Module 2
Human Interventions in the Water Cycle

Background Information

Humans need water. Water is essential from a nutritional standpoint to help sustain life, it's required for agriculture to grow crops, and it's also used for a variety of residential, recreational, and industrial purposes. However, the human population is growing rapidly, and this places ever-increasing pressure on the finite amounts of water that are available. Furthermore, pollutants that affect water quality effectively decrease the supply because there is less available useable water. Pollutants that enter water from a single identifiable source are referred to as **point source pollutants**. Examples include municipal sewage, sewage from animal feedlots, and industrial discharges. Pollutants can also come from **non-point sources**, which are sources that are from a widespread area such as agricultural runoff, pollution from roadways, and runoff from residential landscapes in cities, suburbs, or towns.

Petr Kratochvil

Agricultural Water Use

Agriculture in the United States accounts for 80 percent of the nation's consumptive water use. For example, rice, a dietary staple for billions of people around the world, and cotton, used as a fiber for the manufacture of clothing, require tremendous amounts of water to grow. Furthermore, the animal agriculture industry has a large impact on water consumption. According to some sources, grain-fed beef requires 100,000 liters of water for every one kilogram of food, and 3,500 liters of water are needed to produce one kilogram of broiler chicken meat.

Where we choose to grow crops and raise market animals also has impacts on water consumption and water quality. Some **watersheds** may lack sufficient water supplies for suitable agricultural production; however, through human interventions such as **irrigation**, **diversions**, and **impoundments**, sufficient water supplies can be obtained. Irrigation is a process whereby water is applied artificially to land for the purpose of assisting in crop production This is accomplished by diverting water from one area to another, typically through pipes, canals, or ditches. Water impoundments, areas where water collects (e.g., reservoirs or ponds) that are the result of the construction of a dam or embankment, or by digging a large depression in the earth, often times facilitate irrigation. Furthermore, impoundments may serve as surface water sources for fish, and wildlife, aquaculture, recreation, and fire control.

Agriculture can have adverse impacts on water quality. For example, pesticides (insectisides, herbicides, fungicides, etc.) are commonly used on crops in order to ensure adequate production; however, these chemicals can enter surface and groundwater supplies and lead to environmental and health-related concerns. Additionally, animal agriculture produces large amounts of waste, including manure, bedding, spilled feed, and carcass disposal that must be managed properly in order to prevent or reduce adverse effects on the quality of water supplies.

Petr Kratochvil

Peter Griffin

Residential Water Use

The average per capita water consumption in the United States exceeds 550 liters (250 gallons) per day, the most of any country. Activities that consume large amounts of water include flushing the toilet (26% of household indoor water use), laundry (22%), bathing (19%), and watering outdoor landscaping (averages vary by climate). Household water conservation efforts, through strategies such as decreasing the amount of time spent bathing or using lawn sprinklers, or through the use of technologies such as low-flow toilets or shower heads, can make a significant difference in the amount of water consumed. Such efforts are paramount because the rapidly growing human population places increased pressure on the water supply.

As with agricultural regions, the water quality in residential areas can also be compromised through point and nonpoint source pollutants. Domestic **wastewater treatment (sewage treatment)** facilities address some issues associated with water quality in residential areas. Wastewater needs to be treated because it may contain harmful **pathogens**, **toxins**, and **organic matter** that can have damaging effects on human health and the health of the local watershed.

Residential wastewater treatment is typically a four-step process:

1. In the preliminary treatment phase, large objects (e.g., sticks and other debris) are removed when the water passes through a large bar screen.

2. During primary treatment, impurities such as solid waste (which settles to the bottom) and oils (which rise to the top) are physically separated from the water.

3. The secondary treatment phase is where micro-organisms digest dissolved organic matter from the wastewater.

4. In the final treatment phase, any remaining harmful micro-organisms are killed using chlorine or ultra-violet disinfection. Prior to the treated water being returned to surface water sources, excess chorine is removed.

Industrial Water Use

Industries, small and large, use large quantities of freshwater on an annual basis. In fact, according to one source, industrial water usage accounts for 20 percent of the annual water supply in the United States. Furthermore, **effluents** (waste discharges) from manufacturing processes release pollutants that affect surface water sources and groundwater. Examples include heat (**thermal pollution**), nutrients (increased nutrient loads can cause **euthrophication**, a process that depletes the **dissolved oxygen** supply), and toxic chemicals and heavy metals that can build up in the tissue of plants and animals in increasing amounts through the food chain (a process called **bioaccumulation**). A common example of bioaccumulation is mercury, a pollutant from sources such as coal combustion and metal processing. When mercury is in the water, it passes to bacteria and plants and then to small fish; these small fish are then consumed by larger fish, and ultimately the larger fish are eaten by fish-eating birds or mammals. By the time it reaches the animals at the upper end of the food chain the concentration of mercury can be up to one million times higher than in the source water. In order to reduce their impacts on water resources, some industries have modified their manufacturing processes to minimize waste production or recycle their wastes, while many others use some type of **industrial wastewater treatment** technology in order to treat their wastewater.

Recreational Water Use

Water is used for recreational purposes directly and indirectly. For example, freshwater lakes and reservoirs are commonly used for fishing, boating, and swimming. These activities do not typically impact water quantity; however, excessive irrigation of recreational venues (sometimes referred to as **recreational irrigation**) such as golf courses, particularly in arid regions where annual precipitation is low and surface water and ground water availability is limited, can affect water supplies. Recreational activities associated with surface waters typically have a greater impact on water quality through pollution (e.g., oil, cleansers, paint scrapings, and human sewage). Adverse impacts can be minimized, however, when individuals maintain equipment properly and develop ecologically-friendly practices such as waste reduction and recycling.

