Exploring Aquifers Lesson One:
"Geology of Aquifers"

Academic Questions: What are the parts of an aquifer?
How much water does an aquifer hold?
Is all aquifer water usable?

Objective(s):

- To identify the major components of an aquifer
- To learn to measure water storage in an aquifer
- To evaluate water quality in an aquifer

Key Terms: water table, zone of aeration, zone of saturation, bedrock, carbonate, impervious layer, confining layer, artesian springs, sinkhole, faults, permeable layer, water bearing layer, contributing zone, recharge zone, confined zone, storage capacity, salinity, Total Dissolved Solids (TDS), estuarine, parts per million (ppm), serial dilution, desalinization
Click here for definitions to Exploring Aquifers vocabulary.

Process (Activities):

Part One: Creating an Aquifer Model

1. Share the following information with the students:
   An aquifer is an underground storage of water that people use as a fresh water drinking supply. The water in an aquifer is stored in geologic formations--in other words rock. These rocks are porous and can hold water much like a sponge holds water. Aquifers have different zones: for collecting water, for water entering the ground, and sometimes, for confining water.

2. Have the students work in collaborative teams to gather information about the different types of aquifers, the different layers in an aquifer and the different aquifer zones. (See the Resource section for websites to use.) Students will use this information to create an aquifer model. Each team will chose an aquifer type found in Texas. These models should clearly differentiate between aquifer types of substrate and have visible differences between the recharge surfaces and impervious layers. Models need to be built in containers with transparent sides, such as 10-gallon aquariums or clear plastic cases.

   All models should have these areas built in and marked:
   - Water Table
   - Zone of aeration
   - Zone of saturation
   - Bedrock
   - Water bearing layer
   - Creeks
   - Lakes

   The carbonate and sandstone/carbonate aquifers also have:
   - Impervious layer
   - Confining layer
   - Artesian springs
   - Sinkhole
   - Faults

The model will become the central component of the project and should be large enough to accommodate future additions. Students will continue to add information to the model as they learn about the natural and human systems that rely on the aquifers and waterways specifically found in their county.

Possible materials for the creation of the model might include:

- Container (plastic case or 10 gallon aquarium)
- Plastic tubing
- Pump from a liquid soap container
- Panty hose
- Household sponges
- 5 gallon bucket of sand
- 5 gallon bucket of gravel
- Broken bricks
- Outdoor carpeting
- Modeling clay
- Watering bucket

3. Handout the following student directions for designing and creating their unique aquifer mode. Click here to print out this handout.
   a. Choose a material or materials to act as the water bearing layer.
      __ Sponge __Gravel __ Sand __Bricks
   b. How thick will your water-bearing layer be?
      __2 inches ___5 inches __7 inches
   c. Will there be a topsoil layer? Choose a material to act as the soil layer.
      __Gravel __ Sand __Outdoor carpeting
   d. How thick will your topsoil layer be?
      __1/2 an inch ___1 inch __ 1 and 1/2 inches
   e. Will there be a confining layer? Choose a material to act as a confining layer.
      __ Clay __ Cloth
   f. Place the plastic tubing in the container and hold upright as the layers are added.
   g. Be sure to cover the bottom of the plastic tube with a piece of panty hose. Hold the panty hose in place with a rubber band. The panty hose will stop any gravel or sand from clogging the tube when you pump the water.
   h. Put the pump in the top hole of the plastic tubing.
   i. Identify if your model had the following features and describe what those features look like:
      - Bedrock layer
      - Water bearing layer
      - Permeable layer
      - Impervious layer
      - Contributing zone
      - Recharge zone
      - Confined zone

4. Have students simulate water entering the aquifer contributing and recharge zones in their models. Discuss with students what parts are critical in their models to ensure water enters the aquifer. What features of the model affect the way rainfall gets into the aquifer?

Part Two: Measuring Water Storage in Aquifers

1. Teach students about porosity and permeability. Point out that porosity is not equal to permeability since porosity is the percentage of the total volume of the rock consisting of voids, while permeability is the capacity of a rock to transmit fluids.

   The different types of porosity in rocks include:
   - Porosity resulting from well sorted sedimentary grains (sand and gravel with pore size = 12 to 45% volume).
   - Porosity in poorly sorted sedimentary deposits, where much of the space between large grains is filled with smaller grains.
   - Porosity in cemented sedimentary rocks (sandstone), where the cementing material fills the space between the grains.
   - Porosity due to fractures.
   - Porosity due to fractures enlarged by dissolving activity.

   Porosity changes with depth. When there are two miles thick of substrate resting on top of the material, the overlying rock compresses the voids and porosity diminishes.

   Permeability of rock depends on the connections between the voids. As a rule, shale, dense limestone, unfractured granite, and quartzite have low permeability. Conglomerates, sandstones, fractured basalt, and fractured and dissolved limestones exhibit high permeability.

