SURFACE WATER
DAM IT UP!

Overview

This activity is designed to teach students about watersheds, surface water, and the storage capacity of dams. Students will actually build a watershed with a dam on it and compete to see whose dam will store the greatest quantity of water.

Subjects: Science, Social Studies
Group Size: teams of four
Estimated Teaching Time: Two hours
Curriculum Framework: IA, ID, IIIA1, IIIA2, IIIB1, IIIB2, IIIB3
Environmental Education Framework: Goals IA, IIA, IIIA, IVA, IVB
Vocabulary: contour lines, dam, divides, lateral, reservoir, runoff, spillway, surface water, topographic map, water cycle, water table, watershed

Objectives

Students will:

- define watershed.
- comprehend the purposes of dams.
- describe how dams helped Phoenix grow.
- using available materials, apply their knowledge of watersheds and design a dam that will store water for three minutes.

Background

Phoenix is fortunate to have surface and groundwater sources. **Surface water** sources are those that come from rivers, canals, lakes and reservoirs above ground. A **watershed** is all the land area that contributes runoff to a particular body of surface water. It is a catch basin guiding all precipitation and runoff into a specific river system. **Divides** are marked by ridges between drainage areas or watersheds. Students may be familiar with the Continental Divide, an imaginary line that divides the North American continent through the western states. On one side of the Continental Divide streams flow to the Atlantic Ocean, on the other to the Pacific Ocean. Triple Divide Peak in Glacier-Waterton Lakes International Park marks a divide where water can flow to the Atlantic (via streams in the Missouri-Mississippi watershed), Pacific (via the Columbia watershed) or Arctic Oceans (via the Saskatchewan-Nelson watersheds to Hudson Bay).

Prehistoric people diverted the natural flow of streams and rivers. The growth of human populations in the area of a watershed usually results in greater and greater diversion. Canals and dams are two methods of surface water diversion.

Modern-day Phoenicians have always had an adequate water supply, thanks to pioneers who developed canals dug originally by the Hohokam and also convinced federal officials to build dams to store surface water. Canal delivery systems and water storage reservoirs behind dams enabled Phoenix to become the tenth largest city in the U.S. in population and third largest in land area.

PHOENIX-AREA DAMS. One of the first water projects authorized under the federal Reclamation Act of 1902 was started in the Phoenix area. Valley farmers organized themselves as the Salt River Valley Water Users' Association, pledging the lands of the members of the association as collateral to guarantee repayment of a federal construction loan. A dam was to be built on the Salt River, where water could be stored and reclaimed for later use.

On March 18, 1911, President Theodore Roosevelt dedicated Roosevelt Dam, the world's tallest masonry dam, east of Phoenix. This storage dam fed the existing canal system, providing a permanent water supply for Phoenix and the surrounding areas. Before Roosevelt Dam was completed, Valley residents had no control over the amount of water flowing into the Salt River. Sometimes droughts caused the land to become parched. When it rained, too much water flowed through the Valley, flooding homes and businesses.

There are several major dams in the Phoenix area. Water from the Salt River watershed is held in Roosevelt Lake behind Roosevelt Dam, Apache Lake behind Horse Mesa Dam, Canyon Lake at Mormon Flat Dam, and Saguaro Lake behind Stewart Mountain Dam. On the Verde River watershed, Horseshoe Dam is the first upstream dam, forming Horseshoe Lake. Then Bartlett Dam creates Bartlett Lake. On the Agua Fria River is the New Waddell Dam, designed to store Agua Fria River runoff and Colorado River water for Central Arizona Project use. Coolidge Dam, at the confluence of the Gila and San Carlos Rivers, was designed in 1927-28 and is currently being rehabilitated because of safety concerns. It could be operational in 1995. Bartlett and Horseshoe Dams will also be undergoing modification to ensure their stability and accommodate the largest flood believed possible to occur.

Water from the Salt and Verde both flow downstream to Granite Reef Diversion Dam. This dam does not store water but diverts flow into the Arizona Canal, north of the river, and through the South Consolidated Canal. The Salt River Project manages dams and canals on the Salt and Verde Rivers. Salt River Project's dams were built for water storage, not flood control.

The Flood Control District of Maricopa County has dozens of dams, channels, levees, floodways, and diversion projects. Their mission is to manage floodplains and drainage to prevent injury and loss of life and to minimize property damage in the county.