Photo Courtesy of NileGuide

Activity
From Storm Clouds to the Ocean: Chance Encounters of Wandering Water

Activity Overview

Humans use water for a variety of purposes, and impacts can affect the quality and quantity of water available. The activity engages youth by having them participate as "rain drops" in the water cycle, passing through a watershed in random fashion from one learning station to another. Depending on where the "rain drops" land will determine their "chance encounters" within the watershed. Will they be used by nature, or will they be used by human activities?

Time Required

- Set-up: Approximately 30 minutes
- Activity: Approximately 1 hour

Concepts and Vocabulary

- Bioaccumulation: The accumulation of substances, such as pesticides or heavy metals, in organisms in increasing concentration up the food chain.
- Dissolved oxygen: Refers to oxygen molecules that are dissolved in water, which aquatic organisms such as fish and crustaceans depend on for survival.
- Diversion: Moving surface or groundwater from one area to another, typically through pipes, canals, or ditches.
- Effluent: A discharge of liquid waste.
- Eutrophication: A process whereby bodies of water receive excess nutrients that stimulate the growth of algae and plants. Eutrophication results in the depletion of dissolved oxygen.
- Impoundment: An area where water collects (e.g., reservoir or pond) that is the result of the construction of a dam or embankment, or by digging a large depression in the Earth.
- Industrial wastes: Water pollutants from industrial processes.
- Irrigation: Applying water artificially to land for the purpose of assisting in crop production.

Joel McNee

Concepts and Vocabulary (continued)

- Non-point source pollution: Pollutants that come from a widespread area.
- Organic matter: Residues of dead plants or animals in some state of decay.
- Pathogen: Disease-causing agents, such as some bacteria, viruses, or fungi.
- Point source pollution: Pollutants that come from a single identifiable source.
- Recreational irrigation: The irrigation of recreational venues (e.g., golf courses).
- Thermal pollution: The discharge of heated water from industrial processes into a body of water. The subsequent rise in temperature endangers aquatic life.
- Toxin: A substance that is poisonous to an organism.
- Watershed: An area of land where ground water and surface runoff drain to the lowest point in that region.
- Wastewater: Water whose quality has been adversely affected by human activity.
- Wastewater treatment: Processes that treat wastewater in order to remove contaminants. Includes municipal wastewater treatment and industrial wastewater treatment.

Life Skills

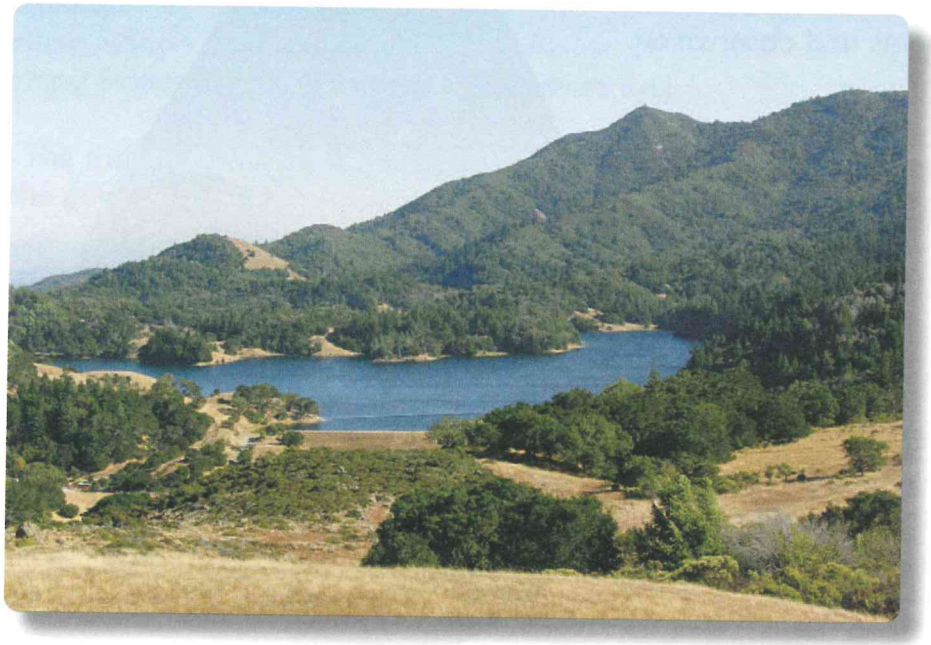
Activities that promote positive youth development advance the development of life skills. Life skills promoted through this activity include:

- Head: Keeping Records, Wise Use of Resources, Critical Thinking, Decision Making
- Heart: Sharing, Concern for Others, Communication, Cooperation, Social Skills, Sharing
- Hands: Responsible Citizenship, Contributions to Group Effort, Teamwork
- Health: Healthy Lifestyle Choices, Disease Prevention

Volunteer Tip: For more information on life skills, please visit http://www.extension.iastate.edu/4h/lifeskills/

