WATER FOR LIFE
LESSON

DRIVING QUESTION: HOW DO WELLS WORK?

Recommended Grades: K – 6; Adaptations for 7 – 12.

Classroom or Center Activities	*Outside or Larger Space Activities*	*Technology-Based Activities*	*Stem-to-Go Take Home*	*Field Work and/or Natural Area Needed*
X	X	X	X	X

Materials: Three clear plastic cups, pea gravel, play sand, food coloring, pourable pitcher or graduated measuring cup of water, (1) 10 or 25 milliliter graduated cylinder (measuring spoons and cups can be substituted if needed), two plastic straws, scissors, dropping pipet or medicine dropper that can fit tightly inside a straw, Water Test Strips for testing aquarium water.

Teacher Prep: <15 Minutes

Participant activity: 30 minutes

Objectives:

1. Predict then observe how water moves (infiltrates) through the earth to become groundwater that is stored in an aquifer.
2. Use metric measurements and calculate how much water an aquifer can hold (porosity).
3. Observe how water and contaminants move thorough aquifers (permeability).
4. Infer which aquifers are more vulnerable to pollution, like pesticides and fertilizer.
5. Measure chemical parameters to determine if water is within safe levels.
6. Apply observations from the aquifer models to connect with water quality issues in North Carolina.

STEM Skills

S: Predict and test hypotheses.

T: Use tools to measure metric units.

E: Apply a model to real world issues.

M: Analyze and interpret data through graphs.

Teacher Tips: WATER FOR LIFE

Plan ahead: Inexpensive graduated cylinders and dropping pipets are available through Carolina Biological or craft stores, such as Oriental Trading Company, or Michael's. To make your own graduated cylinder, use a medicine dropper to fill known levels in an empty film container or glitter tube. Use a fine tipped permanent marker to mark the increments in milliliters on the side.

Total prep: <15 minutes to make copies, mark cylinders, assemble materials

Safety: Small gravel may be a choking hazard. Participants may need a reminder not to squirt water or dye at one another. Spills may be slippery. Food coloring may dye clothing. Please note: the data collected for water quality may not be able to determine if water is safe to drink.

Sensory Integration Issues: If participants struggle with fine motor skills needed for pipets, pre-pour measured amounts or substitute a teaspoon of 5 milliliters.

Cost: Approximately $3 per person. Generally, pea gravel and play sand purchased from home improvement stores are cost-effective for large groups. Do **not** buy "aquarium sand" from the pet store. It is coated to prevent water from moving through it.

What else do I need? Paper towels/rags. Optional: Clementine oranges for each participant. Optional: Aquarium test strips used for STEM To-Go can be purchased through pet stores.

Clean Up: Hands, equipment, and surfaces can be washed with soap and water. Do not pour sand/ gravel in the sink.

