Stormwater Floodplain Simulation System

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User's Guide

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ACKNOWLEDGMENTS

The development of the WARD'S Stormwater Floodplain Simulation System was a uniquely collaborative effort between WARD'S Natural Science and two principle scientists/developers—Mark Walton (senior hydrologist at the NOAA National Weather Service Grand Rapids, Michigan office) and Dave Chapman (science teacher at Okemos High School in Okemos, Michigan). With their vision and persistence, and the support of the Michigan Stormwater-Floodplain Association, they were able to create early prototypes that became the foundation of this finished commercial model.

The dangers of flooding and the importance of floodplain management cannot be understated. With this new model and the activities outlined in this User's Guide, students and educators of all ages will gain a new appreciation for floodplains in river basin dynamics and the factors that impact flooding events. We gratefully acknowledge the work of Mark Walton and Dave Chapman in the development of this model and in the preparation of this Guide. In honor and appreciation of their efforts, 10% of all proceeds from each model sold will be donated by WARD'S to the Michigan Stormwater-Floodplain Association Scholarship Fund.

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UNPACKING YOUR SYSTEM

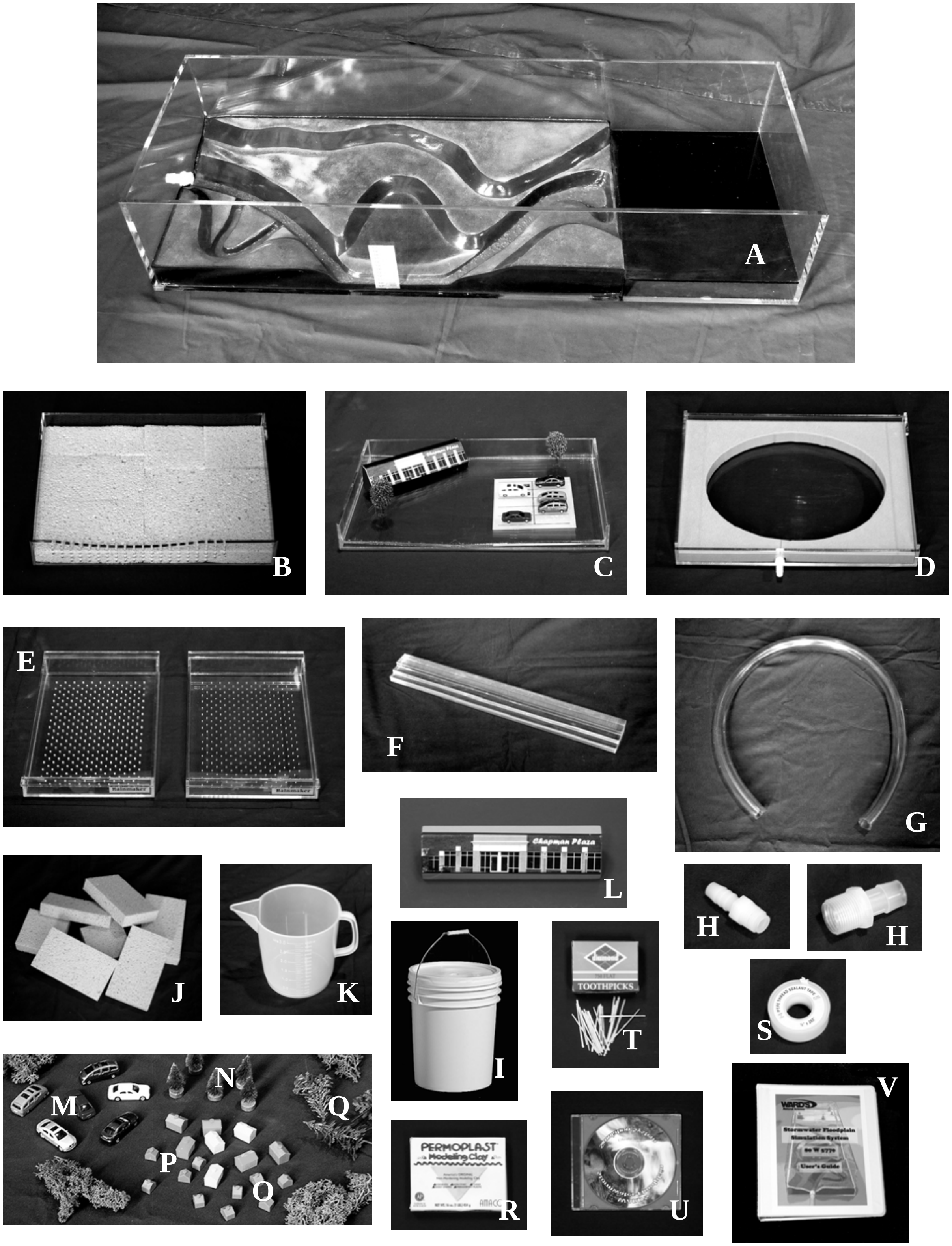
Your WARD'S Stormwater Floodplain Simulation System includes everything you'll need to conduct a variety of innovative watershed modeling scenarios and experiments. Central to the system is a large, clear, acrylic watershed tank and a series of innovative headwater trays and accessories. All components are shipped in two cartons and packed with the utmost care for damage-free arrival. If, however, obvious damage has occurred during shipment, please notify WARD'S Customer Service Department immediately and retain all boxes and packing materials. Carefully unpack both cartons and remove all components and parcels. Inspect all packing materials before discarding to ensure all parts have been accounted for. Review the list of components below. Please contact WARD'S Customer Service Department (1-800-962-2660) if you discover any hidden damage or missing items.

Large Carton Contents:	**Quantity:**
A. Acrylic Watershed Tank (46 3/4"L x 16 1/2"W x 9"H)	1
B. Wetland Headwater Tray (acrylic)	1
C. Parking Lot/Plaza Headwater Tray (acrylic)	1
D. Retention Pond Headwater Tray (acrylic)	1
E. Rainmakers - High & Low Rate (acrylic)	2
F. Slope Adjustment Bar (acrylic)	1
G. Drain Hose - 3 ft. (vinyl)	1
H. Drain Fittings - Large & Small (nylon)	2

Small Carton Contents:	
I. Water/Catch Buckets (5 gallon)	2
J. Cellulose Sponges (green)	6
K. Graduated Pitcher (3L)	1
L. Plaza Storefront Model	1
M. Miniature Vehicles*	5
N. Miniature Trees (assorted)*	13
O. Miniature Houses*	12
P. Miniature Buildings*	6
Q. Natural Moss (2.5 oz. pkg.)	1
R. Modeling Clay (1 lb. pkg.)	1
S. Teflon Tape (roll)	1
T. Toothpicks (box)	1
U. Resource CD** with Student Copymasters, Glossary, and Hydrograph Spreadsheet	1
V. Teacher/User's Guide Binder	1

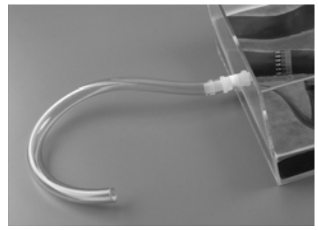
** Sizes, styles, and colors of components may vary*
*** System Requirements: Adobe Acrobat Reader; Excel-compatible spreadsheet software*

SYSTEM COMPONENTS

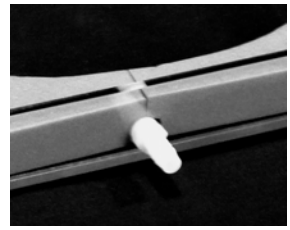


GETTING STARTED

After checking to make sure all components are accounted for, remove the large Acrylic Watershed Tank (A) from the shipping/storage carton and place it on a level, solid surface. This is best accomplished with two people. Hand-holds have been built in at either end of the tank to aid in lifting and transporting the model. Now, locate the drain hose (G) and larger nylon drain fitting (H). Using the teflon tape (S) provided, wrap the threads on the fitting, and install the fitting into the opening at the end of the tank. Carefully thread the fitting into the opening, but do not over tighten. Once in place, install the drain hose over the end of the fitting. During operation, the drain hose should hang off the edge of the countertop or table you are using so that the water from the model will drain into the catch bucket. Now install the smaller fitting (H) into the opening in the side of the Retention Pond headwater tray (D) in the same manner. This fitting does not require a drain hose.

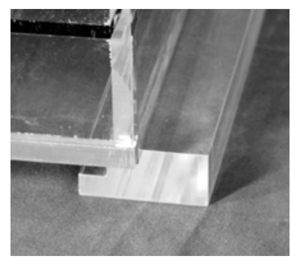


Drain Hose Installation



Retention Pond Fitting

Familiarize yourself with the various headwater trays and components in your system. Each headwater tray fits snugly into the tank and rests on the black headwater platform when in use. Use the trees and moss provided to decorate your landscape in any manner you desire. You may want to use a small amount of modeling clay to secure some of the cars, trees, and other accessories to the flat acrylic surfaces. The tank slope adjustment bar (F) provided will allow you to experiment with varying slope angles of from 1°-4°. Simply place the bar under the headwater end of the tank at the setting desired.



Slope Adjustment Bar

Care and Handling

Your WARD'S Stormwater Floodplain Simulation System is constructed of high-quality materials designed to aid in both visual appeal and performance. Many of the key components are made of clear acrylic. While structurally strong, acrylic can also scratch easily, so you should only use a soft cloth and water for cleaning. **<u>Never</u>** use cleaning solutions or solvents with acrylic as this may cause cracking and crazing to occur. After using your system, carefully drain any water from the tank and dry up any excess water remaining on surfaces with a soft sponge or cloth. Leaving standing water in your model over a prolonged period of time may cause staining and mold growth. **<u>Never</u>** use any abrasive cleaners on the landform model, as this will scratch and damage the painted fiberglas surface.

Carefully follow all instructions for proper use of your system as outlined in this guide. If questions or problems occur, contact WARD'S Customer Service Department (1-800-962-2660) for technical assistance.

MODEL CONCEPTS AND USE

The WARD'S Stormwater Floodplain Simulation System is a large-scale and visually striking model that features a large clear acrylic tank, a colorful hand-painted resin landform insert, and three different headwater trays and two rainmaker trays to simulate several real world environmental scenarios that students can recreate and modify.

Developed for education and outreach in cooperation with the Michigan Stormwater Floodplain Association, the model has already drawn considerable interest from hydrologists, floodplain managers, and disaster planning groups from around the nation—and it's no wonder. Flood related deaths in the U.S. account for more fatalities than any other natural disaster. This new model offers a real opportunity to educate children and adults alike about the dangers and impact of unplanned development and human activity in the floodplain.

Through the use of this model, students will explore the value of wetlands and retention ponds in flood management. They will construct their own levees and witness how stream flow is affected and can impact downstream communities during times of high runoff. They will simulate ice damming and other seasonal risks in the floodplain. They will measure runoff volume and construct their own hydrograph of stream flow over time. Most importantly, they will work as a team to find and test solutions to a variety of floodplain problems simulated by the model. This in-depth study guide will also introduce students to new concepts such as "No Adverse Impact®", "Turn Around Don't Drown™", "runoff footprint", "green gardens", "green roofs", and "porous pavement"—all new tools in the management of our critical watershed resources.

The activities outlined in this User's Guide are appropriate for students in grades 7-12, college and university programs, public outreach and education, and may also be modified and performed as demonstrations for younger age groups.

OUTLINE OF ACTIVITIES

Here is a brief overview of the activities presented in this Guide.

ACTIVITY 1 - Case Study: The Story of a Flooded Community. The flood caught the community completely off guard. How did so much damage occur? No one could remember it flooding here before—at least not in the last 25 years. What is different now? Group brainstorming and class discussion on each group's hypothesis will determine prior knowledge and introduce a glossary of hydrology terminology.
Time Allotment: 15-25 minutes.

ACTIVITY 2 - Fate of Rain: Discover what happens to rainwater falling in developed and natural environments. Explore surface conditions that result in rainwater infiltrating groundwater aquifers, into soil, evaporating and running off.
Time Allotment: 15-25 minutes.

ACTIVITY 3 - Modeling Flood Risk Factors: What happens to a river and its associated floodplains when wetlands are replaced with a mall? Model rainfall on wetlands, observe and collect data to determine the affects on the river's flow rate downstream. With this dynamic model, replace the Wetland Headwater with the Parking Lot/Plaza Headwater tray and determine the affects development has on the river and associated floodplains. The use of land may or may not affect the river flow by communities upstream, but the affect can be significant downstream.
Time Allotment: 45-50 minutes.

ACTIVITY 4 - Modeling Man-Made Attempts to Minimize Flooding: Can man control flooding? Explore man-made levees and retention ponds. Using the Parking Lot/Plaza Headwater tray, place clay levees in various areas to protect houses within the floodway and floodplain down river. Determine where the levees are most effective. Place the Retention Pond Headwater tray under the Parking Lot Headwater tray. Observe and record the impacts on the river and associated floodplains.
Time Allotment: 45-50 minutes.

ACTIVITY 5 - Factors Affecting Flood Forecasting: Students investigate the factors that contribute to or help avoid flooding. The relationship between the storm, soil, and surface conditions will determine changes in the river stage and ultimately the risk of flooding.
Time Allotment: 15-25 minutes.

ACTIVITY 6 - Planning a Flood Safe Community: Student groups are provided a topographical map and map symbols to plan a flood safe community. Each brainstorming team will present their plan to the classroom community. The community will discuss possible improvements.
Time Allotment: 45-50 minutes.

ACTIVITY 7 - River Crest Analysis: A major storm dropped 2.5 inches of rain in six hours on the city of Jackson. Students are given a watershed map with Jackson and two other cities the Chapman River flows through. With hydrographs, classroom hydrologists determine crest height, crest time and if the flood stage was exceeded in Jackson, Lansing and Grand Rapids.
Time Allotment: 45-50 minutes.

EXTENSION ACTIVITY 8 - Turn Around Don't Drown: Did you know the highest percent of flood-related deaths is due to vehicles being driven into hazardous flood water? The next highest percentage is due to walking into or near flood waters. These types of drowning can be prevented. Students locate their local National Weather Service office to obtain copies of the Turn Around, Don't Drown handout. Student groups will make a video, a poster, or a power point presentation on flood safety. Visit: http://tadd.weather.gov

PRE-LAB PREPARATION

Prior to performing activities, please review the background information, terminology, and important hydrological concepts with students to better aid understanding. A condensed version of this background information may be found at the beginning of each student copymaster. Activity copymasters and a complete glossary of key terms are provided on the Resource CD.

NATIONAL SCIENCE EDUCATION STANDARDS

Summary of activities and standards met.

	LAB ACTIVITY							
	1	2	3	4	5	6	7	8
Standard K-12: Unifying concepts and processes								
Systems, order, and organization	●	●	●	●	●	●	●	●
Evidence, models, and explanation	●	●	●	●	●	●	●	●
Change, constancy, and measurement	●	●	●	●	●	●	●	●
Standard A: Science as Inquiry								
Abilities necessary to do scientific inquiry	●	●	●	●	●	●	●	●
Understandings about scientific inquiry	●	●	●	●	●	●	●	●
Standard B: Physical Science								
Conservation of energy and increase in disorder		●	●	●	●	●	●	●
Interaction of energy and matter					●	●	●	●
Standard D: Earth & Space Science								
Energy in the earth system	●	●	●	●	●	●	●	●
Geochemical systems	●	●	●	●	●	●	●	●
Origin and evolution of the earth system	●	●	●	●	●	●	●	●
Standard E: Science & Technology								
Abilities of technological design	●	●	●	●	●	●	●	●
Understandings about science and technology	●	●	●	●	●	●	●	●
Standard F: Science in Personal & Social Perspectives								
Personal and community health	●		●	●	●	●		●
Natural resources	●	●	●	●	●	●	●	●
Environmental quality	●	●	●	●	●	●	●	●
Natural and human induced hazards	●		●	●	●	●	●	●
Science and technology in local, national, and global challenges	●	●	●	●	●	●	●	●
Standard G: History & Nature of Science								
Science as a human endeavor	●	●	●	●	●	●	●	●
Nature of scientific knowledge	●		●	●	●	●	●	●

BACKGROUND

What is a floodplain?

