Overwithdrawal: Removal of groundwater over a period of time that exceeds the recharge rate.

Percolation: The movement of water through the openings in rock or soil.

Permeability: Capability of a substance to transmit water (porous rock, sediment, or soil); the rate at which water moves through rocks or soil.

Plume: An underground pattern of contaminant concentration created by the movement of groundwater beneath a contaminant source.

Point source contamination: Contaminants discharged from any identifiable point.

Pore space: Openings between geologic material found underground. Also referred to as void space or interstices.

Porosity: The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated small grain sand contains less water than coarse gravel.

Precipitation: The part of the hydrologic cycle when water falls, in a liquid or solid state, from the atmosphere to earth (rain, snow, sleet, hail, etc.).

Recharge: Replenishment of groundwater supplies when water such as rain or snow melt is added to an aquifer.

Remediation: Containment, treatment, or removal of contaminated groundwater or the containment, treatment, or removal of contaminated soil above the water table.

Runoff: Precipitation that flows across the surface of the land to streams, rivers, and lakes.

Safe yield: The amount of water that can be taken from a source of supply over a period of years without depleting the source beyond its ability to be replenished naturally. Also referred to as sustainable yield.

Saturation zone: The portion of the earth's crust that's saturated with water. The upper surface of this zone, open to atmospheric pressure, is known as the water table.

Surface water: Water above the surface of the land, including lakes, rivers, streams, ponds, floodwater, and runoff.

Sustainable yield: See safe yield.

Transpiration: The process by which water absorbed by plant roots is evaporated into the atmosphere from plant leaves.

Unconfined aquifer: Groundwater that is below porous materials such as soil, sand, and gravel.

Unsaturated zone: The zone immediately below the land surface where the pores contain both water and air, but are not completely saturated or soaked with water. Also referred to as the aeration zone or vadose zone.

Water cycle: See hydrologic cycle.

Water table: The top of an unconfined aquifer; indicates the level below which soil and rock are saturated with water.

Water treatment: The processes of making water more acceptable for a desired use (such as drinking, industrial processes, or to discharge into the environment without adverse impact).

Well: A hole drilled or bored into the earth to obtain water.

Well closure: The process of sealing a well that is no longer being used to prevent groundwater contamination and harm to people and animals.

Well screen: Part of a well that prevents sediment and rock particles from clogging the well and from being pumped into the water supply.

Well siting: The process of selecting a location (or site) to install a well that will allow access to adequate water quantity and offer protection to water quality.

Withdrawal: The removal of water from a surface water or groundwater source.

GROUNDWATER is one of our most valuable natural resources. It nourishes our families and communities, helps grow our food, is an important part of watersheds, and recharges surface water and wetlands. Everyone needs to understand and appreciate groundwater, and take action to protect it.

The Groundwater Foundation makes learning about groundwater fun and understandable for youth and adults.

Groundwater Foundation
601 Dempsey Rd.
Westerville, OH 43081
1-800-858-4844
www.groundwater.org

www.awesomeaquifer.com

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GROUNDWATER FOUNDATION

The Awesome Aquifer Kit is a fun and educational groundwater kit that includes everything you need to construct your very own groundwater flow model. It includes accessories and detailed activity instructions for experiments that demonstrate:

- aquifer construction
- connections between surface water and groundwater
- porosity and permeability
- contamination and remediation

AWESOME AQUIFER KIT CONTENTS:

- durable, clear plastic activity and storage box with lid
- illustrated activity book
- well simulators
- contamination and remediation supplies
- aquifer construction materials

awesome aquifer

ADVANCED HYDROGEOLOGY KIT

TABLE OF CONTENTS

Groundwater is the water we drink and the water that grows our food. We all rely on groundwater in some way, and groundwater relies on us to protect it. Learn more, get involved—collectively we make a difference!