Subject Links

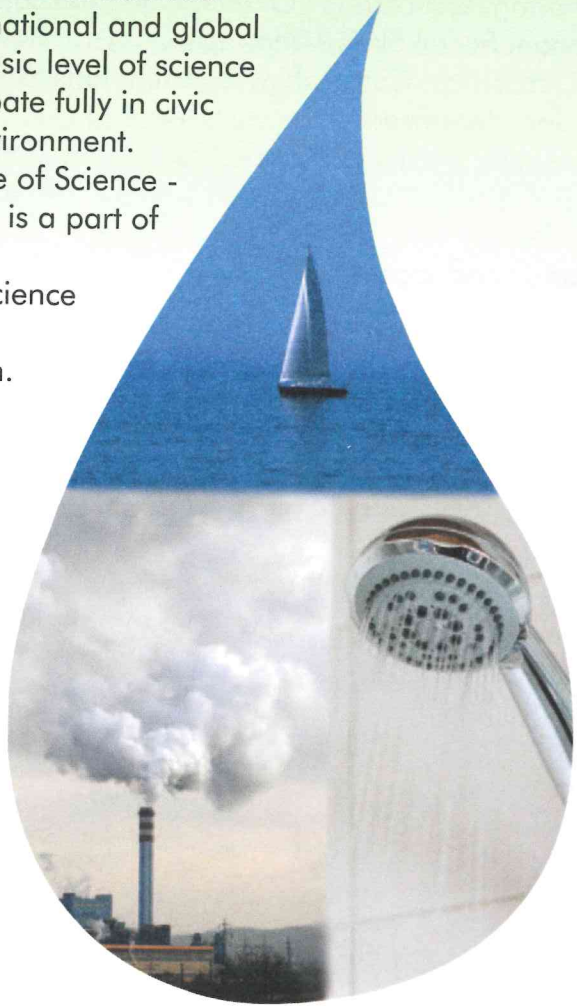
- Science and Language Arts



National Science Education Standards Supported

- Unifying Concepts and Processes Standard - Fundamental science concepts that unify and connect scientific disciplines
  - -Evidence, models, and explanation.
  - -Change, constancy, and measurement.
- Content Standard A: Science as Inquiry Standards
  - -Abilities necessary to do scientific inquiry
  - -Understanding about scientific inquiry
- Content Standard D: Earth and Space Science
  - -Energy in the earth system
  - -Geochemical cycles
- Content Standard F: Science in Personal and Social Perspectives
  - -Population growth - Limitation of human populations in relation to resource availability.
  - -Natural resources - Increasing human consumption places stress on the natural ecosystem.
  - -Environmental quality - Natural ecosystems procesess may be impacted and changed by humans in ways detrimental to both nature and humans.
  - -Natural and human-induced hazards - Changes in environment designed by humans can bring benefits as well as hazards.
  - -Science and technology in local, national and global challenges - Everyone needs a basic level of science understanding in order to participate fully in civic processes that can impact the environment.
- Content Standard G: History and Nature of Science - Science as a human endeavor - Science is a part of society and all youth can be scientists.
  - -Nature of scientific knowledge - Science knowledge is built on evidence from experiments and observation.

Volunteer Tip: For more information on the National Science Education Standards, please visit http://www.nap.edu/openbook.php?record_id=4962



Suggested Groupings

- Pairs or groups of three

Materials Needed

**Materials provided*

- 1/2 gallon of water for a group of 10 youth or 1 gallon of water for a group of 20 youth
- 2 clear gallon buckets/containers to hold the resulting waste water
- For each group: 3-5, 12 oz. plastic or paper cups (**Note**: Groups use a new cup each time through the water cycle)
- 7, six-sided dice
- 4 fl oz. of dishwashing detergent
- 1.75 oz. container of chocolate sprinkles
- ¼ cup salt
- 1 roll of toilet paper
- Small bottle of maple syrup
- 3-4 cups of either cereal or crackers (crushed)
- 4 tablespoons
- 1 teaspoon
- 2 white coffee filters
- 2 funnels
- ½ cup of vegetable oil
- Cup of grass or other plant matter (e.g. cut green grass, leaves, etc.)
- ½ cup of soy sauce
- Yellow food dye (0.25 fl oz.)
- Red food dye (0.25 fl oz.)
- Green food dye (0.25 fl oz.)
- 2 bottles of blue food dye (0.25 fl oz.)
- 2 cups of soil
- Flip chart paper and writing implements
- 1 calculator
- *Learning Station Set-Up Map (Appendix A)
- *Learning Station Action Directives (Appendices B-L)

Note: The materials will be divided among 11 learning stations. Set up the learning stations using the guide provided in Appendix A.

Materials Needed (Listed by Learning Station)

Materials for the Cloud Learning Station (#1)
- 1 die
- 1/2 gallon of water for a group of 10 youth or 1 gallon of water for a group of 20 youth
- For each group: 3-5, 12-oz. plastic or paper cups (**Note**: Groups use a new cup each time through the water cycle)

Materials for the Erosion Learning Station (#2)
- 1 die
- 1 cup of soil
- 1 tablespoon

Materials for the Urban Runoff Learning Station (#3)
- 1 die
- ½ cup vegetable oil
- 1 small bottle (0.25 fL oz.) of blue food dye
- 1 tablespoon

Materials for the Agriculture Runoff Learning Station (#4)
- 1 die
- 1 small bottle (0.25 fL oz.) of red food dye
- 1 small bottle (0.25 fL oz.) of green food dye
- Cup of grass or other plant matter (e.g. cut green grass, leaves, etc.)
- 1 cup of soil

Materials for the Groundwater Learning Station (#5)
- 1 die
- ¼ cup salt
- ½ cup of soy sauce
- 1 tablespoon
- Cards

Materials for the Reservoir Learning Station (#6)
- Cards

Materials for the Residential Learning Station (#7)
- 1 die
- 1 teaspoon and 1 tablespoon
- 4 fl oz. of dishwashing detergent
- 1.75 oz container of chocolate sprinkles
- 1 small bottle of maple syrup
- 3-4 cups of either cereal or crackers (crushed)
- 1 roll of toilet paper

Materials for the Industrial Learning Station (#8)
- 1 die
- 1 small bottle (0.25 fL oz.) of blue food dye
- 1 small bottle (0.25 fL oz.) of yellow food dye

Materials for the Agriculture Irrigation Learning Station (#9)
- 1 die
- 1 calculator

Materials for the Water Treatment Learning Station (#10)
- 1 clear gallon bucket/container
- 1 funnel
- 2 white coffee filters

Materials for the Ocean Learning Station (#11)
- 1 clear gallon bucket/container
- 1 funnel

Eryanne Edgerley

Getting Ready

- Make copies of Appendices B-L to place at respective learning stations.
- Organize learning stations as shown in Appendix A.
- Set up materials for each learning station as listed on pages 34-35.
- Divide youth into pairs or groups of three.
- Provide each pair or small group with one piece of flip chart paper and writing implements.

