The Extraction of Natural Gas through Hydraulic Fracturing on the Marcellus Shale Formation in Pennsylvania

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Overview:
The method of natural gas extraction known as hydraulic fracturing is currently one of the most debated issues in Pennsylvania. Both the economic potential and the environmental impact concerns related to this method of drilling may affect us in the foreseeable future. An introduction on this topic would help students who currently receive instructional units on Land and Water in grade 4, and Land Forms in grade 6, in the School District of Philadelphia curriculum. I believe a short unit providing background knowledge and relevant hands on activities would enhance the current curriculum and help prepare our students for the future.

Rationale:
As a science specialist teacher, I meet with every class for one 45- minute period per week. My lessons must be concise, engaging, and compliant with the State and School District guidelines. My students come from a working class neighborhood with supportive parents. Most students enjoy coming to science class, and enjoy participating in "hands on" activities. These activities also help bridge the connections between other subjects such as math, social studies and reading. Students are much more willing to write, make tables, graphs, or charts, and do oral reports when they are connecting these activities to their book learning. Relevant, high quality websites, books, and videos also are effective tools for both me and my students in keeping up with the newest information. These are also helpful in gaining background knowledge in order to present the "Big Picture" in a science concept.

Objectives:
The students will be able to:

- Identify basic geological formations as related to the state of Pennsylvania
- Explain how fossil fuels are formed

- Define natural gas and its uses, environmental/economic impact, and locate where it is found in Pennsylvania
- Define the hydraulic fracturing process, state the economic/environmental impact and locate where it is happening and possible future sites
- Recognize both the economic and environmental concerns as they are related to the issue of energy extraction
- Work cooperatively in small groups
- Develop informed opinions on the topic of hydraulic fracturing in the state of Pennsylvania
- Conduct scientific investigations, record observations and conclusions
- Identify the interaction of land and water and the possible effects man has on the environment.

Strategies:
Students will be given background knowledge through the use of handouts, tables, graphs, charts, diagrams, books, videotapes, and short lectures. Hands on scientific investigations will be done in two of the five lessons. Elements from the Environmental Protection Agency are included. These lessons give the students a clearer understanding of the interaction of water and land, and how man may have a dramatic effect on his natural surroundings. Students will work in groups of 4-6, and will be evaluated through teacher observation of their classroom performance, following directions, working cooperatively, and the handling and implementation of equipment. Students will complete a "Do Now" activity paper given at the start and end of each lesson. Each group will be given the opportunity to give a brief oral presentation at the conclusion of the unit in which they will state their case for or against hydraulic fracturing in Pennsylvania.

Background Information:
Geology
The structure of the earth is divided into 3 parts. A good analogy for teaching about the earth's interior is a piece of fruit with a large pit such as a peach or plum. If we cut the piece of fruit in half, we will see that it is composed of 3 parts: a very thin skin, a seed of significant size located in the center, and most of the mass consisting of the flesh. If we cut the earth in half, we would see a very thin crust on the outside a core of significant size in the center and most of the mass of the earth contained in the mantle. The crust is made up of thin oceanic rock mainly basalt and thicker continental crust is composed primarily of granite. The low density of the continental rock allows it to "float" on the much denser mantle below. The earth's mantle is thought to be composed of olivine-rich rock. It has different temperatures at different depths, the lowest temperatures is immediately below the crust and increases with depth. The highest temperature occurs where the mantle material is in contact with the heat-producing core. Rocks in the upper mantle are cool and brittle, while rocks in the lower mantle are hot and soft. Rocks in the upper mantle are brittle and brake under stress and cause earthquakes. The core is thought to be composed of iron and nickel alloy. The core is earth's source of internal heat because it contains radioactive materials, which release heat as they break down into more stable substances (http://geology.com/nsta.earth-internal-structre.shtml).

Types of Rock

Geologists consider rocks to be of three types: Sedimentary, Metamorphic and Igneous.

- Sedimentary rock is made up of loose pieces of minerals and rocks. It also may contain the remains of living things. Solid rock is broken down and loose pieces are then eroded and moved by running water, wind, waves, or ice and deposited somewhere else. In certain conditions and over very long periods of time, sediment becomes compacted and cemented into sedimentary rock. Burial increases the temperature in the sediment and the pressure on it. As that happens, new minerals are deposited around the grains of sediment, cementing them into solid rock. If a rock sample is sedimentary it will have layers and partially worn grains.
- Igneous rocks come from melted rock material called magma formed deep within the earth. Most rocks are a mixture of more than one kind of mineral, which is forced to the surface in the form of lava. Most igneous rocks are very hard and are made of interlocking crystals.
- Metamorphic rock is a rock that has become changed from some original rock by high temperature or pressure, usually both, as it is buried. The rock does not melt, but new minerals grow in the rock at the expense of the original rock, while the rock remains solid (Smith, 2003).

Shale

Shale is a fine grain sedimentary rock that forms from the compaction of silt and clay-size mineral particles that we commonly called "mud." This composition places shale in a category of sedimentary rocks known as "mudstones." Shale is distinguished from other mudstones because it is fissile and laminated. "Laminated" means that the rock is made up of thin layers. "Fissile" means that the rock readily splits into thin pieces along the laminations (www.geology.com/ rock/shale.shtml).

Water

A water molecule contains two atoms of hydrogen and one atom of oxygen (H_2O). The hydrogen atoms have a positive charge and the oxygen atom has a negative charge. These charges cause water molecules to be attracted to each other (via hydrogen bonds), thereby creating strong surface tension. Water is the only substance that naturally exists in three states on Earth: solid, liquid, and gas. Water is stored on the Earth's surface in places such as glaciers, ice caps, oceans, lakes, ponds, rivers, and streams. Some water infiltrates into the ground and is stored in soil, porous rock, and aquifers. Water covers approximately 70% of the Earth's surface but approximately 97% of the Earth's water contains too much salt to drink or use for other purposes. Usable surface water and ground water represents less than 0.5% of all water on Earth (encyclopedia science, 2004. Pp 40-41, 216-217. DK Publishing Inc.). Of the Earth's freshwater, 68% is in the form of glaciers, icecaps, and snow cover, 30.8% is groundwater, and about 0.3% is in lakes and rivers (http://www.ec.gc.ca/water/en/e_quickfacts.htm).