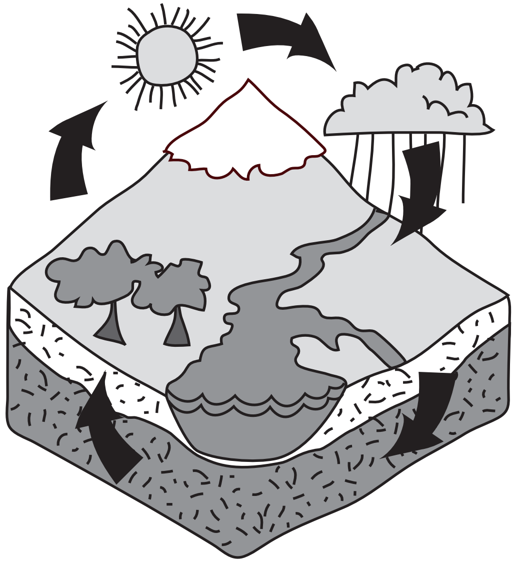
GROUNDWATER FOUNDATION

The Groundwater Foundation is a nonprofit organization that connects people, businesses, and communities through local groundwater education and action, making us all part of the solution for clean, sustainable groundwater. The Groundwater Foundation is operated by the National Ground Water Association.

GETTING STARTED WITH GROUNDWATER

Water Makes the Earth a Dynamic Planet

Water is constantly on the move—it evaporates, condenses, and returns to the earth as precipitation in a cycle called the water cycle or hydrologic cycle.



Groundwater is an important part of the water cycle. Precipitation and snowmelt replenish, or recharge, groundwater supplies. Groundwater is discharged from springs into lakes and streams, evaporates, forms clouds, and the cycle begins again. Water is also absorbed by plant's roots, which nourishes the plant then evaporates from the leaves in a process called transpiration.

GROUNDWATER GLOSSARY

Aquifer: Underground geological formations capable of storing and yielding water.

Area of influence: The land surface overlying the cone of depression.

Artesian well: A well tapping a confined aquifer. The water in the well does not need to be pumped because it is under pressure and forced to the surface naturally.

Condensation: The process in the hydrologic cycle by which a vapor becomes a liquid; the opposite of evaporation.

Cone of depression: The zone around a well in an unconfined aquifer that is normally saturated, but becomes unsaturated as a well is pumped.

Confined aquifer: Groundwater that is bound between layers of impermeable substances like clay or dense rock.

Confining layer: Geologic material with little or no permeability; water does not pass through this layer or the rate of movement is extremely slow.

Conservation (water conservation): The use of water-saving methods to reduce the amount of water needed for homes, lawns, farming, and industry.

Contaminant: Any substance that when added to water (or other substance) makes it impure and potentially unfit for consumption or use.

Depletion: The loss of water from surface water reservoirs or groundwater aquifers at a rate greater than that of recharge.

Discharge: An outflow of water from a stream, pipe, groundwater aquifer, or watershed; the opposite of recharge.

Drawdown: The lowering of the groundwater level caused by pumping.

Drought: An extended period with little or no precipitation.

Evaporation: The conversion of a liquid (water) into a vapor (or gaseous state) usually through the application of heat energy during the hydrologic cycle; the opposite of condensation.

Flow rate: The time required for a volume of groundwater to move between points.

Groundwater: Water found in the spaces between soil particles and cracks in rocks underground (located in the saturation zone). Groundwater is a natural resource that is used for drinking, recreation, industry, and growing crops.

Groundwater quality: The chemical, physical, and biological characteristics of groundwater with respect to its suitability of a particular use.

Groundwater under the direct influence: A source of groundwater located close enough to surface water to receive direct surface water recharge.

Hydrogeology: The study of groundwater.

Hydrologic cycle: (also known as the water cycle) The paths above and below the earth's surface that water takes through its various states—vapor, liquid, and solid—as it moves through the ocean, atmosphere, groundwater, etc.

Hydrology: The study of all waters of the earth.

Impermeable: A material through which water cannot pass.