Opening Questions/Prompts

Ask the pairs/small groups to discuss their responses to the following questions/prompts and to record their thoughts on the flip chart paper provided.

- Explain what you know about different ways humans use water.
- Explain what you know about different types of water pollutants.
- Discuss what you know about how different types of pollutants are removed from water.

Procedure (Experiencing)

1. Position all pairs/small groups in the Rain Cloud as indicated in Appendix A.

2. Explain to the group that the water in their cups represent a raindrop. As they fall out of the sky, their raindrop will have an adventure through the water cycle.

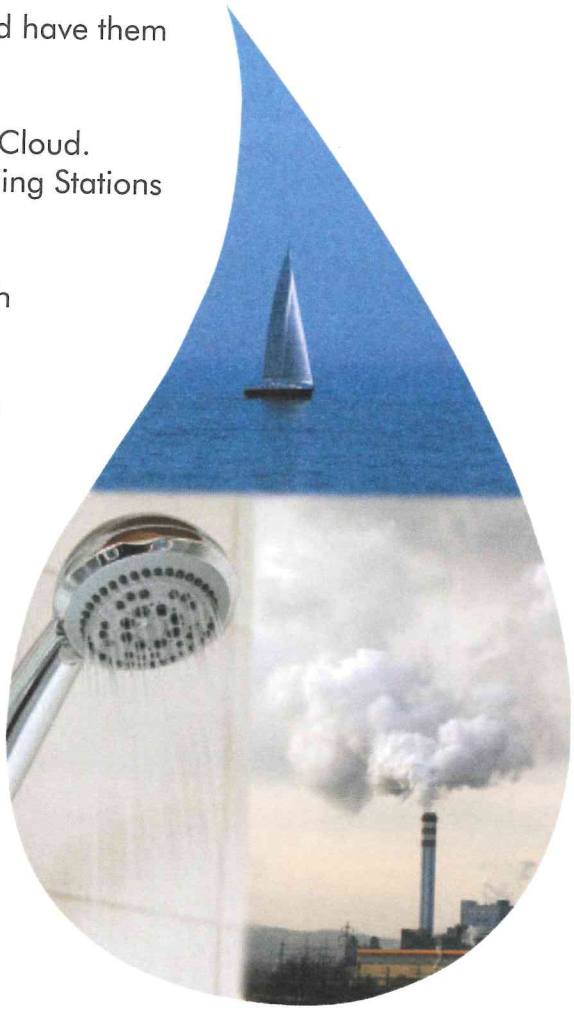
3. Provide each pair/small group with one cup and have them fill their cup half full of water from the bucket.

4. Let each group role the die, in turn, at the Rain Cloud. Group proceeds to their respective Runoff Learning Stations indicated by Appendix A.

5. Each pair/small group of youth journeys through different paths taken by rain water.

6. Once the youth reach either the water treatment center or the ocean and their cups are empty, they proceed back to the Rain Cloud (Home).

7. The game ends when the water source is used up and the resulting water is contained in either the waste water treatment station bucket or the ocean bucket.



Sharing, Processing, and Generalizing
Once the bucket of water at the rain cloud is empty, have the students make observations of the resulting mixture of water in the waste water treatment bucket and the ocean bucket. Have students discuss their observations and, if necessary, use targeted questions to help students get to specific concepts. For example:

1. What interpretations can students make from observing the resulting mixture of water?

2. What effects will the mixed water have on the quality and quantity of the water in our natural water cycles?

3. Does the water resulting from the filtering activity look or smell clean?

4. Have the students develop a discussion that focuses on the effects of pollutants from our daily actions upon entering the natural water cycle and how our pollutants can indirectly effect our well-being.

Note: Ask youth to share their ideas verbally or record them on the flip chart paper.

Concept and Term Discovery/Introduction
At this point, it is important to ensure that the concept and vocabulary terms have been introduced or discovered by the youth. (**Note**: The goal is to have the youth discover terms and concepts on their own.): bioaccumulation, dissolved oxygen, diversion, effluent, eutrophication, impoundment, industrial wastes, irrigation, non-point source, organic matter, pathogen, point source, thermal pollution, toxin, watershed, wastewater, wastewater treatment. It may be helpful to direct the group to each learning station and ask for observations and thoughts relating to each human intervention: industrial, agricultural, and residential.

Calvin Teo

Concept Application

The true test of learners' understanding is when they can apply new knowledge and skills to authentic situations. When engaging youth in inquiry-based learning, hands-on activities serve as vehicles for learning new concept knowledge and skills; however, it is the application of new knowledge or skills to independent, real-world situations that is the critical factor in the learning process. Thus, to complete the cycle of experiential learning it is important to provide youth specific opportunities for authentic applications. Suggestions for real-world applications for the *From the Storm Clouds to the Ocean: Chance Encounters of Wandering Water* activity include:

- Identify the primary source(s) of water for your community (e.g., groundwater, reservoirs). Determine how the different sectors of your community - agricultural, residential, industrial, and recreational - impact water use. Propose strategies to conserve water associated with these sectors of your community.

- Identify potential pollutants that are associated with the use of water by agricultural, residential, industrial, and recreational activities in your community. Propose strategies to decrease pollution associated with these activities.

