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Get the Ground Water Picture

Have you ever wished you had a window into the earth so you could see what's beneath your feet?

Grade Level
Middle School, High School

Subject Areas
Environmental Science, Math, Government

Duration
Preparation time: Part I: 30 minutes; Part II: none needed; Part III: 15 minutes

Activity time: Part I: 30 minutes; Part II: 30 minutes; Part III: 50 minutes

Setting
Indoor

Skills
Organizing information (matching, charting); Analyzing (identifying patterns); Interpreting (inferring, translating)

Charting the Course
To help students understand how ground water relates to the water cycle, they can participate in "The Incredible Journey." To understand the amount of water underground, "A Drop in the Bucket" demonstration is effective. In "Blue Planet," students are introduced to the concept of residence time. Issues concerning ground water contamination are addressed in "The Pucker Effect" and "A Grave Mistake."

Vocabulary
ground water system, substrate, geologic cross section, aquifer, unconfined surface aquifer, confined/artesian aquifer, impervious/impermeable layer, permeable layer, percolate, water table, down gradient, gravitational energy, recharge area, discharge area, hydrogeologist, pressure energy, well log, runoff, watershed, zone of saturation, zone of aeration

Summary
Students learn about basic ground water principles as they create their own geologic cross section or Earth window.

Objectives
Students will:

- identify the parts of a ground water system.
- compare movement of water through diverse substrates.
- relate different types of land uses to potential ground water contamination.

Materials
Part I
- *Three clear, 12-ounce plastic bottles* (with tops cut off and holes punched in bottom) *or the same number of plastic cups* (with holes punched in bottom or three cups per lab group)
- *Gravel*
- *Sand*
- *Clay* (If unable to obtain clay locally, place unscented, nonclumping kitty litter in a blender and grind until fine. Mix with enough water to make moist.)
- *Hand-held magnifying lens*

Part III
- *25 1" × 12" strips of white paper* (Number the back of the strips 1 through 25.)
- *Blue crayon or colored pencil*
- *Copies of* ***Well Log Ground Water Chart***
- ***Well Log Ground Water Chart*** *Answer Key*

Making Connections
Out of sight is out of mind. Because ground water is hidden below Earth's surface, students do not have a visible reference point as they do when they look at surface water (e.g., lakes, rivers). Ground water is a source of drinking water and depending upon where students live, they may drink ground water every day. Students may have seen a windmill or pump that draws water from the ground. Windmills can serve as surface indicators of ground water. They also generate electricity. Creating a geologic cross section helps students become aware of this hidden source of water.

Background
Ground water is one of Earth's most valuable natural resources. The water stored in the pores, cracks and openings of subsurface rock material is ground water. Wells dug by hand or machine have been used throughout history to retrieve water from the ground. Scientists use the word aquifer to describe an underground formation that is capable of storing and transmitting water.

Aquifers come in all shapes and sizes. (See definitions in Parts of a Ground Water System.) Some aquifers may cover hundreds of square miles and be hundreds of feet thick, while others may only cover a few square miles and be a few feet thick. Water quality and quantity vary from aquifer to aquifer and sometimes vary within the same system. Some aquifers can yield millions of gallons of water per day and maintain water levels, while others may only be able to produce small amounts of water each day. In some areas, wells might have to be drilled thousands of feet to reach usable water, while in other areas, water can be located only a few feet down. One site might contain several aquifers located at different depths and another site might yield little or no ground water.

The age of ground water varies from aquifer to aquifer. For example, an unconfined surface aquifer might hold water that is only a few days, weeks or months old. On the other hand, a deep aquifer that is covered by one or more impermeable layers may contain water that is hundreds or even thousands of years old.

The rate of movement of ground water varies based on the rock material in the formation through which the water is moving. After water percolates down to the water table, it becomes ground water and starts to move slowly down-gradient. Water movement responds to differences in energy levels. The energies that cause ground water to flow are expressed as gravitational energy and pressure energy. (These are both forms of mechanical energy.) Gravitational energy comes from the difference in elevation between the recharge area (where water enters the ground water system) and discharge area (where water leaves the system). Pressure energy (hydraulic head) comes from the weight of overlying water and earth materials. Ground water moves toward areas of least resistance. (Ground water encountering semi-impervious material, such as clay, will slow down significantly; when it moves toward an open area, such as a lake, water's rate of movement will increase.)

Hydrogeologists (scientists who study ground water) know that the above variables exist and that to really "get the ground water picture," they must drill wells. Wells provide the best method of learning the physical, hydrologic and chemical characteristics of an aquifer. As a well is drilled deeper and deeper into the ground, the drill passes through different rock formations. The driller records the exact location of the well, records the depth of each formation and collects samples of the rock material penetrated (e.g., sandstone, sand, clay). This data becomes part of the well's record or well log. The driller's record provides valuable information for determining ground water availability, movement, quantity and quality. The well driller then caps and seals the well to protect it from contamination.