By the time you feel thirsty, your body has already lost more than 1% of its total water. (http://www.allaboutwater.org/drink-water.htlml). A person can live for up to one month

without food, but only about one week without water. In the United States, the average person pays 25 cents for their water each day (http://www.epa.gov/safewater/kids/water_trivia_facts.html). In many developing countries, the only way to get safe drinking water is through private venders who charge up to ten times more than piped water would cost. In many African cities, up to 80% of the population obtains their water in this manner. In Namibia, up to 20% of the family income is spent on water (plus payment to use the toilet). (http://www.wateryear2003.org/en/ev.php-URL_ID=5970&URL_DO=DO_TOPIC&URL_SECTION=201.html)
The latest assessment of American surface waters found that, of those assessed, 39% of the river and stream miles, 45% of lake, pond, and reservoir areas, and 51% of estuary areas were impaired (http://www.epa.gov. /owow/monitoring/nationswaters/waters2.pdf)
A leaky tap that drips once per second can waste 10,000 liters of water in one year. (http://www.epa.gov/safewater/kids/behydrologica.htlm)

Groundwater

Groundwater is water that fills cracks and other openings in beds of rock and sand. Each drop of rain that soaks into the soil moves downward to the water table, which is the water level in the groundwater reservoir. Groundwater does not normally occur in underground streams, lakes, or veins. Groundwater is found in soils and sands able to retain the water – much like a sponge holds water (www.ngwa.org). About 30.1% of the earth's fresh water is estimated to be ground water. About 90% of our freshwater supplies lie underground, but less than 27% of the water Americans use comes from underground sources (Estimated Use of Water in the United States in 2005, U.S. Geological Survey Circular 1344, October 2009). Groundwater is a renewable resource. In most parts of the country, water removed from the ground is constantly replaced. In some parts of the country, such as arid and semiarid regions, a low rate of replenishment is exceeded by the rate of groundwater pumping, resulting in problems of ground water mining. Adequate time is needed to allow replenishment of underlying groundwater reservoirs (aquifers); such areas must be properly managed in order to prevent water-soluble waste products stored in these areas from infiltrating and polluting the underground supply. Private household wells constitute the largest share of all water wells in the United States; more than 13.2 million year-round occupied households have there own wells (American Housing Survey, U.S. Bureau of the Census, 2008). Michigan, with an estimated 1,121,075 households served by private water wells, is followed by Pennsylvania, North Carolina, New York, and Florida (U.S. Census, 1990).

Aquifers

An aquifer is an underground layer of rock or soil that holds the water that we call groundwater. The word "aquifer" is derived from the Latin "aqua," meaning water, and "fer" meaning to yield. The ability of a geological formation to yield water depends on two factors - porosity and permeability. Porosity is determined by how much water the soil or rock can hold in the spaces between its particles (as with a sponge). Permeability means how interconnected the spaces are so that water can flow freely between them.

There are two types of aquifers. One is a confined aquifer, in which a water supply is sandwiched between two impermeable layers (geological layers which water cannot pass through). These are sometimes called artesian aquifers because when a well is drilled into this layer, the pressure is so great that water may spurt to the surface without being pumped. The other type of aquifer is the unconfined aquifer, which has an impermeable layer (or one of lower permeability) under but not above it. It is the most common type. The top surface of the groundwater is called the water table. The water table depth varies from area to area and fluctuates (rises and falls) due to seasonal changes and varying amounts of precipitation. Excessive pumping from the aquifer can also lower the water table. Perhaps the largest aquifer in the world is the Ogallala Aquifer located in the mid-western part of the United States. This aquifer is estimated to be more than two million years old. It underlies parts of 8 states stretching about 800 miles (1288km) from South Dakota to Texas (http://water.epa/gov/learn/kids/drinkingwater/upload/thewater-sourcebooksgradelever-3-5).

Shale Gas Production

A key element in the emergence of shale gas production has been the refinement of cost-effective horizontal drilling and hydraulic fracturing technologies. The two processes, along with the implementation of protective environmental management practices, have allowed shale gas development to move into areas that would have previously been inaccessible (http://www.gwpc.org/e-librarydocuments/general/shale%2).

Hydraulic Fracturing

Hydraulic fracturing is the process of creating fissures, or fractures, in underground formations to access natural gas. “The fractures are created to extend from the well bore. Typically, in order to create fractures, a mixture of water proppants (sand or ceramic beads) and chemicals are pumped at high pressure into the rock or coal formations. Eventually, the formation will not be able to absorb the fluid as quickly as it is being injected. At this point, the pressure created causes the formation to crack or fracture. The fractures are held open by the proppants, and the oil or gas is then able to flow through the fractures to the well. Some of the fracturing fluids are pumped out of the well and into surface pits or tanks during the process of extracting oil, gas and any produced water, but studies have shown that anywhere from 20 to 40% of the fracking fluids remain underground” (http://www.earthworksaction.org/fracingdetails.cfm).

Horizontal Drilling

Horizontal drilling method used vertical drilling from the surface down to the desired level. Then, the drill bit turns at a near 90-degree angle and bores into a natural gas reservoir horizontally. Drill sites are designed to utilize as small an area as possible that can still safely accommodate a drilling rig and associated equipment. This new method of drilling allows several wells to be accommodated from the same surface site.

How a Well Is Completed

The process of setting up the rig, drilling, stimulating, and installing operational equipment for a single shale well takes approximately two to eight weeks. Once the drilling is completed, the drill site is reduced to a minimum area for surface equipment.