Floodplains play a vital and critical role in the life of a watershed or river basin. A **watershed** is the land area that drains into a specific body of water, such as a lake, stream, or river. It is also known as a river basin. The terms "watershed" and "river basin" are synonymous and can be used interchangeably. A **floodplain** is that area adjacent to a stream or river that is periodically covered with high water.

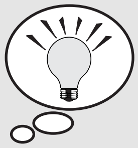
Floodplain

The floodplain is an important part of the river basin because it provides a place for the water to go when it cannot be contained within the river channel. When water spreads out over the floodplain, the flow velocities are dramatically reduced, and the energy of the river is dissipated. Excess energy associated with high flows is dissipated when water spreads out across the floodplain. Vegetation slows the water's velocity, and the roots hold the soil in place, reducing erosion. This relieves the pressure on stream banks and allows the water to be stored, thereby reducing the amount of flooding that occurs downstream.

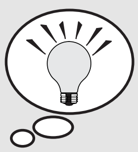
The floodplain is formed by the river itself through the natural process of erosion and deposition along the river channel. Over time, the river channel can and will move across the floodplain, eroding and re-depositing material. This erosion and deposition of bank material is another mechanism by which the erosional energy in the river is dissipated in the floodplain. Floodplains are meant to flood; it is nature's way of dealing with excess water.

Why are floodplains important?

As the United States continues to grow and develop, flood damages are increasing. The current trend is to allow development to occur without considering the adverse impacts on other properties within the river basin or on future flooding potential. This has contributed to steadily rising flood losses and is increasing the potential for future flood damage. Floods are the leading cause of natural disaster losses in the United



DID YOU KNOW?
FEMA statistics show that homes in a floodplain are 27 times more likely to incur damage from a flood than from a fire during a 30-year mortgage.



DID YOU KNOW?
Flash floods occur when water rises rapidly along a stream or low-lying urban area. Most fatalities and damage from flash flooding tend to occur in areas immediately adjacent to the stream, due to heavy rain, dam failure, levee breaks, rapid snowmelt, or ice jams. Flash floods can be produced when slow moving or multiple thunderstorms linger over the same area. Faster moving storms are less likely to produce flash flooding.

States. In fact, floods cause greater loss of life and property in the United States than any other type of natural hazard, and the threat is increasing. Over three-quarters of all federal disaster declarations are due, at least in part, to flooding. In an effort to reduce this threat, communities should consider the benefits and values of floodplains.

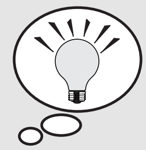

Floodplain

Floodplains constitute about 7% of the United States land area and represent a valuable national resource. Floodplains store flood waters during high flows; are a source of biological productivity and diversity; and are used for many human activities, including agriculture, grazing, parks and recreation, transportation, housing, and commercial development. The cost of maintaining the natural processes of floodplains is far less than what it would take to build facilities to correct flood, stormwater, water quality, and other community problems caused by residential and commercial development within the floodplain.

<u>What are the benefits of floodplains?</u>

Floodplains store floodwaters, recharge groundwater used for drinking, filter stormwater runoff and provide habitat for a wide variety of animals. Floodplains enhance biological productivity by supporting a high rate of plant growth. This helps to maintain biodiversity and the integrity of ecosystems. Floodplains provide excellent habitats for fish and wildlife by serving as breeding and feeding grounds. They also create and enhance waterfowl habitats and help to protect habitats for rare and endangered species. In addition, floodplains help to:

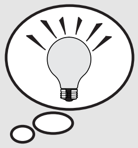
- Reduce flood velocities & flood peaks
- Reduce erosion potential and associated impacts
- Stabilize soils
- Accommodate stream meander
- Facilitate water infiltration and aquifer recharge
- Reduce sediment loads & the amount of sediments in rivers
- Improve water quality & moderate water temperatures
- Process organic and chemical wastes
- Protect the physical, biological, & chemical integrity of water
- Provide green space and open space for recreation
- Provide natural vegetation that filters out impurities & uses excess nutrients



DID YOU KNOW?

The relative frequency of various degrees of flooding has traditionally been identified by the number of years between occurrences (e.g., a 25-year flood). This does not literally mean that such a flood only occurs once in that many years. It is actually a statement based on historical records, and it is often defined as the probability of such a flood occurring in a given year.

Many people believe that a 100-year flood should happen once every 100 years, but that is not how it works. A 100 year flood is one which has a 1% chance of occurring in any given year. A 50 year flood is one which has a 2 % chance of occurring. A good example is a coin flip. The probability that a coin will come up heads is 50-50. It is entirely possible to flip a coin and have it come up heads three or four times in a row. So, for a 100-year flood we should really be referring to it as a "1%-annual-chance flood", and it is entirely possible to have several "100-year floods" in a row.



DID YOU KNOW?

Historically, many towns, homes and other buildings have been built on floodplains where they are highly susceptible to flooding,. Why did they do this? There are several key reasons:

- This is where water is most readily available
- Floodplain land is usually very fertile for farming
- River transportation was a key economic factor in the founding of many communities
- Rivers represent cheap sources of transportation, and are often where railroads are located
- Flat land is easier to develop and build on than steep land
- People generally enjoy the living environment and aesthetics of riverfront locations

- Enrich agricultural lands by sediment deposits
- Restore and enhance forests. Riparian forests provide important shade to waterways, which help moderate water temperature and raise oxygen levels.
- Provide areas for parks, bike paths, open spaces, wildlife conservation areas and aesthetic features important to communities. Assets such as these make the community more appealing to potential employers, investors, residents, property owners and tourists.

What are the detrimental impacts that development can have on floodplains?

- Increases the magnitude and frequency of flooding
- Reduces flood storage; runoff reaches the river much faster
- Increases stream bank erosion
- Increases the volume of surface runoff
- Increases stream velocities & decreases base flow
- Increases stream channel widening and down cutting
- Can eliminate or alter pool/riffle structure
- Increases movement of stream channel across the floodplain
- Increases sedimentation and sediment loads in streams
- Increases pollutants entering stream; reduces water quality
- Increases nutrient loading in streams, which leads to increased vegetative growth
- Increases water temperatures
- Increases bacterial contamination during low water flows
- Reduces diversity of aquatic ecosystem
- Negatively impacts wetlands, riparian buffers, and springs

What is “No Adverse Impact®”

No Adverse Impact® (NAI) is an approach to floodplain management that ensures the action of one property owner or a community does not adversely impact the properties and rights of other property owners, as measured by increased flood peaks, flood stage, flood velocity, erosion, sedimentation, costs now and costs in the future. A no-adverse-impact approach focuses on planning for and lessening flood impacts resulting from land use changes. It is essentially a “do no harm” policy that will significantly decrease the creation of new flood damages. “No adverse impact” means that your neighbor should build in such a way that does not increase the risk of flooding to your property or others. “No Adverse Impact®” is endorsed by the Association of State Floodplain Managers.

What is a wetland?


Wetlands

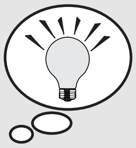
Wetlands are areas where water saturates the soil or covers the land for most or all of the year. There are three major types of wetlands: marshes which are water covered areas dominated by emergent plants like cattails and grasses; swamps which are wooded wetlands; and bogs which are characterized by floating mats of vegetation around some lakes. Wetlands function as natural sponges that trap and slowly release surface water, rain, snowmelt, groundwater and floodwaters. Trees, root mats, and other wetland vegetation also slow the speed of floodwaters and distribute them more slowly over the floodplain. This combined water storage and braking action lowers flood heights and reduces erosion. Wetlands within and downstream of urban areas are particularly valuable, counteracting the increased rate and volume of surface-water runoff from pavement and buildings. The holding capacity of wetlands helps control floods and prevents waterlogging of crops. Preserving and restoring wetlands, together with other water retention strategies, can often provide the level of flood control otherwise provided by expensive dredging operations and levees. Wetlands can be lost through the slow natural process of succession where the wetland gradually fills in due to erosion from nearby higher ground. Most wetland loss in the last 200 years is due to human activities such as draining or filling the wetlands for farming, cities, housing, highways, business and industrial construction. Federal, state, and local laws now exist in many places to protect wetlands.

What are the benefits of wetlands?

- Acre for acre, wetlands provide habitat for more wildlife and plants than any other terrestrial environment.
- They filter pollutants from surface runoff, trapping fertilizers, pesticides, sediments and other contaminants.
- The help recharge groundwater supplies when connected to groundwater aquifers.
- They contribute to natural nutrient and water cycles, and produce vital atmospheric gases, including oxygen.
- They provide commercial and recreational value to our human economy by producing plants and animals of interest to those who hunt, fish, and observe wildlife.
- They are a nutrient trap preventing enriching nutrients from entering lakes and rivers causing eutrophication.

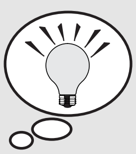
HYDROLOGIST

A hydrologist is a scientist who studies the movement, distribution, and quality of water throughout the Earth. Hydrologists apply scientific knowledge and mathematical principles to solve water-related problems in society: problems of quantity, quality and availability. They may be concerned with finding water supplies for cities or irrigated farms, or controlling river flooding or soil erosion. Or, they may work in environmental protection: preventing or cleaning up pollution or locating sites for safe disposal of hazardous wastes. Most hydrologists generally work within the fields of earth or environmental science, physical geography, geology or civil and environmental engineering.



DID YOU KNOW?

Rivers are dynamic systems and are constantly evolving; it is natural for rivers to flood. A river's natural inclination to flood becomes a real problem only when we build in harm's way and promote unwise use of our floodplains. Floodplains in their natural state play an important and critical role in the overall health of a river. Solutions to flooding along a river involve reducing the "runoff footprint" of the entire watershed.



DID YOU KNOW?

A **green roof** is a roofing system that utilizes vegetation to absorb rain water and reduce heat absorption. Sometimes known as "living roofs," green roofs also serve several other purposes for a building, including providing insulation, creating a habitat for wildlife, and helping to lower urban air temperatures.

- Wetlands reduce flooding by absorbing runoff from rain and melting snow, and by slowly releasing excess water into rivers and lakes. (One acre swamp when flooded to a depth of one foot contains 330,000 gallons of water which is not contributing to the risk of flooding.)

How are floodplains and wetlands different?

Wetlands do not have to be associated with a river system, whereas a floodplain is typically that area adjacent to a stream or river that is periodically inundated by high water. Many floodplains are not wetlands, and many wetlands do not lie within floodplains. However, wetlands often reside within the low lying and wetter portions of floodplain areas. Wetlands are typically underwater for longer periods of time and have more saturated soils than floodplains. Floodplains and wetlands also typically have different types of plant species. Wetland plants are adapted for saturated soils, whereas many floodplain plants are not.

A New Concept: Runoff Footprint

What is a runoff footprint? The **runoff footprint** is defined as a measure of the impact by human activities on flooding, or the potential for flooding, in terms of the amount of water that is discharged (runs off) from a drainage area over a given time period. The ultimate goal with any type of development within the watershed is to have no increase in the runoff footprint within the watershed. In order to address flooding issues for a community along a particular river, one must address the impact of development on the runoff footprint within the entire watershed. Ideally, the impact of human activities within the watershed should not result in a higher runoff footprint than the natural environment that existed before development. It is not necessarily a good practice to have a zero-runoff footprint from a development as it can negatively impact the natural runoff process required for the health of a river system. Some stormwater best practices used by developers to reduce their runoff footprint include rain gardens, green roofs, bioswales, pocket wetlands, reforestation, porous pavements, minimizing impervious surfaces within the development, and practicing low impact development.

Green Roofs

ACTIVITIES

ACTIVITY 1 - Case Study: A Flooded Community

OBJECTIVES:

- Examine and understand the importance of floodplains.
- Gain familiarity with basic terminology used in stormwater and floodplain management.
- Reflect on the factors that may affect the risk of flooding and generate a list.
- Practice designing experiments for testing a hypothesis.

TIME ALLOTMENT: 15-30 minutes

MATERIALS NEEDED PER GROUP:

Paper and pens
Newsprint
Markers
Glossary of Terms (see PDF on Resource CD)

BACKGROUND:

As the United States continues to grow and develop, flood damages are increasing. This has contributed to steadily rising flood losses and is increasing the potential for future flood damage. Floods are the leading cause of natural disaster losses in the United States. In fact, floods cause a greater loss of life and property in the United States than any other type of natural hazard, and the threat is increasing. Over three-quarters of all federally-declared disaster declarations are due, at least in part, to flooding. In an effort to reduce this threat, communities should consider the benefits of floodplains and wetlands.

A floodplain is that low area adjacent to a stream or river which provides a place for the water to go when it cannot be contained within the river channel. Floodplains are used for many human activities, including agriculture, grazing, parks and recreation, transportation, housing, and commercial development. Wetlands are areas where water saturates the soil or covers the land for most or all of the year. Wetlands function as natural sponges that trap and slowly release surface water, rain, snowmelt, groundwater and floodwaters. Floodplains and wetlands are a part of the larger watershed. A watershed is the land area that drains into a specific water body such as a lake, stream, or river. What happens in a watershed affects the movement of water through it to lakes, streams, or rivers.

DID YOU KNOW?

Gilbert White was a pioneer in floodplain management and listed eight ways human activities can adjust to flooding:

- **Elevation** of the land surface or a building
- **Flood Abatement** or watershed management
- **Flood Protection** with levees, channels, or other engineering devices
- **Emergency Measures** to temporarily protect people and property
- **Structural Alterations** to buildings and infrastructure, such as floodproofing
- **Land Use** to arrange development in ways that lessen damage
- **Relief** for victims, from private or public sources
- **Insurance** as a way to build up funds and indemnify those who suffer flood damage

(Reference: Association of State Floodplain Managers "Floodplain Management 2050" Report of the Second Assembly of the Gilbert F. White National Flood Policy Forum, November 6 – 7, 2007.)

NOTES TO INSTRUCTOR

Read the background materials and the case study and print out and review the glossary terms found on the Resource CD with students before starting this activity.

PROCEDURE:

1. Review the background materials with your instructor and discuss why floodplains are important and the benefits of floodplains.

2. Consider the following story:

   A flood has just occurred in a community. The people living in that area were completely surprised. Although it is situated along a river, none of the residents could remember it flooding here before---at least not in the last 25 years. In fact, the generally attractive and safe nature of the area is one reason many of them moved to this community.

3. Now consider this question:

   "*What factors in the community could be different now that may have had an impact on the flooding?"*

4. Working in small groups, brainstorm about factors that may have affected flooding in this area.

5. Write down and discuss your group hypotheses and possible reasons for the flooding, using your new understanding of watershed and floodplain management.

6. Now present your group's ideas to the entire class. What are some ways you might find out whether or not the factors presented by each group could play a role in increasing the risk of flooding?