Besides storing water and controlling the flow of the rivers, six Phoenix-area dams produce hydroelectricity: Coolidge, Horse Mesa, Mormon Flat, New Waddell, Roosevelt, and Stewart Mountain. Dams provide recreation and refuges for birds, and conserve soil by preventing erosion that might result from flooding.

DAM CONSTRUCTION. From the beginning of recorded history, people have constructed barriers across water ways to store and divert water. The irrigation knowledge of ancient Egyptians was carried by the Moors to Spain, and then quickly traveled through Europe. When the Pilgrims came to the New World, they built dams that turned their water wheels to grind corn and saw trees.

The artificial lake behind a dam is called a reservoir. The part of a dam over which flood waters flow is the spillway. Water may pass over the crest of the dam itself, or nearby in chutes, tunnels, or shafts. A passage through the dam itself used for lowering the water level of the reservoir is called the sluice. The penstock are pipes for conducting water to the power turbines in hydroelectric dams. The flow of water through spillways, sluices, and penstocks is regulated by control gates.

Dam classification is based upon their materials, design, and methods of construction. Materials include concrete or masonry, earth, rock, steel, and timber. Plain or reinforced concrete is more often used than masonry. Concrete dams are either solid gravity, hollow gravity, or arched.

Solid gravity dams, the most common type of all concrete dams, are made of concrete holding back water by its own weight. They are thicker at the base than at the crest. These are considered the most permanent type of dam, and they require the least maintenance. In cross section, they look like a triangle, broad at the base and narrow at the crest. They are built in this shape because water pressure becomes greater with the depth of water.

Hollow gravity or buttress dams are made of less concrete than solid gravity dams, relying on their structure more than their weight to resist the force of the water. A thin facing is supported at an incline by a series of triangular buttresses, or piers. Hollow gravity dams may be of three types: multiple arch, flat slab, and multiple dome. The multiple arch dam (Bartlett Dam is an example) consists of many arches supported on buttresses. The flat slab dam is a straight wall resting against buttresses. The multiple dome dam is similar to the multiple arch dam, having domes instead of arches. The Coolidge Dam on the Gila River is an example.

Arched dams rely on their weight and arch form for strength. These dams consist of a horizontal curve using the principle of the arch for strength against water pressure. They are curved upstream, transmitting the force of the water to the canyon walls. The Roosevelt Dam was originally built as a masonry thick arch dam and modified recently to a concrete gravity arch design.

Earth dams are made by building an embankment of gravel, sand, and clay across a river. Often an inner wall of concrete or other watertight materials prevents leakage under and through the dam. In a rolled-fill dam, however, earth is hauled onto the dam and rolled tight with heavy machinery. In hydraulic-filled dams, water in pipes carries and distributes earth to the dam. The placing of the earth is so controlled that the finer, watertight materials form the core in both cases. Gravel toes are often used to give stability to the slopes. A heavy layer of rock on the upstream face protects the dam against erosion. The world's largest dams by volume are earth dams - 274,026,000 cubic yards of water can be held at the New Cornelia Tailings Dam built in 1973 (in AZ) for the storage of mine tailings (source: Compton's Encyclopedia). The New Waddell Dam (Lake Pleasant) is a zoned earthfill dam, replacing the concrete multiple arch construction of the Old Waddell Dam. Other earthfill dams in the Phoenix area include Adobe, Cave Buttes, Dreamy Draw, and New River. All are flood control dams.

Rock dams are made by placing a wall of rocks across a river. On the upstream side, a waterproof facing of reinforced concrete, timber, or steel is then built.

ENVIRONMENTAL IMPACT. Though useful for generating electrical power, controlling floods, providing recreation, and ensuring a predictable water supply, dams are often controversial. When valleys upstream from a dam are flooded, humans and wildlife are dislocated. Sites rich in Native American history, riparian vegetation, wildlife habitat, and unique scenic beauty have been buried by many dams in the west. While fishing for some species may improve in a reservoir, other fish cannot survive.

Dams also impact the flow of streams below them. Reducing the flow of water to downstream populations can affect industry, agriculture, and people's very existence. The Pima and Maricopa people nearly starved to death at the turn of the century because their irrigation waters were diverted upstream.

Another controversial aspect of dams and flood control projects is that people feel they can safely build in floodplains. The unpredictability of nature can then cause even greater losses in property and lives.