Water for Life Lesson Plan

1. Print it out:
    a. Print out one copy per group: the water cycle from USGS. https://water.usgs.gov/edu/graphics/watercycle-usgs-screen.jpg
    b. Print out one copy of the water survey for each group. https://www.epa.gov/sites/production/files/2017-03/documents/ws-kids-test-your-watersense.pdf
    c. Print one copy per group of the lab print out from NC CAP's Water for Life.
    d. Optional: for 7 – 12th graders, print out or direct students to a pre-assessment on groundwater. https://water.usgs.gov/edu/activity-tf-groundwater.html
2. Activate prior knowledge: The activities involving food/water may be effective at snack time.
    a. How much water do we need? Who uses the most water?
        i. Online water Survey: How much water do we use? Water conservation printable quiz: https://www.epa.gov/sites/production/files/2017-03/documents/ws-kids-test-your-watersense.pdf
    b. (optional) Earth as an Orange/Water Quantity and water distribution using Clementine oranges and fractions: Use a Clementine or another easy to peel orange to model the small fraction of fresh water available for humans.
        i. Where is the world's fresh water? On earth, 97% of water is salt water that humans cannot drink. Peel the orange, and put aside all but one section of the orange.
        ii. Of the 3% of Earth's fresh water, most of the water is found in ice caps and glaciers (not near people). Break that one session into 1/3, and set that aside.
        iii. Of the remaining fresh water, most of it is under the ground, where people need a well to get to it. Set another 1/3 of the orange aside.
        iv. Of the remaining fresh water on the surface of the earth, most of it is found in lakes, then swamps, then rivers and creeks. So, of the 1/3 that is left, you can eat that amount of the orange. This activity was adapted from PLT's Earth as an Apple.
    c. (optional) Taste Test: What does clean water taste like and smell like? What is "water quality" How much does water cost? Compare the price of "fancy" bottled water to water straight from the faucet. Have a "blind" taste test. Can you really tell the difference between bottled water and tap water? Take a vote and tally your results. How do they compare with North Carolina? With other states? With the world? https://water.usgs.gov/edu/activity-watertaste.html
    d. (optional): Water chemistry test: Water is called "the universal solvent," which means that most things break down in water. What kinds of "solutes" are dissolved in your water? The API 5 in 1 Test Strips are easy and economical test strips to explore water chemistry.
    e. (optional) Water Cycle Dance: This is more of a chant to familiarize participants with the water cycle terminology in a fast and fun way by pretending to be a water molecule. It is effective to say the chant once yourself while doing the motion, then prompt the participants to repeat the chant as they copy your motion.
        i. Begin by asking participants to spread around the room, at least arm's length away from one another. The chant is in bold.
        ii. **Evaporation, water vapor all around!** (randomly dispersed participants, spread out around the room, arms raised out to the side and waving around.) Now is the time to explain that the sun is the energy that powers the water cycle. Most of the world's water (about 96.5%) is saltwater in the ocean, but the sun heats it up and changes it from a liquid water to a water vapor.
        iii. **Condensation, into a cloud!** (prompt everyone to put their arms down and come into one irregularly shaped lump all facing into the center of the cloud.) Clouds form when water vapor condenses back into a liquid.

iv. **Precipitation, raining all around!** (prompt everyone to turn to the outside of the clump of people, raise their hands straight up, and wiggle their fingers as they drop their arms down in front of them. Precipitation includes rain,

v. **Runoff, runoff, running on the ground!** (by this point, participants are ready to move away from one another and they, indeed will run. To avoid collisions, remind them that they can still "runoff" using walking feet. Instruct them to keep moving, spreading out away from each other. Then say, "Wait! STOP. SINK!" Everyone should freeze in place for the next step. Then sit, then lay on the floor facing up while you tell them the story of the Ogallala aquifer.

vi. **Infiltration, into the ground!** (Explain that now they are water molecules that are slowly percolating or infiltrating in between the soil water particles,

3. Procedure:

a. Set up the wells: Fill a clear plastic cup about halfway with sand. Fill the other plastic cup with approximately the same amount gravel. Do not tamp or even it out. Compaction can skew the results. These materials represent two types of aquifers: sand and gravel. The spaces in between the particles are the pores. Right now, they are filled with air. Cut a plastic straw in half. Place one section in the center of each cup. That is your well.

b. Predict and test porosity by making puddles: Predict - how much water you think each aquifer can hold? Write it down. Measure water in your graduated cylinder (or measuring cup). Write down how much you start with. Use the dropping pipet to "rain" drops of water along the surface of the aquifer. Watch the water percolate (infiltrate) through the pockets of air. Then when the entire aquifer is filled, and all the pores are saturated with water, you will see puddling at the surface of the cup. Stop, and measure the amount of water you applied. Then repeat the process for the other aquifer. Which aquifer held more water - sand or gravel? How close was your prediction? Generally, if the materials are not patted down, participants will find that sand will hold more water (higher porosity) than gravel. Participants may be surprised that being able to see the large gaps in the gravel do not mean there is more space for water than in the sand. Compare what happens when soil is saturated with water in the cup.

c. Add the pollution to the surface: For this step, make sure that participants do NOT put the food coloring into the straw (well). Add three drops of food coloring on the surface of the aquifer.

d. Remove the pollution through the well: Use the dropping pipet to carefully remove water from the well. Measure how much water must be removed before the food coloring shows up. The faster the pollution moves through the aquifer, the higher the **permeability**, or connectedness of the pore spaces.