7. What experiments or data might you use to evaluate whether these factors could be important contributors to flooding?

ASSESSMENT:

1. Review your class responses to the question: **"***What factors in the community could be different now that may have had an impact on the flooding?"* Which of the factors you discussed do you think might be most critical?
   Responses will vary, but might include the following:

   Urbanization; dam break; increase in development in the basin; increase in impervious areas in the basin; frozen soils; saturated soils; record rainfall rates; debris dam/ backwater flooding; loss of vegetation (due to fire); above normal precipitation for the year; rapid snowmelt with rain (dependent on time of year and location)

NOTES TO INSTRUCTOR

Be sure to spend adequate time reviewing the background information thoroughly with students prior to starting the activity. The intent of this activity is to both assess students' prior knowledge and understanding about factors affecting the risk of floods, and also to get them to think about how to test their ideas with the model and to work as a team.

Organize them into small groups, and encourage them to think through how scientists could set up experiments to test their hypotheses. If the idea of testing on a small replica of a watershed is suggested, use this opportunity to talk about what scientific models are and how important they are in research.

DID YOU KNOW?

An excellent resource for stormwater management best practices can be found in the United States Environmental Protection Agency publication number EPA 231-B-05-002, *"Using Smart Growth Techniques as Stormwater Best Management Practices"*.

ACTIVITY 2: Fate of Rain

OBJECTIVES:

- List the four primary routes of rainwater after it has hit the ground.
- Identify which routes of rainwater are increased and decreased when there is a more impermeable surface in a watershed.
- Identify why wetlands are important for minimizing the risk of flooding.

TIME ALLOTMENT: 10-15 minutes

MATERIALS NEEDED PER GROUP:
Student copymaster with Figures 2.1 and 2.3
Pens or pencils

BACKGROUND:
In this activity, you will explore what happens to rainfall as it hits the ground, and how it is transported in the watershed. Refer to **Figure 2.1 - Fate of Rain** in your activity worksheet. Notice that it has a downward arrow representing rain falling on a particular area. There are four other arrows going in appropriate directions representing evaporation, runoff, infiltration into soil, and infiltration into a groundwater aquifer. With each arrow is a number representing the percentage of the rain that leaves by each path. This data is based on a study of a typical natural field.

PROCEDURE:

1. Study **Figure 2.1 - Fate of Rain** and **Figure 2.3 - Surfaces Impact on Rainwater**. Using this information, answer the Assessment questions that follow.

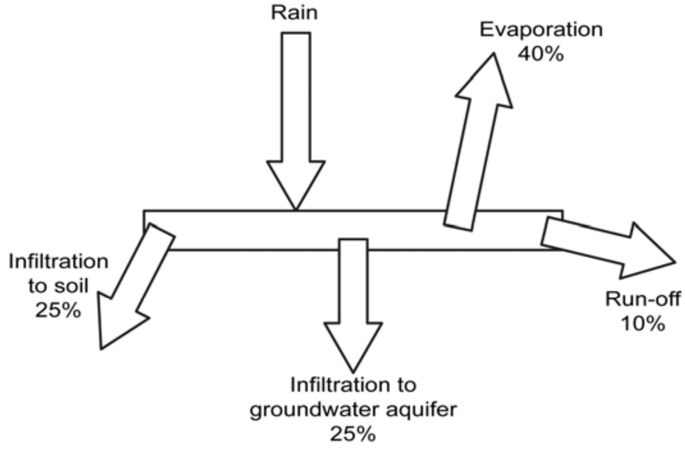


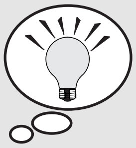
Figure 2.1—Fate of Rain

NOTES TO INSTRUCTOR
This activity can be completed either by individual students or in small groups (2-3 students per group).

You may want to scan and project Figures 2.1 and 2.3 to further discuss with your class. You can also find these Figures on the Resource CD.

Supplemental Activity: Assign students to research, either on-line or at their school library, the following terms: permeability, infiltration, evaporation, runoff, aquifer, soil moisture, urbanization, rain gardens, and green roofs.

This activity can also be extended to include broader experiments in porosity and permeability and infiltration rates. See your WARD'S Geology catalog or website for additional products and activity ideas.



DID YOU KNOW?

Infiltration is the process by which water on the ground surface enters the soil. *Infiltration rate* is a measure of the rate at which soil is able to absorb rainfall or irrigation. Gravity and capillary action are two principal forces that govern the infiltration process. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity.

Infiltration rates are affected by soil characteristics. For example, sandy soils have large pore spaces between each grain that allows water to infiltrate more quickly. In contrast, clay-rich soils have much smaller clay-sized particles and an interlocking texture that may impede or even block infiltration. These soil characteristics, types of cover vegetation, soil-water content and temperature, and rainfall intensity all play a role in controlling infiltration rate.

ASSESSMENT:

1. If the ground is paved over, which of these routes for rainwater will be prevented?
   Infiltration to soil and infiltration into aquifers would be prevented.

2. In areas where 100% of the land is paved, which routes would most likely increase?
   Evaporation and runoff would likely increase.

3. What do you think would happen to the water if only 25% of the land surface was paved over?
   Runoff and evaporation will increase, but not as much as in areas with 100% paving.

4. If the ground contained a lot of clay rather then sand, which route do you think would be impacted the most?
   The answer assumes some prior student knowledge of the properties of clay to swell when wet and to block water movement. Therefore, the presence of clay would impede infiltration along the soil and aquifer routes.

5. If we were investigating snow rather than rain, would any of your answers be different?
   There would be some evaporation, but water would not be able to travel the other routes until the snow melts.

6. Look at **Table 2.2**. For the ground conditions listed, fill in the appropriate responses and answer the summary question that follows.

Table 2.2 - Fate of Rain

Conditions in Area	What routes would increase?	What routes would decrease?
Frozen ground	**Runoff & evaporation**	**Infiltration into soil/ aquifer**
More wetlands	**Infiltration, evaporation**	**Runoff**
Sandy soil	**Infiltration**	**Runoff**

7. What condition or combination of conditions would increase the risk of flooding in nearby rivers?
The risk of flooding would increase if there is an increase in impermeable surfaces, the ground is frozen, or there is a loss of wetland.

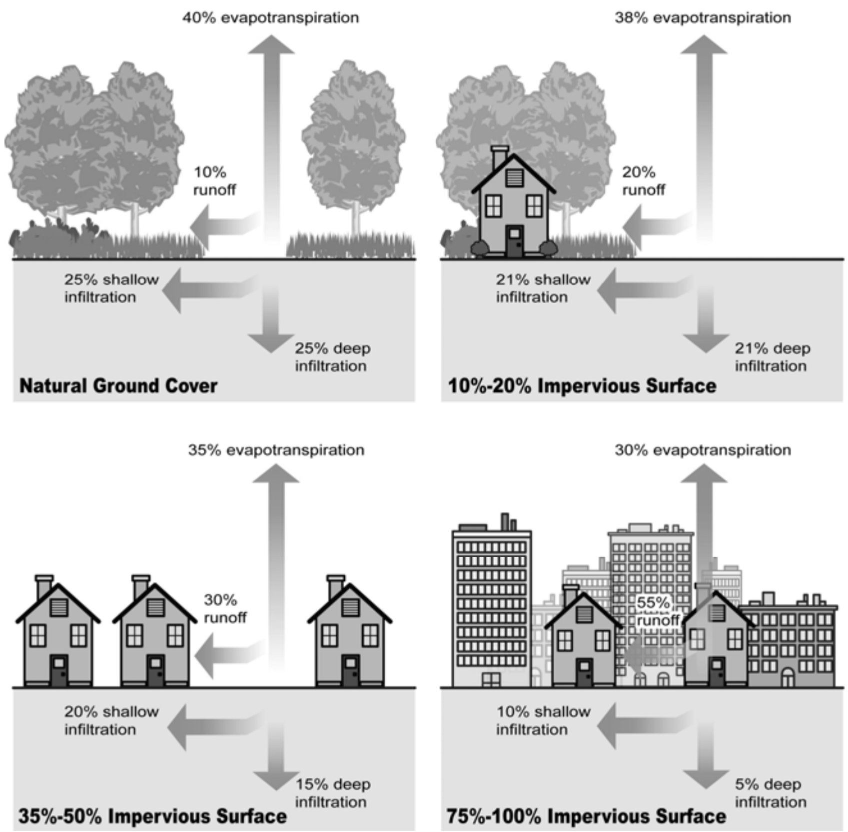


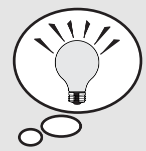
Figure 2.3 - Surfaces Impact on Rainwater

(Illustration based on "Stream Corridor Restoration: Principles, Processes, and Practices", 10/98, by the Federal Interagency Stream Restoration Working Group.)

8. Now look closely at Figure 2.3. List the four primary routes rainwater takes after it hits the ground?
The four primary routes of rainwater are evaporation, shallow infiltration into soil, deep infiltration into aquifers, and runoff.

9. Which routes of rainwater would be prevented if the ground were paved over?
Infiltration into soil and aquifers routes.

10. If the ground were paved over, where would most of the water go?
Most of the water would run off.



DID YOU KNOW?

Urban planners and developers are now making use of new paving materials called "porous" or "permeable" pavement. These materials replace standard asphalt and concrete in certain applications and allow significant amounts of water and air to pass around and through the paving material. This reduces runoff from parking lots and other formerly impermeable surfaces and allows precipitation to percolate down through to the soil and into the groundwater system. Permeable paving surfaces keep pollutants in place in the soil or in other material underlying the roadway, and also prevent stream erosion problems.

For more facts on porous pavement, visit the following website: www.stormwatercenter.net

11. List three changes in a watershed that would increase the risk of flooding?
The risk of flooding would increase if there was an increase in impervious surfaces, the ground was frozen, a loss of wetlands, or if the soil was saturated with water.

12. List three changes in a watershed that would decrease the risk of flooding?
The risk of flooding would decrease if there was an increase in wetland area, addition of rain gardens or green roofs on buildings, use of retention or detention ponds, removing pavement or installing permeable pavement

ACTIVITY 3: Modeling Flood Risk Factors

OBJECTIVES:

- Develop hypotheses on what causes floods.
- Design and successfully carry out experiments to test these hypotheses.
- Plot and analyze data derived from wetland and parking lot headwater experiments.
- Determine the timing of the flood crest, crest height, amount of runoff, and the runoff footprint for each experiment.
- Recognize the floodplain, floodway, bankfull stage, and flood stage for a stream.
- Identify how changes in a watershed impact a river's flood crest, flow, velocity, erosion, sedimentation, and risk of flooding.

TIME ALLOTMENT: Allow about 10 minutes for each experiment. In a typical class time of 45 to 50 minutes, students should be able to complete at least 4 experiments.

MATERIALS NEEDED PER GROUP:
The activities are performed as one large group; all materials for this activity are shared.

SHARED MATERIALS:
Stormwater Floodplain Model
Wetland Headwater Tray
Parking Lot/Plaza Headwater Tray
Rainmaker Trays (2) High/Low Rainfall Rates
Outflow Drain Hose
Catch Bucket
Water Bucket & Water Source
Graduated Pitcher 3L

NOTES TO INSTRUCTOR
The initial discussion for this activity is completed with the entire class. Before using the model, spend time reviewing the various parts and operation of the unit with the class before assigning tasks.

In Activities 3 & 4, you will be asked to break the class up into 4 groups to perform a number of experiments with the model. Each group can then rotate tasks as they move through the exercise.

Miniature Houses
Miniature Vehicles
Sponges (6)
Miniature Trees & Shrubs
Tank Slope Adjustment Bar
Stopwatch (not included)
Student Copymasters for Activity 3 (Resource CD)
Data Table and Graphing Spread Sheet (Resource CD)*
PC Computer/Projector (recommended)

NOTES TO INSTRUCTOR
*If using a computer with a projector to display data in near-real time, load the supplied spreadsheet file into the computer and assign a student for data entry. **Make sure not to overwrite the original file supplied with the model.**

PRE-LAB PREPARATION:

Prior to the activity, set up the model on a sturdy table where it can be easily viewed on all sides by the entire class. The drain hose needs to be attached to the drain spout. Adjust the location of the model on the table so that the drain hose hangs off the end of the table and into a large catch bucket. The end of the model opposite the drain spout should be propped up by the tank slope adjustment bar (second notch) to create the desired slope in the model. Place the Wetland Headwater and the Parking Lot/Plaza Headwater trays on the table next to the Model.

HAVE STUDENTS EXAMINE THE HEADWATER UNITS, BUT DO NOT TELL THEM WHAT THEY ARE.

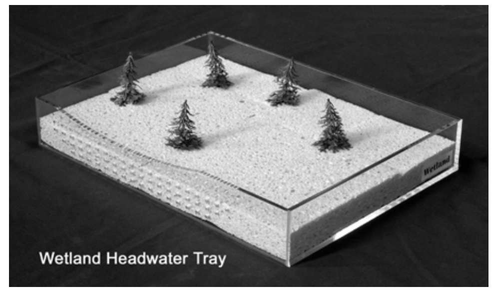
NOTES TO INSTRUCTOR
The two headwater units for this activity are designed to represent wetlands or natural areas and an impermeable surface such as pavement or frozen ground. The term **river stage** refers to how high the river surface is. It is a measurement of height (feet in the United States) above an arbitrary level just below the river bed at that location. Storm sewers and the efficient ditches that come with urban drainage systems speed up flood flows. There is more runoff in the river basin as a result of urbanization. The water moves faster, increasing flooding downstream.

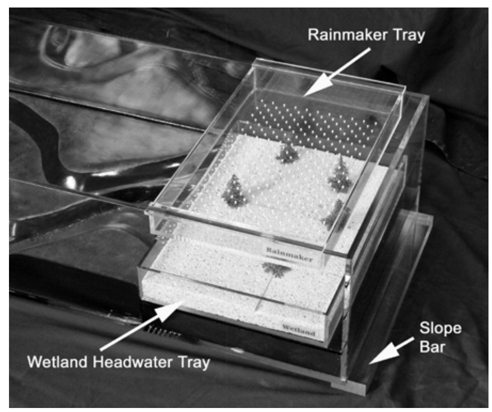
Fill the bucket provided with enough water for at least four trials (about 12 Liters). Have the 3L graduated pitcher nearby at the table. You may want to pre-mark the pitcher at the 2.8L level to make measuring easier between trials.

SETTING UP THE MODEL - Part 1

The first part of this activity models an “undeveloped watershed” and uses the Wetland Headwater tray. To prepare the tray, pre-soak the 6 pre-cut sponges in water and squeeze out the excess water from each one. The sponges are ready if no additional water drains out when gently squeezed. If the sponges are too dry, you may not get any runoff generated for the river to flow. If the sponges are too wet, you may get flooding. The goal is to get the sponges moist enough so that you get enough runoff to create a flow in the stream without causing water to flow into the floodplain.

NOTES TO INSTRUCTOR
Helpful hint: Before removing the Wetland Headwater tray, squeeze some of the excess water out of the sponges into the water bucket before removing the tray.





Place the prepared sponges in the bottom of the Wetlands Headwater tray and arrange them to fit snuggly into the space. Place or fasten a few miniature trees and shrubs onto the surface of the sponges to add realism. Now place the Wetlands Headwater tray into the tank on the black platform panel that abuts the landform. Make sure that the tray is positioned snugly against the edge of the landform.