Paolo Neo

References

California Department of Public Health. (2007). Public drinking water systems. Retrieved from: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/.

City of San Francisco Public Utilities Commission. (2009). Wastewater enterprise. Retrieved from: http://sfwater.org/mc_main.cfm/MC_ID/14.

Council of Great Lakes Governors. (2008). Our waters diversions of great lakes water [Brochure]. Wisconsin: Great Lakes Water Institute.

Gleick, P., Palaniappan, M., Cooley, H., Morikawa, M., & Morrison, J. (2009). The world's water 2008- 2009: The biennial report on freshwater resources. Washington, D.C.: Island Press.

Hendricks, P. (1998). Targeting life skills model. Retrieved from Iowa State University Extension website: http://www.extension.iastate.edu/4H/lifeskills/.

Merriam-Webster's collegiate dictionary. (2009). Retrieved from: http://www.merriam-webster.com/.

National Academies Press. (1996, January 1). *National Science Education Standards*. Retrieved from: http://www.nap.edu/catalog.php?record_id=4962

Perlman, H. (2009, April 16). Water use: wastewater treatment. United States geological survey. Retrieved from usa.gov website: http://ga.water.usgs.gov/edu/wwvisit.html.

State of Victoria, Australia, Department of Primary Industry, agriculture, food, and forestry. (2010, May 1). Irrigation. Retrieved from: http://www.dpi.vic.gov.au/dpi/nrenfa.nsf/childdocs/-80E62E2EAB672EE24A256B520005A0AF-11AF46B80DF604E0CA256C4B00033C54?open.

United Nations Natural Resources Management and Environment Department. (1993). Land and water integration and river basin management: Conjunctive use of surface and groundwater. Retrieved from: http://www.fao.org/docrep/v5400e/v5400e0c.htm

United States Environmental Protection Agency. (2009, April 10). Lead in drinking water. Retrieved from: http://www.epa.gov/ogwdw/lead/.

United States Environmental Protection Agency. (2006, November 28). Drinking water and health: what you need to know. Retrieved from: http://www.epa.gov/safewater/dwh/index.html.

United States Environmental Protection Agency. (2009, March 13). For teachers (grades 9-12). Retrieved from: http://epa.gov/safewater/kids/teachers_9-12.html.

Waitakere city council. (2009). Wastewater education. Retrieved from: http://www.waitakere.govt.nz/Abtcit/ei/EcoWtr/wstewater/.

National Sustainable Agriculture Information Service. (2009). Water quality, conservation, drought and irrigation. Retrieved from: http://attra.ncat.org/water_quality.html.

Wiggins, G., & McTighe, J. (2005). Understanding by design. Virginia: Association for Supervision and Curriculum Development.

United States Department of Agriculture. (2004). Irrigation and water use. Retrieved from: http://www.ers.usda.gov/briefing/wateruse/

Diagram of Room Set-Up for Learning Stations

Station 1

Station 4

Station 5

Station 9

Station 2

Station 6

Station 8

Station 3

Station 7

Station 10

Station 11

Learning Station 1 Cloud

You are a raindrop falling from a cloud. Will you be used by nature, or will you be used by human activities?

Rain - Surface Runoff

Rain falls to the Earth and lands on a variety of objects: ground, trees, buildings, roads, lakes and streams. The path it takes will determine how it is used and the potential pollutants it will pick up along the way.

Directions

1. Role a die and follow the path according to the number you roll:
    a. **Roll 1**: You fall into a manmade reservoir.
    Proceed to the Reservoir Learning Station (#6)

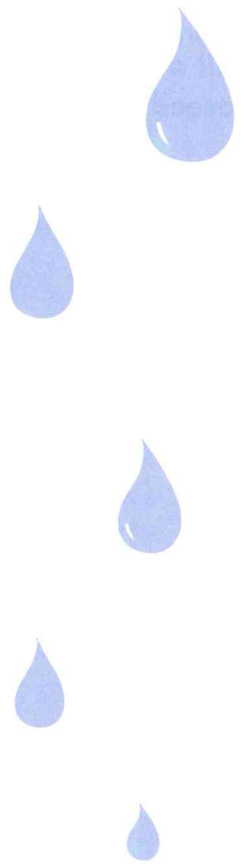
    b. **Roll 2**: You fall onto the ground and seep into the Earth.
    Proceed to the Groundwater Learning Station (#5)

    c. **Roll 3**: You fall onto the ground and run over a hillside.
    Proceed to the Erosion Runoff Learning Station (#2)

    d. **Roll 4**: You fall over a city.
    Proceed to the Urban Runoff Learning Station (#3)

    e. **Roll 5**: You fall over farmland.
    Proceed to the Agriculture Runoff Learning Station (#4)

    f. **Roll 6**: You are not heavy enough to fall out of a cloud yet.
    Stay in the cloud and return to the back of the line.