Pools found in caves are usually filled with ground water.

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If contaminants such as hazardous waste, chemicals, heavy metals or oil collect on the surface of the ground, rain or runoff percolating into the soil can carry these substances into ground water. When hydrogeologists or water quality specialists analyze the quality of ground water, they consider land-use practices in the watershed and in the vicinity of the well.

Procedure

Warm Up

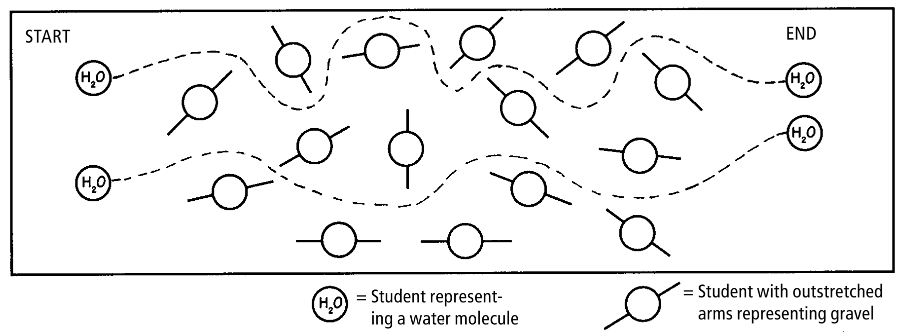
- Tell students they are about to learn how they can "get the ground water picture."
- Explain that hydrogeologists study wells to learn the types of rock material located below ground.
- Ask students to draw pictures representing what they think it looks like underground (texture and color of rock formations) or to write brief descriptions of what happens to water after it seeps into the ground.

The Activity

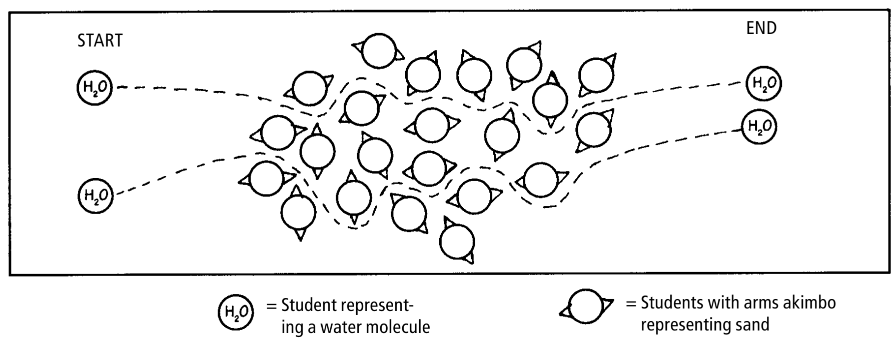
Part I

1. **Conduct a ground water demonstration or lab to learn how water moves through rock materials, such as gravel, sand and clay.**
2. **Place gravel, sand and clay in separate clear containers.** Have students look closely at each container. (A hand-held magnifying glass works well.)
3. **To demonstrate that ground water moves through underground rock formations, pour water into each container; observe and discuss the results.**
4. **Which container emptied the fastest? The slowest?** How would the different materials influence water movement in natural systems?

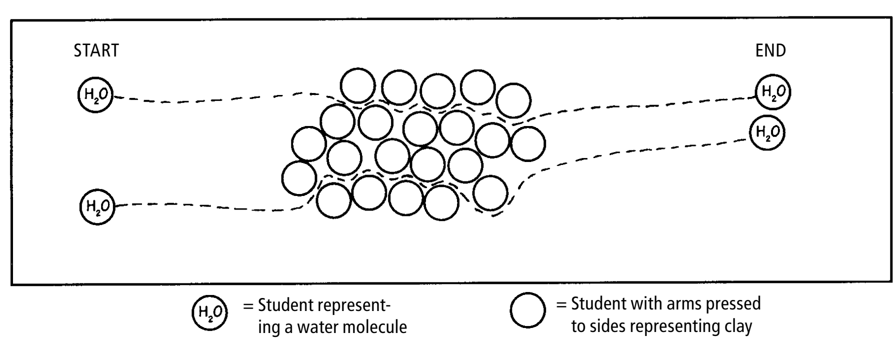
A Water Movement Through Gravel



B Water Movement Through Sand



C Water Movement Through Clay



Part II

(May be appropriate for younger students.)

1. **Conduct a ground water movement activity to show how different sizes and kinds of rock material affect water movement.**
2. **Select three or four students to become molecules of water.** The rest of the students will be rock material.
   a. **Water Movement Through Gravel:** Students become gravel by raising arms outstretched. Students should be able to rotate and not touch other students. The goal of the students representing water molecules is to move (flow) through students representing gravel to the other side of the room. (See illustration A.)