4. Data Collection: Participants will measure and write down how much water the aquifers held (porosity). Then, they will measure and write down how much water was removed from inside the well when the food coloring showed up (permeability).

5. Collaboration: Participants should work together to measure and compare their results with other groups. Put a tally in the front of the room. Which aquifer has higher porosity? (Generally, sand.) Which aquifer has higher permeability? (Generally, gravel).

6. Data analysis: Wells are often the only source of water in arid (dry or desert) places. Which well do you think is a better water source, sand or gravel? Why?
7. Resources and Adaptation by participants' ages.
   a. For K – 2: Focus on participants not putting the drops inside the straw (well). Prompt them to watch the color move through the water. They are watching infiltration, a part of the water cycle as the pollution moves through the connected spaces.
   b. For 3 – 5th grades: Ask participants to choose modeling either point source or non-point source pollution. If participants put all of the drops in one spot, that might model point source pollution from a waste water treatment plant in a city, or a leaky gasoline tank under an old gas station, or factory putting out a chemical, or a hog farm's waste lagoon. If participants spread out the three drops of pollution, then it might model non-point source pollution that is carried by rain and runoff across the land, like fertilizer from a corn field or people putting fertilizer on their lawns, or oil in a parking lot puddle from an old car.
   c. For 3 – 7th grades: Does it matter how close the pollution is to the well? What would happen if your straw/well was cracked? Would the pollution get into the well faster? This lends itself to the concept of well head protection. If a farmer uses a garden hose to clean out a pesticide tank near his/her well, then that chemical could get inside the well and contaminate his drinking water.
   d. For 5 – 12th grades: Water chemistry and public health are linked together through the Flint, Michigan community whose public water system caused them to be exposed to Lead, which can cause health and learning problems.
   e. For 7th -12th grades: In addition to wells becoming contaminated from nitrates or pesticides, there are three groundwater issues that have made headlines in North Carolina.
      i. Fracking involves injecting water with other chemicals to force natural gas out of the ground. In North Carolina, some studies have said that the layers of rock containing natural gas tend to be deep within the earth and very far below groundwater. Layers of clay may form a barrier between the gas bearing rock and shallower aquifers. Several studies claim that fracking is unlikely to contaminate North Carolina's groundwater, but many people still worry about fracking as a source of pollution in groundwater. It is very difficult to clean groundwater once it is polluted.
         1. Frack Fights: Fracking information contains strong opinions, contradictory facts, and opposing arguments with easily detectable bias. When does information become propaganda? Ask participants to produce a pro/con fact list on fracking. What do they think? Fracking debates can be a fun project for debate teams, Envirothon teams, and Language Arts connections.
         2. Model Fracking: To model fracking you will need the original materials, plus a small amount of clay or play dough, two different lengths straws so that one goes deep to the bottom of the cup, and one only about an inch deep into the aquifer, and two different dropping pipets. Fill the cup hallway with the aquifer. Form a clay pancake as an impermeable barrier. Put the longer straw into the cup and pat down the layer of clay around the well. Then add the second layer of gravel and the second well, making sure it does not punch through the clay. Saturate the aquifer. Then use one dropping pipet to pick up several drops of food coloring. Using force, squirt the "contaminated" water into the deeper well. Use the clean pipet to remove water out of the other well. What factors may determine whether groundwater would be vulnerable for contamination?
      ii. Saltwater Intrusion: For communities that live near the coast, groundwater can either be fresh or salt water (saline). As a community pumps fresh water out of their wells, a wedge of the denser salt water from the ocean gets sucked into the aquifer, which can make the water unfit for people to drink. To model salt water intrusion and groundwater contamination, use two different colors of food coloring. Prior to assembling the aquifer, place one drop of food coloring in the

bottom of the empty cups, add a teaspoon of salt and roll it around in the food coloring. Add a few drops of water so that the salt dissolves. Then cover it with the gravel aquifer. Repeat the process with the sand aquifer. Continue with the regular assembly of the aquifers, but add a different color of food coloring at the surface. Proceed with the extraction of water from the well. Which colors show up faster?

iii. Corporate Responsibility and Government Oversight: Sometimes surface water pollution from point source pollution can contaminate neighboring wells. Two companies have been considered good neighbors because they provide jobs, make things we need, and contribute to communities. They also have been in the news because their industrial wastes have been deemed point sources of pollution that are contaminating surface and groundwater.