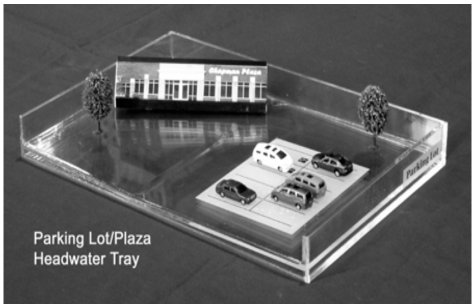
NOTES TO INSTRUCTOR
Between each experimental run, be sure to drain the model as completely as possible, and dry off any landform surfaces lightly with a soft cloth or paper towels. Lifting the headwater end of the model, using the hand hold, may speed this process.

Set a few miniature houses and buildings in the large floodplain and bluff areas and also downstream along the inside shores of the oxbow lake. Add miniature trees to the landscape as desired. Place the high-rainfall-rate-Rainmaker tray (large holes) directly over the Wetland Headwater tray in the model. The lips of the tray rest on the sides of the tank wall. Make sure that the Rainmaker tray is centered over the Wetland Headwater tray.

SETTING UP THE MODEL - Part 2

In the second part of the activity, students model a "developed watershed" and use the Parking Lot/Plaza Headwater tray. To conduct this exercise, simply replace the Wetland tray with the Parking Lot/ Plaza tray in the tank. Place the tray in the same position on the black panel platform adjoining the landform and river basin.

Add miniature cars to the parking spaces and the Chapman Plaza storefront building to the Parking Lot tray. Add trees and



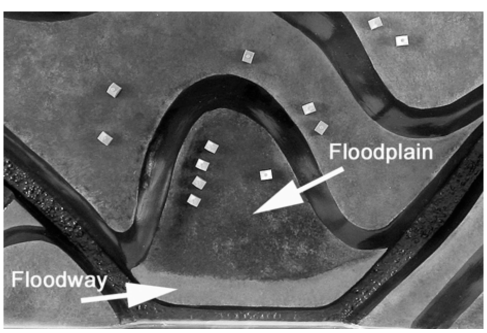
shrubs as desired. Use a small piece of modeling clay to keep them in position. Set a half dozen of the miniature houses in the large floodplain and a couple in the oxbow area, with the rest placed in various areas on higher ground. Place the high-rainfall-rate-Rainmaker tray in the model as before, and make sure the tray is centered over the Parking Lot tray.

OBSERVING THE MODEL WITH STUDENTS

Before starting any activities with the model, it is recommended that students first understand the parts of the unit and how the Stormwater Floodplain Model is to be used. Here are some suggestions:

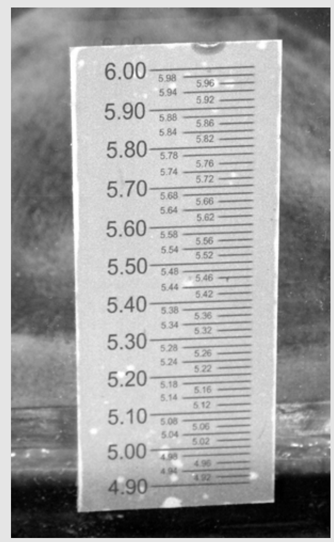
1. Present the Stormwater Floodplain model to the class. Show students where the stage levels can be measured using the staff gage on the side of the model and along the riverbank downstream, the alternative ways of introducing rain, and the various headwater upland inserts (but do not tell them what they represent; only point out their physical features).

2. Point out the floodplain and the floodway in the model. Ask the students why this may be an important distinction?



   The floodplain and the floodway both provide flood storage. Typically the highest river depths and velocities are contained within the floodway and pose the most hazard to life and property. No development should occur within the floodway. Development that causes no adverse impact is permissible in the floodplain.

3. Have students suggest experiments that can be performed with the model to address ideas they arrived with previously in Activity 1 and Activity 2. List or project these ideas on the board (or on newsprint).



Staff Gage

NOTES TO INSTRUCTOR

Review with your class how to take a proper reading of the water level using the Staff Gage printed on the side of the tank's side wall along the river. In this activity, students will be calling out their river level readings every 5 seconds.

There is also a second gage mounted on the riverbank downstream near the river outlet. As an added activity, students may wish to monitor water levels at this downstream location as well.

4. Enlist students' ideas of how to quantify the suggested experiments. Project the list or write on the board.
   If not listed, suggest measuring the amount of water added to and coming out of the model, the time intervals of measurements, and the depth (or "stage") of the stream.

5. Discuss the concept of "bankfull stage" of a stream.
   Bankfull is defined as an established gage height at a given location along a river or stream above which a rise in water surface will cause the river or stream to overflow the lowest natural stream bank somewhere along the river. Bankfull stage is not necessarily the same as flood stage.

6. Enlist student volunteers to determine what the bankfull stage is for this model and record this in student data sheets.

7. Explain flood stage to students.
   Flood Stage is defined by the National Weather Service as an established gage height for a given location above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood (or in some cases flash flood) warnings is linked to flood stage. Not necessarily the same as bankfull stage.

8. Enlist two other student volunteers to determine the flood stage for this model., and record this in student data sheets.

PROCEDURE - Part 1: RUNNING THE WETLANDS HEADWATER EXPERIMENT

Divide the class into four groups of 5-8 students. Make the following assignments in each group: rainmaker, river reader, timer, recorder, data entry into spreadsheet (if plotting data using computers), levee builder (not used in Activity 3), and one student to measure runoff output.

1. The first experiment uses the Wetlands Headwater in the Stormwater Floodplain model. Assign the first group to run the first experiment and the other groups to make observations. Explain that each of the four groups will run one of the experiments, so everyone will have a chance to "play" with the model. For subsequent experiments, different students will take turns pouring in the water and observing the river stage. At the end of each experiment, the results need to be recorded by every student and will be used later to answer questions.

2. To run the first experiment modeling an undeveloped basin, insert the Wetlands Headwater tray into position on the headwater platform in the tank, and center the high-rainfall-rate-Rainmaker tray over the Wetlands Headwater tray.

3. Have the student assigned to be “rainmaker” fill the pitcher with water from the water bucket (or a faucet) up to the 2800ml (2.8L) line on the pitcher.

4. Before starting, have the river reader measure the beginning height of the river and have the students record that value for time “0”.

5. Students who are not performing the experiment should be observing the larger picture of events in the watershed. Students taking measurements may not even see when it is flooding or if houses are being moved.

6. Timing begins when the rainmaker begins pouring the water into the Rainmaker tray. The timer needs to alert the river reader to take a reading every 5 seconds. It will take several readings before the runoff reaches the river.

7. Have one student from the group record the river stages (height) as they are called out. If you are using a computer and are plotting the data into a spreadsheet, have an additional student conduct data entry. The river reader calls out a river height every 5 seconds for the recorder to input into the data sheets. Observations every 5 seconds will typically need to be made for at least 2 minutes, or until the river ceases to flow.

8. Once the river ceases to flow, have one student measure the runoff by pouring the water in the catch bucket back into the graduated pitcher. Record the volume of water measured in the data sheet.

9. After running each experiment, report your observations to the rest of the class., and record this in the data sheet.

10. Determine the timing of the crest, the crest height, and the runoff footprint. Record this in the space provided in the data sheet. Note that a formula for calculating the Runoff Footprint is also provided in the data sheet.

NOTES TO INSTRUCTOR

Additional experiment idea: Run the same two experiments using the insert for the rainmaker tray that generates slower rainfall rates.

Additional experiment idea: Use the wetland-headwater tray with frozen sponges (place the wet sponges in a zip lock bag and place in the freezer overnight). Contrast and compare the results from the “frozen sponges” with the experiment using the “moist” sponges. The “frozen sponges” will simulate rain on frozen ground. One can also place finely crushed ice in the river and add a bridge just downstream from the large floodplain. The ice will be carried downstream and jam up against the bridge forming an ice jam. The ice jam will result in backwater flooding in the large floodplain located just upstream of the bridge.

ACTIVITY 3
DATA RECORDING SHEET

Headwater Type: ___Wetlands_________________________________

Amount of water added: **2800ml**

Time interval of readings: **5 seconds**

Time (minutes:seconds)	**Gage Height**
00:00	
00:05	
00:10	
00:15	
00:20	
00:25	
00:30	
00:35	
00:40	
00:45	
00:50	
00:55	
01:00	
01:05	
01:10	
01:15	
01:20	
01:25	
01:30	
01:35	
01:40	
01:45	
01:50	
01:55	
02:00	
02:05	
02:10	
02:15	
02:20	
02:25	
02:30	
02:35	
02:40	
02:45	
02:50	
02:55	
03:00	

Bankfull Stage: ________________________

Flood Stage: _________________________

Timing of crest: _______________________

Crest height:__________________________

Rainfall
(amount of water added): _______________

Runoff
(amount of water that
came out of model): ___________________

Amount of water that must
have stayed in the model: _______________

Runoff footprint (%) =
(runoff amount/amount of
water added) X 100 ____________________

ACTIVITY 3
DATA RECORDING SHEET

Headwater Type: Parking Lot

Amount of water added: **2800ml**

Time interval of readings: **5 seconds**

Time (minutes:seconds)	Gage Height
00:00	
00:05	
00:10	
00:15	
00:20	
00:25	
00:30	
00:35	
00:40	
00:45	
00:50	
00:55	
01:00	
01:05	
01:10	
01:15	
01:20	
01:25	
01:30	
01:35	
01:40	
01:45	
01:50	
01:55	
02:00	
02:05	
02:10	
02:15	
02:20	
02:25	
02:30	
02:35	
02:40	
02:45	
02:50	
02:55	
03:00	

Bankfull Stage: ________________________

Flood Stage: ________________________

Timing of crest: ________________________

Crest height: ________________________

Rainfall
(amount of water added): ________________

Runoff
(amount of water that
came out of model): ____________________

Amount of water that must
have stayed in the model: ________________

Runoff footprint (%) =
(runoff amount/amount of
water added) X 100 ____________________

PROCEDURE - Part 2: RUNNING THE PARKING LOT/ PLAZA HEADWATER EXPERIMENT

1. To run the second experiment modeling a developed basin, replace the Wetlands Headwater with the Parking Lot/ Plaza Headwater tray. Have a second group repeat the experiment following the same procedure outlined in Part 1 of this activity. Record the results in your data sheets.

2. After performing these activities, review your data with your team and design additional experiments using the model that are based on what you have discovered in Activities 1 & 2.

Alternative Procedures for younger students:
Run the experiments just as described, but omit the measurements. Have students describe what they see in non-quantitative terms (e.g., “It’s flooded the low area” or “It got deep fast but also dropped fast”).

ASSESSMENT:
Assessment for this exercise is to be completed at the end of Activity 4.

ACTIVITY 4: Man-Made Attempts to Minimize Flooding

OBJECTIVES:

- Explore options for protecting residents and property from flooding.
- Successfully carry out experiments using a physical model.
- Plot and analyze data derived from their own and pre-defined experiments.
- Determine the timing of the flood crest, crest height, amount of runoff, and the runoff footprint for each experiment.
- Compare and contrast the flood prevention effectiveness of man-made levees and retention ponds.
- Describe some of the impacts levees and retention ponds have on communities downstream.
- Explain some of the impacts levees and retention ponds have on stream flood characteristics.
- Identify how changes in a watershed impact a river’s flood crest, flow, velocity, erosion, sedimentation, and risk of flooding.
- Describe the function of retention ponds and explain how they reduce the risk of flooding.

DID YOU KNOW?
Runoff from parking lots, storm sewers, and the efficient ditches that come with urban drainage systems, speed flood flows. The result of urbanization is that there is more runoff in the river basin and it moves faster, increasing flooding downstream. A faster running river has more energy, which leads to more erosion and the capability to carry more sediment. Urbanization also changes the timing of flows along the tributaries. If one sub-watershed develops faster than usual, the flood will leave sooner than it used to, possibly arriving at the main channel at the same time as the peak arrives from another tributary, causing increased flooding downstream.

NOTES TO INSTRUCTOR
As flooding occurs in the floodplain during these activities, many of the houses will be carried downstream in the process. While providing a dramatic image for the students, the smaller houses can also block the outlet and drain hose in the tank and cause even more flooding downstream. You can use this as a real life example of debris jamming along bridges and culverts during floods in those scenarios, or you may wish to advise students to simply “snag” the houses before they enter the drain hose and block the system. If houses do get stuck in the outlet fitting, they can be easily pulled out with tweezers or simply pushed through into the catch bucket.

TIME ALLOTMENT: Allow about 10 minutes for each experiment. In a typical class time of 45 to 50 minutes, students should be able to complete at least 4 experiments (Activities 3 and 4).

MATERIALS NEEDED PER GROUP:
Because the activities are performed as one big group, all materials for this activity are shared. Each student will need a pen or pencil and should have a copy of the data sheet for each experiment run.

SHARED MATERIALS:
Stormwater Floodplain Model
Parking Lot/Plaza Headwater Tray
Retention Pond Headwater Tray
Rainmaker Trays (2) High Rainfall Rate and Low Rainfall Rate
Outflow Drain Hose
Catch bucket
Water Bucket
Water Source
Graduated Pitcher 3L.
Miniature Houses
Miniature Vehicles
Miniature Trees & Shrubs
Tank Slope Adjustment Bar
Modeling Clay
Stopwatch (not included)
Student Copymasters for Activity 4 (Resource CD)
Data Table and Graphing Spreadsheet (CD)*
PC Computer/Projector (recommended)

PRE-LAB PREPARATION:
Set up the model as outlined in Activity 3. There are two experiments students will perform. Both utilize the Parking Lot/ Plaza Headwater tray. Students will model the effect of clay levees in the floodway and floodplain in the first experiment. In the second experiment, they will place the Retention Pond Headwater tray under the Parking Lot tray to view the impact of adding this structure to the scenario.

As in Activity 3, divide the class into four groups of 5-8 students. Make the following assignments in each group: rainmaker, river reader, timer, recorder, data entry into spreadsheet (if plotting data using computers), levee builder (not used in Activity 3), and one student to measure runoff output. If one group performed a particular task in Activity 3, rotate those assignments.

NOTES TO INSTRUCTOR
*If using a computer with a projector to display data in near-real time, load the supplied spreadsheet file into the computer and assign a student for data entry. **Make sure not to overwrite the original file supplied with the model.**

NOTES TO INSTRUCTOR
As students speculate on various ways they might mitigate the impact of floodwaters on the houses situated in the floodplain, introduce the idea of building houses on stilts in flood-prone areas. Ask them to research areas of the country where this type of construction is already taking place. See if they want to simulate this type of construction in their model by making stilts for the houses out of toothpicks. To do this, fill the center portion of each house with modeling clay, and insert equal cut lengths of toothpick into each corner. Anchor the "stilts" to the floodplain with more clay. How do the houses fare when they run their experiment again?

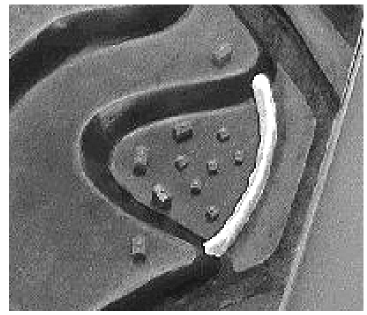
House on Stilts

NOTES TO INSTRUCTOR

Additional experiment idea: Run the same two experiments using the insert for the rainmaker tray that generates slower rainfall rates.