It seems unlikely more dams will be built in the Valley. Orme Dam was canceled in the late 1970s. Cliff Dam, designed for flood control, water conservation and dam safety on the Verde River, was canceled in 1988. When an active eagle's nest was discovered in the proposed reservoir area in 1985, the cost-benefit balance tipped too far and fund raising ceased. Old dams are now being modified to store additional water and help control floods. More efficient methods of storing water underground and more conservative use of our water resources by all users seem more acceptable methods of assuring our water supply.

Procedure

Part 1: BUILD A WATERSHED

activity adapted from Water Wisdom and Water Matters

1. Teacher demonstration: Make a watershed model in a large plastic box by molding aluminum foil or plastic sheet over crumpled newspaper. Shape hills and form a valley channel for the stream so that water will flow from the high ground through the valley at the front of the box.

2. Describe the foil or plastic as a model of the earth's surface over which surface water flows from the crests of hills to the valleys that lie between them. Drop colored water at the top of one divide, pointing out how the water runs off to one side or the other to form a stream. Use a blue marker to draw runoff from one side of the ridge, yellow to mark the runoff to the other side. Where the two watersheds join, draw the "big" stream green. Each side of the ridge forms its own small watershed. As the tiny streams join, their watersheds combine to form larger watersheds. Spray water, observing how precipitation runs through the watersheds. Point out how rapidly the water moves over the surface.

3. Simulate groundwater by placing paper towels over part of the valley surface and again spraying from the ridge tops. Runoff is slowed and water absorbed until the paper towel is saturated. Help students observe that the faster the water comes, the greater the runoff.

Materials

- map of Phoenix-area dams, see ARIZONA SURFACE WATER FEATURES map on page 66
- aluminum foil or plastic sheeting
- newspaper
- eyedropper
- waterproof markers
- one or two liters of water, colored with 2-4 drops of blue food coloring
- sugar cubes (at least two, can be colored with markers)
- spray bottle filled with water
- water source
- several one liter bottles
- plastic boxes - at least shoebox size, one per team
- TYPES OF DAMS, one per team
- dam construction materials: clay (oil-based modeling, Plasticine recommended; about 1 pound per team), toothpicks (2 boxes), straws (100 per project), small rocks, paper clips, wire, or anything else available
- watch with second hand, for timing how long the dams last

4. Place a red sugar-cube house in one ridge valley, and a white house near the mouth of the river. Dam the watershed below the red house with a slab of clay or Plasticine. Spray or pour water slowly so that it collects above the dam. Keep adding water as you ask:
   What is happening to the river? (Point out that a "lake" is forming where there was no lake, and that no water passes through the dam at first.) What happens to animals living in and around the upstream part of the river? ... the downstream part of the river? What good effects will the dam have for animals and people above the dam? ... below the dam? How would you feel about the dam if you lived in the red house? How would you feel about the dam if you lived in the white house?

5. Remind students that Phoenix would not be the city it is today without human's ability to store and transport water. Given that Phoenix gets major rains only twice a year, only a few thousand people would survive without water storage methods that make water available year round. Dams make it possible to store water for use during dry periods and control floods when runoff is heavy. Dams equalize the water supply for crops and people throughout the year. Dams can store floodwater and provide a steady supply of water for all users.
   Share the map that displays the major dams in the Phoenix area. Remind students that these dams serve other purposes besides residential water use: limited flood control, hydroelectric power generation, and waters for irrigation and manufacturing.

Part 2: DAM IT UP

We strongly recommend this part of the activity be conducted outside.

1. In this part of the activity students will build their own watersheds and dam them up! They may use any materials provided; other materials only with permission and if there are enough available for other teams who may wish to use them.

2. There are no right answers nor should students need other rules. Give them the time in which they must build their watersheds and dams (at least a half hour), and then test the designs as students complete their work. The dams must hold water for three minutes. Pour water slowly, beginning with one liter of water for a shoebox-size container. For those dams that hold the starting volume for three minutes, add water until the dams burst!

3. Time and record the actual storage times. Celebrate by having the "winners" describe their watershed design and their dam construction techniques. Try it again!

Extensions

1. Challenge students to identify ways they and their community dam, divert and transport water. Students dam their bathtubs with drain plugs, divert water with shower curtains, and transport water using straws. What other examples can they think of?

2. Take a field trip to a dam to learn more about water storage, hydroelectric power generation, and/or dam safety and obsolescence. Horse Mesa Dam and Mormon Flat Dam have pumped-storage units where the same water is used repeatedly to generate electricity. Coolidge Dam was closed because its water holding ability was questionable and the towns of Hayden, Kearny and Winkelman were in potential danger.