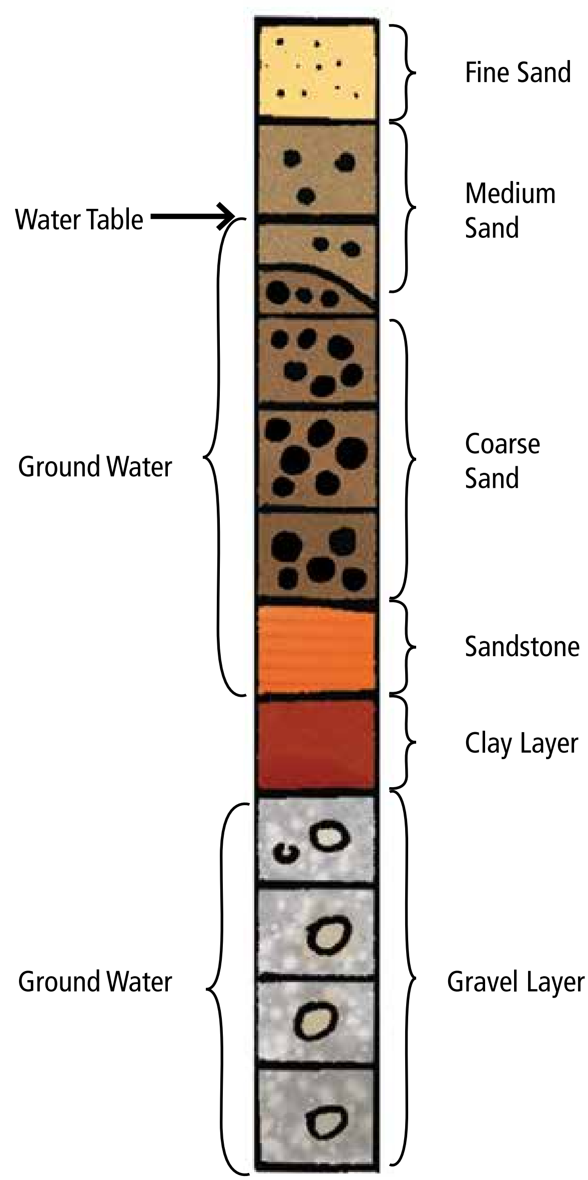
   b. **Water Movement Through Sand:** Students become sand by extending arms, bending them at the elbows and touching waists with fingertips. Students should stand so their elbows are almost touching. The water molecules will experience some difficulty this time but should still reach the other side. (See illustration B.)

   c. **Water Movement Through Clay:** Students become clay particles by keeping arms at their sides and huddling together. They should be very close together, making it a formidable task for water molecules to move through the clay. Without being rough, the water molecules should slowly push their way through the clay. The water molecules may be unable to move through the clay at all. (See illustration C.)

Part III

1. **Hand out strips numbered 2-24 to students (students can work individually or in pairs) and copies of the *Well Log Data Chart*.** The paper represents the length of a well that has been dug. Students will receive data about the location and types of rock materials in their wells and transfer this information to their strips of paper to make well logs.
2. **Demonstrate how to record the information from the *Well Log Data Chart* onto the individual well logs (paper strips). Divide the paper strip labeled 1 into 12 inches. This is the well log for Well #1. Show students the information for Well #1 in the *Well Log Data Chart*.** In the first column in the chart, the water table level is noted. Mark the level of the water table on the well log at the

Sample Well Log, Well #1



appropriate location (2 inches from the top); use a double line. In the second column in the chart, the level of fine sand is noted (0 to 1 inch). Mark the top square in the well log with speckled dots. In the third column of the chart is medium sand (1 to 2 ½ inches). Mark the well log with larger dots between 1 and 2 ½ inches below the top. Proceed through the rest of the rock layers noted for Well #1 on the *Well Log Data Chart.* Complete the drawing by coloring (light blue) the area between the water table and the top of the clay layer. Also color the gravel layer. The blue represents ground water. The clay layer forms a barrier that the water cannot penetrate. The completed well log should look like *Sample Well Log, Well #1.*