1. Chemours, near Wilmington, makes a variety of chemicals used in everyday items like Teflon pans as well as industrial chemicals. They discharged a chemical from its plant called GenX. At the time, there were not any rules against putting the chemical out into the river, because it was not officially considered toxic, but now neighboring wells and waterways have high levels of what some people say is a potentially harmful chemical. This issue will likely remain in the headlines.
2. Duke Energy funds a lot of positive programs for the environment and for education. Duke Energy also provides electricity to millions of people, much of which was produced by burning coal to power electric plants. Coal's waste product is Coal Ash, which Duke Power stored in ponds lined with impermeable clay. Some of these ponds are leaking and/or overflowed, which allowed coal cash, which contains toxic heavy metals and radioactive elements, to contaminate the Dan River as well as groundwater near the waste sites. Recently, Duke Power asked the state for permission to raise people's power bills/electricity rates. If the state owns the water, should tax funds be used to pay for the damage? Should the company pay for the clean-up? Should power bills help pay for the cost of the clean-up? What do you think?
3. Sometimes, companies that pollute go bankrupt from their problem. Then the EPA's Superfund program may be applied to use taxes collected from industry to clean up hazardous sites. Is there a Superfund site near you? Check out this map. https://www.epa.gov/superfund/search-superfund-sites-where-you-live#map

8. Clean up and Conclusion: Be very careful not to get rocks or sand into the sink. The sand and gravel can be rinsed off with paper towel in a colander to remove the food coloring and reused in terrariums or to reduce erosion in a muddy path.

Resources utilized for the development of the Water for Life

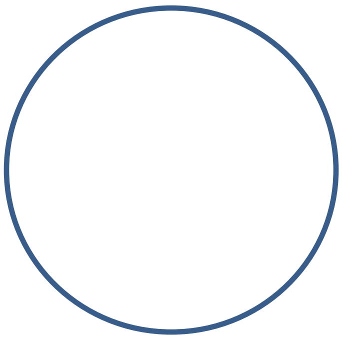
This lesson was adapted from *Project Wet, Every Drop Counts* and the following resources.

https://www.epa.gov/superfund/search-superfund-sites-where-you-live#map
https://water.usgs.gov/edu/activity-watertaste.html
https://water.usgs.gov/edu/graphics/watercycle-usgs-screen.jpg
https://www.epa.gov/sites/production/files/2017-03/documents/ws-kids-test-your-watersense.pdf
https://water.usgs.gov/edu/activity-tf-groundwater.html
https://www.epa.gov/sites/production/files/2017-03/documents/ws-kids-test-your-watersense.pdf
https://19january2017snapshot.epa.gov/www3/watersense/pubs/indoor.html
https://www.epa.gov/sites/production/files/2017-02/documents/ws-ourwater-falw-family-fact-sheet.pdf
https://www.usgs.gov/special-topic/water-science-school
https://www.dailymail.co.uk/sciencetech/article-3101363/Have-drunk-dinosaur-urine-glass-water-contains-100-Jurassic-pee-claim-scientists.html
https://www.fayobserver.com/news/20190306/tests-show-high-levels-of-genx-in-chemours-wells
https://www.scientificamerican.com/article/duke-ordered-to-stop-groundwater-pollution-at-north-carolina-coal-plants/
https://www.newsobserver.com/latest-news/article222355625.html

DRIVING QUESTION: HOW DO WELLS WORK?

Have you heard this poem, "Water, Water everywhere, but not a drop to drink." Did you know that 97% of the Earth's water is too salty (**saline**) for humans to drink?

Let's make a pie graph!