SETTING UP THE MODEL - Part 1

For the first experiment, place a half dozen houses in the large floodplain and a couple downstream in the oxbow area, with the rest placed in various areas on higher ground. Place the Parking Lot tray into position in the tank on the black headwater platform as done before. Center the high-rainfall-rate-Rainmaker tray over the Parking Lot tray. Ask the students what ideas they can think of to protect the community from flooding. If levees aren't suggested, describe that option and test it. Have a student use the modeling clay to build a levee in the large floodplain to protect the community along the river. Ask the class to determine the best height and position of the levee in the floodplain to protect the homes.



Clay Levee

SETTING UP THE MODEL - Part 2

The second experiment uses the Retention Pond Headwater tray in the model. To set up the second activity, refer to Figure 4.2. Remove the Parking Lot tray from the headwater platform and replace it with the Retention Pond Headwater tray. Next, place the Parking Lot tray on top of the Retention Pond tray so that it rests directly on the raised side panels. Make sure the back end of the Parking Lot tray is pressed up against the back wall of the tank, while the Retention Pond tray abuts the normal position against the landform. This will create an open space between the front of the two trays, allowing the runoff from the Parking Lot to flow into the Retention Pond during the experiment. Center the high-rainfall-rate-Rainmaker tray over the Parking Lot tray.

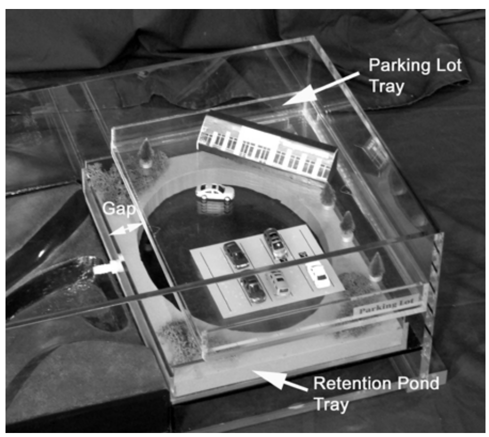


Fig. 4.2 - Parking Lot/Retention Pond Setup

Fill one of the buckets with enough water for at least four trials (about 12 liters). Have the pre-marked graduated pitcher at the table.

ADDITIONAL BACKGROUND:

The United States has thousands of miles of **levee systems**—usually earthen embankments designed and constructed to contain, control, or divert the flow of water to provide some level of protection from flooding. Some levee systems date back as far as 150 years; some were completed recently or are underway. Levee systems built for agricultural purposes provide flood protection and flood-loss reduction primarily for farm fields. Other systems—urban levee systems—were built to provide flood protection and flood-loss reduction for population centers and the industrial, commercial, and residential facilities within them.

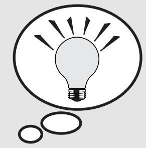
Earthen Levee

Because levees prevent flow into the floodplains, they take away the natural functions and benefits of floodplains discussed in our first activity. Levees only reduce the risk to individuals and structures behind them, they do not eliminate the risk. Levees should be considered as flood loss reduction structures, not flood protection structures. No levee system provides full protection from all flooding events to the people and structures located behind it. Some level of flood risk exists in these levee-impacted areas.

Retention ponds are man-made low areas designed to capture and store runoff for a limited period of time before being released through an outlet, at a controlled release rate. They are currently required in many zoning ordinances for business areas, apartment complexes, or other developed areas.

A retention pond is constructed to contain a permanent pool of water (not to be confused with a detention pond, which only contains water immediately after a rainfall event). Both types of ponds are constructed in neighborhoods and commercial developments to provide a means for capturing stormwater runoff.

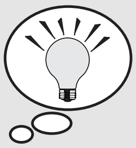
Retention Pond Under Construction



DID YOU KNOW?

The first known levees ever constructed date back to nearly 2600 BC in the Indus Valley civilization in northern India and Pakistan. Levees were also constructed in ancient Egypt over 3,000 years ago along the Nile River. This system of levees stretch for over 600 miles. The ancient Mesopotamians and Chinese also built levees.

Levees are only as strong as their weakest point, so their height and standards of construction need to be consistent along their entire length to be successful. Because of this, some historians believe that construction of ancient levees required a strong central authority to guide the building of levees and to insure the quality of the work.



DID YOU KNOW?

Advantages of levees:

- Constructed out of readily available materials
- If not overtopped, results in no water on protected structure
- No alteration of structure needed

Disadvantages of levees:

- Can impede flow of water in floodplain
- Can block natural drainage
- Susceptible to scour and erosion
- Gives false sense of security
- Takes up property space
- Can encourage further development within the floodplain
- Once levee has been breached, water does not leave quickly

Most development replaces open land and forest with impervious surfaces such as roofs, roads, driveways, and parking lots (i.e., surfaces that water runs off of instead of soaks into). As stormwater runs off these impervious surfaces, it enters streams and rivers at a much faster rate and may cause stream bank erosion and flooding downstream.

Stormwater Runoff

Retention ponds are most often designed to reduce the rate of runoff water leaving a development in order to prevent flooding downstream. Retention ponds also provide an important water quality function. Brief heavy rainstorms carry debris and pollutants from lawns, driveways and streets straight into the ponds. The ponds allow suspended pollutants to settle out before the water enters local streams and rivers. These suspended pollutants can include soil, debris from roadways, dissolved metals, organic waste (such as pet and goose droppings), and dissolved nutrients (such as those found in lawn fertilizer.) Thus retention ponds can play an important role in keeping pollutants from reaching our rivers and streams.

PROCEDURE - Part 1: Developed Basin with Levee

1. What can be done to protect life and property from flooding? Make a list on the board. Discuss the best options with the rest of the class. Test at least 2 of these options with your model.

2. The first experiment in this activity uses the Parking Lot/ Plaza Headwater tray in the Stormwater Floodplain model. With the Parking Lot tray in place in the model, use the modeling clay provided to build a levee to protect the homes located in the large floodplain.

3. Discuss with the rest of the class how to best construct and position the levee to protect the homes from flooding most effectively.

4. Assign a levee maker group to construct the levee.

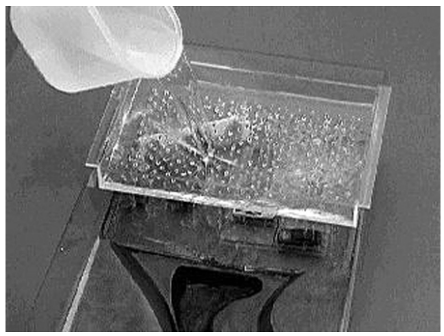
5. Prepare your data sheets to record information as you did in Activity 3.

6. Center the high-rainfall-rate Rainmaker over the Parking Lot tray in the model.

7. As in Activity 3, have the river reader measure the beginning height of the river and record that value for time "0" in your data sheet.

8. Have the rainmaker you've assigned fill the pitcher from the water bucket (or faucet) up to the 2800-ml line on the pitcher.

9. Data collecting and timing begins when the assigned rainmaker begins pouring the water into the rainmaker tray. The water should be poured at a consistent rate, making sure the rate does not exceed the capacity of the rainmaker tray. The timer needs to alert the river reader to take a reading every 5 seconds. It will take several readings until the runoff reaches the river.



Pouring Water into Rainmaker

10. Have one student from your group record the river stages as they are called out. If you have a computer and are plotting the data into a spreadsheet, have an additional student conduct data entry. The river reader calls out a river height every 5 seconds for the recorder to input into the data sheets. Observations every 5 seconds will typically need to be made for at least 2 minutes or until the river cease to flow.

11. Once the river ceases to flow, have one student measure the runoff by pouring the water that drained into the catch bucket back into the pitcher. Record the volume measurement in your data sheet.

12. After each experiment, share your observations with the rest of the class. Record your observations in your data sheet.
.

13. From the data you've recorded, determine the timing of the crest, the crest height, and the runoff footprint for this experiment.

NOTES TO INSTRUCTOR

This activity is specifically designed for students to test and record the impact of introducing levees and retention ponds in the floodplain system. If time permits, have students perform additional experiments to test other ideas or solutions they may have to reduce flooding. Use this opportunity for students to brainstorm and display their knowledge of floodplain principles to solve problems.

ACTIVITY 4
DATA RECORDING SHEET

Headwater Type: ___Parking Lot—Levee___________________________

Amount of water added: **2800ml**

Time interval of readings: **5 seconds**

Time (minutes:seconds)	Gage Height
00:00	
00:05	
00:10	
00:15	
00:20	
00:25	
00:30	
00:35	
00:40	
00:45	
00:50	
00:55	
01:00	
01:05	
01:10	
01:15	
01:20	
01:25	
01:30	
01:35	
01:40	
01:45	
01:50	
01:55	
02:00	
02:05	
02:10	
02:15	
02:20	
02:25	
02:30	
02:35	
02:40	
02:45	
02:50	
02:55	
03:00	

Bankfull Stage:
____

Flood Stage: __________________________

Timing of crest: _________________________

Crest height:___________________________

Rainfall
(amount of water added): ________________

Runoff
(amount of water that
came out of model): ____________________

Amount of water that must
have stayed in the model: ________________

Runoff footprint (%) =
(runoff amount/amount of
water added) X 100 _____________________

ACTIVITY 4
DATA RECORDING SHEET

Headwater Type: ___Parking Lot - Retention Pond________________

Amount of water added: **2800ml** Time interval of readings: **5 seconds**

Time (minutes:seconds)	Gage Height
00:00	
00:05	
00:10	
00:15	
00:20	
00:25	
00:30	
00:35	
00:40	
00:45	
00:50	
00:55	
01:00	
01:05	
01:10	
01:15	
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01:35	
01:40	
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01:55	
02:00	
02:05	
02:10	
02:15	
02:20	
02:25	
02:30	
02:35	
02:40	
02:45	
02:50	
02:55	
03:00	

Bankfull Stage: ________________________

Flood Stage: _________________________

Timing of crest: ________________________

Crest height:__________________________

Rainfall
(amount of water added): _______________

Runoff
(amount of water that
came out of model): ___________________

Amount of water that must
have stayed in the model: _______________

Runoff footprint (%) =
(runoff amount/amount of
water added) X 100 ____________________

NOTES TO INSTRUCTOR

Review additional setup instructions and Figure 4.2 with students, if needed, from “Setting Up the Model—Part 2” (page 28) before running the activity.

NOTES TO INSTRUCTOR

Because of the slow release of water from the retention pond, the runoff into the river will occur over a long time and river levels will hold steady for quite awhile. As a result, it will be sufficient to take readings for the same time period (approximately 2-3 minutes) as the other experiments. If time permits, the total runoff output can be measured; some runoff will remain in the retention pond by design.

NOTES TO INSTRUCTOR

If using the model with younger students, omit the measurement portion if it is beyond their scope. Run the experiments just as described, but simply have students describe what they see in non-quantitative terms (e.g., “It flooded the low area” or “It got deep fast but also dropped fast”).

PROCEDURE - Part 2: Developed Basin with Retention Pond

1. For this experiment, remove the Parking Lot tray from the headwater platform and replace it with the Retention Pond tray. Place the Retention Pond tray into the tank on the head water platform snugly against the edge of the landform.

2. Now place the Parking Lot tray on top of the Retention Pond tray so that it rests on the raised side extensions of the lower tray. Make sure the back end of the Parking Lot tray is pressed against the rear wall of the tank. There should be about a 1” gap between the front edges of the two trays when properly placed.

3. Center the high-rainfall-rate-Rainmaker tray over the Parking Lot tray.

4. Repeat the same procedure as in Part 1 of this Activity and record your results.

5. Analyze and discuss your results with the rest of your class and answer the Assessment questions that follow.

ASSESSMENT (Parts 1 & 2):

1. Did the levee prevent flooding? Explain your answer.
   Answer is dependent on how well the levee was built. If it was not built high enough or was wrongly placed, the community may get flooded anyway.

2. Describe how the retention pond prevented flooding?
   It held the runoff and released water gradually.

3. Choose the correct answer. What impact did the levee have on the smaller floodplain with the oxbow (and any community) downstream?
   (a) It had no impact
   (b) It reduced flooding
   (c) **It caused more flooding downstream**

4. Describe the headwater condition(s) that produced flooding in the model?
   The impermeable parking lot produced flooding.

5. What headwater condition(s) reduce the chance of flooding?
   Wetland and retention ponds reduced the chance of flooding.

6. List other real-world developed and undeveloped land conditions that might be represented by the three headwater trays.
   The three inserts might represent wetland, retention ponds, rain gardens, parking lot, buildings, driveways and roads (urban development), or frozen ground and saturated soils.

7. List four major impacts on a river system that occur due to the loss of floodplains, wetlands, and other natural water storage areas.
   Increase flood crest, increased velocity, increased flow, increased erosion and sedimentation

8. As a group, discuss the consequences of these four impacts on the watershed.
   - An increased risk of flooding in both magnitude and frequency
   - a loss of wetland habitat
   - a decrease in water quality
   - more stream erosion of banks

9. Describe how urbanization impacts the velocity, crest, flow, and erosion of a river?
   Urbanization increases all of them

10. When forecasting floods, which factor is more critical or more important…rainfall or runoff?
    Runoff is most critical. If rainfall is absorbed into aquifers or into the ground, flooding would not be prevalent.

11. Summarize what you've learned so far by making a T-table in your notes. ***This is a table with two columns, each with a heading above the cross of the tee.**

    The title of the table should be **"Factors that Affect the Risk of Flooding"**. One column will have the heading **"Increase Risk"** and the other column with the heading **"Decrease Risk".** Take a few minutes to make as complete a table as you can. Discuss your table with those around you to share ideas and make your lists more complete.

DID YOU KNOW?

Advantages of retention ponds:

- Decreased potential for downstream flooding
- Decreased stream bank erosion
- Improved water quality due to the removal of suspended solids, metals, and dissolved nutrients.
- Provide wildlife habitat

Disadvantages of retention ponds:

- Can be overtopped
- Can be a drowning/safety hazard
- Take up valuable land space
- Can breed mosquitoes

DID YOU KNOW?

In India, deaths and damage due to increasingly intense flooding has been on the rise in recent years. What has been causing this? While some point to climate change, others point out that rapid urbanization has been a major contributing factor. According to a recent report of the UN Population Fund, by the year 2030, over 40% (about 600 million people) of India's population will be living in urban or semi-urban areas. That compares to 28% now and only 23% twenty years ago. Over the years, the affluent urban population created embankments to protect their towns and cities from flooding. As a result, the floodwaters have not been allowed to overflow traditional areas and dissipate naturally. Instead, they are now diverted to poorer villages and rural areas downstream. Long-time village residents report that floodwaters that used to swell and return to their river channels within a few hours, now rise much higher and stay for months. How might a No Adverse Impact policy help these villagers?

Table 4.3: Factors that Affect the Risk of Flooding T-Table

Increase Risk	Decrease Risk
Impermeable land surface	**Significant wetland area**
Urban development	**Retention basin**
Frozen ground	**More permeable soils (e.g., sandy)**
Saturated soils	**More ground cover vegetation**
Less ground cover vegetation	**Smaller amount and intensity of rainfall**
Greater amount and intensity of rainfall	

12. Study the T-Table below. Put an 'X' in the box to indicate if the man-made structure had an effect that impacted the river.