3. Decide the evaporation rate from the surface of the Roosevelt Dam at maximum capacity. Roosevelt Dam's maximum surface area is equal to 19,199 acres, total maximum capacity 1,609,168 acre-ft., yielding an average maximum depth of 83.8 feet [Volume(V)= height(h) x r^2]. Evaporation rate formula: Rate(R)=Volume(V)/ r^2. Note that besides surface area, temperature, humidity and wind also impact evaporation rates.

   Or design an experiment with three different size containers, exposing different surface areas using the same volume of water. Also experiment with closed containers and open containers of the same size. Students will see that having deep reservoirs with minimum surface areas will reduce water loss due to evaporation. The volume of water evaporated is directly proportional to the surface area exposed to the air.

4. Build models of the watersheds in the Phoenix area, or of the watershed in which you live. Decide if there is enough water flow now to support the people who live in its boundaries. Add storage and diversion dams, and build major delivery routes, adding canals and laterals to your model.

Evaluation

1. What is a watershed? Use a drawing to help explain your words.

2. Describe at least three purposes of dams.

3. How did dams help Phoenix grow into the metropolitan area it is today?

Resources

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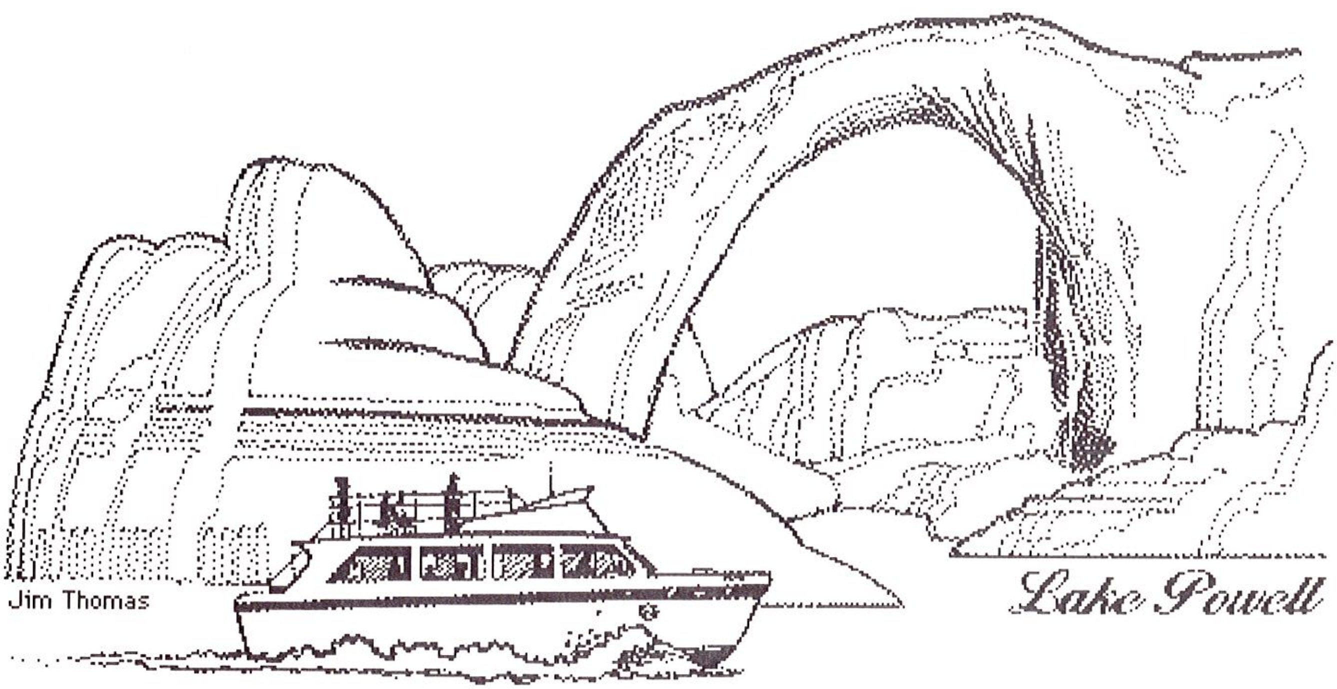
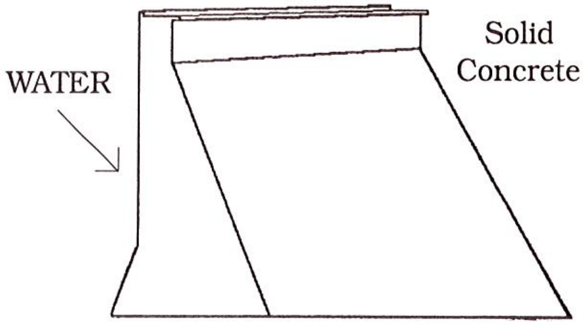
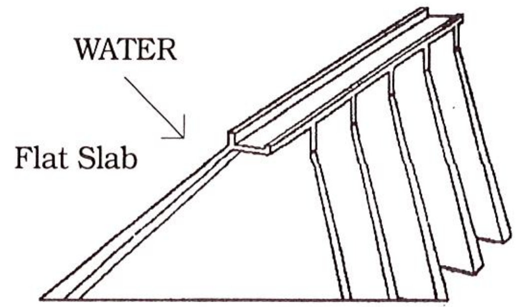