Infiltration: The process of water soaking into the soil and sub-layers.

Leachate: Liquids that percolate through soil while carrying undesirable substances or contaminants.

Mining: See overwithdrawal

Monitoring well: A non-pumping well, generally of small diameter, that is used specifically to measure the elevation of the water table and analyze water quality.

Nonpoint source contamination: Contamination discharged over a wide land area, not from one specific location.

Overdraft: See overwithdrawal.

13. Once groundwater is contaminated it can be costly and difficult to remediate.

- **Remediation** is the containment, treatment, or removal of contaminated groundwater, or the containment, treatment or removal of contaminated soil above the water table.

14. Remediate the contaminated groundwater (colored water). Fill one of the small plastic measuring cups half full with charcoal. *TIP: Before the charcoal is used for the first time, it must be rinsed thoroughly with cool water to remove excess dust then thoroughly dried.*

15. Dispense the colored water from the syringe into the cup with the charcoal, filling the cup ¾ full.

16. Make a lid for the cup.

a) Cut a small piece (roughly 4 x 4 inches) of plastic cling wrap so that it fits over the top of the cup (plastic cling wrap is not included in kit).

b) Secure the plastic to the cup with a rubber band.

17. Gently shake the cup with the contaminated water and charcoal for 30-60 seconds.

18. Remove the plastic wrap and rubber band.

19. Make a second lid from a piece of coffee filter paper.

a) Cut a small piece (roughly 4 x 4 inches) of coffee filter.

b) Secure the piece of coffee filter to the cup with a rubber band.

20. Invert the cup and drain the water from the cup through the filter into the second plastic measuring cup.

21. The water should no longer be the color of the food dye. *TIP: The water may need to be filtered a few more times through a piece of coffee filter in order to separate out all the charcoal dust particles. Depending upon the concentration of food dye, this process may need to be repeated.*

Extension

A. Experiment with other materials for building a filter or treatment device such as small sponges, floral foam, cheese cloth, etc.

B. Experiment with other materials for contaminating the groundwater, such as powdered drink mix.

C. Research other forms of water treatment and groundwater remediation. Discuss prevention of groundwater contamination versus the cost of clean-up.

Learn More

www.awesomeaquifer.com
www.groundwater.org/action
www.groundwater.org/get-informed

CLEAN YOUR KIT AFTER EACH USE

To extend the life of your Awesome Aquifer kit, rinse all parts with water after each use and allow to air dry.

TIP: Pour gravel, sand, or carbon into a mesh colander or strainer for easy rinsing.

Groundwater can be found almost everywhere. Think of groundwater as water that fills the spaces between rock, sand, and soil underground, in much the same way that water fills a sponge.

Groundwater begins in the water cycle as precipitation that soaks into the ground. Groundwater is stored in—and moves slowly through—layers of soil, sand and rock called **aquifers**. Water in aquifers is brought to the surface naturally through a spring or can be **discharged** into lakes and streams. Groundwater can also be extracted through a **well** drilled into the aquifer, which is a pipe in the ground that brings groundwater to the surface, generally by a pump. Some wells, called **artesian wells**, do not need a pump because of natural pressures that force the water up and out of the well.

The **water table**, which is the top of where an aquifer is saturated with water, may be deep or shallow, and may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise, or an extended period of dry weather may cause the water table to fall. In some areas of the world, people face serious water shortages because groundwater is used faster than it is naturally replenished.

Groundwater Is Important to Everyone!

About 45 percent of the U.S. population depends on groundwater for its drinking water. Groundwater is also one of the most important sources of water for irrigation. Groundwater supplies water for surface water bodies such as rivers, streams and wetlands. When groundwater is used faster than it is recharged, it is depleted, which can be a serious problem. Streams and wetlands may dry up, irrigation and domestic wells can run dry, and cities, countries, and homes can run short of water.