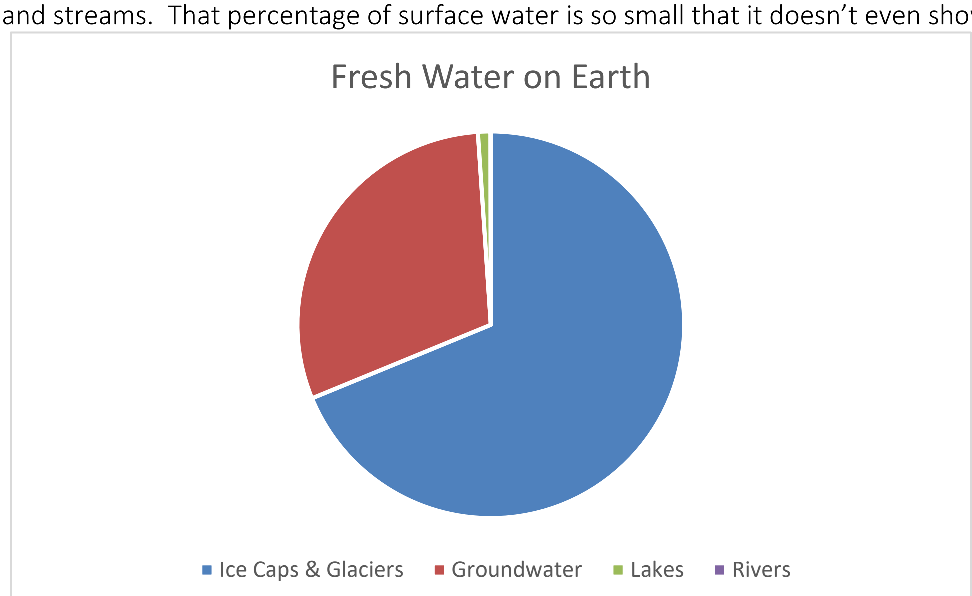
Color in the percentages on the circle. Choose one color for salt water and another color for fresh water.

97% Salt Water
3% Fresh Water

Conservation means using a resource wisely so that we don't run out. Why do you think it is important to protect and conserve our fresh water?

___

Now, let's see look closer at that 3% of the Earth's fresh water. About **68.7%** of the Earth's fresh water is stuck in **ice caps and glaciers** (actually, mostly in Antarctica). Most people don't live anywhere near ice caps and glaciers. The next biggest source of fresh water is **groundwater (30.1%)** that is stored in rocks called **aquifers**. Then, the remainder of fresh water **(0.3%)** is stored in **lakes** (especially the U.S.A.'s Great Lakes) and **swamps**, with just a tiny bit of fresh water found in **rivers** and streams. That percentage of surface water is so small that it doesn't even show up on our pie graph!



Groundwater is really important for people who live in places where there is not enough rain to grow food, to drink, or to raise livestock. In the United States, many of our crops are grown with an ancient water source called the Ogallala Aquifer, which stretches from Nebraska down to Texas. This water is more than 10,000 years old! We are using that groundwater faster than it can fill back up, or "**recharge**" through the process of infiltration, where water wiggles its way from the surface down through the soils to be stored in an aquifer below.

So, how can we keep our wells and our groundwater safe? Let's make a model. Today, we're going to compare sand and gravel aquifers. You will need a graduated cylinder, three clear plastic cups, water, one dropping pipet, two straws, food coloring, sand, and gravel.

1. Fill one clear plastic cup with water. Set it aside.
2. Fill a plastic cup about halfway with sand. Don't pat it down, just pour it in.
3. Fill a plastic cup about halfway with gravel. Don't pat it down, just pour it in.
4. Which one do you think will be a better aquifer (source of water)?

I think that ______________________________ will be a better aquifer because
____.

Procedure:

1. Fill your graduated cylinder to 25 milliliters. Inside the cylinder, the water curves called a meniscus. The bottom of the curve is where you read the number. See the picture to the left.

2. Set up the wells: Fill a clear plastic cup about halfway with sand. Fill the other plastic cup with approximately the same amount gravel. Do not tamp or even it out. Compaction can skew the results. These cups model two types of aquifers: sand and gravel. The spaces in between the particles are the pores. Right now, they are filled with air. Cut a plastic straw in half. Place one section in the center of each cup. That straw is your well.


