Investigating Aquifers

Grade:6-8 & 9-12	Implementation Practice: Developing and Using Models, Designing Solutions, Engaging in Argument from Evidence, Analyzing and Interpreting Data
Subject Area: Earth Science	Estimated Duration: Two 45-minute class period with one intervening 30-minute homework

Learning Objective(s):
Students will be able to:

- **investigate** uses of groundwater
- **develop** an aquifer model and **evaluate** porosity and permeability
- **argue using evidence** from geoscience data human impacts on groundwater
- **evaluate** a solution to minimize human impacts on groundwater

Standards Supported

NGSS	Performance Expectation **MS-ESS3-1.** Construct a scientific explanation based on evidence for how the uneven distribution of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **HS-ESS2-2**. Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that causes changes to other Earth systems. **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.		
	Disciplinary Core Idea(s)	Science and Engineering Practices	Crosscutting Concept(s)
	• ESS2.A: Earth Materials and Systems • ESS3.C: Human Impacts on Earth Systems • ETS1.B. Developing Possible Solutions	• Developing and Using Models • Constructing Explanations and Designing Solutions • Analyzing and Interpreting Data • Engaging in Argument from Evidence	• Stability and Change • Influence of Science, Engineering, and Technology on Society and the Natural World • Science Addresses Questions About the Natural and Material World

Materials Needed

- Internet enabled devices
- Investigating Aquifers Student Sheet

For aquifer model:

- Bottom only of one 2-liter soda bottle per group with spout cut off approximately 5 inches below the spout
- Enough dry, pea-size gravel to fill all the containers 3/4 full.
- One 100-mL graduated cylinder for each group.
- Ruler with metric units for each group
- Water: approx. 200ml per group

For investigating porosity:

- 2 100 ml beakers or 9oz plastic cups (containers) per group
- Enough sand and pea-size gravel (both dry) to fill beakers or cups ⅓ of the way.
- One 100-mL graduated cylinder for each group.
- water: approx. 200 ml

For investigating permeability:

- Two 2-liter soda bottles per group with spouts cut off approximately 5 inches below the spout. Need both bottom and spout.
- Enough dry pea-size gravel and sand to fill the overturned spout of each container ⅓ full. Note: Each group will fill one spout with gravel and one with sand.
- Two cotton balls
- One 100-mL graduated cylinder for each group.
- Water: approx. 200 ml per group
- A way to measure time

Suggested Implementation Timeline

Have students complete the Engage, Explore, and Explain portions in the first class period. If time permits, have them begin work on the Elaborate. Students should complete the Elaborate at home and be prepared to discuss their findings. Emphasize that they will not be able to continue with the Evaluate portion of the learning experience without having spent the requisite time and effort on the Elaborate. When students complete the Claim, Evidence, Reasoning portion of the Evaluate, make it known in advance that their peers will provide feedback on their work. Research shows that when students know that their work will be published, the quality improves.

Instructor Notes

For the sake of time and materials, it is possible to complete the three components of the Explain as a demonstration. It is recommended that the instructor try out the Explain components prior to conducting them with students. It's also recommended that the instructor prepare soda bottles prior to implementing the activity with students. To save time, the instructor can prefill plastic bags with sand and gravel for each group.

Background Information

What is groundwater and how is it used?

While surface water is what many people think of when they think of their water supply, groundwater, water held underground in soil and rocks, is an important source of usable water. Some of the precipitation that falls on the ground infiltrates into the subsurface. A portion is pulled downward by gravity through the soil until it reaches rock material that is saturated with water. This process is called groundwater recharge. Water in the saturated groundwater system moves slowly and may eventually discharge into streams, lakes, and oceans, thus making groundwater a part of the water cycle.

The water table is the level below which the ground is saturated, or full of, water. The ground above the water table, the unsaturated zone does not stay saturated. The dirt and rock in the unsaturated zone contain air and some water and support vegetation. The saturated zone below the water table has water that fills the tiny spaces (pores) between rock particles and the cracks (fractures) of the rocks. The water in the saturated zone is the groundwater.

Groundwater supplies drinking water for 51% of the total U.S. population. 64% of groundwater is used for irrigation to grow crops and is an important component in many industrial processes. In addition, groundwater is a source of recharge for lakes, rivers, and wetlands, supporting the biodiversity that lives in these habitats

What is an aquifer and how are they impacted by human activity?
A huge volume of water exists as groundwater, but is only found in usable form via aquifers, underground formations of water-bearing permeable rock. Water is held in the pore spaces between the solid materials that make up the aquifer. Some materials have higher porosity, effectively more space to hold water. The permeability of the aquifer is related to the shape and connectedness of the pores spaces. An aquifer with high permeability will allow water to flow more easily and be used more readily. Some aquifers are closer to the surface and some are deeper. Groundwater is accessed for human use through wells, structures dug into the ground to access the groundwater which is then pumped out.