In addition, groundwater is susceptible to pollutants. There is a very real concern that the amount of groundwater contamination may increase as toxic chemicals that have been dumped on the ground during the past several decades move slowly into groundwater supplies. As a result, we all need to protect groundwater quality and quantity.

How Can I Help Protect and Conserve Groundwater?

You can begin by learning everything you can about groundwater. The experiments in the *Awesome Aquifer Kit* are a great place to start! You can do other important things in your home, too. For example, everyone can:

1. Dispose of chemicals properly.
2. Take used motor oil to a recycling center.
3. Limit the use of fertilizer, pesticides and other toxic chemicals.
4. Take short showers.
5. Shut off water while brushing teeth.
6. Run full loads of dishes and laundry.
7. Detect and fix leaky faucets.
8. Water outside only when necessary.
9. Keep a pitcher of drinking water in the refrigerator.
10. Teach others about groundwater.

And remember, groundwater is a very important part of the hydrologic or water cycle. If groundwater supplies are depleted, there will be less water in our lakes and rivers and less for us to use. All living things depend on water for life. Although it is hidden, groundwater is key to life everywhere on Earth.

THE AWESOME AQUIFER KIT INCLUDES:

- Clear plastic container
- Illustrated activity book
- Gravel, sand, and clay
- Activated carbon charcoal*
  *The carbon charcoal must be thoroughly rinsed and dried before it is used for the first time.
- Nylon hose
- Plastic tube
- Rubber bands
- Syringe
- Hand pump
- 2 small plastic measuring cups
- Liquid food dye
- Coffee filter

NOTE: Be sure to thoroughly rinse and dry all components after each demonstration. Refer to page 13 for directions.

NATIONAL EDUCATION STANDARDS

Activities in the Awesome Aquifer Kit are correlated to the following Next Generation Science Standards (NGSS):

K-ESS3-1, K-ESS3-3, 2-ESS2-2
K-2-ETS1-1, K-2-ETS1-2, 2-ESS1-1
HS-ESS2-5, MS-ESS3-1
2-ESS2-3, HS-ESS3-1, MS-ESS2-4

OTHER THINGS TO TRY THAT AREN'T INCLUDED IN THIS KIT

Experiment with different materials and tools from around your home to see how you can improve the design and function of your Awesome Aquifer Kit model. Try some of these common household items with the Kit's activities, and see what else you can learn about groundwater:

- Floral foam or styrofoam
- Cotton ball
- Sponge
- Foil
- Cling wrap
- Drinking straw
- Eye dropper
- Cheese cloth
- Window screen
- Paper towel
- Plumber's putty
- Other colors of food dye
- Powdered drink mix
- Baking soda and vinegar
- Spray or squeeze bottle
- Paper clip
- Toothpick or thumb tack
- Decorative plastic foliage or aquarium plants
- Different grade (size) gravel and sand

CLEAN IT UP: *CAN CONTAMINATED WATER BE CLEANED?*

Materials

- Water
- Clear plastic container
- 2 small plastic measuring cups
- Plastic tube
- Hand pump
- Gravel
- Clay
- Nylon hose
- Rubber bands
- Liquid food dye
- Syringe
- Activated carbon/charcoal (rinse and dry prior to first use)
- Coffee filter
- Small piece of plastic cling wrap or similar plastic (not included)

Procedure

1. Pour gravel into the clear plastic container and spread out evenly.
2. Slowly pour water into the container. Stop adding water when about half of the gravel is saturated.
3. Scoop gravel from the middle of the container, digging down to the water table. Push the gravel to the sides of the container to create a lake.
4. Build two wells. One well will be made from the plastic tubing provided.
  a) Cut a small piece of nylon hose (about 1 inch by 2 inches), and fold in half.
  b) Cover one end of the tube with the nylon securing it with a rubber band.