3. **Have students fill in their well logs based on the numbers on their strips of paper and the information in the *Well Log Data Chart* (if a strip is labeled 6, the student uses data from Well # 6).** Make sure students note the land use existing above their well sites.
4. **When they have completed their well logs, ask students to answer questions based on their well logs.**
   a. The horizontal scale of the cross section is 1 inch = 1 mile. The vertical scale is 1 inch = 50 feet. How many miles are horizontally represented in the cross section? (25 miles.) How many feet are vertically represented in the cross section? (12 x 50 = 600 feet.)
   b. How many feet below the surface is the water table? (Answers will vary.)
   c. Ask each student to imagine a drop of water falling on the surface above his or her well. What pollutants might this drop of water pick up as it filters into the ground? (Students can refer to the land use practice above their well, but may conclude they need additional information.)
   d. Have students describe the drop's movement down the column. Through which layers would it move the fastest? The slowest?
   e. At which layer might the drop's movement be restricted? Explain to students that only a slight amount of water would pass through the clay. Have them speculate on the source of the water beneath the clay level (in the gravel layer).
5. **Have students assemble their well logs in order and tape them to a wall. Distribute to each student the *Reference Illustrations* and the *Well Log Ground Water Chart* (Cross Section). Compare students' well log cross sections to the chart.**
   a. Provide the definitions listed in the box labeled *Parts of a Ground Water System* and have students locate these parts on the ***Well Log Ground Water Chart*** (Cross Section).
   b. Ask students what direction the ground water is moving in the unconfined aquifer. (Predominantly moves from left to right.)
   c. What are water sources for the unconfined aquifer? (Rainfall, wetlands, the river.)
   d. How long would it take the water in the sandstone formation to move from Well #1 to Well #15? (Assume the water moves at a constant rate and flows at 100 feet per day [1 mile = 5,280 feet].) (14 x 5,280 = 73,920 / 100 = 739.2 days.)
   e. Now that students know about the land use above other well sites and the direction water flows, how would they answer question 4c?
   f. Have students refer to the *Cone of Depression* diagram in the *Reference Illustrations*. Explain that the cone of depression results from water being drawn up the well. Ask them to locate the cone of depression on the ***Well Log Ground Water Chart*** (Cross Section).
   g. Instruct students to refer to the *Ground Water System* (Simplified) diagram in the *Reference Illustrations*. What are possible sources of water in the confined aquifer portion of their well? (Compare answers to 4e.)

Wrap Up

- If they had to drill a well, which sites would students consider most favorable on the ***Well Log Ground Water Chart*** (Cross Section)?
- Students may be interested in learning about the rock formations beneath their community. The city water department might have a geologic cross section for the city or region. Students could attempt to interpret the maps.

Project WET Reading Corner

Faulkner, Rebecca. 2007. *Beneath the Surface.* Chicago, IL: Heinemann Library.

Learn what discoveries can be found in some of the most inaccessible places on Earth.

Friend, Sandra. 2002. *Sinkholes.* Sarasota, FL. Pineapple Press, Inc.

Learn how underground forces from water, earthquakes, caverns and the like can create holes that suddenly open to the surface.

Gibbs, Louis Marie. 1998. *Love Canal: The Story Continues.* Gabriola Island, BC, Canada: New Society Publishers.

Written 20 years after the famous community became the focus of a heated debate about soil and ground water contamination, and the need to protect the environment.

Hoff, Mary King and Mary M. Rodgers. 1991. *Our Endangered Planet: Rivers and Lakes.* Minneapolis, MN: Lerner Publications.

The authors describe the global uses and abuses of ground water and suggest ways to preserve this valuable resource.

Lindop, Laurie. 2005. *Cave Sleuths.* Minneapolis, MN: Lerner Publications Co.

Explore underwater caverns with teams of scientists who discover everything from vast underwater lakes to creatures that live in total darkness.

Project WET Foundation. 2000. *Discover Ground Water and Springs.* Bozeman, MT: Project WET Foundation.

Illustrated children's activity booklet exploring the topics of ground water and springs.

Verne, Jules. 1864. A *Journey to the Center of the Earth.* Mineola, NY: Dover Publications.

Classic fictional tale of a group of adventurers who find a path to the very center of Earth.

West, Krista. 2009. *Layers of the Earth.* New York, NY: Chelsea House Publishers.

Explore what's under the Earth from the soil to the core and cover such topics as geology and geohydrology.

Assessment

Have students:

- compare the movement of water through diverse substrates in a ground water lab or demonstration (***Part I).***
- simulate how water moves through sand, gravel, clay (***Part II***).
- construct a well log (***Part III***, steps 2 and 3).
- analyze possible effects on ground water based on interpretations of the well logs (**Part III**, steps 4 and 5).
- identify the parts of a ground water system (***Part III, step 5).***
- determine when additional data are needed to draw valid conclusions (***Part III***, steps 4 and 5).

Extensions

Does your school have its own well? If so, consider visiting the well site and performing a survey of possible pollution sources in the well's vicinity. What are they and where are they located? Should something be done to remove them? What are the options? The water quality of your school's well is public information and would make an interesting study. Has your school experienced water quality problems?