Table 4.4: Impact of Man-Made Structures on the River

River Impacts	Effects of Levee	Effects of Retention Pond
Increase flood crest	**X**	
Decrease flood crest		**X**
Increase velocity	**X**	
Decrease velocity		**X**
Increase flow	**X**	
Decrease flow		**X**
Increase erosion/ sedimentation	**X**	
Decrease erosion/ sedimentation		**X**

13. Comparing the effectiveness of the levee and the retention pond, which one has the least negative effect on areas downstream?
Retention pond

ACTIVITY 5: Factors Affecting Flood Forecasting: Summary and Evaluation

OBJECTIVES:
- Describe various factors that impact flooding.
- Describe relationships between storm, soil, and surface conditions and changes in a river stage and the risk of flooding

TIME ALLOTMENT: 15-25 minutes

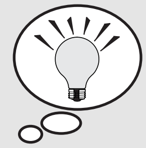
MATERIALS:
Pencil with Eraser
Student Copymasters for Activity 5 (Resource CD)

PRE-LAB PREPARATION:

Students will draw upon what was observed from the previous activities to complete the **Factors Affecting Flood Forecasting Table** in this activity. They may not have had experiences with changing slope, vegetation cover, rain intensity, location or direction of storm movement. You may need to help them think through how these conditions affect runoff and stream stage.

1. Refer to the "Factors Affecting Flood Forecasts" worksheet. Along the left side of the handout are variables that can affect the chance of flooding. Instruct students to consider what would happen if each factor increased (either over time at one stream - or going from one river to another river). Then, for each factor, have them fill in the columns to the right with either up or down arrows, as best they can, based on what they learned in the previous activities.

2. Have students fill out the table individually, but allow them to ask questions or discuss individual variables with other students. Circulate around the class to assess their work, give suggestions, and answer questions. Changing slope, vegetation cover, rain intensity, and location or direction of storm movement may be new concepts. Encourage them to think carefully about each and make the most logical choice about what will happen.



DID YOU KNOW?
Flood forecasting is the use of real-time precipitation and streamflow data to forecast flow rates and water levels for periods ranging from a few hours to a few weeks ahead, depending on the size of the watershed. Flood forecasting can also make use of forecasts of precipitation in an attempt to extend the lead-time available.

Flood forecasting is an important component in establishing "flood warnings". The outcome of flood forecasting is a set of forecast time-profiles of channel flows or river levels at various locations. The task of a "flood warning" is to make use of these forecasts to make decisions about whether warnings of floods should be issued to the general public or whether previous warnings should be rescinded or retracted.

ANALYSIS:
Factors Affecting Flood Forecasts

Characteristics of Basin or Storm	**Trend**	**Runoff**	**Infiltration**	**Crest**	**Timing of Crest** (Circle One)
Soil Moisture	⇧	↑	↓	↑	**Earlier** or Later
Soil Type					
Fine/Clay	⇧	↑	↓	↑	**Earlier** or Later
Coarse/Sandy	⇧	↓	↑	↓	Earlier or **Later**
Slope	⇧	↑	↓	↑	**Earlier** or Later
Vegetation	⇧	↓	↑	↓	Earlier or **Later**
Rainfall Intensity	⇧	↑	↓	↑	**Earlier** or Later
Time of Year					
Winter		↑	↓	↑	**Earlier** or Later
Summer		↓	↑	↓	Earlier or **Later**
Distribution of Rainfall					
@ Outlet				↑	**Earlier** or Later
@ Headwater				↓	Earlier or **Later**
Storm Movement					
Headwaters to Outlet				↑	**Earlier** or Later
Outlet to Headwaters				↓	Earlier or **Later**

Fill in the table above with ↑ for increases and ↓ for decreases and circle either earlier or later for the timing of the crest.

BACKGROUND:

<u>Factors that impact flooding and flood forecasting</u>

Soil moisture – Increased soil moisture increases the runoff potential and decreases the infiltration capacity. This results in a higher and earlier flood crest.

Soil Type – Fine soils, such as clays, increase the runoff potential because of their lower infiltration capacity. This results in a higher and earlier flood crest. Coarse soils, such as sand, decrease the runoff potential because of their higher infiltration capacity. This results in lower and later flood crests.

Slope – Steeper slopes increase the runoff potential and decrease the infiltration capacity, resulting in a higher and earlier flood crest.

Vegetation – Increased green vegetation reduces the runoff potential and increases the infiltration capacity, resulting in a lower and later flood crest.

Rainfall Intensity – Increased rainfall intensity increases the runoff potential because it rains faster than the rainfall can soak into the ground. This results in a higher and earlier flood crest.

Time of Year – Winters in the northern regions have dormant vegetation and possibly frozen soils, which increase the runoff potential and decrease the infiltration capacity (the ability for water to be absorbed in the ground). The result is a higher and earlier flood crest. Summers have abundant green vegetation and non-frozen soils, which decrease the runoff potential and increase the infiltration capacity. This results in a lower and later flood crest.

Distribution of Rainfall – If the majority of the rain falls near the outlet (mouth) of the river, it will result in higher and earlier flood crests. If the majority of the rain falls near the headwaters, it will result in lower and later flood crests.

Storm Movement – If the storm moves from the headwaters to the outlet (down the basin), the flood crest will typically be higher and earlier. If the storm moves from the outlet to the headwaters (up the basin), the flood crest will typically be lower and later.

DID YOU KNOW?

NOAA’s National Weather Service issues river forecasts and warnings for approximately 4000 locations in the United States using the National Weather Service River Forecasting System (NWSRFS). The U.S. National Weather Service (NWS) provides river and flood forecasts and warnings in the United States for protection of life and property.

The NWSRFS is a robust river and hydrologic forecast system that utilizes complex computer modeling. As such, the system includes all necessary hydrologic and routing models as well as data handling and presentation systems. This system has been in operation for over 20 years and is constantly refined and improved. The NWSRFS is used in the United States and in other countries throughout the world, including People’s Republic of China, Panama, Republic of South Africa, Nicaragua, and El Salvador.

PROCEDURE:

In this activity, you will draw upon what you have observed from previous activities to complete the worksheet "Factors Affecting Flood Forecasts". You may need to think through how some conditions affect runoff and stream stage. Discuss factors you are unsure about with other students in your class and with your instructor.

1. Locate the worksheet "Factors Affecting Flood Forecasts". Along the left-hand side of the handout are variables that can affect the chance of flooding. Consider what would happen if each factor increased—either over time at one stream, or going from one river to another river. Then, for each factor, fill in the columns to the right with either up (increased risk of flooding) or down (decreased risk of flooding) arrows, based on what you have learned in the previous activities.

2. In the last column, circle how these factors might affect the timing of the crest (Earlier or Later).

3. After completing the handout, and answer the Assessment questions that follow.

ASSESSMENT:

1. From your observations and analyses, what conditions generally increase the risk of flooding?
   Student answers may vary, but should include a variety of factors, including rainfall intensity, vegetation, soil type, time of year, etc.

2. For each of the following conditions, answer whether they would tend to (a) increase, (b) decrease, or have (c) no affect on the flood crest in a river.

   a. Steeper slope **(a) increase**
   b. Soil contains more sand then clay **(b) decrease**
   c. Heavy rain in a short period of time. **(a) increase**
   d. Soil saturated with water (can't accept any more water) **(a) increase**
   e. Rain storm in early spring when the ground is still frozen. **(a) increase**

ACTIVITY 6: Planning a Flood Safe Community

OBJECTIVES:
- Explain how land use decisions can increase or decrease the risk of flooding.
- Describe how land use actions in one community can affect the risk of flooding in a downstream community.
- Articulate reasons for land-use regulation.

TIME ALLOTMENT: 45-50 minutes

MATERIALS NEEDED PER GROUP:
Topographic Map Symbols Sheet
Scissors
Tape
Glue
Colored pencils or markers (optional)
Student Copymasters for Activity 6

MATERIALS NEEDED FOR PRESENTATIONS:
Scanned Topographic Map for Projecting and
PowerPoint[tm] Presentations
or
Overhead Projector with Overhead Masters & Topo Map
Newsprint
Markers

BACKGROUND:
Land-use planning and regulation is almost exclusively done by local governments. Laws allow a local government to designate the type of use allowed in different areas of their community. Traditionally, zoning designations such as residential, commercial, or agricultural, prevent incompatible land use (e.g., factory next to homes or traffic attracting shopping centers next to neighborhoods) and is also a convenience (e.g., preserving land for industry next to railroads or shipping docks). Land use regulations also include building codes (e.g., spacing and set back of buildings from the road), attempts to retain rural character of an area (e.g., farmland preservation efforts), even population and traffic controls (e.g., designating density of housing).

Environmental, health, and safety concerns have increasingly become considerations in establishing land use regulation. Protection of wildlife habitat, groundwater recharge areas, and flood risk reduction falls under these topics. The quality of life, health, and safety of humans and the broader environment usu-

NOTES TO INSTRUCTOR
An enlarged copy of the map and topo map structure symbol cut-outs might be useful when each group presents their plan to the rest of the class. Other options could include newsprint and markers, an overhead projector with transparency masters of the map, or a computer presentation of their plans using PowerPoint™ or some other presentation software.

ally underlie all plans. These can sometimes come into conflict with what is perceived as individual property rights, where the rights of the larger community and rights of the individual property owner may seem to be contradictory. Such conflicts are nearly eliminated if land is zoned or designated before it is purchased, so that the owner knows the restrictions on the land ahead of time.

CAREER FOCUS

LAND-USE PLANNER

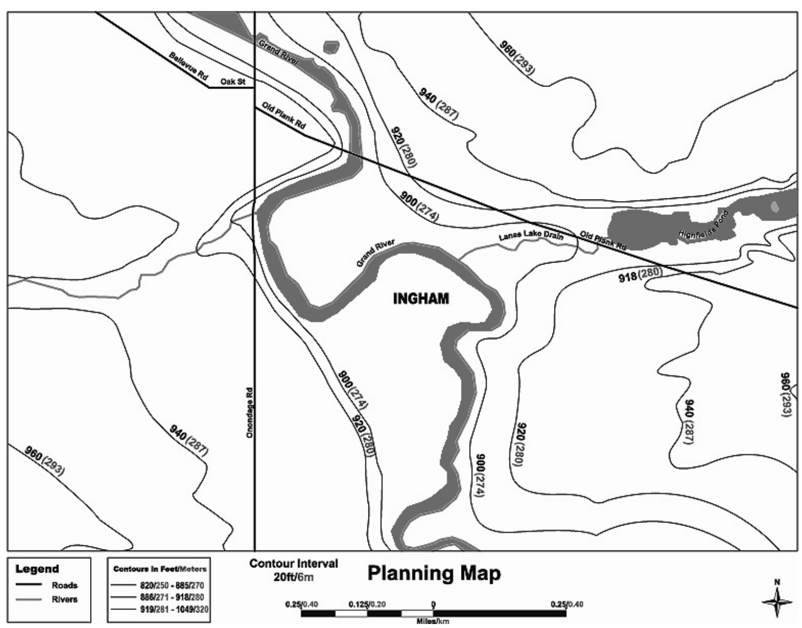
A Land-Use Planner is a professional who works in the field of land-use planning for the purpose of maximizing the effectiveness of a community's land use and infrastructure. They formulate plans for the development and management of urban, suburban, and rural areas, typically analyzing land use compatibility as well as economic, environmental and social trends. In developing their plan for a community (whether commercial, residential, agricultural, natural or recreational), land-use planners must also consider a wide array of issues such as sustainability, air pollution, traffic congestion, crime, land values, legislation and zoning codes.

PRE-LAB PREPARATION:

Make copies and hand out to all students the copymaster worksheets for Activity 6. Prior to performing the activity, make sure that students possess a basic understanding of how to read and use topographical maps and are familiar with topographical map symbols.

PROCEDURE:

1. Locate the Planning Map for the future town of Ingham found on your worksheet. Your group's task is to decide how various areas on the map are to be used to minimize the loss of life and property in the event of flooding. Think about whether your choices will decrease the chance of flooding or decrease the risk to life and property if flooding occurs. As town planners, your land use decisions will impact the long-term health and safety of the community.



Ingham Town Planning Map

2. Examine the map and the overall topography of the area and the location of rivers and streams and their floodplains. Next, identify and locate the map symbols for the following structures:

1 – School
1 – Hospital
1 – Golf Course
2 – Public Parking Lots
1 – Picnic Area
1 – Cemetery
1 – Campground
1 – Parks
10 – Houses
3 – Businesses
1 – Wastewater Treatment Plant
1 – Water Filtration Plant (Drinking water)
1 – Emergency Management Center/Police HQ
1 – Landfill (Garbage Dump)

You may add more buildings and other land uses, such as farms, parks (picnic areas, playgrounds, etc.), wetlands, catch basins, and zoning designations. It would be helpful to first identify areas which are probably floodplains and possible wetlands. If you are unfamiliar with how to read topographic maps and contour lines, ask your instructor for additional help.

3. When you are finished with your Planning Map, your group will present its plan to the rest of the class. (See the Shared Materials section for ideas about how to facilitate this.) With each presentation, all groups should evaluate the merits of each plan. What are some good ideas? How might each plan be improved? Other than good planning and design, what are some other factors that might influence the town's ability to implement the best plan?

4. Now, consider how each plan would affect the next community downstream. Discuss any plan which minimized flooding by speeding the water downstream (by use of levees or straightening the river). Were there any actions which reduced the risk of flooding in one place but would increase the risk in a downstream community?

5. List actions that would reduce flooding for both the community taking the action and also any communities downstream.

6. Answer the Assessment questions that follow.

ASSESSMENT:

1. Where is one of the worst places to build a home if you don't want to risk it being flooded?
   Building in the floodway or floodplain

2. Explain how the placement of buildings can affect the risk of flooding to other buildings?
   Placement of buildings in the watershed increases the impervious surfaces (that cannot absorb water) in the basin which increases overall runoff and flooding. Building levees to protect buildings may cause increased flooding for buildings in floodplains without levees. Runoff from one building may also flow down to other buildings located at lower elevations.

3. The construction of buildings often results in changes to the area surrounding the building. Describe one such change and explain how it might affect the risk of flooding.
   Construction of new buildings can impact the ability of surrounding soils to absorb runoff, particularly if more impermeable construction debris and fill is used in final landscape grading. Many new buildings also need parking lots which increase the impervious surfaces in the area and increase runoff that can lead to flooding.

4. Describe how land use in one community can increase the risk of flooding in another community downstream.
   The impervious surfaces (roads, buildings, parking lots, etc.) in the community upstream increase the runoff going to the river and can result in higher river flows that impact downstream communities.

ACTIVITY 7: River Crest Analysis

OBJECTIVES:

- Describe what a river crest is and what produces it.
- Describe how a wave crest moves downstream, including a typical speed for such crests.
- Explain how flooding can occur in an area even when the storm did not occur there.
- Relate the impact of land use to the size of river crests and potential of flooding produced by a rainstorm.

DID YOU KNOW?

The third deadliest flash flood in US history took place along the normally placid Willow Creek in the foothills of eastern Oregon in 1903. The creek burst its banks during an intense rain and hail storm, and the nearby city of Heppner was almost completely destroyed by the floodwaters. 220 of Heppner's 1,400 residents died in the flood.

During the great Los Angeles flood of 1938, two significant cyclones moved through the region dumping more than 10" of rain over a 5 day period. Massive debris flows moved out from the San Gabriel Mountains into the Los Angeles Basin. Although Los Angeles County experienced damage, Riverside and Orange counties bore the brunt of the flooding. A total of 5601 homes were destroyed, and an additional 1500 homes were left uninhabitable. The three transcontinental railroads connecting Los Angeles to the outside world suffered washed out bridges and flooded lines, isolating the city for some time. The death toll was 115. The result of this flood was the Flood Control Act of 1941, which authorized the U.S. Army Corps of Engineers to build a series of concrete sewers.