  Use the hand pump provided for the second well.
  a) Cut a small piece of nylon hose (about 1 inch by 2 inches) and fold in half.
  b) Cover one end of the tube with the nylon securing it with a rubber band.
5. Insert the wells in two different corners of the model on opposite sides of the lake. The end of the tube with the nylon cover is the bottom of the well.
6. Pump water from each well, one with the syringe, the other with the hand pump. Observe the water that is pumped. The water should be clear.
7. Fill one of the small measuring cups with water.
8. Add 2-4 drops of liquid food dye to the cup of water. This cup of colored water will represent contamination.
9. In one of the corners of the model that does not house a well, slowly pour the entire cup of contamination.
10. Observe the contaminant as it infiltrates the groundwater.
11. Pump water from the well that is closest to the contaminant spill with a syringe. *TIP: Pump until water drawn from well is colored.*
12. Set the syringe filled with the colored water aside.

10. Observe the contaminant as it infiltrates the groundwater.

11. Pump the well on the opposite end of the model. Watch the surface water as the well is being pumped. Notice the color of the water that was pumped from this well. Collect the pumped water in a separate container.

12. Pump the well that is closest to the contamination site. Notice the color of the water that was pumped from this well.

- In groundwater, a pattern of concentrated contaminant created by the movement of groundwater beneath a contaminant source is called a **plume**. Contaminants generally spread laterally in the direction of groundwater movement. The source site has the highest concentration of contamination, while further away from the source the concentration is decreased.

13. Discuss how this contamination can affect humans and the environment.

Extension

A. Experiment with other ways to contaminate the groundwater that are representative of real threats to groundwater quality. **Do not use actual hazardous and harmful chemicals.** What are some potential groundwater contamination sources produced by human activities? What are examples of naturally-occurring groundwater contamination sources?

- Groundwater quality is characterized by the chemical, physical, and biological characteristics of the water with respect to its suitability for a particular use.

B. Demonstrate the difference between point and non-point contamination.

- **Point source contamination** is contamination discharged from any identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types.
- **Non-point source contamination** is contamination discharged over a wide land area, not from one specific location. It occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients, road salt, and pesticides.

C. Demonstrate how well closure can prevent contamination of groundwater. What impact does a well have on groundwater quality?

- **Well closure** or properly abandoning a well is the process of sealing a well that is no longer being used.

Learn More

www.awesomeaquifer.com

www.groundwater.org/contamination

GROUNDWATER AND SURFACE WATER: *ARE THEY CONNECTED?*

Materials

- Water
- Clear plastic container
- Gravel

Procedure

1. Pour gravel into the clear plastic container and spread out evenly.

- An **aquifer** is an underground geologic formation able to store and yield water. The gravel in this container will represent land and an **unconfined aquifer**.

2. Add water. Slowly pour the water near a wall of the container, which will allow the water infiltrating the aquifer to be more visible. Stop adding water when about half of the gravel is saturated.

- **Groundwater** is water found underground in the cracks and spaces between soil, sand, and rock. Groundwater is a natural resource that is used for drinking, recreation, industry, and agriculture. Groundwater is stored in aquifers.
- Groundwater **recharge** occurs when water added to an aquifer, for example when rainwater or surface water seeps into the ground.
- **Infiltration** is the flow of water from the land's surface into the subsurface.

3. Locate the water table.

- The **water table** is the top of the groundwater or the top of an aquifer. The area below the water table is called the **saturated zone**. The area above the water table, that does not contain water, is called the **unsaturated zone.**

4. Scoop gravel from the middle of the container, digging down to the water table. Push the gravel to the sides of the container allowing the water to create a lake.

- **Surface water** is water above the surface of the land, including lakes, rivers, streams, ponds, floodwater, and runoff.

5. Slowly add more water, pouring the water on the gravel close to the sides of the container. Again, watch how the water **percolates** down through the gravel and becomes groundwater. This time, observe what happens to the level of the surface water.

- **Discharge** is the outflow of water from one location to another. For example, when poured on the surface, the water infiltrated the ground and became groundwater. The water then discharged from the aquifer into the lake, causing the level of the lake to rise.