To demonstrate surface water filtration of sediment and materials carried by water, ask four students to represent water molecules and to lightly attach balloons to themselves with tape. These balloons represent materials picked up by water molecules as they move across the surface of the ground. Have several students representing soil particles stand elbow to elbow to form Earth's surface. As the "water molecules" pass through the "soil," the balloons will be "brushed off" (because of the proximity of the students). This represents how soil can filter out sediment and debris carried by water.

Have each of the water molecules rub a little flour on the sides of their arms. The flour represents the small but visible materials that can still be carried by water as it moves downward from the surface as it becomes part of ground water. The students who were soil particles are now rock particles and stand side by side to represent different types of rock material (gravel, sand, and clay). As the water molecules move through the rock material, some of the flour rubs off on the rock material. Although some material is removed by rock filtration, some is still retained by the water molecules.

Water that looks or tastes pure and is odorless is not necessarily potable. Water quality specialists know that odorless, colorless and tasteless contaminants are found in water. These substances are detected through testing; a sample of water is collected and analyzed for specific contaminants (bacteria, nitrates, arsenic and so forth).

Assign half of the students in class to be water molecules and the rest rock particles. Cut small pieces of paper and on each write one of the following: bacteria, nitrate, arsenic, lead. Secretly distribute these pieces of paper to about half of the water molecules and tell students to hide them in their pockets. Have the water molecules move through the students, standing side by side, who represent rock particles.

After they have all passed through, ask students (except for the "contaminated" water molecules), "Do you believe that the water that just filtered through the rock particles is clean; that is, would you be willing to drink it?" Students will likely answer, "Yes." Have the contaminated water molecules remove the contaminants from their pockets. Remind students that even though water may "appear" clean, it may still carry contaminants that are only detected through testing.

Parts of a Ground Water System

• Water Table:

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

• Confined Aquifer:

An aquifer bound above and below by impermeable layers that transmit water significantly slower than the aquifer. The water level in a well that taps a confined aquifer will rise above the top of the aquifer, because the confined aquifer is under pressure; this is also called an artesian aquifer.

• Unconfined Aquifer:

An aquifer in which the upper boundary is the top of the water table.

• Permeable Layer:

Portion of aquifer that contains porous rock materials that allow water to penetrate freely.

• Impermeable Layer:

Portion of aquifer that contains rock material that does not allow water to penetrate; often forms the base of unconfined aquifers and the boundaries for confined aquifers.

• Zone of Saturation:

The part of a water-bearing formation in which all spaces (between soil particles and in rock structures) are filled with water.

• Zone of Aeration:

Portion of unconfined aquifer above the water table where the pore spaces among soil particles and rock formations are filled with air.

PHOTO CREDIT: © ck2007 | Dreamstime.com

Farms used to rely on the power of the wind to tap into ground water aquifers in many western states. Today, wells and electric powered pumps pull water from underground aquifers to the surface for use.

Teacher Resources

Books

Soukhome, Jennifer, Graham Peaslee, Carl Van Faasen and William Statema. 2009. *Watershed Investigations: 12 Labs for High School Science.* Arlington, VA: National Science Teacher Association.

The downloadable chapter "Groundwater Contamination" consists of a two-part investigation where students model the effects of groundwater contamination and then track its flow.

Journals

Colburn, Alan. 2010. "The Prepared Practitioner: Groundwater–A Green Issue." *Science Teacher,* 77 (2), 8.

Dickerson, Daniel L., John E. Penick, Karen R. Dawkins and Meta Van Sickle. 2007. "Groundwater in Science Education." *Journal of Science Teacher Education,* 18 (1), 45-61.

Grady, Julie R. and Andrew S. Madden. 2010. "Integrating the Sciences to Investigate Groundwater Pollution." *Science Activities: Classroom Projects and Curriculum Ideas,* 46 (4), 7-14.

Lacosta-Gabari, Idoya, Rosario Fernandez-Manzanal and Dolores Sanchez-Gonzalez. 2009. "Designing, Testing, and Validating an Attitudinal Survey on an Environmental Topic: A Groundwater Pollution Survey Instrument for Secondary School Students." *Journal of Chemical Education*, 86 (9), 1099-1103.

Mohr, Beth A. 2009. "Feeling Blue in the South Valley: A Case Study of Nitrate Contamination in Albuquerque's South Valley." *Bulletin of Science, Technology & Society,* 29 (5), 408-420.