Learning Station 2 — Erosion

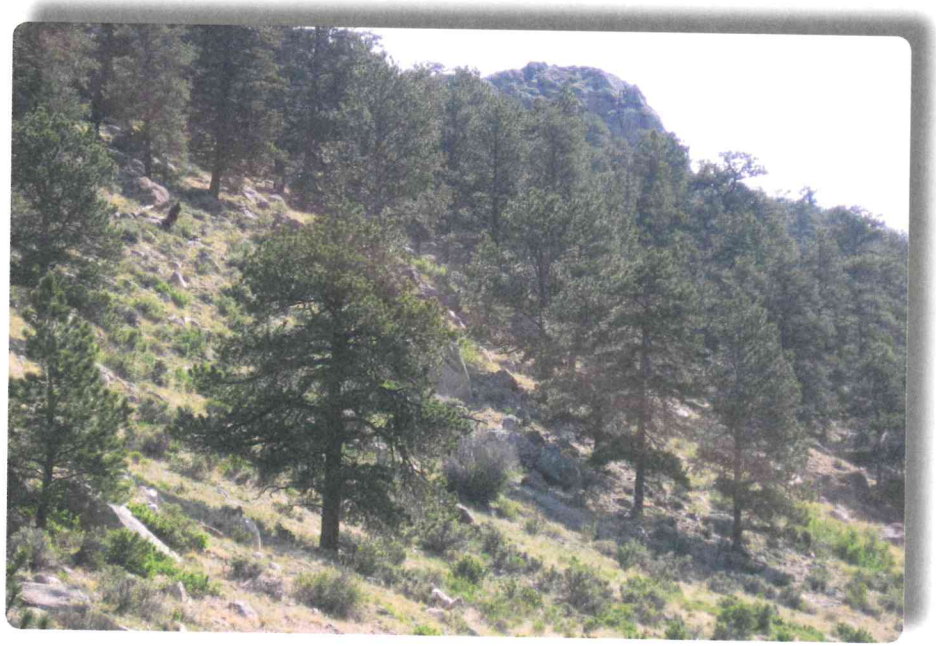
Your raindrop collects sediment, rock and soil as it runs down a hillside, in a process called **erosion**. Rapid erosion in an ecosystems can cause a decrease in **surface water quality** and **biodiversity**. It can also lead to mudslides and other natural disasters.

Directions

1. Add one tablespoon of soil to your water.

2. Roll the die.
   a. **Roll even**: Your raindrop runs into a reservoir.
      Proceed to the Reservoir (#6).

   b. **Roll odd**: Your raindrop runs into the ocean.
      Proceed to the Ocean (#11).



Eryanne Edgerley

Learning Station 3 Urban Runoff

Your raindrop lands in an urban area with many surfaces that do not allow water to effectively soak into the ground, such as asphalt and concrete. Common surface runoff pollutants that can occur in urban areas include lawn fertilizers, pesticides, automobile fluids, road deicing chemicals, household chemicals that are improperly disposed of, sediments, pathogens, fertilizers/nutrients, hydrocarbons, garbage, and metals.

Directions

1. Roll the die.
   a. **Roll 1 or 2**: Your raindrop is polluted with automobile oil on a road and drains off into the surrounding soil.
      Add 1 tablespoon of vegetable oil to your water to represent automobile oil.
      Proceed to the Ocean (#11).

   b. **Roll 3 or 4**: Your raindrop is polluted with automobile oil and runs into a storm drain and enters the sewer system.
      Add 1 tablespoon of vegetable oil to your water to represent automobile oil.
      Proceed to the Water Treatment Center (#10).

   c. **Roll 5 or 6**: Runoff from your lawn reaches the street carrying fertilizers and pesticides and enters the storm drain and enters the sewer system.
      Add a few drops of blue food dye.
      Proceed to the Water Treatment Center (#10).

Learning Station 4

Your raindrop lands on active farmland. Agriculture can have adverse impacts on water quality.

Directions

1. Roll the die.
   a. **Roll 1 or 2**: Your raindrop is polluted with a residue pesticide and/or herbicide. Add three drops of red food dye. Pesticides and herbicides are commonly used on crops in order to ensure adequate production; however, these chemicals can enter the environment and lead to environmental and health-related concerns.

   b. **Roll 3 or 4**: Your raindrop is polluted with excess nitrogen causing an algal bloom. Add three drops of green food dye.
   Excess nitrogen and phosphorous from fertilizers can cause a rapid increase in plant and algal growth. When the plants and algae decompose they reduce oxygen levels in the water. If oxygen levels decrease too low, they can create a hypoxic zone devoid of aquatic life.

   c. **Roll 5**: Your raindrop is polluted with animal waste. Add a small handful of grass or other plant/straw matter. Animal agriculture produces large amounts of waste, including manure, bedding, spilled feed, and carcass disposal that must be managed properly in order to prevent or reduce adverse effects on the quality of water supplies.

   d. **Roll 6**: Your raindrop falls onto organic farmland not using chemicals and is not polluted. Due to runoff, excess soil erodes into the surrounding surface water causing sediment pollution. Sedimentation clouds the water, reduces oxygen, and is detrimental to aquatic life. Add a small handful of soil to your raindrop.

2. Roll the die again.
   a. **Roll even**: Your raindrop runs down a stream into the environment.
   Proceed to the Ocean (#11).

   b. **Roll odd**: Your raindrop runs down a stream into a reservoir.
   Proceed to the Reservoir (#6).

Learning Station 5 Groundwater

Groundwater comes mainly from rain or snow that percolates into the ground by gravity, saturating soil and rock beneath the earth's surface. Groundwater contains the bulk of the world's freshwater supply and is commonly used for irrigation and industrial purposes. It connects bodies of water through discharge points such as springs and lakes and enters through recharge areas such as aquifers or permeable soils and rocks.

Directions

1. Roll the die.
    a. **Roll 1 or** 2: Your raindrop is polluted with salt. Add one teaspoon of salt to your raindrop. Saltwater intrusion can contaminate groundwater by mixing saltwater with freshwater and can adversely affect freshwater ecosystems.

    b. **Roll 3 or 4**: Your raindrop is polluted with human containments from leaking sewage pipes. Add one tablespoon of soy sauce to your raindrop. Human causes of groundwater contamination include underground sewage pipes and landfills. Because of its deep location beneath the Earth's surface, cleaning up contaminated groundwater is a difficult and expensive process.

    c. **Roll 5 or 6**: Your raindrop remains clean underground.