6. Add water directly to the lake. Watch the water table level. The water in the lake is recharging the aquifer, causing the water table to rise.

- When a source of groundwater is located close enough to surface water to be recharged, the groundwater is **under the direct influence** of surface water. Groundwater under the direct influence of surface water can easily be contaminated by surface pollution.

Extension

A. Demonstrate how groundwater is a part of the hydrologic cycle (think about surface water, evaporation, condensation, precipitation, runoff, recharge, groundwater, discharge, surface water). Use a spray bottle or cup with holes punched in the bottom to sprinkle rain on the model, add hills, and a river to the model.

B. Add different layers of strata to your model by using different materials (different grades of gravel, sand, soil, clay, etc.). Include a confined aquifer or confining layer to the model. Experiment with different materials such as sand, clay, or foil to create bottoms of the surface water bodies in the model.
- **Confined aquifers** exist where the groundwater is bounded between layers of impermeable substances like clay or dense rock (such as shale or granite). When under enough pressure, water will be forced to break through the Earth's surface forming an artesian spring. A well installed in a confined aquifer will have water flowing freely from it and not require the power of a pump. This type of well is called an **artesian well**.
- A **confining layer** is a geologic material with little or no permeability or hydraulic conductivity. meaning water is not able to pass through this layer or the rate of movement is extremely slow. *TIP: Use the modeling clay to make a confining layer by pressing the clay tightly to all edges and making a thin layer of clay across the surface. More sand or gravel can be added to the top.*

PUMPING THE SUPPLY: *IS GROUNDWATER A RENEWABLE RESOURCE?*

Materials
- Water
- Clear plastic container
- Gravel
- Clay
- Nylon hose
- Rubber band
- Hand pump
- 2 small plastic measuring cups

Procedure
1. Pour gravel into the clear plastic container and spread out evenly.
2. Slowly pour water into the container. Stop pouring water when about half of the gravel is saturated.
3. Scoop gravel from the middle of the container, digging down to the water table. Push the gravel to the sides of the

CONTAMINATION CLUES: *HOW DOES GROUNDWATER BECOME POLLUTED?*

Materials
- Water
- Clear plastic container
- Gravel
- Clay
- 2 small plastic measuring cups
- Plastic tube
- Hand pump
- Nylon hose
- Rubber bands
- Liquid food dye
- Syringe

Procedure
1. Pour gravel into the clear plastic container and spread out evenly.
2. Slowly add the water into the container. Stop adding water when about half of the gravel is saturated.
3. Scoop gravel from the middle of the container, digging down to the water table. Push the gravel to the sides of the container to create a lake.
4. Build two wells. One well will be made from the plastic tubing provided.
   a) Cut a small piece of nylon hose (about 1 inch by 2 inches), and fold in half.
   b) Cover one end of the tube with the nylon securing it with a rubber band.

   Use the hand pump provided for the second well.
   a) Cut a small piece of nylon hose (about 1 inch by 2 inches) and fold in half.
   b) Cover one end of the tube with the nylon securing it with a rubber band.
5. Insert the wells in two different corners of the model on opposite sides of the lake. The end of the tube with the nylon cover is the bottom of the well.
6. Pump water from each well with the syringe. Observe the water that is pumped. The water should be clear.
   - A **monitoring well** is a well that is used only to draw water samples for water testing as well as water table depth.
7. Fill one of the small measuring cups with water.
8. Add 2-4 drops of liquid food dye to the cup of water. This cup of colored water will represent contamination.
   - A **contaminant** is any substance that when added to water (or another substance) makes it impure and unfit for consumption or its intended use. Some potential groundwater contaminants include pesticides, fertilizers, road salt, motor oil, untreated waste water, landfill leachate, chemicals from mining and industry, and leaking underground storage tanks.
9. In one of the corners of the model that does not house a well, slowly pour the entire cup of contamination.