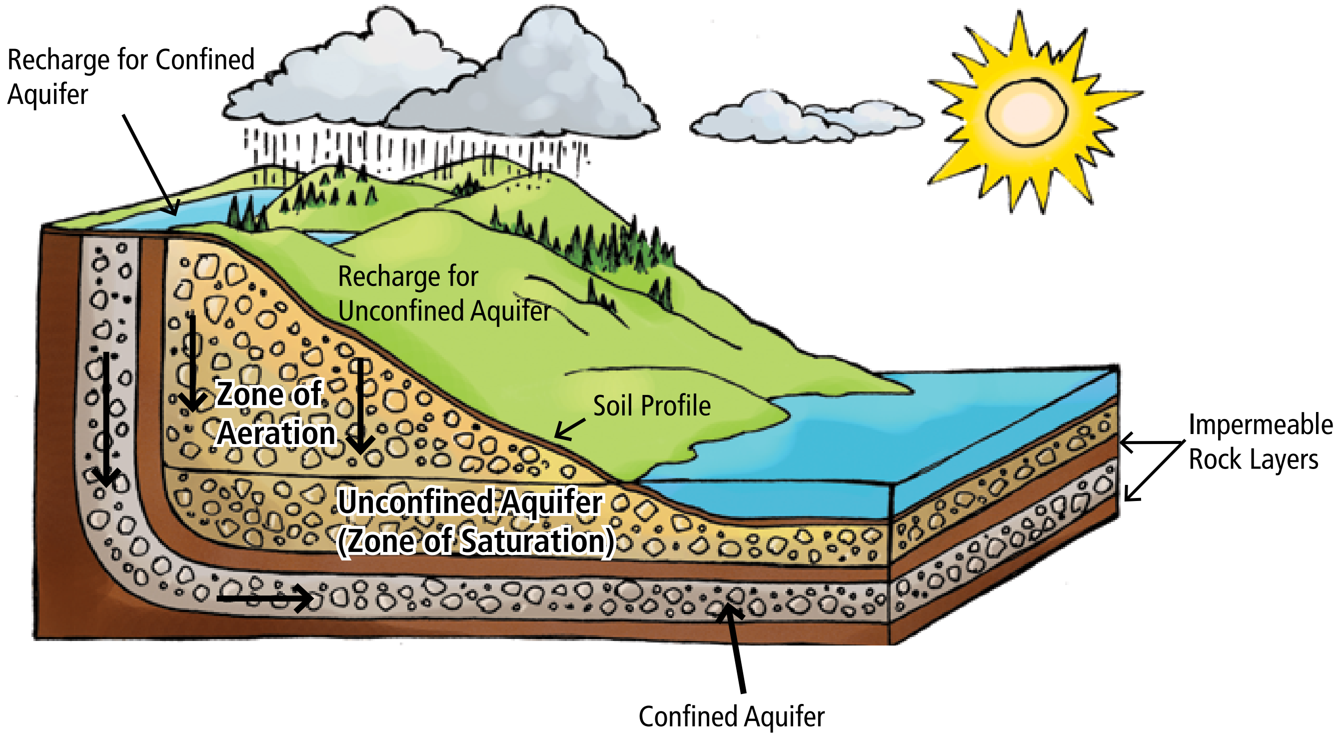
Vowell, Julie and Marianne Phillips. 2007. "A Drop through Time." *Science and Children,* 44 (9), 30-34.

NOTE: Ground water flow models are available through many companies and are an excellent tool to illustrate ground water concepts.

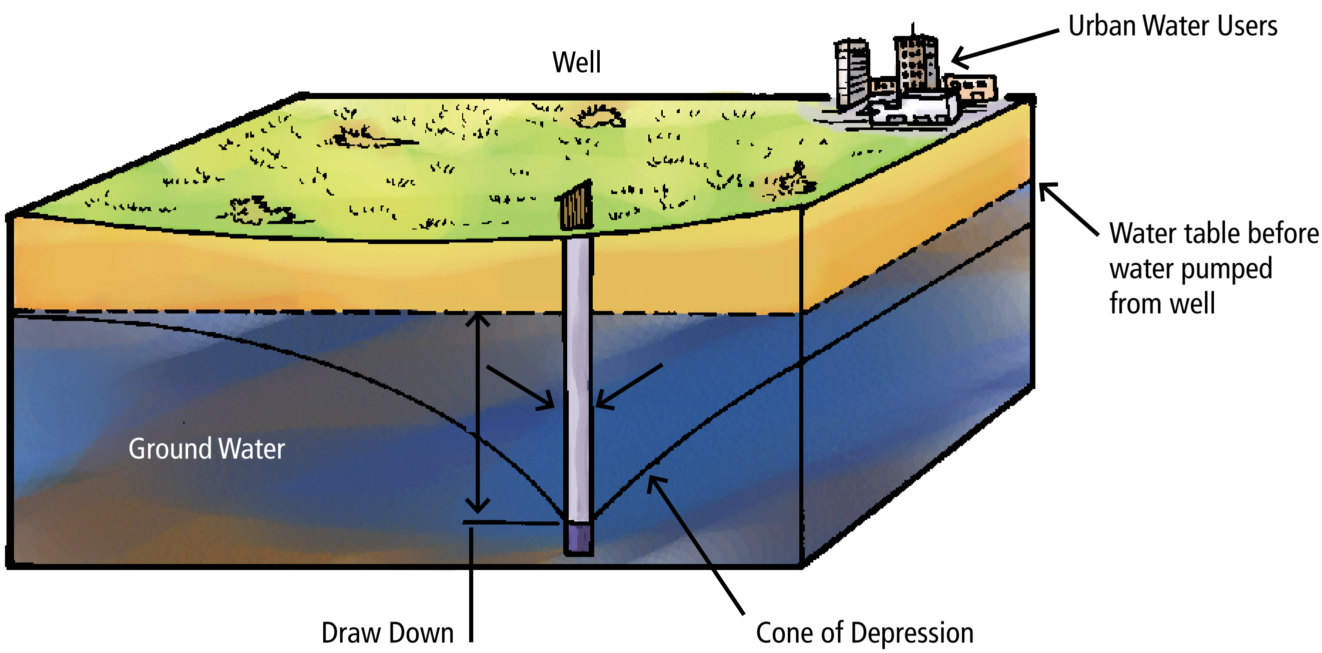
PHOTO CREDIT: © Jim Parkin | Dreamstime.com