2. Select one card.

Learning Station 5 Cards

Note: Duplicate cards as needed. You may want to print extra copies of each card to offer a larger stack.

Card #1

An aquifer is a formation of soil and rocks that allow groundwater to be pumped out of the ground. Your raindrop is drawn up from the ground from a city's drinking well.

Proceed to the Residential Learning Station (#7)

Card #2

An aquifer is a formation of soil and rocks that allow groundwater to be pumped out of the ground. Your raindrop is drawn up from the ground to irrigate a local farmer's crop.

Proceed to the Agriculture Irrigation Learning Station (#9)

Card #3

An aquifer is a formation of soil and rocks that allow groundwater to be pumped out of the ground. Your raindrop is drawn up from the ground for industrial purposes.

Proceed to the Industrial Learning Station (#8)

Card #4

An aquifer is a formation of soil and rocks that allow groundwater to be pumped out of the ground. Through difference in pressure underground, your raindrop was formed through a spring and has reached the Ocean.

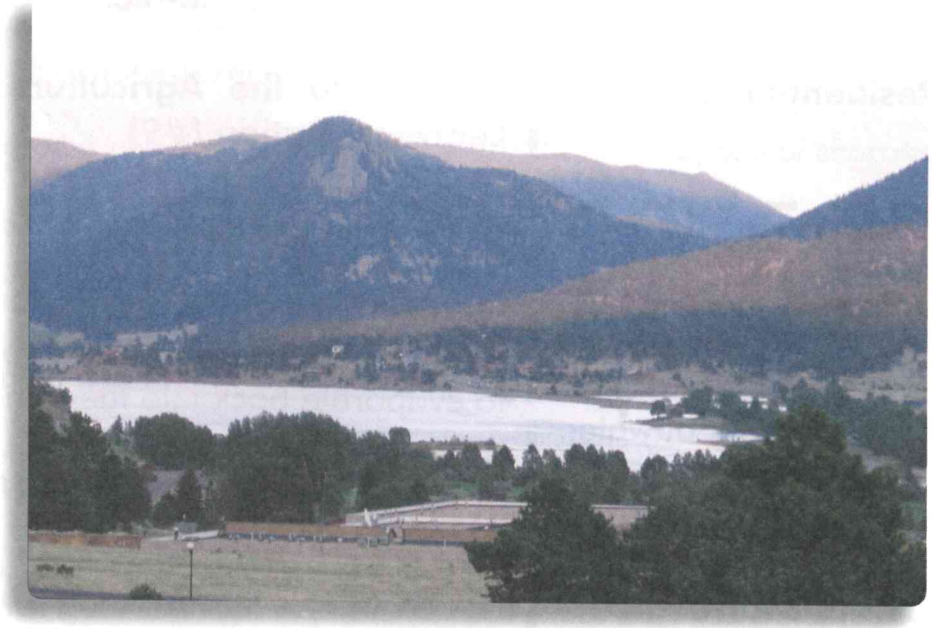
Proceed to the Ocean (#11)

Learning Station 6 Reservoir

A reservoir is an artificial lake used to store water. These man-made bodies of water are typically created by constructing a dam across a river. The water held in reservoirs are used for drinking water, irrigation, hydroelectric power, flood control, fire control, animal agriculture, and recreation. However, this construction of a dam changes the aquatic ecosystem and affects aquatic life upstream and downstream. Additionally, sediment that accumulates due to erosion limits the water storage capacity of the reservoir.

Directions

1. Select one card.



Eryanne Edgerley

Learning Station 6 Cards

Note: Duplicate cards as needed. You may want to print extra copies of each card to offer a larger stack.

Card #1

Reservoirs are commonly used to hold water for household uses and drinking water. Your raindrop has been pumped from the reservoir for household purposes.

Proceed to the Residential Learning Station (#7)

Card #2

Many reservoirs are used to store water to be used for agricultural purposes. Your raindrop has been pumped and transported for uses in a local farmer's crop.

Proceed to the Agriculture Irrigation Learning Station (#9)

Card #3

Reservoirs may store water for use in small or large industries. Many larger industries require a large amount of water. For example, nuclear power plants need a significant amount of water for cooling.

Proceed to the Industrial Learning Station (#8)

Card #4

A sudden heat wave causes your raindrop to evaporate back into the raincloud.

Proceed back to the Cloud (#1)

Learning Station 7 Residential

The average per capita water consumption in the United States exceeds 550 liters (250 gallons) per day, the most of any country. Activities that consume large amounts of water include flushing the toilet (26% of household indoor water use), laundry (22%), bathing (19%), and watering outdoor landscaping (averages vary by climate).

Throughout our daily activities, we accumulate numerous pollutants that enter our water cycle when flushed down the drain. Sewage, soap, food scraps, toilet paper, medicine, detergents, toothpaste, common household cleaners, and other chemicals are some examples of common residential pollutants that can enter the water cycle. Some of these pollutants can contribute to waterborne illnesses and can injure and kill aquatic life.

Directions

1. Roll the die.
    a. **Roll 1**: Your raindrop is polluted with phosphorous from the dishwashing detergent. Add one tablespoon of dishwashing detergent.

    b. **Roll 2**: Your raindrop is polluted with human waste. Add one teaspoon of chocolate sprinkles.

    c. **Roll 3**: Your raindrop is polluted with leftover medicine flushed. Add one tablespoon of maple syrup.

    d. **Roll 4**: Your raindrop is polluted with food wastes. Add one tablespoon of cereal/crackers.

    e. **Roll 5**: Your raindrop is polluted with other household waste. Add a square of toilet paper.

    f. **Roll 6**: The household uses phosphate-free laundry detergent. Your raindrop remains clean.