2. Have students compare the ability to store water by the different substrates and the availability of water in the different substrate by completing the following experiment. (Note: Storage ability of the different substrates is compared by pouring a measured amount of water from a graduated cylinder into the substrate containers. Availability of stored water in different substrates is compared by measuring the amount of water that can be drained from the containers.) Ask students to predict which material will hold the most water. Ask students to repeat the groundwater experiment they conducted in the introduction activities to test their hypothesis, this time using the water-bearing substrate they used in their aquifer models:
   a. Fill tall clear container three fourths full of the same substrate used in their model for the water-bearing portion of the aquifer.
   b. Pour a measured amount of water into the container. (You might want to allow students to add a small amount of red or blue food coloring so that they can see the water movements.)
   c. Continue pouring water until the water table is at the surface of the material, or the zone of saturation is at ground level. Be sure to keep a running total of the amount of water poured into each container.

3. Ask the students to predict which material will have the most water availability. Will it be the material with the most storage ability? Have students compare the availability of water in the different substrates using the following steps.
   a. Place a hand pump from a soap dispenser into the container, with the intake protected by pantyhose or a screen. Place the pump all the way to the bottom.
   b. Pump the water into a cup. After a set amount of time, all water removal should stop. This is to differentiate the substrate porosity, which allows water movement.
   c. Measure the amount of water removed from the container. Is it equal to the amount that entered the substrate? Where is the remaining water?

4. Have the students estimate the storage capacity in their aquifer models and label. What percentage of that water is available for removal? Discuss with students the importance of both attributes for an aquifer's substrate material.

Part Three: Exploring the Usability of Aquifer Water

1. Share the following information with the students:
   Aquifers are prized drinking water sources because the water is generally pure and clear and clean, needing very little water treatment. One reason is the filtration that occurs as water percolates down through sand and gravel layers. Another reason is that in natural areas the rainwater that enters the aquifer does not pick up much pollution. Not all aquifer water has the same purity, however. Some groundwater carries dissolved substances, including salts, and is considered saline, or "bad water." These saline waters occur naturally for different reasons.

2. Have students research water standards for drinking water's total dissolved solids (TDS) and salinity. A good link for information is on the Cyberways and Waterways web site in Real World Issues under SaltTrack Web Links:
   http://www.cyberwaysandwaterways.com/en/realWorldIssues/issues/index.xml?show=Salinity Below is a list of water standards for several different uses of water.

Designated Use Limits

USE	LIMITS (mg/l)
Human consumption	500 TDS (250 chloride, 250 sulfate)
Irrigation	500-1,000 TDS (250 mg/l chloride)
Brewing	Light beer 500 TDS, Dark beer 1,000 TDS
Pulp and paper	Fine paper 200 TDS, Groundwood paper 500 TDS
Boiler feed water	50 to 3,000 TDS, depending on pressure
Canning/ freezing	850 TDS
Aquatic life	Varies, depending on natural conditions

3. Ask students to predict the impact of salt in freshwater. Share with students the following information:

   - *Drinking water effects: High levels of total dissolved solids may impart an objectionable taste to drinking water. Chloride, in particular, has a low taste threshold. Sodium sulfate and magnesium sulfate levels above 250 mg/l in drinking water may produce a laxative effect. Excess sodium may affect those restricted to low sodium diets and pregnant women suffering from toxemia (EPA, 1986).*
   - *Industrial effects: Dissolved salts may either encrust or corrode metallic surfaces. Salt in intake water may interfere with chemical processes within the plant (EPA, 1986).*
   - *Aquatic system effects : Some freshwater organisms are able to tolerate low dissolved solids levels. If total dissolved solids increase in the water body, a shift to more salinity-tolerant species can be expected (James and Evison, 1979). High salinity may interfere with the growth of aquatic vegetation. Salt may decrease the osmotic pressure, causing water to flow out of the plant to achieve equilibrium. Less water absorbed by the plant causes stunted growth and reduced yields. High salt concentrations may cause leaf tip and marginal leaf burn, bleaching, or defoliation (Perfetti and Terrel, 1989).*
   - *Estuarine aquatic life effects: It is generally tolerant of fluctuating salinity levels. Under natural conditions, estuarine water may fluctuate between fresh and brackish, depending on the flow rate of the river discharging into the estuary. Aquatic organisms inhabit zones in the estuary according to preferred salinity levels. Thus, if the volume of fresh water entering the estuary fluctuates sufficiently to cause a change in the salinity patterns, species may be displaced and the ecosystem disrupted (EPA, 1986).*
   - *Lake oxygenation effects: Salt water has a higher density than freshwater and tends to sink and form a dense layer in the bottom of the lake. This saline layer does not mix*

with oxygenated surface lake water, leading to decreased dissolved oxygen levels along the lake bottom (Gower, 1980).