EXPLORE PERMEABILITY: *DOES WATER MOVE AT DIFFERENT SPEEDS?*

Materials

- Water
- Gravel
- Sand
- Syringe
- Clear plastic container
- Small plastic measuring cup
- Writing utensil
- Paper
- Stopwatch (optional)

Procedure

1. Estimate which material water will travel through the fastest – sand or gravel. Record your theories on a sheet of paper.

2. Take the syringe apart by removing the inside piece of the syringe.

3. Fill the syringe to the top with gravel.

4. Measure one ounce of water with one of the small cups.

5. Hold the syringe with gravel above the clear plastic container.

6. Pour the water into the syringe.

7. Observe the speed of the water as it travels through the syringe.
- The time required for a volume of groundwater to move between two points is called the **flow rate**. Typically groundwater moves very slowly, sometimes only inches per year.

8. Empty the syringe. Wash out and dry.

9. Fill the syringe with dry sand.

10. Repeat steps 3-8.

11. Discuss which material (sand or gravel) was able to transmit water at a faster rate.

12. Discuss which material (sand or gravel) is more permeable.
- **Permeability** is the capacity of transmitting water. The rate at which water moves through rock, soil, or sand. In this activity, the water moves at a faster rate through the gravel than the sand.

13. Discuss if porosity and permeability are related concepts.
- Materials with more **pore space** (or open space) can hold a larger volume of water. More pore space also provides a quicker flow of water through the material. Materials that have a higher porosity tend to have a higher permeability. Clays, however, have a very low permeability but are very porous. Clays can hold a lot of water but do not release water quickly. Materials that cannot transmit water are called **impermeable**. Shale and granite layers are examples of materials often considered impermeable.

Extension

A. Use a clock or stopwatch to time the rate the water travels through the material.

B. Does the permeability change when the material is compacted? Tap the bottom of the container while adding the sand or gravel in order to compact and settle the material. *TIP: Best if done in containers larger than the syringe provided, such as a funnel.*

container to allow the water to create a lake.

4. Cut a small piece of nylon hose (about 1 inch by 2 inches), and fold into a smaller square.

5. Cover the end of the hand pump tube with the nylon, securing it with a rubber band. This creates a well and well screen.
- A **well** is a bored, drilled or driven shaft, or a dug hole whose purpose is to reach underground water supplies to inject, extract, or monitor water.
- A **well screen** is a part of a well that prevents sediment and rock particles from clogging the well and from being pumped into the water supply.

6. Insert the well into the gravel. Choose a location and depth that will allow an adequate amount of water to be pumped. *TIP: The well should be inserted so that the base (with the nylon cover) touches the bottom of the container. Placing the well against the side of the container and stabilizing it with a small amount of clay can be helpful.*
- Water quality protection, adequate water quantity, and accessibility for inspection and maintenance should all be considered when finding a location to install a new well. The process of selecting a location for a well is called **well siting**.

7. Pump the water out of the container with the well. *TIP: Use two small plastic cups or other container to hold the pumped water*.
- **Withdrawal** is the removal of water from a body of surface water or groundwater source.

8. Observe the level of the water table and the lake as the well is pumped.

9. Continue to pump the well. What begins to happen to the amount of water available for withdrawal?
- **Drawdown** is the lowering of the groundwater level caused by pumping.
- If water is being pumped but no water is added to the aquifer, what will happen? **Depletion** is the loss of water from surface water reservoirs or groundwater aquifers at a rate greater than that of recharge.
- Withdrawal of groundwater over a period of time that exceeds the recharge rate is referred to as **overwithdrawal**, **overdraft**, or **mining** of the aquifer.

11. Discuss the complications that may result from mining an aquifer.

12. Recharge the aquifer by adding water to the container.

13. Again, pump the well. As the water is withdrawn add water to the aquifer by having it rain over the container.
- **Safe** or **sustainable yield** is the amount of water that can be taken from an aquifer over a period of time without depleting the source beyond its ability to be replenished naturally.