A “Christmas Tree” is placed on top of the existing well site to control and regulate the flow of gas into a pipeline in order for the gas to be transported to market though a regional pipeline system. A typical “Christmas Tree “structure is about 6 feet tall. At the conclusion of this process, well developers begin the land reclamation process, with developers seeking to leave behind a small footprint for each well site. The land restoration process involves landscaping and contouring the property as close as possible to pre-drilling conditions, according to Marcellus Shale Coalition (http://www.naturalgas.org/shale/shalewells.asp).

Water Use in Deep Shale Gas Exploration

Water is an essential component of deep shale gas development. Hydraulically fracturing a typical horizontal deep shale gas well requires an average of 4.5 million gallons per well. In addition to water, sand and other additives are used to allow hydraulic fracturing to be performed in a safe and effective manner. Additives in the hydraulic fracturing fluids include a number of compounds found in common consumer products (http://www. chk.com/naturalgas/pages/basics.asp). The percent by volume of a typical Marcellus shale hydraulic fracturing fluid is comprised of 99% water and sand and 1% of other additives. These other additives include acid, corrosion inhibitors, iron control, antibacterial agents, scale inhibitor, friction reducers, surfactants, gelling agents, and breakers. The fluid is injected into deep shale gas formations and is typically confined by many thousands of feet of rock layers.

After fracturing is completed, the internal pressure of the geologic formation causes the injected fracturing fluids to rise to the surface where it may be stored in tanks or pits prior to disposal or recycling. Recovering fracturing fluids is referred to as flowback. Disposal options include discharge into surface water or underground injection. Surface water discharges of the flowback are required by the National Pollutant Discharge Elimination System (NPDES) program which requires flowback to be treated prior to discharge into surface water or underground injection. Treatment is typically performed by wastewater treatment facilities. Underground injection of flowback is regulated by either the EPA Underground Injection Control (UIC) program or a state with primary UIC enforcement authority (http://water.epa.gov/type/groundwater/uic/classII/hydraulicfracturing/well_hydrowhat.cfm).

Management of fracturing fluid is of great environmental concern. “Pits” have been used to hold drilling fluid wastes. The containment of fluids within a pit is the most critical element in the prevention of contamination of shallow ground water. Failure of a tank, pit liner or the line crying fluid (“flow line”) can result in a release of contaminated materials directly into surface water and shallow ground water. Depending on the state, there are a number of rules regarding pits and the protection of surface and groundwater. Flowback can be comprised of as little as 3% and as much as 80% or more of the total amount of water and other material that were in the fracturing formation. New systems have been developed that avoid the use of pits. One technology that is becoming more common is the closed loop fluid handling systems. These systems avoid the use of pits by keeping fluids within a series of pipes and tanks throughout the entire process. Since fluid is never placed into contact with the ground, the likelihood of groundwater contamination is minimized (http:wellsite-ds.com/? p=2164).

Natural Gas

Natural Gas is a nonrenewable fossil fuel formed millions of years ago from the decayed remains of animals and plants that built up in thick layers. This organic matter was trapped beneath sand and silt that was changed to rock. Some of the organic matter was changed into coal and oil and some into tiny bubbles of odorless natural gas. To get natural gas, geologist study rock samples that are likely to contain gas and oil to help locate natural gas deposits. Seismic surveys, echoes from a vibration source, are used to collect information about rocks formations below. Deposits may be found on land or in the ocean. Natural gas is found in 50 countries around the world, and in 33 states in this country. Wells are drilled and the gas flows up through the well to the surface and is put into large pipelines. Most natural gas is stored before it is delivered to consumers in underground storage systems. It remains there until it is put back into large pipelines called "mains." From there it goes to smaller "service" lines that are connected to buildings and homes. Natural gas can be stored and transported as a liquid when it is chilled to -260 degrees F. When changed to a liquefied natural gas (LNG) it takes up $1/600^{th}$ of the space and large amounts can be shipped in chilled trucks or ships before being changed back into a gas and put through the pipeline.

About 25% of the energy used in the United States comes from natural gas. Most of our natural gas is obtained in this country; however some is also imported from Canada. The United States has large amounts of natural gas, with new deposits still being found. There is enough natural gas to last for several decades at present usage levels. The major consumers for natural gas in the United States include electric power production, industrial, residential, and commercial users. More than half of the homes in the U.S. use natural gas as their main source of heat. Some products use natural gas as raw material: plastics, paints, antifreeze, dyes, and medicines are just a few. It is also used in the production of paper, clothing, steel, glass, and many other commonly used products. Natural gas was originally used in the 1800s as fuel for streetlights. Robert Bunsen invented the "Bunsen Burner" in 1825. The Bunsen burner mixes air with natural gas. This demonstrated that natural gas could be used in a variety of ways. Construction of pipelines for home usage were not built until after World War II, and continued through the 1950s and 60s (www.fossil.energy.gov/education//energylessons/gas/index/htlm, p.1-4).