TYPES OF DAMS

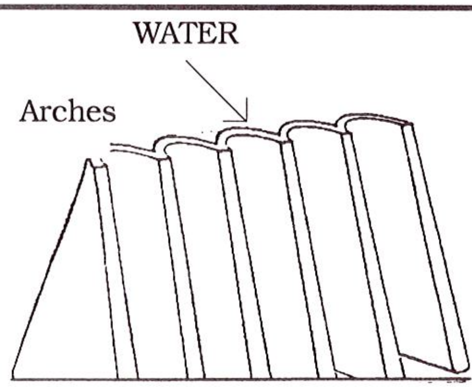
Directions: Your team is to build a watershed model and dam up its main river. You may use any materials you wish from the supplies made available by your teacher. Your team will compete with others to see which dams will hold the greatest volume of water for at least three minutes. Remember, your dam is to be built to stop the water flow and form a reservoir to store water. Sample dams are shown to give you some ideas for your construction.



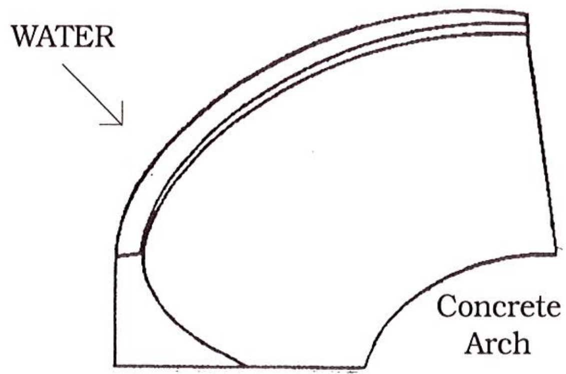
SOLID GRAVITY DAM



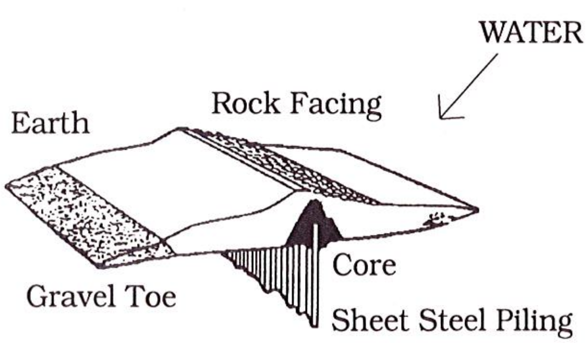
FLAT SLAB DAM
HOLLOW GRAVITY OR BUTTRESS



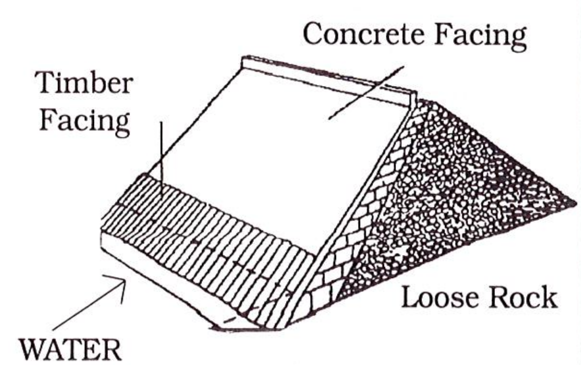
MULTIPLE ARCH DAM
HOLLOW GRAVITY OR BUTTRESS



ARCHED DAM



EARTH DAM



ROCK DAM

Drawings adapted from Compton's Multimedia Encyclopedia