TIME ALLOTMENT: 15-20 minutes

MATERIALS NEEDED PER GROUP:
Student Copymasters for Activity 7 (Resource CD)
Pen or Pencil

BACKGROUND:
After a rainstorm a river usually continues to rise even after the rain stops. This is important because the risk of flooding does not stop when the rain stops. In addition, flooding can occur on a river even when the rain fell a long distance away.

Rain occurring in one part of a watershed will result in more water in the river in that vicinity. The surface of the river will rise. A hydrologist would say there is an increase in the river's "stage". But other parts of the river initially are unaffected. As the newly added rainwater in the river moves downstream, other areas will experience rising water. If viewed over time, it would look like a bulge or crest in the river as it travels downstream. Hydrologists investigate these crests by constructing a hydrograph. When completing Activities 3 & 4 in this series, you created simple hydrographs. These are graphs of stream surface height at one location over time. In this investigation, the hydrographs represent three locations along a single river.

The National Weather Service defines flood stage as an established gage height for a given location above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood (or in some cases flash flood) warnings is linked to flood stage.

Jackson - Chapman River

The forecast point at Jackson tends to have two peaks. The first peak is a result of urban runoff and outflow from the combined overflow from the treatment plant. The plant has an outlet just upstream of the gage. The first peak tends to be the highest peak and is very difficult to forecast. The second peak occurs due to runoff from the headwaters.

Lansing - Chapman River

The Chapman River at Lansing is located 64 river miles downstream from Jackson.

DID YOU KNOW?

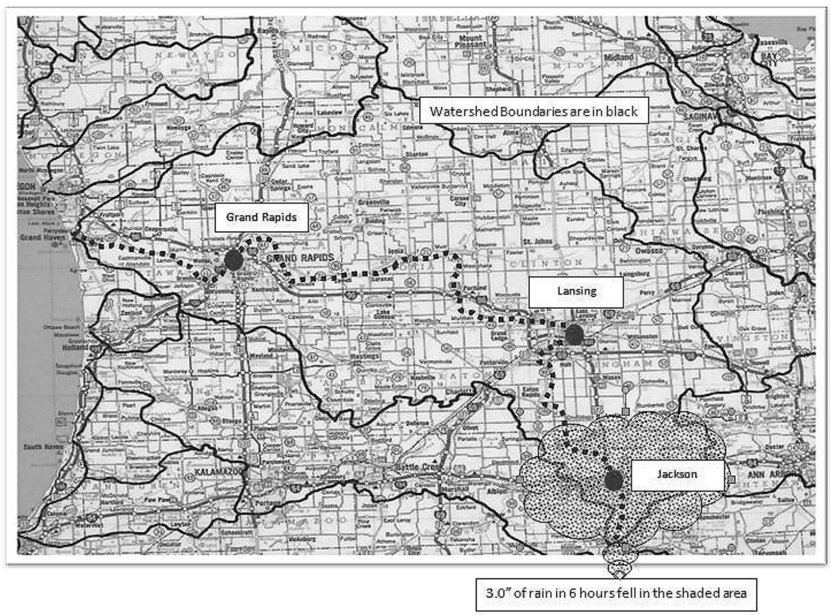
In the United States, the U.S. Geological Survey (USGS) is the principal federal agency tasked with maintaining records of natural resources. Within the USGS, the Water Resources Division carries the responsibility for monitoring water resources.

A **stream gage** refers to a site along a stream where measurements of volumetric discharge (flow) are made. To establish a stream gage, USGS personnel first choose a site where the geometry is relatively stable and where there is a suitable location to make discrete direct measurements of streamflow using specialized equipment. Often this will be at a bridge or other stream crossing. Technicians then install equipment that measures the **stage** (the elevation of the water surface) or, more rarely, the **velocity** of the flow. Additional equipment is installed to record and transmit these readings (via a telemeter) to the Water Science Center office where the records are kept. The USGS has a Water Science Center office in every state within the US.

Grand Rapids – Chapman River

The Chapman River at Grand Rapids is located 175 miles downstream from Jackson. A sharp rise may occur in the first 24 hours due to the contribution from local tributaries and urban areas if the rainfall is localized. It will also show a slow rise or leveling off trend until the water from upstream makes its way down to Grand Rapids. The crest at Grand Rapids is mostly a function of the water coming down from upstream.

Figure 7.1 - Chapman River Watershed Map

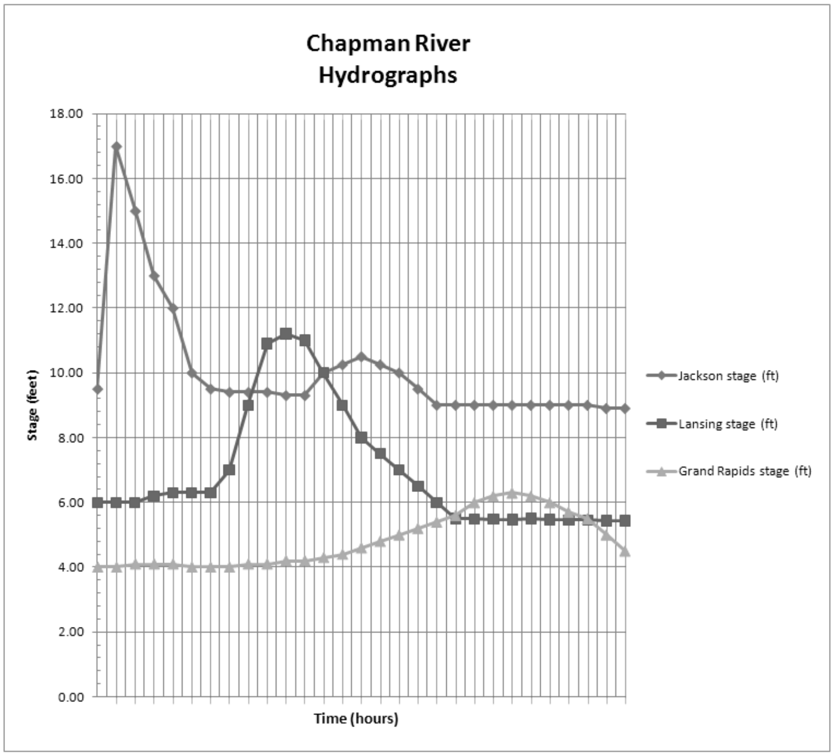


PROCEDURE:

1. Refer to **Figure 7.1 - Chapman River Watershed Map**. Note the river, watershed, and the cities. The objective of this activity is to observe how the river changes over time as a result of a heavy rainstorm that occurs in the area around Jackson.

2. Refer to **Figure 7.2 - Chapman River Hydrographs**. Each graph shows the height of the river at that location over a given time frame following the storm. The intent here is to identify the flood crest—the highest point the river reaches—and follow its movement downstream.

3. Work through the activity and Assessment questions. If you are uncertain about how to answer the last few questions, just imagine what might happen and give your best logical answer.



Time (hours)	Jackson stage (ft)	Lansing stage (ft)	Grand Rapids stage (ft)
0	9.50	6.00	4.00
6	17.00	6.00	4.00
12	15.00	6.00	4.10
18	13.00	6.20	4.10
24	12.00	6.30	4.10
30	10.00	6.30	4.00
36	9.50	6.30	4.00
42	9.40	7.00	4.00
48	9.40	9.00	4.10
54	9.40	10.90	4.10
60	9.30	11.20	4.20
66	9.30	11.00	4.20
72	10.00	10.00	4.30
78	10.25	9.00	4.40
84	10.50	8.00	4.60
90	10.25	7.50	4.80
96	10.00	7.00	5.00
102	9.50	6.50	5.20
108	9.00	6.00	5.4
114	9.00	5.50	5.6
120	9.00	5.49	6
126	9.00	5.48	6.2
132	9.00	5.47	6.3
138	9.00	5.50	6.2
144	9.00	5.47	6
150	9.00	5.46	5.7
156	9.00	5.46	5.5
162	8.90	5.43	5
168	8.90	5.43	4.5

Figure 7.2 - Chapman River Hydrographs

NOTE

NOTES TO INSTRUCTOR

For further enrichment, here is an extended breakdown of hydrograph analysis and terminology:

A hydrograph is a graphical representation showing changes in the discharge of a river over periods of time. The discharge is measured at a certain point in a river and is typically time variant.

- **Rising limb:** the part of the hydrograph up to the point of peak discharge
- **Falling limb:** the part of the hydrograph after the peak discharge
- **Peak discharge:** the highest point on the hydrograph when there is the greatest amount of water in the river
- **Lag time:** period of time between peak rainfall and peak discharge
- **Discharge:** volume of water in a river at a given time

ANALYSIS:

After a rainstorm, runoff begins to reach the river causing it to rise and possibly to flood. This can be observed in the first graph of the Chapman River at Jackson. This graph shows the river height or "stage" along the left side, and time along the bottom (in hours). A rainstorm occurring in the Jackson area causes the river to rise, and then later it will fall as that "extra" water flows downstream. Refer to **Figure 7.1 - Chapman River Watershed Map** and observe the location of each city used in this activity. The storm occurs at time zero, and the highest point reached by the river is called the **crest**. Note carefully the units along both axes of the graphs. Then use the graphs (called hydrographs) to answer the following questions.

1. For Jackson, with a flood stage of 14 feet:
   What was the crest height? **17 feet**
   What was the crest time? Time = **6 hours**
   Was flood stage exceeded? **Yes**

2. For Lansing, with a flood stage of 11 feet:
   What was the crest height? **11.2 feet**
   What was the crest time? Time = **60 hours**
   Was flood stage exceeded? **Yes**

3. For Grand Rapids, with a flood stage of 18 feet:
   What was the crest height? **6.3 feet**
   What was the crest time? Time = **132 hours**
   Was flood stage exceeded? **No**

4. How long did it take the crest to move from Jackson to Lansing?
   54 hours; 2 days + 6 hours

5. How long did it take the crest to move from Jackson to Grand Rapids?
   126 hours; 5 days + 6 hours

6. On average, how fast was the crest moving between Jackson and Lansing, which is a distance of 64 river miles? (Speed = distance/ time)
   Speed = 1.2 mph (Distance = 64 river miles/time = 54 hrs.)

7. On average, how fast was the crest moving between Lansing and Grand Rapids, which is a distance of 175 river miles?
   Speed = 1.4 mph (Distance = 175 river miles/time = 126 hrs.)

NOTES TO INSTRUCTOR

You may wish to use a projection system to display the map and hydrographs to the entire class during discussion of their analyses. Both images can be found on your Resource CD.

Flood stage: An established gage height for a given location above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood (or in some cases flash flood) warnings is linked to flood stage. Not necessarily the same as bankfull stage.

8. As the crest traveled downstream, did the crest generally reach the same height, increase in height, or diminish in height?
   Diminished in height

9. Would the crest occur <u>sooner</u> in Jackson if the area where the rain fell had (a) more wetlands or (b) more paved areas?
   (b) more paved areas

10. Would the crest be <u>larger</u> in Jackson if the area where the rain fell had (a) more wetlands or (b) more paved areas?
    (b) more paved areas

ASSESSMENT:

1. Describe a river crest. Under what conditions would you observe one?
   A crest is the highest stage in a river at a specific location for a given time period. River crests are observed whenever you have significant runoff reaching the river.

2. Once a crest is produced in a river after a rainstorm, why doesn't the river stay that high?
   The river levels lower as the crest moves downstream out of the area of interest. When the rainfall stops and all the runoff has reached the river, there is nothing to sustain the high river levels as the volume of water moves downstream, and the river falls back to normal levels.

3. A river crest traveling down the Chapman River would take how long to travel 40 miles?
   (a) a few minutes **(c) a little over a day**
   (b) a few hours (d) 3 days

4. Explain why flooding may occur on a river, even when it did not rain in the area where the flooding took place.
   Flooding may occur on a river from rainfall that took place upstream. When subsequent runoff from that rainfall event flows downstream, it may cause river levels to rise, triggering possible flooding in the area.

5. If more wetlands are filled in, it would tend to cause river crests after a storm to be:
   (a) higher
   (b) lower
   (c) unaffected

NOTE

NOTES TO INSTRUCTOR

As an extension activity, you may want to ask students to locate and contact the nearest USGS Water Science Center Office in your state. See if they can find out where stream gages may be installed in your area and what kind of data has been collected by the USGS for those stations following recent major rainfall events. They can start by visiting the USGS website at: www.USGS.gov.

ACTIVITY 8: Turn Around Don't Drown™ (Extension/Enrichment)

OBJECTIVES:

- Examine and understand the dangers associated with driving over a flooded road.
- Reflect individually and collectively about the reasons people drive over flooded roadways.
- Develop an educational campaign strategy with the goal of reducing the number of people who drive over a flooded road.
- Design and produce posters and/or other media as part of the "Turn Around, Don't Drown" campaign.

TIME ALLOTMENT 1-2 days

MATERIALS NEEDED PER GROUP:

Each student needs a copy of the handout "Turn Around, Don't Drown". Copies of the handout can be obtained by contacting your local National Weather Service office in your area or by going to the following web site: **http://tadd.weather.gov/**

Each group (or individual) needs materials for making a poster (construction paper, markers, crayons, or paint, etc.). If video or electronic products are to be produced, access to computers and/or video equipment must be provided.

TADD is a NOAA National Weather Service campaign to warn people of the hazards of walking, or driving a vehicle, through flood waters.

BACKGROUND:

What Is Turn Around Don't Drown™ (TADD)?

TADD is a NOAA National Weather Service campaign to warn people of the hazards of walking, or driving a vehicle, through floodwaters.

Why is Turn Around Don't Drown™ So Important?

Each year, more deaths occur due to flooding than from any other severe weather related hazard. The Centers for Disease Control reports that over half of all flood-related drownings occur when a vehicle is driven into hazardous floodwater. The next highest percentage of flood-related deaths is due to walking into or near floodwaters. Why? The main reason is people underestimate the force and power of water. Many of the deaths occur in automobiles as they are swept downstream. Of these drownings, many are preventable, but too many people continue to drive around the barriers that warn you the road is flooded.

What Can I Do to Avoid Getting Caught in This Situation?
Most flood-related deaths and injuries could be avoided if people who come upon areas covered with water followed this simple advice: **Turn Around Don't Drown™**.

The reason that so many people drown during flooding is because few of them realize the incredible power of water. A mere six inches of fast-moving flood water can knock over an adult. It takes only two feet of rushing water to carry away most vehicles. This includes pickups and SUVs.

Driving on Flooded Roadways

If you come to an area that is covered with water, you will not know the depth of the water or the condition of the ground under the water. This is especially true at night, when your vision is more limited. Play it smart, play it safe. Whether driving or walking, any time you come to a flooded road, **TURN AROUND DON'T DROWN™!**

<u>Follow these safety rules:</u>

- Monitor the NOAA Weather Radio, or your favorite news source for vital weather related information.
- If flooding occurs, get to higher ground. Get out of areas subject to flooding. This includes dips, low spots, canyons, washes etc.
- Avoid areas already flooded, especially if the water is flow ing fast. Do not attempt to cross flowing streams. **Turn Around Don't Drown™**
- Road beds may be washed out under flood waters. NEVER drive through flooded roadways. **Turn Around Don't Drown™**
- Do not camp or park your vehicle along streams and washes, particularly during threatening conditions.
- Be especially cautious at night when it is harder to recognize flood dangers.