Vocabulary Term/ List

Aquifer – a subsurface rock or sediment unit that is porous and permeable enough to transmit water

Aquifer - (artesian) - an aquifer that is bound above and below by impermeable rock or sediment layers; must have enough pressure that when tapped by a well the water will rise above the top of the aquifer

DEP – Department of Environmental Protection

Core – major subdivision of the earth's structure located at the center of the earth, 2000 miles thick

Crust – outer thin layer of the earth 3 to 30 miles thick
Groundwater - water, such as rainfall, that sinks into the ground
Habitat Fragmentation – the reduction and isolation of patches of natural environment
Hydrologist – scientist who studies water
Igneous rock – rock that has solidified from molten or partially molten materials (magma)
Impermeable – not permitting water or other fluid to pass through
Mantle – major subdivision of the earth's internal structure located between the base of the crust and overlying core
Metamorphic rock – rock that has been changed into a different type of rock through heat and pressure or the action of chemical fluids
Methane – a colorless, flammable, odorless, hydrocarbon gas (CH_4), which is the major component of natural gas. Methane is a greenhouse gas
Mercaptan – strong smelling substance added to natural gas
Natural Gas – a gaseous mixture of hydrocarbon compounds, the primary being methane
Percolation – the passing or seeping of groundwater or any liquid through a permeable material
Pores – small spaces between earth materials
Sedimentary Rock – are formed by the accumulation of sediment
Shale – elastic sedimentary rock that is made up of clay particles and weathering debris; it typically breaks into thin flat pieces
Shale Gas – refers to the natural gas that is trapped within shale formations
Sedimentary rock – layered rock that results from the consolidation of sediment
Unconfined aquifer – an aquifer containing unpressurized groundwater, having an impermeable layer below but not above
Water table – the top surface of the groundwater

Classroom Activities

This unit is intended to be a follow up to the Land and Water Unit (Grade 4) and/or the Landforms Unit (Grade 6) that are required by the School District of Philadelphia. New material focusing on groundwater, the water table, and aquifers will be introduced. The lessons will include background material on Geology, Natural Gas, the possible effects of the Hydraulic Fracturing process, and the environment will be addressed. Lessons and materials adapted from the Environmental Protection Agency will be used.

Lesson 1- INTRODUCTION

Objective: students will be introduced to the idea of gas exploration in the state of Pennsylvania; basic geography of Pennsylvania (map); review basic earth structure (focus on the crust), three kinds of rocks (focus on sedimentary - shale), and the formation of fossil fuel (focus on natural gas). An Earth Structure video will be used.

Materials/Resources:

- Vocabulary List
- Pennsylvania topography map
- Petroleum/Natural Gas Formation diagram

- Bill Nye video “Earth” and response paper
- “Do Now” Activity paper

DO NOW paper

Date	Name
Topic:	Objective:
Activity:	What did I do?
What did I observe?	What do I think it means?

Lesson 1 - Outline

A. Earth Structure

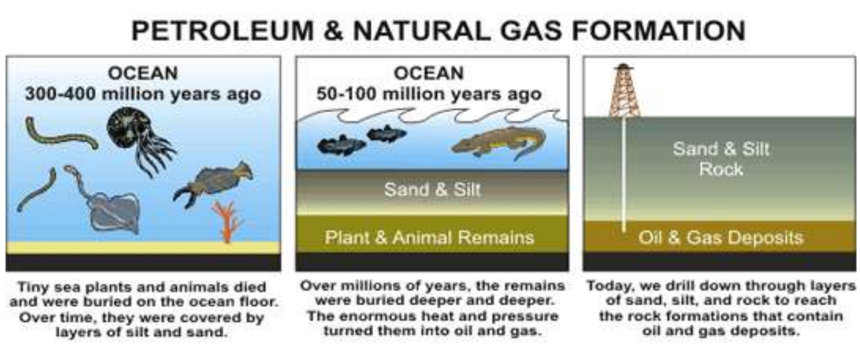
1. Core
2. Mantle
3. Crust

B. Types of Rocks

1. Igneous
2. Metamorphic
3. Sedimentary – (Shale)

C. Fossil Fuels

1. Petroleum (oil) & Natural Gas



(Source: U.S Energy Information Administration - Public Domain)

D. Geography of Pennsylvania

1. Borders
2. Waterways
3. Mountains

E. Bill Nye guided question response paper

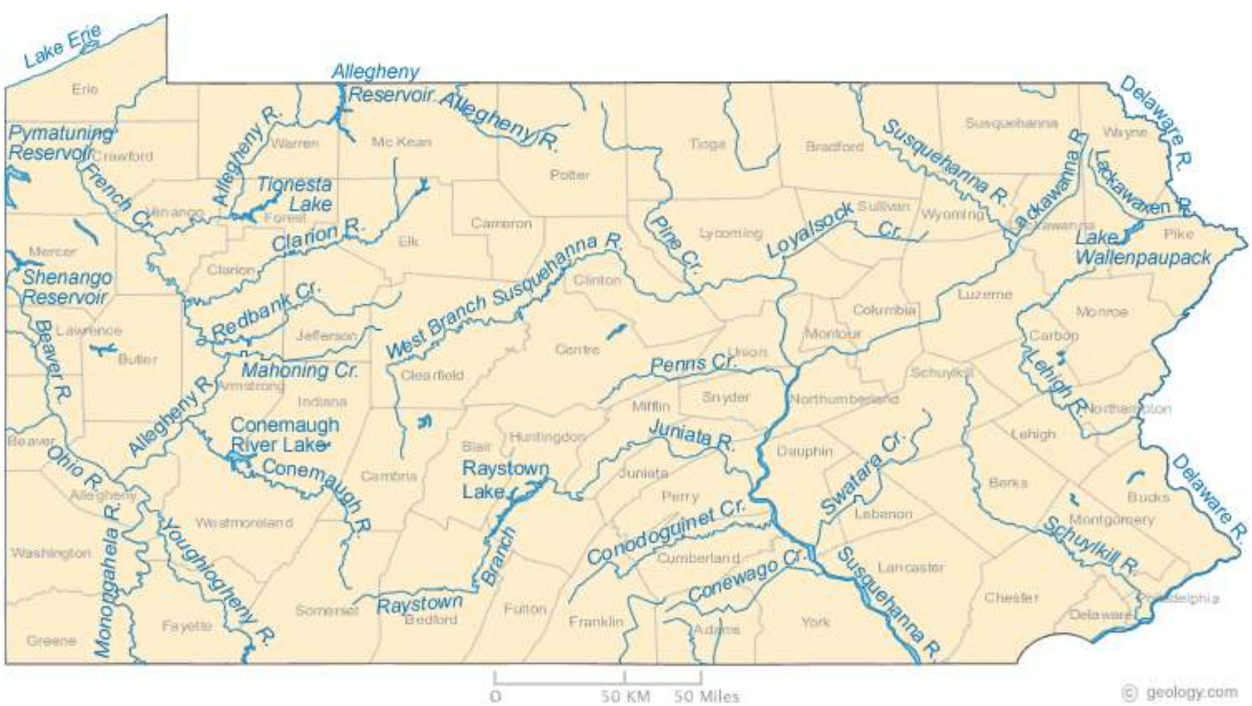
1. We live on which part of the Earth? ________________
2. The center of the Earth is called___________.
3. What helps us to know what is inside the Earth? _________________
4. Melted Rock inside the Earth is called__________________.
5. How many kinds of volcanoes are there? __________________
6. Large pieces of land on the Earth are called__________________.
7. Scientists believe the Earth was once one large piece of land called_______________.
8. A machine that measures the strength of an earthquake is called a_________ __________