3. Predict and test porosity by making puddles: How much water you think each aquifer can hold? Write it down. Measure water in your graduated cylinder. Write down how much you start with. Use the dropping pipet to "rain" drops of water along the surface of the aquifer. Watch the water percolate (infiltrate) through the pockets of air. Then when the entire aquifer is filled, and all the pores are saturated with water, you will see puddling at the surface of the cup. Stop, and measure the amount of water you applied. Then repeat the process for the other aquifer.




4. Add the pollution to the surface: For this step, make sure that participants do NOT put the food coloring into the straw (well). Add three drops of food coloring on the surface of the aquifer.


5. Remove the pollution through the well: Use the dropping pipet to carefully suck out/remove water from the well. Measure how much water must be removed before the food coloring shows up. The faster the pollution moves through the aquifer, the higher the **permeability**, or connectedness of the pore spaces.


Data Collection: How much water with the aquifer hold?

Part 1: Porosity: The amount of spaces that can be filled with water or air.

I predicted that gravel will hold this much water: _____________________ milliliters
The actual amount of water that the gravel held: _____________________ milliliters
My prediction was ______________________ more than/less than/equal to the actual amount.

I predicted that sand will hold this much water: _____________________ milliliters
The actual amount of water that the sand held: _____________________ milliliters
My prediction was ____________________________ more than/less than/equal to the actual amount.

Part 2: Permeability: The connectedness of spaces that can be filled with water or air.

How much water did you remove from the well before the food coloring showed up?
Gravel: _____________________ milliliters
Sand: _____________________ milliliters
The __________________ aquifer was contaminated by pollution faster.

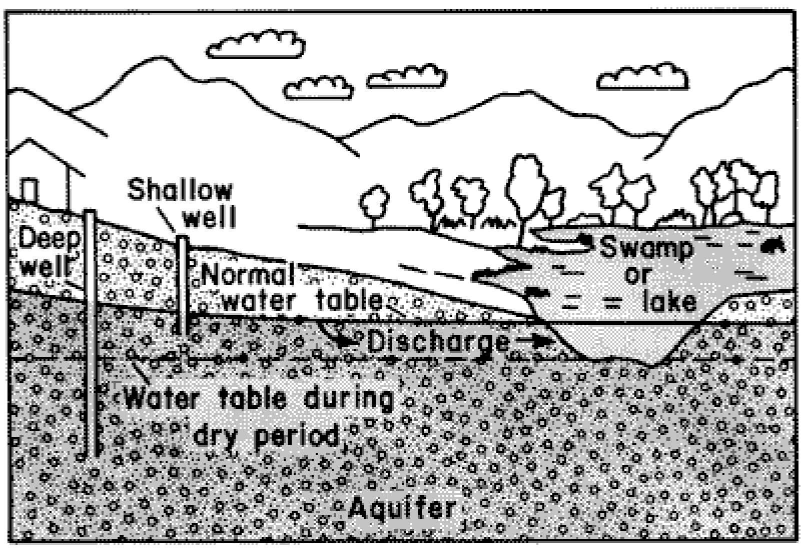
Data Analysis: Which aquifer held more water and had higher porosity? Why do you think this might have worked out this way?

The "connectedness" between pore spaces is called PERMEABILITY. Highly permeable rocks allow easy movement of water through their pore spaces. Based on your data, which aquifer is more permeable, the sand or the gravel?

Conclusion: If you could choose what type of aquifer for your home's well, would you choose drilling a well into sand or gravel? Why?

Use the figure to answer the following questions.

1. Which of these wells would be a better source of water? The shallow well or the deeper well? Why?



2. If someone dumped a barrel of oil in the swamp, could it get into the homeowner's wells? Why or why not?

3. In arid (desert/dry) climates, groundwater is often the only source water. If a person uses water faster than it can be recharged from the water cycle, then the well can run dry. Which do you think would be a better aquifer in a dry region, sand or gravel?

THINK ABOUT IT: As you are cleaning up, think about how hard it is to get the food coloring out of the sand and gravel. Apply your model to pollution of groundwater. Do you think it is easy or hard to clean pollution out of groundwater? Is it more difficult or less difficult than cleaning pollution from water in rivers and the ocean?