NOTES TO INSTRUCTOR

Point out to the students that many people die each year from doing just what you have been discussing. It also costs taxpayers a lot of money to rescue people and remove flooded cars. Note that the handout they have was written by NOAA National Weather Service as part of an education campaign to get people to stop driving over flooded roads. Tell them that they are going to be asked to come up with their own ideas about how to contribute to this campaign.

Have your small groups (or subgroups or individuals) produce at least one item for their advertising campaign from their brainstorming session. Younger students might simply make posters to be placed around the school or the community. Older students should be encouraged to produce video or computer-based presentation. When complete, have students share or display their work.

PROCEDURE:

1. Think about yourself or someone you may know driving up to a road that has water on it. Write down all the reasons why you think someone might continue to drive into the water. After a few minutes of thinking and writing, share your ideas with the rest of the class. Make a master list on the board. Group together similar ideas.

2. Visit the NOAA Website: **http://tadd.weather.gov** and research the focus and objectives of the "Turn Around Don't Drown™" (TADD) program.

3. Break into small groups (2-4 students each) to brainstorm ideas for a TADD education campaign. Think creatively about how you want to do this—not just fliers, but also television ads, internet pop-ups, pod-casts, websites, activities in drivers training classes, movie theater pre-film presentations, and posters. Try to address the reasons you gave before about why some people drive over roads with water over them.

ASSESSMENT:

1. What percent of flood related drownings occur when a vehicle is driven into floodwaters? **(Over one-half or 50%)***

2. Most vehicles can be swept away by moving water that is as little as __**2**__ feet deep.

3. What are some reasons people drive over flooded roadways? **Accept a variety of answers: people don't think the water is very deep; they think their vehicles are too heavy to be carried away; the water isn't moving very fast; they don't think or know about the risk; they believe another vehicle drove across that section of road earlier, etc.**

4. What does the phrase "Turn Around, Don't Drown" mean? **When driving toward a flooded section of a road, you should turn the car around and drive away. This will avoid any risk of your car being carried away by the floodwater and you drowning.**

5. Describe your contribution to the TADD campaign (poster, video, etc.) including an explanation of how this is expected to change drivers' behavior.
Answers will vary. Look to see if their explanations are logical, reasonable, and do not include any misinformation.

Glossary of Terms

100-year flood – A large, but infrequent, flood event that has a 1% chance of occurring in any given year (occurs, on average, once every 100 years).

100-year floodplain – Areas adjacent to a stream or river that are subject to flooding during a storm event that has a 1% likelihood of occurrence in any given year (occurs, on average, once every 100 years). Most municipalities require a floodplain development permit for new development within areas mapped as the 100-year floodplain.

Aquifer - A permeable body of rock capable of yielding quantities of groundwater to wells and springs.

Bankfull – The full capacity of the stream channel to the top of the bank on either side. The bankfull discharge is the flow at which water first overtops the banks onto the floodplain, which occurs, on average, every 1.2 to 2.0 years. Bankfull flow is largely responsible for the shape of the stream channel and is sometimes called the channel-forming flow.

Bankfull stage - An established gage height at a given location along a river or stream, above which a rise in water surface will cause the river or stream to overflow the lowest natural stream bank somewhere in the corresponding reach. The term "lowest bank" is however, not intended to apply to an unusually low place or a break in the natural bank through which the water inundates a small area. Bankfull stage is not necessarily the same as flood stage.

Base flow – The portion of stream flow that comes from groundwater seepage into the channel; this constitutes the natural dry weather flow in the stream.

Biological diversity - The variety and complexity of species present and interacting in an ecosystem, and the relative abundance of each.

Bioswales - Stormwater runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters. Bioswales improve water quality by infiltrating the first flush of storm water runoff and filtering the large storm flows they convey.

Certified floodplain manager - The Association of State Floodplain Managers has established a national program for professional certification of floodplain managers. The program recognizes continuing education and professional development that enhance the knowledge and performance of local, state, federal, and private-sector floodplain managers. The role of the nation's floodplain managers is expanding due to increases in disaster losses, the emphasis being placed upon mitigation to alleviate the cycle of damage-rebuild-damage, and a recognized need for professionals to adequately address these issues. Floodplain managers come from a variety of curricula and backgrounds; there is no college-level degree program for floodplain management. This certification program will lay the foundation for ensuring that highly qualified individuals are available to meet the challenge of breaking the damage cycle and stopping its negative drain on the nation's human, financial, and natural resources.

Channel – A natural or artificial watercourse with a definite bed and banks that conveys continuously -or-periodically-flowing water.

Channelization – Straightening or deepening of a natural stream channel.

Chemical wastes - Wastes that consist of or contain harmful chemicals.

Culvert – A pipe or closed conduit for the free passage of surface drainage water. Culverts are typically used by highway departments to control water running along and under the road, and to provide a crossing point for water from roadside drainage ditches to the stream, as well as for routing tributary streams under the roads. Landowners also use culverts to route roadside drainage ditch water under their driveways.

Debris – Floating or submerged material, such as trash, branches, logs, or other vegetation transported by a stream.

Degradation (degrading or down cutting) – The general and progressive lowering of a channel due to downward erosion of the streambed over a relatively long channel length. A degrading stream may have high, unstable banks and be disconnected from its floodplain.

Detention pond - A storm-water management facility installed on, or adjacent to, tributaries of river, stream, lake or bay. It is designed to protect against flood and, in some cases, downstream erosion by storing water for a limited period of a time.

Dike (levee) – An embankment to confine or control water, often built along the banks of a river or stream to contain over-bank flow and prevent inundation of floodplain development.

Discharge (stream flow) – The rate of flow passing a fixed point in a stream, expressed as a volume of water per unit time, usually cubic feet per second (cfs).

Erosion – The detachment and movement of soil or rock fragments by water, wind, ice, or other geological agents. In streams, erosion is a natural process that can be accelerated by poor stream management practices.

Flood - any high flow, overflow, or inundation by water which causes or threatens damage.

Floodplain (see also 100-year floodplain) – Any flat or nearly flat lowland bordering a stream that is periodically inundated by water during floods. The floodplain acts to reduce the velocity of floodwaters, increase infiltration, reduce stream-bank erosion, and encourage deposition of sediment. Vegetation on floodplains greatly improves these functions.

Floodplain management - Floodplain management includes structural and non-structural measures, flood loss reduction efforts, education, warning, evacuation, insurance, flood mitigation, watershed-based planning and management, and many other approaches. The intent is to focus attention on improving many aspects of the relationship between human activity, the flood hazard, and the flood-prone lands, rather than simply on minimizing property damage.

Flood stage – An established gage height for a given location above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood (or in some cases flash flood) warnings is linked to flood stage. Not necessarily the same as bankfull stage.

Floodway – That portion of the floodplain required to store and discharge floodwaters without causing potentially damaging increases in flood heights and velocities.

Grade (gradient) – The slope of a stream, measured along the length of the stream channel.

Green roof - A roofing system that utilizes vegetation to absorb rainwater and reduce heat absorption.

Green space - Open, undeveloped land with natural vegetation.

Groundwater – Water beneath the earth's surface, found at varying depths, where every space between soil or rock particles is filled with water.

Headwater - Where a river begins.

Hydraulics – The applied science that deals with the behavior and flow of liquids. When used in reference to a stream, hydraulics refers to the processes by which water flows within the channel.

Hydrograph - A graphical representation of stage or discharge at a point on a stream as a function of time.

Hydrologic cycle – The global circulation of water above, on, and below the surface of the Earth. The cycle consists of four stages: storage (in the ground, oceans, lakes, rivers, ponds, ice caps, and glaciers), evaporation, precipitation, and runoff.

Hydrology – The science that deals with the occurrence and movement of water in the atmosphere, upon the surface, and beneath the land areas of the Earth. In reference to a particular stream, the hydrology is the amount and timing of water flow into the stream.

Impervious – Those surfaces that cannot effectively infiltrate rainfall and snow melt (e.g. rooftops, pavement, sidewalks, driveways, etc.). Impervious cover causes an increase in the volume of surface runoff.

Incised stream – A stream in which degradation (erosion of the streambed) has caused deepening of the channel to a point where the stream is no longer connected to its floodplain.

Infiltration – The process of water percolating into the soil.

Instability (unstable) – An imbalance in a stream's capacity to transport sediment and maintain its channel shape, pattern, and profile.

Intermittent stream – A stream or portion of a stream that flows in a well-defined channel during the wet seasons of the year, but not the entire year.

Invasive plant – A species of plant that is not native to a region and has the ability to compete with and replace native species in natural habitats. Invasive plants present a threat when they alter the ecology of a native plant community.

Kinetic energy – Energy of motion. The kinetic energy of a stream is equal to one-half the mass of water, times the square of the velocity at which the water is moving.

Levee – See dike.

Meander – Refers to both the winding pattern of a stream ("meander bends") and to the process by which a stream curves as it passes through the landscape (a "meandering stream"). A meandering stream channel generally exhibits a characteristic process of bank erosion and point bar deposition associated with systematically shifting meanders.

National Flood Insurance Program – Federal program that makes available subsidized flood insurance in those jurisdictions within which the local government regulates development in identified flood hazard areas. Local regulations must be at least as stringent as federal standards.

Natural stream design – A stream restoration method that uses data collection, modeling techniques, and stable or reference channels in the design of ideal channel configurations.

No Adverse Impact® – No Adverse Impact® floodplain management is an approach which ensures that the action of one property owner or a community does not adversely impact the properties and rights of other property owners, as measured by increased flood peaks, flood stage, flood velocity, erosion, sedimentation, costs now, and costs in the future. A No Adverse Impact® approach focuses on planning for and lessening flood impacts resulting from land use changes. It is essentially a "do no harm" policy that will significantly decrease the creation of new flood damages. No Adverse Impact® means that your neighbor should build in such a way that does not increase the risk of flooding to your property or that of others. This management approach is endorsed by the Association of State Floodplain Managers.

Nutrients – Essential chemicals, including nitrogen and phosphorous, that are needed by plants and animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms.

Organic waste - A type of waste typically originating from plant or animal sources, which may be broken down by other living organisms.

Pattern (of a stream channel) – The shape of a stream as seen from above or on a map.

Peak flow – The maximum stream flow from a given storm condition at a specific location.

Porous pavement - A hard surface that can support some vehicular activities, such as parking and light traffic, and which can also allow significant amounts of water to pass through. Conventional asphalt pavement consists of a mixture of large and small stone particles bonded together with asphalt tar. For porous pavement, the smaller particles are left out and the percentage of tar is reduced.

Point bar – A stream deposition feature usually found on the inside of a bend; consists of sand, gravel, or other sediment and lacks permanent vegetation.

Pool – A stream feature in which water is deeper and slower than in adjacent areas. Pools typically alternate with riffles along the length of a stream channel.

Potential energy – Energy that results from gravitational pull on an object. The potential energy in a stream is equal to the weight of water times the elevation of a specified point relative to the mouth of the stream.

Profile – The shape of a stream drawn along the length of its channel to show both the streambed and the water surface.

Rain garden - A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, and parking lots.

Reach – The continuous, uninterrupted extent of water.

Retention pond - A manmade pond where stormwater is directed and held.

Riffle – A stream feature in which water flow is shallow and rapid compared to adjacent areas. Riffles typically alternate with pools along the length of a stream channel.

Riparian – The area of land along a stream channel and within the valley walls where vegetation and other land uses directly influence stream processes.

Riparian buffer (or stream buffer) – Zone of variable width along the banks a stream that provides a protective natural area along the stream corridor.

Riparian rights – The rights of an owner whose land abuts water.

Riprap – Broken rock placed on a streambank or other surface to protect against scouring and erosion.

River basin – see watershed

Rock vanes – Rock structures built below the water level to control the direction of flow within a stream.

Root wad – Stream-bank stabilization technique in which a one or more tree trunks are embedded in the stream bank with the root mass facing the flow to dissipate energy.

Roughness (hydraulic roughness) – In a stream, roughness refers to the frictional resistance to flow.

Runoff – See surface runoff.

Runoff footprint - a measure of the impact by human activities on flooding, or the potential for flooding, in terms of the amount of water that is discharged (runs off) from a drainage area over a given time period.

Scour – The process by which the erosive action of flowing water removes material from the bed or banks of a stream.

Sediment – Solid material, both mineral and organic, that is being transported or has been moved by air, water, gravity, or ice from its site of origin (streambank or hillside) to the place of deposition (in the stream channel or on the floodplain).

Stable – Although no stream is truly stable in the sense that it doesn't change over time, a stream may be described as stable if it is in dynamic equilibrium, with no appreciable change from year to year.

Storm flow – The portion of stream flow that comes from surface runoff and constitutes the main component of high stream flows during rainy weather.

Storm hydrograph – A graph of stream discharge against time for a single storm event.

Stormwater – Surface runoff; generally referred to as stormwater when the surface runoff is from developed areas.

Stormwater management – The use of structural or non-structural practices that are designed to reduce storm water runoff and mitigate its adverse impacts on property, natural resources, and the environment. Structural practices involve construction of systems that provide short-term storage and treatment of storm-water runoff. Non-structural techniques use natural measures to reduce pollution levels, do not require extensive construction efforts, and/or promote pollutant reduction by eliminating the pollutant source.

Stratiform rainfall – Generally, light rain consisting of small droplets; often associated with broad, layered clouds (stratus or nimbostratus).

Stream – A natural watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

Streambed (bed) – The bottom of a stream channel bounded by banks.

Stream bank (bank) – The sides of a stream channel between which the flow is normally confined.

Stream restoration – The process of converting an unstable, altered, or degraded stream corridor, including the adjacent riparian zone and flood-prone areas, to its natural stable condition; recent and future watershed conditions are a consideration in the process.

Stream stabilization – The in-place stabilization of a severely eroding streambank and/or streambed. Although stabilization techniques address the immediate problem, they may not restore the system's dynamic equilibrium.

Sub-watershed – A part of the watershed. The division may be based on branches of a river and/or political jurisdictions.

Surface runoff (see also storm water) – The portion of precipitation or snow melt that reaches the stream channel by flowing over the land surface.

Transpiration – The process by which water taken up by plants is returned to the atmosphere by evaporation from leaves.

Triage approach to stream assessment – A process for moving from recognition of a stream problem to selection of an appropriate intervention, based on a relatively quick assessment of the problem, the causes, and the urgency of the situation.

Tributary – A stream that feeds into another stream; usually the tributary is smaller in size than the main stream.

Velocity – In streams, the speed at which water is flowing, usually measured in feet per second.

Water bar – A shallow trench or diversion ditch that diverts surface runoff from roads, fire breaks, or skid trails into a dispersion area. Water bars are used to disperse flow, minimize erosion, and enhance conditions for re-vegetation.

Watershed – A unit of land on which all the water that falls (or emanates from springs) collects by gravity and runs off via a common outlet (stream).

Wetland – An area that is permanently or periodically saturated by water with vegetation adapted for life under those soil conditions. Swamps, bogs, fens, and marshes are wetlands.

Zero datum - In hydrologic terms, a reference "zero" elevation for a stream or river gage. This "zero" can be referenced (usually within ten feet of the bottom of the channel) to mean sea level, or to any other recognized datum.

(Portions of the Glossary were used with permission from *"Stream Processes A Guide to Living In Harmony with Streams"* prepared by Janet Thigpen, Southern Tier Central Regional Planning and Development Board)