This endless field of sunflowers in Kansas is watered by ground water from the Ogallala Aquifer.

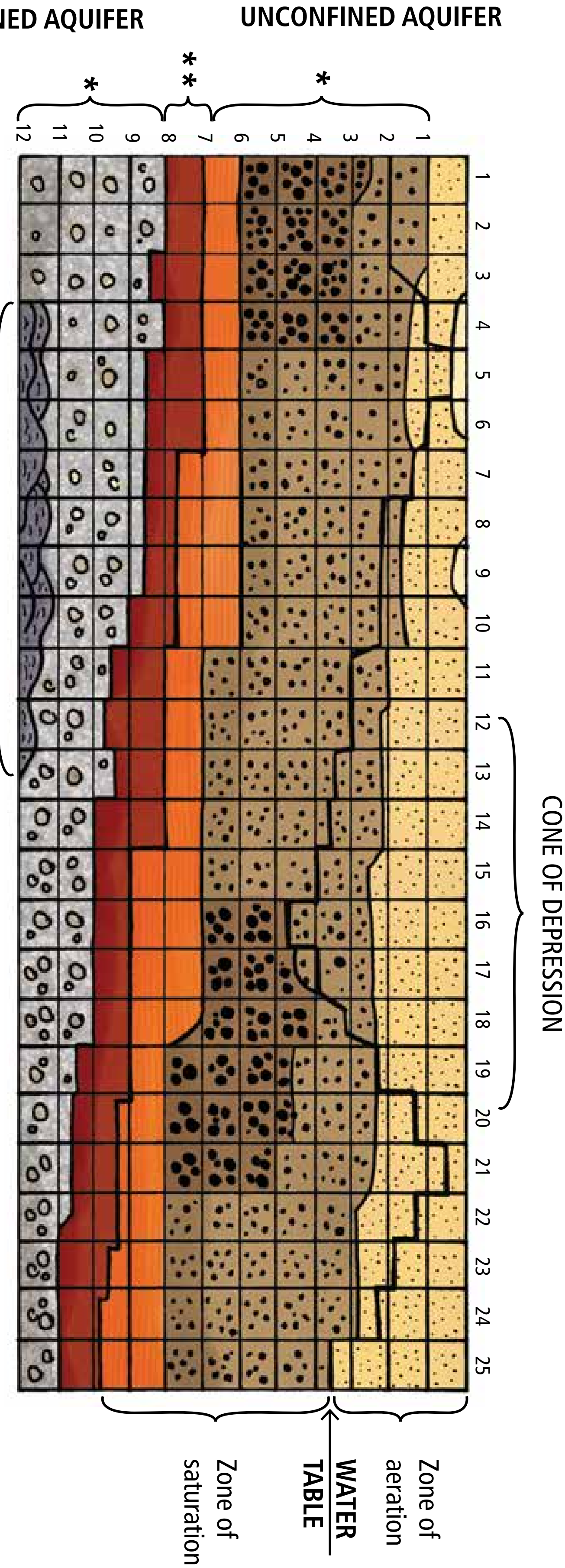
Ground Water System (Simplified)



Cone of Depression



Well Log Ground Water Chart (Cross Section)



KEY:

* Permeable layers

* * Imperemeable layer (clay)

Note: numbers in vertical columns and horizontal rows for this hypothetical example are in inches

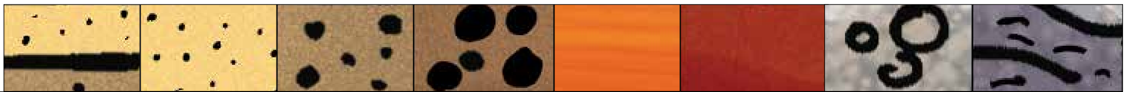
SCALE:

1 horizontal inch = 1 mile

1 vertical inch = 50 feet

1 mile = 5,280 feet

KEY Note: numbers in vertical columns are in inches.