- *Irrigation effects: Salt in the soil may harm crops. Certain salt constituents alone can prove toxic to some plant varieties. Also, high salt concentrations in the soil around plant roots may cause plant dehydration by reversing osmotic conditions (water will flow out of the plant in an attempt to achieve equilibrium). In some cases, rather than destroying a crop, elevated salt levels may simply reduce crop yields and leave the plants prone to disease (Sherrard et al., 1987).*

4. Ask students: "What do we mean by saline water?" Explain when water is saline: it contains significant amounts (referred to as "concentrations") of dissolved salts. In this case, the concentration is the amount (by weight) of salt in water, as expressed in "parts per million" (ppm). If water has a concentration of 10,000 ppm of dissolved salts, then one percent (10,000 divided by 1,000,000) of the weight of the water comes from dissolved salts. Here are parameters for saline water:
   - Fresh water - Less than 1,000 ppm
   - Slightly saline water - From 1,000 ppm to 3,000 ppm
   - Moderately saline water - From 3,000 ppm to 10,000 ppm
   - Highly saline water - From 10,000 ppm to 35,000 ppm
   - Ocean water - 35,000 ppm of salt.

5. Help the students produce a saline solution containing the maximum allowable TDS for drinking water. Make a full cup of 1,000 parts per million of salt water using the following steps:
   a. Weigh the cup, fill the cup with water, and reweigh. Find the weight of the water.
   b. Divide the weight by 1,000 and weigh out this amount of table salt. (1,000 parts of salt per 1,000,000 parts per water is equal to one part salt to 1,000 parts water)
   c. Combine the salt with the water.

   Look in USGS water science site for help in understanding the solution. (http://ga.water.usgs.gov/edu/drinkseawater.html)

6. How many parts per million is the salt? Have the students sample the solution. Use good hygiene with cups or spoons for every student. Perform a series dilution to find at what parts per million the salt no longer is tasted. Do the following steps:
   a. Color the saline water with food coloring. Pour half the water into another cup. Fill the remaining space in the second cup with fresh water. Stir. Pour half of the second cup into a third cup and fill the third cup with fresh water. Repeat for two more cups. How many parts per million is the salt now? (CUP 1 = 1,000 parts, CUP 2 = 500 parts, CUP 3 = 250 parts, CUP 4 = 125 parts, CUP 5 = 62 parts per million).
   b. Have students sample the dilution cups and decide at which level the salt taste was gone. Was the salt gone? Was the food coloring still visible in the final dilution cup? At what dilution will the salt and food coloring be gone?

7. Discuss with students the problem with saline waters in the aquifer. Identify the source of salts in aquifers. Identify the geology of the aquifers that would increase salinity of the water. According to SaltTrackers, the natural concentration of salts is largely influenced by the geologic formation underlying the area. Low salinity is expected in non-faulted areas underlain by igneous geologic formations. High levels of dissolved solids often occur in areas underlain by ancient marine sediments. As time passes, the salts are removed from the sedimentary rocks by wind and water erosion. These elements remain dissolved in surface waters.

8. All students should investigate desalinization technology and the cost to purify 1,000 gallons of water. Review the specific traits of water and principles of matter that allow the reverse osmosis membrane and the freeze thaw technology to work.

9. Have the students add a component to their aquifer models that would hold "bad water." List possible uses for saline waters. The Texas Groundwater Protection Committee's Groundwater Classification System list of uses for saline waters: (http://www.tnrcc.state.tx.us/water/quality/gw/tgpc/gw_class_sys.html)

10. With the older students, test for total dissolved solids in water collected from springs, rivers, creeks, municipal taps, and bottled water labeled "spring water." There are limits being placed on all waterways for allowable TDS, because of the detrimental effects on organisms. As water enters the aquifers carrying an increasing load of dissolved solids, TDS will become a problem. Analytical techniques that can be used, listed in Salttrackers are:
    - Electric Conductivity (EC): Uses a conductivity bridge calibrated with standard seawater solution. The resistance of a sample solution is measured with an electric potential. The solution's ability to transmit electricity is facilitated by increasing salt content. The EC is normally measured in mhos/cm, mmho/cm, or umho/cm (non-SI units) or siemen per meter (s/m) (SI units), depending on dissolved salt concentrations.
    - (0.64 umho/cm= 640 mmho/cm= 640 dS/m= 64.0 cS/m=6.4 mS/m). EC values can be translated into the total quantity of dissolved salts with the following conversions: TDS (mg/l) = 640*EC (mmho/cm) and TDS (mg/l) = 0.64*EC (umho/cm)
    - Density Method: Uses a precise vibrating flow densimeter.
    - Gravimetric Method (APHA 1992): As an example, magnesium is measured using the gravimetric method. Diammonium hydrogen phosphate precipitates magnesium in ammonical solution as magnesium ammonium phosphate. The test can be performed two ways. First, the ammonium salts and oxalate can be destroyed, followed by precipitation of magnesium ammonium phosphate. Second the diammonium hydrogen phosphate can undergo double precipitation without pretreatment (preferable option). Dry and weigh sample. Interferences: Presence of aluminum, calcium, iron, manganese, silica, strontium, and suspended matter might interfere with test. Solution should not contain more than 3.5 g NH_4Cl.