2. Roll the die again.
    a. **Roll 1, 2, 3 or 4**: Your raindrop is flushed and enters the sewer. Proceed to the Water Treatment Center (#10).

    b. **Roll 5 or 6**: Your raindrop runs down a storm drain into the environment Proceed to the Ocean (#11).

Learning Station 8 Industrial

Industries, small and large, use large quantities of freshwater on an annual basis. **Effluents** (waste discharges) from manufacturing processes release pollutants that affect surface water sources and groundwater. Toxic chemicals and heavy metals that can build up in the tissue of plants and animals in increasing amounts through the food chain (a process called **bioaccumulation**).

Heat (**thermal pollution**), nutrients (increased nutrient loads can cause **euthrophication**, a process that depletes the **dissolved oxygen** supply). When **cooling water** is discharged back into surface waters its temperature is typically substantially higher than the water with which it is being mixed. The warmer water holds less dissolved oxygen and disrupts the natural aquatic ecosystem.

Directions

1. Roll the die.
   a. **Roll 1 or 2**: Your raindrop is polluted with waste discharge from a manufacturing plant. Add 3 drops of blue food dye to represent chemicals.

   b. **Roll 3 or 4**: Your raindrop was used in a power plant cooling process and polluted with thermal pollution. Add 3 drops of yellow food dye.
   This can cause a rapid increase in plant and algal growth. When the plants and algae decompose they reduce oxygen levels in the water. If oxygen levels decrease too low, they can create a hypoxic zone devoid of aquatic life because the oxygen levels are too low.

   c. **Roll 5**: The hotel uses green detergent and other environmentally friendly practices. Your raindrop becomes part of the water supply for a hotel that uses green detergents. Some hotels are making a commitment to be environmentally sound.

   d. **Roll 6**: The manufacturing plant treated their wastewater to remove chemicals. Your raindrop remains clean. Some industries have modified their manufacturing processes to minimize waste production or recycle their wastes, while many others use some type of **industrial wastewater treatment** technology in order to treat their wastewater.

2. Proceed to the Water Treatment Plant (#10).

Learning Station 9 Agricultural Irrigation

Agriculture in the United States accounts for 80 percent of the nation's consumptive water use. Where we choose to grow crops and raise market animals also has impacts on water consumption and water quality. Some **watersheds** may lack sufficient water supplies for suitable agricultural production; however, through human interventions such as **irrigation**, **diversions**, and **impoundments**, sufficient water supplies can be obtained.

Irrigation is a process whereby water is artificially applied to land for the purpose of assisting in crop production. This is accomplished by diverting water from one area to another, typically through pipes, canals, or ditches. Water impoundments, areas where water collects (e.g., reservoirs or ponds) that are the result of the construction of a dam or embankment, or by digging a large depression in the earth, often times facilitate irrigation. Furthermore, impoundments may serve as surface water sources for fish, and wildlife, aquaculture, recreation, and fire control.

Efficient irrigation methods conserve water and minimize water contamination. Efficiencies of three types of irrigation systems include:

- **Surface Systems (e.g. wild flood) - 30% efficient** - water is applied to the entire field and can run off the field.
- **Sprinkler System (e.g. traveling gun) - 65% efficient** - operated under pressure through perforated nozzles
- **Micro-Irrigation (e.g. microspray or mist) - 85% efficient** - low pressure systems that spray or sprinkle water over fields.

Directions

1. Choose the irrigation system you want to use.

2. Roll the die. The number rolled symbolizes the volume of water used to irrigate the crops.

3. Calculate the net water applied (cm3) using this formula:
   Net Water Applied (cm3) = Number Rolled x 10 x % efficiency of the irrigations system chosen
   Note: When multiplying by a percentage, convert the percentage to the appropriate decimal equivalent (65% = 0.65)

4. Proceed to the Learning Station based on your calculation:
   a. Net Water Applied >= 20 cm3 = Your raindrop reached the ground and drained into surrounding areas. Proceed to the Agricultural Runoff Learning Station (#4).

   b. Net Water Applied < 20 cm3 = Your raindrop has evaporated. Proceed to the Cloud (#1).

Learning Station 10 Water Treatment

Domestic **wastewater treatment** (**sewage treatment**) facilities address some issues associated with water quality. Wastewater needs to be treated because it may contain harmful **pathogens**, **toxins**, and **organic matter** that can have damaging effects on human health and the health of the local watershed.

Residential wastewater treatment is typically a four-step process:

1. In the **preliminary treatment** phase, large objects (e.g., sticks and other debris) are removed when the water passes through a large bar screen.

2. During **primary treatment**, impurities such as solid waste (which settles to the bottom) and oils (which rise to the top) are physically separated from the water.

3. The **secondary treatment** phase is where micro-organisms digest dissolved organic matter from the wastewater.

4. In the **final treatment** phase, any remaining harmful micro-organisms are killed using chlorine or ultra-violet disinfection. Prior to the treated water being returned to surface water sources, excess chorine is removed.

Directions

1. Pour your raindrop through the filter in the funnel.
   As the water filters through and is collected in the cup below, what observations can you make about the resulting effluent? Is there any residue left on the filter?

2. After pouring your water through the filter, proceed back to the Cloud (#1).

Learning Station 11 Ocean

Water that enters the natural water cycle through rivers, streams, and surface runoff resulting from natural or human-induced activities can have numerous environmental effects. As water travels down to the lowest point, it may pick-up natural or human-created pollutants.

Directions

1. Pour your raindrop into the large bucket (using the funnel if needed).
   As the water filters through and is collected in the cup below, what observations can you make about the resulting mixture?

2. After pouring your water into the bucket, proceed back to the Cloud (#1).

Eryanne Edgerley