Student Grouping: Whole Class

Prior Knowledge Assessment:
In this lesson we will review Earth structure/ types of rocks, and Pennsylvania geography. List student awareness of Pennsylvania's borders, mountains, and major waterways.

Teaching Strategies/Activity/Explanations:

1) Handout Pennsylvania topography map for students to highlight waterways, and locate mountains and bordering states.



2) Review:
   a) Earth structure by completing Earth structure diagram emphasizing the thin nature of the crust.
   b) three type of rocks with emphasis on sedimentary (layered rock) and shale by completing outline.
   c) Petroleum & Natural Gas Formation diagram.

3) Ask students to locate Pennsylvania on a map of the United States, name any bordering states and name any rivers or mountains they may know.

4) Give Pennsylvania map and fill in bordering states highlight rivers and draw ^^^^ where mountains are located.

5) View Bill Nye video and complete guided question response paper

Closure/Assessment:

- Students will complete "Do Now" Activity paper, which has students list the objective and activity at the start of each class and answers the questions: What did I do? What did I observe? What do I think it means?
- Students may report out on their "Do Now" papers
- Complete Bill Nye response question paper

Lesson 2 - Where Does Water Go? Aquifer Experiment

Objectives: Demonstrate how groundwater moves through earth material underground to form aquifers.

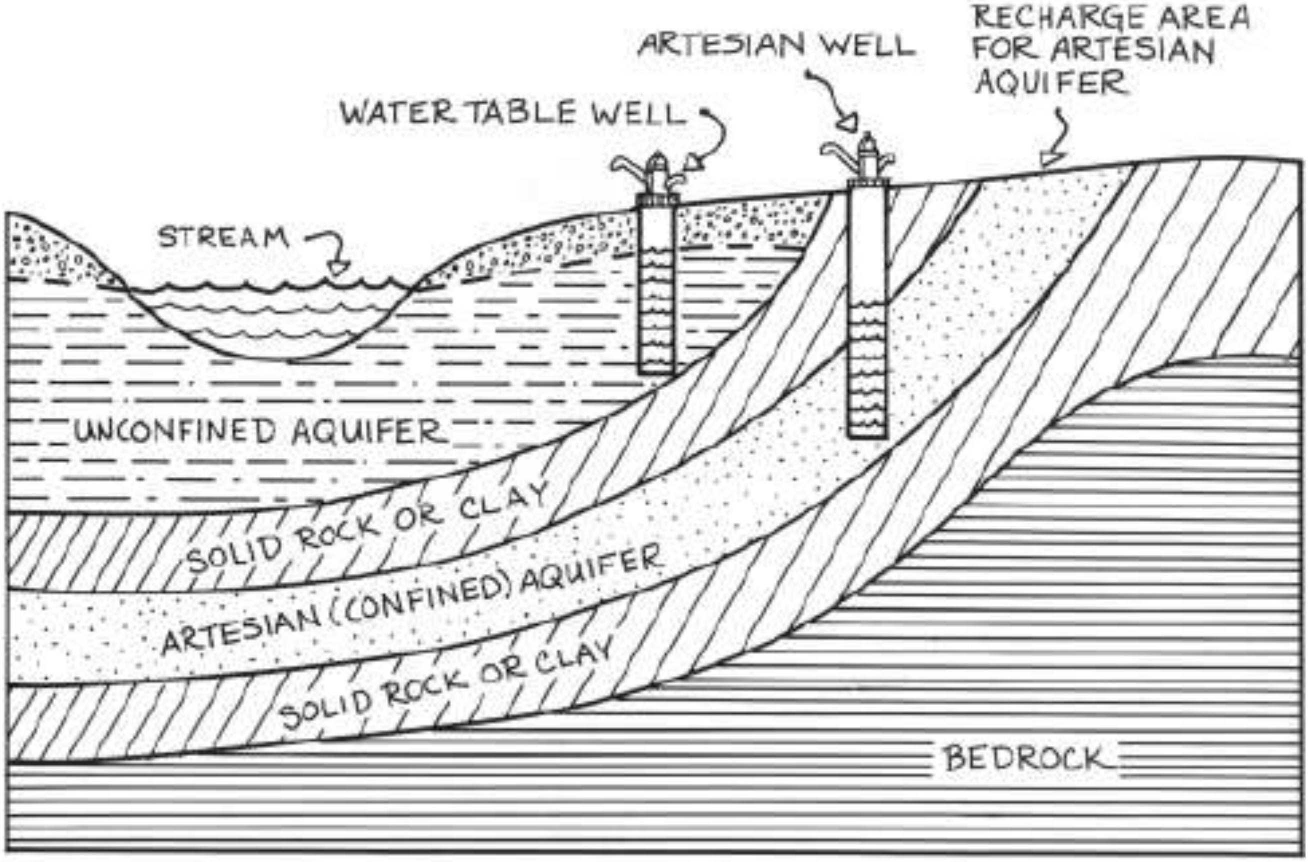
Materials/Resources:
"Do Now" Activity paper
Creating an Aquifer: (for each group)

- Large clear plastic container or bowl
- One large piece of modeling clay that will allow a 2-inch flat pancake to be made by each group for their container
- White play sand that will fill the bottom of the container
- Gravel enough to form a hill down one side of the container
- Blue food coloring
- A bucket of clear water and a small cup
- Aquifer Diagram
- Colored Markers

Procedure:
1) Review knowledge of the water cycle
2) Brainstorm where students think water goes from rain and other sources.
3) Discuss how water acts on different surfaces: paved areas, unpaved areas, mountains, forests, farms, etc. city vs. rural.

