as grandparents who live nearby or elderly neighbors.

11. Write an Action Plan to care for your pets or livestock.

12. Make it a rule to keep your vehicles fueled or other modes of transportation always in working order.

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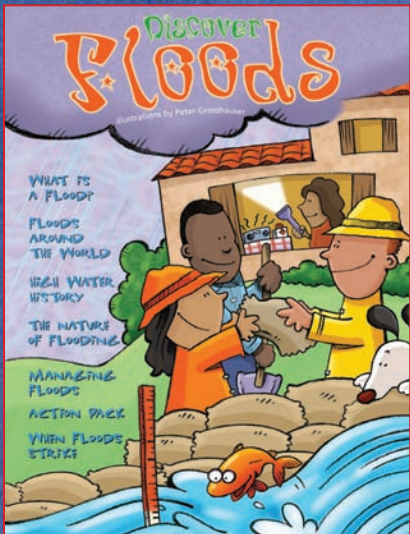

Discover Floods
Kids In Discovery series (KIDs) activity booklet — companion to the ***Discover Floods Educators Guide***

Project WET
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