Human activities can impact both groundwater extent, the amount of water available, typically measured in terms of volume, and the condition, or quality, of groundwater. Groundwater depletion can be the result of changes in precipitation patterns, high withdrawal of groundwater for drinking, irrigation, other human uses, and impervious surfaces that prevent groundwater recharge. Some consequences of aquifer depletion include:

- Reduce surface water flow that disrupts the water cycle and is harmful to the organisms that live in these habitats.
- Land subsidence and sinkhole formation. These changes can damage buildings, roads, and other structures and can permanently reduce aquifer capacity via compaction of the aquifer material.
- Saltwater intrusion. Changes in ground water flow can lead to saline groundwater migrating into aquifers previously occupied by fresh groundwater.

Human activities that impact groundwater condition include pollution from various sources such as pesticides and fertilizers, waste from livestock, landfills, mining, other industrial operations, and chemical spills or leaks from storage tanks. These impacts can render groundwater unsuitable for human use.

The best ways to protect groundwater are to keep it safe from contamination and to conserve water and use it efficiently to reduce withdrawal. Preventing contamination is far less expensive than cleaning up contaminated groundwater. Individuals can help protect groundwater by using chemicals like fertilizers and pesticides sparingly and disposing of waste properly. Resource managers and the general population, especially in rapidly growing urban areas, must work together to protect water sources and conserve water.

In Florida, the Biscayne Aquifer is the primary source of freshwater to the southeastern part of the state, including highly populated, and rapidly growing Miami-Dade. The Biscayne Aquifer is relatively shallow. The Floridan Aquifer, which lies deeper, and the two are separated by a confining layer of dense rock. The Floridan Aquifer spans the state and is too salty to drink. Since the Biscayne Aquifer is so close to the surface, it is vulnerable to pollution. Its proximity to the ocean and climate change-related sea level rise makes it vulnerable to saltwater intrusion. While the Biscayne Aquifer has not seen the increase in depth to water table changes (used to indicate groundwater extent) of some western aquifers, resource managers fear that without development of alternative sources of water, possibly through desalination or significant conservation, the aquifer will tip into severe depletion.

Investigating Aquifers Rubric (HS)

Name:

Glows: Student meets or exceeds performance standard	Performance Standard	Grows: Improvement needed in order to meet performance standard
	- Student can use a model of an aquifer to explain the attributes of porosity and permeability.	
	- Student can identify the water table and both the saturated and unsaturated zones in an aquifer model.	
	- Student can make an argument from evidence for how human actions impact aquifers	
	- Student can make an argument from evidence on the potential for desalination to reduce human impacts on coastal aquifer	

Comments:

Investigating Aquifers Rubric (MS)

Name:

Glows: Student meets or exceeds performance standard	Performance Standard	Grows: Improvement needed in order to meet performance standard
	- Student can use a model of an aquifer to explain the attributes of porosity and permeability.	
	- Student can identify the water table and both the saturated and unsaturated zones in an aquifer model.	
	- Student can make an argument from evidence for how human actions impact aquifers	
	- Student can use evidence and scientific thinking to design a solution to reduce human impacts on groundwater	

Comments:

Name: _____ Date: _____

Investigation Student Sheet

Guiding Expectations

In this learning experience, you will investigate the importance of aquifers and how human activities can impact them for both better and worse. You will model an aquifer to help you visualize groundwater and the attributes of porosity and permeability. You will make an argument using evidence about human impacts to groundwater and evaluate a solution to minimize them.

Engage

1. In the space provided below, list at least three ways you have used water, either directly or indirectly. Discuss your list with a partner and then be prepared to contribute to a whole group discussion. If you are not familiar with the idea of indirect water uses, perform a quick Internet search.

Direct Uses of Water	Indirect Uses of Water

2. Where do you think the water that people use comes from? Where does the water supplied to your community come from? Use the Internet to find the answer to these questions if you are unsure.

Explore

1. Work with a partner to come up with a working definition for each of the following terms: groundwater, aquifer, water table, groundwater extent, groundwater condition. A working definition is one that will change as your knowledge develops. Record your definitions in the table included on the next page.

2. Join up with another partnership and discuss your working definitions. Revise your definitions as necessary.

3. Perform an Internet search for the definitions of each of these terms. Revise your definitions again as needed. Be prepared to ask your instructor any clarifying questions you have about these terms.