4) Creating and Aquifer exercise:
   a) Pour enough sand to cover ¼ inch in the bottom of the container. Pour water into sand, wetting it completely (there should be no standing water on top of the sand). Let students see how the water is absorbed in the sand, but remains around the sand particles, as it is stored in the ground and ultimately forming part of the aquifer.
   b) Have each group flatten the modeling clay (like a pancake) and cover ½ of the sand with the clay (have the students press the clay to one side of the container to seal off that side). The clay represents a "confining layer" that keeps water from passing through it. Pour a small amount of water into the clay. Let the students see how the water remains on top of the clay, only flowing in areas not covered by the clay.
   c) Use the gravel to form the next layer of earth. Place the rocks over the sand and clay covering the entire container. To one side of the container slope the rocks, forming a high hill and a valley. Explain to students that these layers represent some of the many layers contained in the earth's surface. Now pour water into your aquifer until the water in the valley is even with your hill. Students will see the water stored around the rocks. Explain that these rocks are porous, allowing storage of water within the pours and openings between them. They will also notice a "surface" supply of water (a small lake) has formed. This will give them a view of both the ground and surface water supplies, which can be used for drinking water purposes.
   d) Use the food coloring and put a few drops on top of the rock hill as close to the inside wall of the container as possible. Explain to the students that often, old wells are used to dispose of farm chemicals, trash, and used motor oils and these substances can end up in their drinking water. They will see that the color spreads not only through the rock, but also to the surface water and into the sand at the bottom of their container. This is one way pollution can spread throughout the aquifer over time.
      (Environmental Protection Agency Office of Water "The Water Source Book")

AQUIFER DIAGRAM



(Environmental Protection Agency Office of Water "The Water Source Book")

Closure:

- Have students make drawings of their aquifer and use different colored markers to separate the areas of their aquifer diagram.
- Complete "Do Now" paper

Lesson 3 - Groundwater Well Model/ Hydraulic Fracturing Process

Objectives: investigate how Hydraulic Fracturing (fracking) is done, and build a groundwater well model.

Materials/Resources;

- "Do Now" Activity paper
- Hydraulic Fracturing outline
- Hydraulic Fracturing diagram
- Well Model Materials (for each group):
    - 2- liter pop bottle (cut in half)
    - Pump from soap dispenser

- Sand approx. 4-500 mL
- Gravel approx. 4-500 mL
- Food coloring (blue & yellow)
- Water supply
- Cup
- Marker

Procedure/Groundwater Well Model:

1) Explain that in our last lesson we observed how aquifers work, and today we will find out how we can get water to use from them.

2) Creating the Well Model:
   a) Using the 2-liter bottle, fill with 3 to 4 inches (7.5 t0 10 cm) of gravel and sand
   b) Pour in 2 to 3 inches (5 to7.5cm) of water colored blue with food coloring
      i) Tell students that water found beneath the ground is called groundwater
      ii) Explain that the top surface of the water is called the water table. Mark the water table with marker
   c) Place the pump into the gravel with the tube extending into the water.
      i) Tell the students that today a well is usually drilled. It is around 2 to 4 inches (5 to 10 cm) wide and lined with metal or plastic pipe to keep the sides from falling in
      ii) Ask students to notice that the tubing must extend below the water table to work well.
   d) Pump the water out of the model (catching the water in the cup). Have students mark the water level and tell ways the water table gets "recharged," and partially refill with blue water.
   e) Pour yellow water into the bottle; observe what happened to the water.
      i) Explain that while many contaminants can be seen, others cannot and that all contaminants are not of human origin. Ask how we can determine if water is contaminated even if we cannot see the pollutants. (by testing)

   (Environmental Protection Agency Office of Water "The Water Source Book")

3) Have the class examine the Hydraulic fracturing picture/diagram while reading about the fracturing process.

4) Hydraulic Fracturing
   a) What it is:
      i) Known as "fracking," it is the process of creating fissures, or fractures, in underground formations to allow natural gas, oil, and/or water to flow.
   b) How is it done?
      i) First developers begin construction of a drill site or pad by setting up a rig and operational equipment. This takes from 2 to 8 weeks.
      ii) A well is drilled hundreds to thousands of feet below the earth's surface (4,000 to 8,500 feet)

iii) Fluids commonly made up of water, (as much as 5 million gallons) sand and chemical additives are pumped at high pressure to open large fractures that can extend several hundred feet away from the well.

iv) The vertical portion of the well is encased in cement for safety.

v) Horizontal Drilling allows the drill to turn at a near 90-degree angle. This new method of drilling gives the developer the ability to accommodate several wells from the same surface site. This occurs several thousand feet below where any aquifers may be.