Assessment/Evaluation: Using the students' aquifer model and the results of their experiments, ask students to determine which aquifer will be the best source of fresh drinking water in the future. Why or why not? Students should consider what percentage of that water is available for removal over time and how much water in the aquifer is below the bad water line. Finally, ask students to describe attributes of the ideal aquifer.

Conclusion: Using the USGS Aquifer Basics web pages descriptions about rock types found in principal aquifers (capp.water.usgs.gov/aquiferBasics/index.html), have students find the names and locations of aquifers in Texas that have layers of the same material as their models. Have students label their models with a specific aquifer name and location. Have students research the amount of water contained in each aquifer, and the percentage of water that can be removed. Finally, ask students to determine what aquifers in Texas might be at risk of intrusion of bad or saline waters. For the older students, use the Geological Map of Texas, available through the Bureau of Economic Geology, to locate the names of the layers in their aquifer on the generalized charts of rock and time units. Students may investigate the formation of those layers and the historic timeline using geology books, such as Roadside Geology of Texas.

Resources:
Texas water development board “Texas Aquifer Maps” allows students to see city boundaries and county boundaries overlaying the aquifers:
http://www.twdb.state.tx.us/mapandphotos/mp_twdbmaps/aquifer_maps/aquifersindex.htm

The USGS Aquifer Basics web pages contain very helpful information about the rock types found in principal aquifers:
http://capp.water.usgs.gov/aquiferBasics/index.html

The USGS Ground Water web pages include information on how groundwater occurs, the quality of groundwater, and the nation’s groundwater resources:
http://capp.water.usgs.gov/GIP/gw_gip/index.html

The USGA description of the major and minor aquifers in Texas:
http://sr6capp.er.usgs.gov/gwa/ch_e/E-text10.html

A description of the underground water resources of Texas is found in the Handbook of Texas Online:
http://www.tsha.utexas.edu/handbook/online/articles/view/UU/gru1.html

Introduction to the Edwards Aquifer created by Greg Eckhardt:
http://www.edwardsaquifer.net/intro.html

Information about desalinization technology:
http://www.freshwater2000.com/

USGS water science web pages discuss a promising method to desalinate seawater—the "reverse osmosis" method.
http://ga.water.usgs.gov/edu/drinkseawater.html

Roadside Geology of Texas by Darwin Spearing, published by Mountain Press Publishing Company, Missoula, Montana in 1991.

Geologic Highway Map of Texas, published by The American Association of Petroleum Geologists, available from the Bureau of Economic Geology. For further information or to order, please contact Publications Sales Office at 1-888-839-4365 or (512) 471-7144.

Time Frame: One week of 45 minutes class periods.
Grade Level: 6th-12th

TEKS Correlation:
Science
Grade 6: 6.1, 6.2, 6.3, 6.4, 6.14
Grade 7: 7.1, 7.2, 7.3, 7.4, 7.5, 7.8
Grade 8: 8.1, 8.2, 8.3, 8.4, 8.5, 8.12, 8.14
Chemistry: 4.B, 8.B
Aquatic Science: (b)1, 4.B
Environmental Science: (b)1, 4.B, C, 5.B
Geology, Meteorology, and Oceanography: (1), 10.A,C

Mathematics
Grade 6: 6.1, 6.8, 6.11, 6.12, 6.13
Grade 7: 7.3, 7.4, 7.9, 7.13, 7.14, 7.15

Grade 8: 8.5, 8.14, 8.15
Geometry: 6
Precalculus: 2

Technology Applications (Computer Literacy)
Grades 6-8: 2, 4, 5, 7, 8

Social Studies
Grade 6 6.21, 6.22, 6.23
Grade 7 7.8, 7.21, 7.22, 7.23
Grade 8 8.10, 8.30, 8.31, 8.32

English
Grade 6: 6.1, 6.2, 6.5, 6.13, 6.17, 6.20, 6.22, 6/24
Grade 7: 7.1, 7.2, 7.5, 7.13, 7.17, 7.20, 7.22, 7.24
Grade 8: 8.1, 8.2, 8.5, 8.7, 8.10, 8.13, 8.17, 8.18, 8.20, 8.22, 8.24
English I: 1, 4, 6, 8, 13, 15, 16, 21
English II: 1, 4, 6, 7, 8, 13, 15, 16, 21