Term	Working Definitions
Groundwater	
Aquifer	
Water table	
Groundwater extent	
Groundwater condition	

Notes:

Explain

Part 1 - Modeling an Aquifer

1. Have one member of your group obtain the bottom portion of a 2L soda bottle. Fill it ¾ full with dry pea-size gravel.
2. Use a graduated cylinder to measure 50 ml of water. Slowly pour the water into the gravel. Continue adding measured quantities of water to the gravel until only the top 2cm is not saturated with water. NOTE: Make sure to keep track of the volume of water you add.
3. You have just created a model of an aquifer.
4. Record the volume of water that you poured into your aquifer model.
5. Find the top of the water in the model aquifer. This is the **water table**.
6. Measure the height from the bottom of the bottle to the water table. Record this measurement. This zone Is called the **saturated zone**. The top of the saturated zone is the **water table**. The water contained within the saturated zone is the **groundwater**. The rock that contains the groundwater is the **aquifer**.
7. Measure from the surface of the gravel down to the water table. Record this measurement. This zone is called the **unsaturated zone**. If the distance to the water table increases, this could be a sign of groundwater depletion, water-level declines caused by sustained use.
8. In the space below, draw a picture of the model aquifer. Record the vertical thicknesses of the unsaturated zone and the saturated zone on the drawing. Label the water table.

Parameter	Aquifer Model Data
Volume of water in aquifer (ml)	
Vertical thickness of saturated zone (cm)	
Vertical thickness of unsaturated zone (cm)	

Aquifer Model Illustration

Part 2 - Visualizing Aquifer Porosity and Permeability

A. Porosity
    1. Have one person from your group obtain two 9oz containers, one bag filled with dry, pea-size gravel, one bag filled with dry sand, and a graduated cylinder.
    2. Pour the contents of each bag into a separate container, filling each about ¾ full. Predict the amount of water that you think each material can hold. Record your predictions.
    3. Pour water from a filled 100-mL graduated cylinder slowly into the container containing gravel until the water just reaches the top of the material. Record the amount of water held by the gravel.
    4. Repeat step 3 for the sand container.

Porosity Simulation

Prediction
Amount of water (ml) held by gravel: _____
Amount of water (ml) held by sand and gravel mixture: _____

Actual
Amount of water (ml) held by gravel: _____
Amount of water (ml) held by sand and gravel mixture: _____

The ability of an aquifer to hold water is called porosity. Which material had higher porosity? Why do you think this is?

B. Permeability

1. Have one person from your group obtain two cut 2-liter soda bottles, including both tops and bottoms, one bag of dry sand, one bag of dry gravel, two cotton balls, and a 100-mL graduated cylinder.
2. Invert the top of each bottle and place it into the bottom. Place a cotton ball in the narrow part of each bottle top to prevent the sand or gravel from running out.
3. Pour the sand into the top of one bottle, filing it ¾ full.
4. Pour 100 ml of water into the bottle and time how long it takes for the water to drain. Stop timing when the flow slows 2 drops per second. Record the time.
5. Repeat steps 3 and 4 with gravel and the second bottle top and bottom.

Permeability	
Material	Drain Time (sec)
Sand	
Gravel	

Which material has high permeability? How do you know? Why do you think this is?

Elaborate

Use the Internet to investigate how human activities impact aquifers. Then, investigate the process of desalination and how it could possibly be useful in reducing pressure on aquifers in coastal areas. Make sure your sources are credible and cite them by including the name of the website and the url. Record your research in a table like the one below. You may choose to copy this table into another document. Write information in your own words; do not copy/paste from the source.

Human Impacts on Aquifers Research	
Explain groundwater depletion and give at least three of its consequences	
Explain how pollution affects groundwater. Include at least three examples of types of pollutants.	
What is desalination? How does the process work? What are its benefits and drawbacks? How could it possibly reduce pressure on aquifers?	
Questions for my instructor	
Citations	

Evaluate

1. Use the format CER (Claim, Evidence, Reasoning) to evaluate desalination as a method to reduce pressure on aquifers. You may choose to claim that desalination is or is not a potential way to reduce human impacts on groundwater in coastal areas. Do additional research as necessary. Use the CER template to guide you.

CER Template

The *claim* is the conclusion that you have reached in relation to the research question. The *evidence* is scientific data you used to arrive at, and which supports, the claim. To be considered evidence, the data used needs to be relevant to the question. In addition, to adequately support the claim, there needs to be multiple pieces of evidence in support of the claim. The *reasoning* is a logical justification that explains why the data works as evidence to support the claim. You should elaborate on why you chose the data and how the data supports the claim. In addition, you should make a connection to the significance of the claim by including appropriate scientific principles. It is here that you should explore the greater implications of the data and the real-world relevance of the claim.

Claim, Evidence, Reasoning

Claim:

Evidence #1:

Evidence #2:

Evidence #3:

Reasoning: Please use full sentences

2. Complete the Self Reflection below.

Self Reflection

Glows: Things I can do well	Standard	Grows: Things that I need to improve
	- I can use a model of an aquifer to explain the attributes of porosity and permeability.	
	- I can identify the water table and both the saturated and unsaturated zones in an aquifer model.	
	- I can explain the evidence that exists for how human actions impact aquifers	
	- I can make an argument from evidence on the potential for desalination to reduce human impacts on coastal aquifer.	

My favorite part of the investigation was…

The most important thing I learned is…

Something I'd like to know more about is...