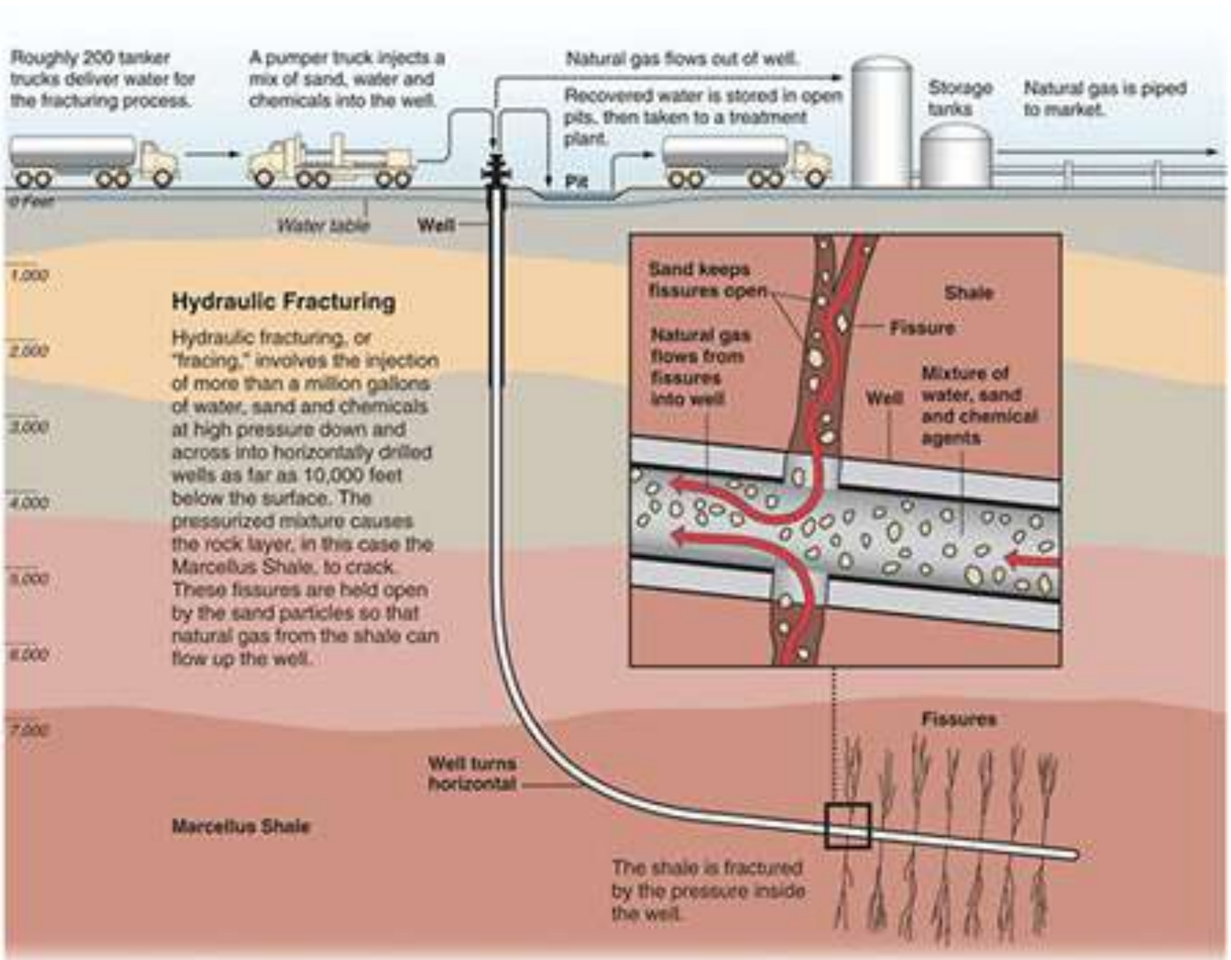
vi) After the fractures are created a propellant agent is pumped into the fractures to keep them from closing after the pumping pressure is released.

vii) After the fracturing the geologic formation causes the injected fracturing fluid to rise to the surface (flowback) where it may be stored in pits prior to disposal or recycling. Much of the flow back is left in the ground however, 20% to 80% of the injected water may "flow-back". This water is very toxic and cannot be treated by wastewater treatment plants.

viii) The natural gas that is recovered is transported though a pipeline or by truck to market.

ix) At the conclusion of this process well developers begin the land reclamation process, with developers seeking to leave behind a small footprint for each well pad site.

WELL DIAGRAM



Graphic by Al Granberg

Closure:
Complete "Do Now" paper: have students write a possible environmental problem or question in "What do I think it means" section of Do Now.

Lesson 4 - Natural Gas: What are the benefits? Hydraulic Fracturing and the Pennsylvania Greenways

Objective: Explain the uses, needs and benefits of natural gas and illustrate the possible impact the future of hydraulic fracturing may have on the state's water.

Resources:

- Natural Gas outline – chart-copy for each student
- Transparencies/ student copies of:
  - Hydraulic Fracturing map
  - "Permitted Gas Wells in PA through 2010"
  - Pennsylvania Rivers Map
  - Marcellus Natural Gas Field Map

