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)

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.

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

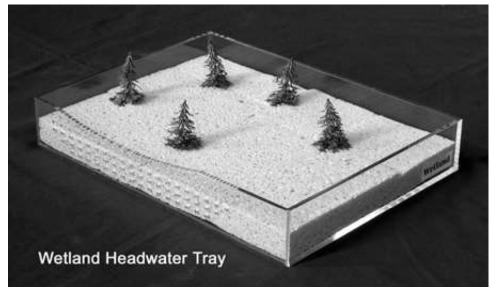
NOTES TO INSTRUCTOR
*If using a computer with a projector to display data in near-real time, load the supplied spreadsheet file into the computer and assign a student for data entry. **Make sure not to overwrite the original file supplied with the model.**

NOTES TO INSTRUCTOR
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.

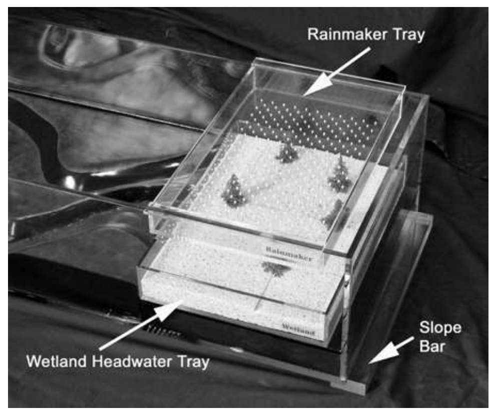
NOTES TO INSTRUCTOR
Helpful hint: Before removing the Wetland Headwater tray, squeeze some of the excess water out of the sponges into the water bucket before removing the tray.

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.

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.



Wetland Headwater Tray



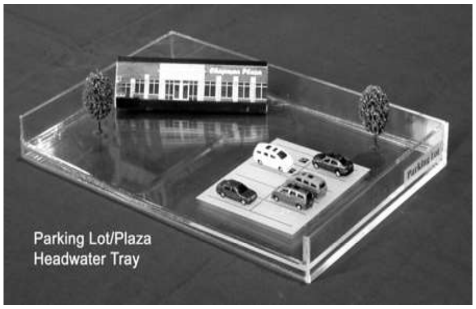
Place the prepared sponges in the bottom of the Wetlands Headwater tray and arrange them to fit snuggly into the space. Place or fasten a few miniature trees and shrubs onto the surface of the sponges to add realism. Now place the Wetlands Headwater tray into the tank on the black platform panel that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

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



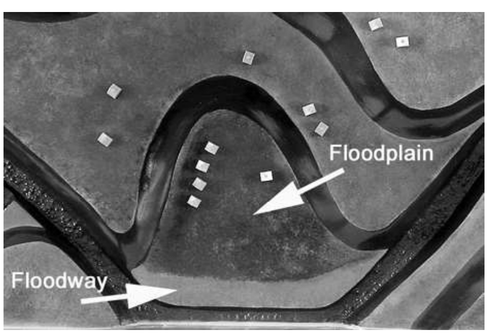
shrubs as desired. Use a small piece of modeling clay to keep them in position. Set a half dozen of the miniature houses in the large floodplain and a couple in the oxbow area, with the rest placed in various areas on higher ground. Place the high-rainfall-rate-Rainmaker tray in the model as before,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

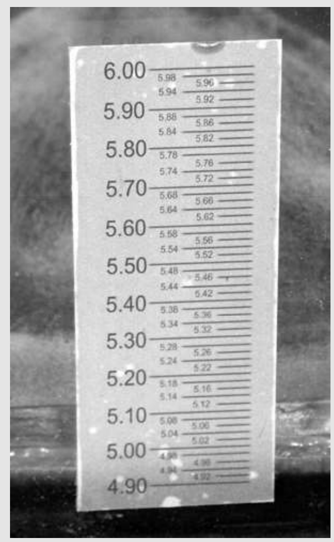
1. Present the Stormwater Floodplain model to the class. Show students where the stage levels can be measured using the staff gage on the side of the model and along the riverbank downstream, the alternative ways of introducing rain, and the various headwater upland inserts (but do not tell them what 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 ____________________

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.

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.

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?

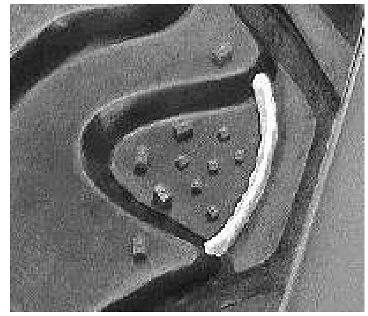
House on Stilts

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.

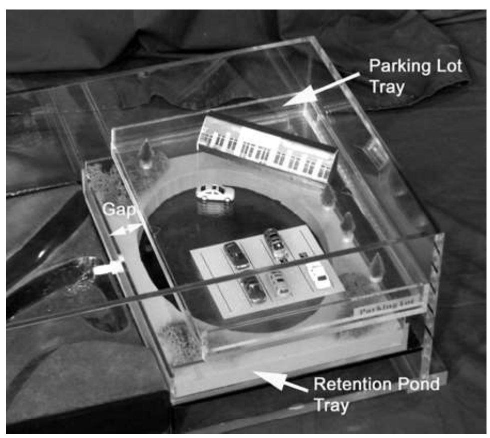


Fig. 4.2 - Parking Lot/Retention Pond Setup

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.

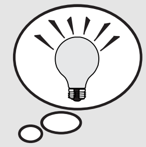
Earthen Levee

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.

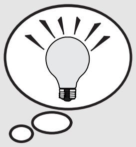
Retention Pond Under Construction



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.

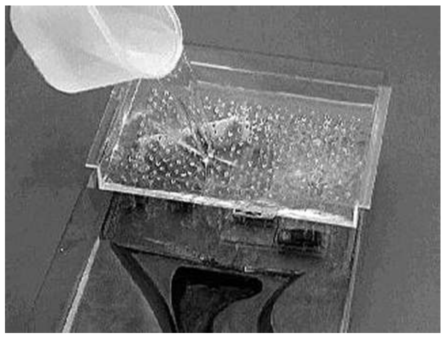
5. Prepare your data sheets to record information as you did in Activity 3.

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	
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 ____________________

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 land form.

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