14. Discuss the value of pumping a well at its safe yield.

Extension

A. Rebuild the aquifer and include a confining layer. How does a confined aquifer respond to drawdown and recharge?

B. Demonstrate the effects of pumping wells at various depths.
C. Research and demonstrate factors affecting well location due to water quality concerns.
D. Rebuild the aquifer with sand or a mixture of sand and gravel. Does the material the aquifer is made of affect the recharge and pumping rates?
E. Demonstrate and explain a cone of depression. *TIP: This is best demonstrated in sand.* The zone around a well in an unconfined aquifer is normally saturated, but becomes unsaturated as a well is pumped, leaving an area where the water table dips down to form a cone shape called the **cone of depression**. The shape of the cone is influenced by porosity and the water yield or pumping rate of the well. The land surface overlying the cone of depression is referred to as the **area of influence**. Generally the faster and greater volume of water being pumped the larger the cone of depression. The cone of depression may cause pollution to travel more quickly to the area around a well.

Learn More

www.awesomeaquifer.com

www.groundwater.org/wells

www.groundwater.org/glossary

www.groundwater.org/watercycle

DISCOVER POROSITY: *WHICH HOLDS MORE WATER, SAND OR GRAVEL?*

Materials

- Water
- 2 small plastic measuring cups
- Syringe
- Gravel
- Sand
- Writing utensil
- Paper
- Calculator (optional)

Procedure

1. Estimate the volume of the small plastic cup in cubic centimeters (cc). Record your estimates on a sheet of paper.
2. Fill the syringe to the 35cc line. Dispense the water from the syringe into the plastic cup until the cup is filled to the rim.
3. Determine how many cubic centimeters of water are held in the cup by subtracting the amount of water left in the syringe from the initial amount, 35cc. Record this amount. For example, if the syringe initially held 35cc and after filling the cup there are 5cc left in the syringe, the cup holds 30cc.
4. Empty and dry the cup.
5. Fill the cup with dry gravel.
6. Estimate how many cubic centimeters of water can be added to the cup filled with gravel. Record your estimation.

7. Fill the syringe with 35cc water. Dispense the water from the syringe into the cup with the gravel.

8. Subtract the amount left in the syringe from the initial amount. This is how much water fits in the spaces between the gravel. Record this amount.
9. Fill the second cup with dry sand.
10. Repeat steps 6-8 with the cup holding the sand.
11. Discuss which material, sand or gravel, was able to hold more water.
12. Discuss which material, sand or gravel, is more porous.
- **Porosity** is the capacity of rock, sand, soil, or other sediment to hold water. Porosity is measured as a ratio of the volume of void spaces in a particular sediment to the total volume of the sediment. Both sand and gravel are porous materials. Coarse gravel is more porous than fine grain sand.

13. To find the porosity of each material first determine the volume of material in each cup. *TIP: The volume of sand and gravel in the cup will be equal to the volume of water the cup is able to hold when full. If the cup holds 30cc of water when filled to the rim, the cup will also hold 30cc of sand or 30cc of gravel.*
14. Divide the volume of water that you were able to add to the material by the total volume of material. This fraction will give you the porosity of the material. Porosity is always expressed as a fraction or percent. For example, if 15cc of water were added to a cup filled with 30cc of gravel, divide 15 by 30 and multiply by 100 to get a percent. In this example the porosity of the gravel would be 50%.

Extension

A. Try the activity again using larger containers. Does the porosity of sand and gravel change?
B. Tap the bottom of the container while adding the sand or gravel in order to compact and settle the material. Does the porosity change when the material is compacted? *TIP: This is best if done in containers larger than the cups provided.*
C. Mix sand and gravel together. Test porosity and compare with results of pure sand and gravel. How does mixing materials affect porosity?
D. Find sands, gravels, and soils with different grain size than provided. Test porosity and compare results. How does grain size affect porosity?

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