Well Number Land Use Type	Water Table	Fine Sand	Medium Sand	Coarse Sand	Sand-stone	Clay Layer	Gravel Layer	Granite
1 farmland	2	0 - 1	1 - 2 ½	2 ½ - 6	6 - 7	7 - 8	8 - 12	—
2 farmland	2	0 - 1	1 - 3	3 - 6	6 - 7	7 - 8	8 - 12	—
3 farmland	2	0 - 1 ½	1 ½ - 3	3 - 6	6 - 7	7 - 8 ½	8½ - 12	—
4 wetland	1	¼ - 1 ½	1 1½ - 3	3 - 6	6 - 7	7 - 8 ¼	8 ¼ - 11 ½	11 ½ - 12
5 wetland	¼	½ - 1 ½	1 ½ - 6	—	6 - 7 ¼	7 ¼ - 8 ¼	8 ¼ - 11 ½	11 ½ - 12
6 wetland	1	¼ - 1 ¾	1 ¾ - 6	—	6 - 7 ¼	7 ¼ - 8 ½	8 ½ - 11	11 - 12
7 farmland	1 ¾	0 - 1 ¾	1 ¾ - 6	—	6 - 7 ¾	7¾ - 8 ¾	8 ¾ - 11	11 - 12
8 farmland	2 ½	0 - 1 ¾	1 ¾ - 6	—	6 - 7 ¾	7 ¾ - 8 ¾	8 ¾ - 11	11 - 12
9 landfill	2 ½	¾ - 1 ¾	1 ¾ - 6	—	6 - 7 ¾	7 ¾ - 8 ¾	8 ¾ - 11	11 - 12
10 industry	2 ½	0 - 1 ¾	1 ¾ - 6	—	6 - 7 ¾	7 ¾ - 9	9 - 11	11 - 12
11 industry	3	0 - 2	2 - 7	—	7 - 8	8 - 9 ¼	9 ¼ - 11 ½	11 ½ - 12
12 urban area	3	0 - 2 ¼	2 ¼ - 7	—	7 - 8 ¼	8 ¼ - 9 ½	9 ½ - 11 ½	11 ½ - 12
13 urban area	3 ½	0 - 2¼	2¼ - 7	—	7 - 8 ¼	8 ¼ - 9½	9 ½ - 11 ½	11 ½ - 12
14 urban area	3 ¾	0 - 2 ¼	2 ¼ - 7	—	7 - 8 ½	8 ½ - 9 ¾	9 ¾ - 11 ½	11 ½ - 12
15 urban area	4	0 - 2 ¾	2 ¾ - 4½	4 ½ - 7	7 - 9	9 - 9 ¾	9 ¾ - 12	—
16 urban area	5	0 - 2 ¾	2 ¾ - 4 ½	4 ½ - 7	7 - 9	9 - 9 ¾	9 ¾ - 12	—
17 farmland	4	0 - 2 ¾	2 ¾ - 4 ½	4 ½ - 7 ½	7 ½ - 9	9 - 10	10 - 12	—
18 wastewater treatment plant	3	¼ - 2 ½	2 ½ - 4		4 - 7 ½	7 ½ - 9	9 - 10	10 - 12
19 farmland	2½	0 - 2 ¼	2 ¼ - 4 ½	4 ½ - 8	8 - 9	9 - 10 ¼	10 ¼ -12	—
20 river	1 ½	¼ - 2 ½	2½ - 4½	4 ½ - 8	8 - 9 ¼	9 ¼ - 10 ½	10 ½ - 12	—
21 river	½	1 - 2½	2 ½ - 5	5 - 8	8 - 9 ¼	9 ¼ - 10 ½	10 ½ - 12	—
22 river	1 ½	¼ - 3	3 - 8	—	8 - 9 ¼	9 ¼ - 10 ½	10 ½ - 12	—
23 national park	2	0 - 3	3 - 8	—	8 - 9 ½	9½ - 10 ¾	10 ¾ - 12	—
24 national park	3 ¼	0 - 2 ¾	2 ¾ - 8	—	8 - 9 ¾	9 ¾ - 11	11 - 12	—
25 national park	3 ¾	0 - 3	3 - 8	—	8 - 10	10 - 11 ¼	11 ¼ - 12	