Grouping:Whole class

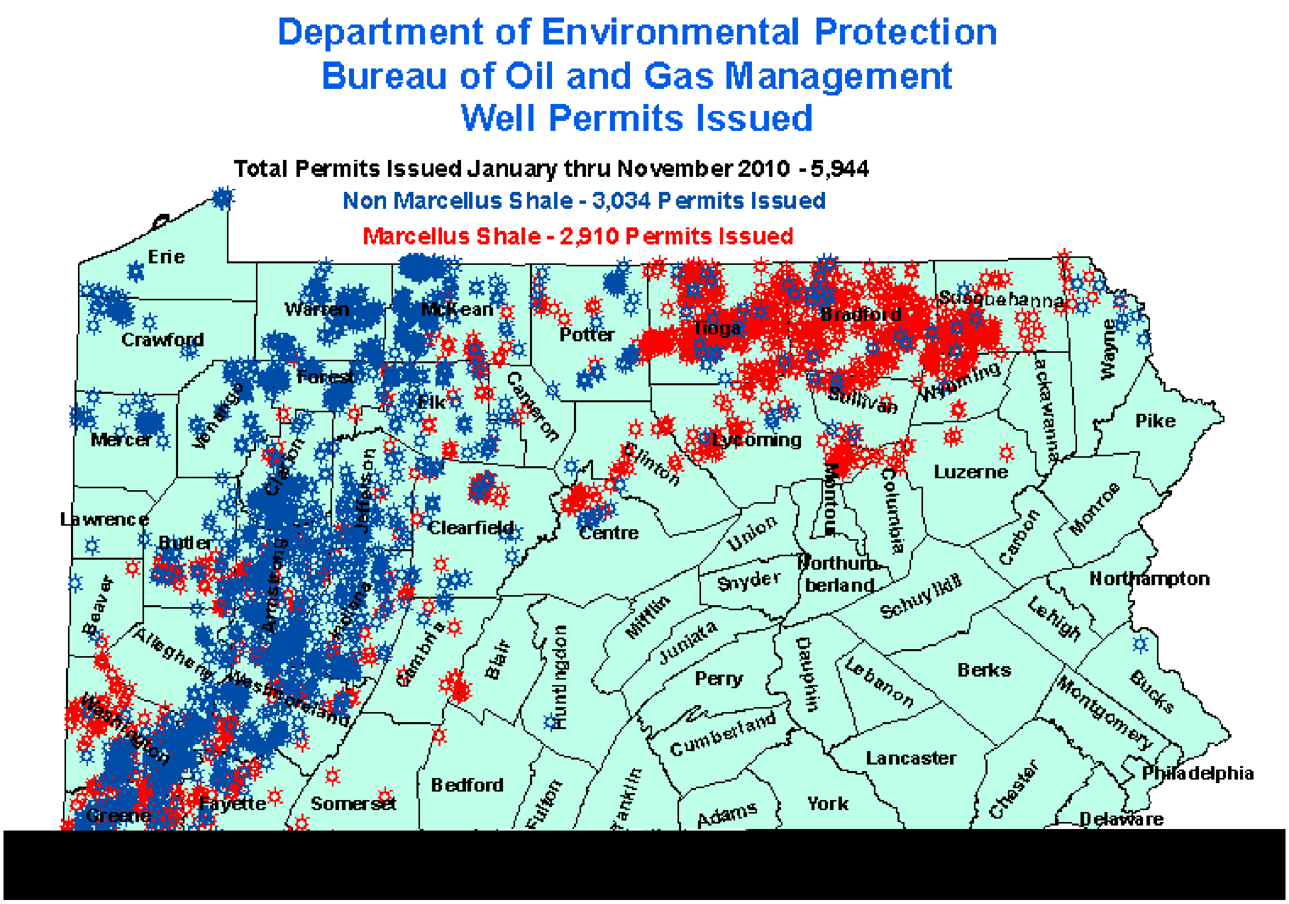
Procedure:

1) Elicit from class possible environmental problems of "fracking" from previous "Well" lesson
2) Go over Natural Gas Benefits outline with class
3) Show where drilling is already taking place in Pennsylvania with Permit map
4) Show Pennsylvania river map
5) Place river map over drilling field map then discuss possible problems
6) Complete "Do Now" paper

Natural Gas Benefits

1. Clean
   a. When used to generate electricity natural gas burns cleaner than other fuels, with less pollutants and no mercury.
   b. Natural gas vehicles emit 30% less CO_2 than gasoline or diesel
2. Abundant
   a. Shale gas makes up 20% of the U.S. gas supply and is predicted to make up 50% in the next 25 years. (IHSCERA.com)
3. Domestic
   a. 1. 98% of natural gas comes from North America, lessening our dependence on foreign oil.
4. Jobs
   a. Natural gas contributes $ 385 billion annually to the U.S. economy and supports over 2.8 million American jobs.
5. Transportation

a. Natural gas costs less than half the price of traditional fuels.
b. 70% of our oil imports go to transportation; greater use of natural gas vehicles will lessen our dependence on foreign oil.
c. Converting one trash truck from diesel to natural gas is the equivalent of taking 325 cars off the road.



Lesson 5 Evaluations
Assign groups of students to debate for or against Hydraulic Fracturing in the state of Pennsylvania. Have groups give at least 5 reasons in support of their opinion.

Appendices
Standards:

PA Science Standard Earth Science
3.5.7.A Describe earth features and processes.
3.5.7.B Recognize earth resources and how they affect everyday life
3.5.7.D explain the behavior and impact of Earth's water systems.
3.5.4.D. recognize the earth's different water resources.

Environmental Health
4.3.7.A. Identify environmental health issues
4.3.7.B. Identify how human actions affect environmental health.

Physical Science, Chemistry and Physics
3.4.4.B Know basic energy types, sources and conversions

Unifying Themes
3.1.7.B describe the use of models as an application of scientific or technological concepts

Science, Technology and Human Endeavors
3.8.B. Explain how human ingenuity and technological resources satisfy specific human needs and improve the quality of life.

Renewable and Nonrenewable Resources
4.2.7.B. Examine the renewably of resources.
4.2.7.C. explain natural resource distribution.

Humans and the Environment
4.8.7.A Describe how the development of civilization relates to the environment.
4.8.7.B. explain how people use natural resources
4.8.7.C. Explain how human activities may affect local, regional and national environments.
4.8.7.D. explain the importance of maintaining the natural resources at the local state and national levels.

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Resources

Video:
"Bill Nye the Science Guy – Earth's Crust and Earthquakes" Disney Education Production 2008
Excellent explanation of the structure of the Earth

"Bill Nye the Science Guy- Lakes and Ponds VHS, Disney
Excellent background information on aquifers, indicator species, and water environments.

Books:
Eco – Predictions. Diana Noonan, Teacher Created Material Publishing 2009.

The Magic School Bus Inside the Earth Joanna Cole, Illustrated by Bruce Degen Scholastic Publishing, 1987.

Magazines:
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