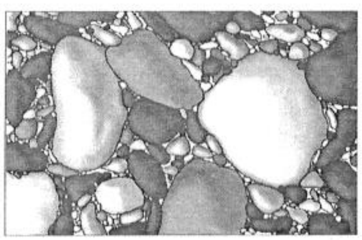
What is groundwater?

Water in the Ground

Like many communities around the world, Fairview's drinking water comes from deep underground. Underground, water isn't stored in lakes or rivers like it is on the surface. It's stored in the tiny spaces between particles of soil, sand, gravel, and even solid rock — anything that contains holes that water can fit inside.

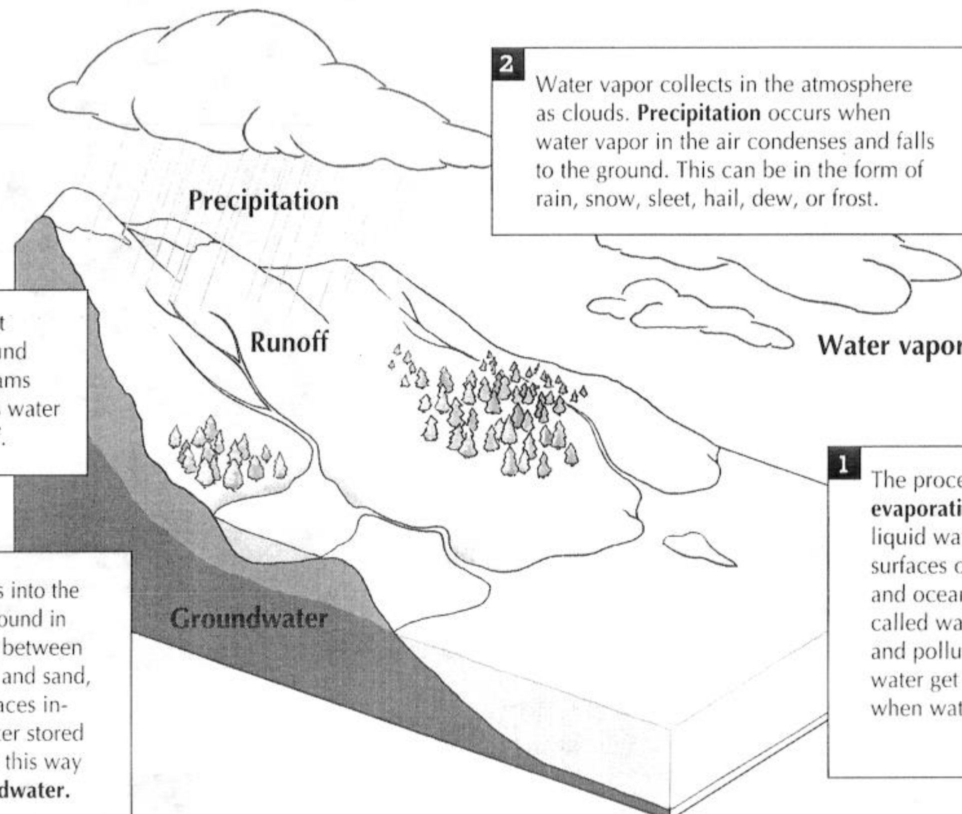


Underground, water sits in the tiny spaces between pieces of sand, gravel, and rock.

Even though most of the spaces underground are small, when you add them all up they can hold a lot of water. In fact only 2 percent of the fresh water in the United States is stored in rivers and lakes on the surface. The rest — 98 percent — is stored underground.

The Hydrologic Cycle

Ever since the beginning of our planet, all the water on Earth has been constantly cycling through the natural environment.



1 The process of **evaporation** changes liquid water on the surfaces of rivers, lakes, and oceans into a gas called water vapor. Salt and pollution in the water get left behind when water evaporates.

2 Water vapor collects in the atmosphere as clouds. **Precipitation** occurs when water vapor in the air condenses and falls to the ground. This can be in the form of rain, snow, sleet, hail, dew, or frost.

3 Some water that falls to the ground collects in streams and rivers. This water is called **runoff**.

4 Water that soaks into the soil sits underground in the tiny spaces between particles of soil and sand, and even in spaces inside rocks. Water stored underground in this way is called **groundwater.**

5 Groundwater moves slowly through the tiny spaces between soil, sand, and rock underground. It eventually comes to the surface at springs, or at the bottom of lakes, rivers, or oceans.

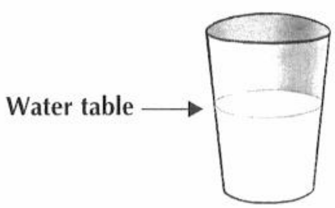
6 Much of the water on Earth eventually makes its way to the oceans.

What is groundwater?

The Water Table

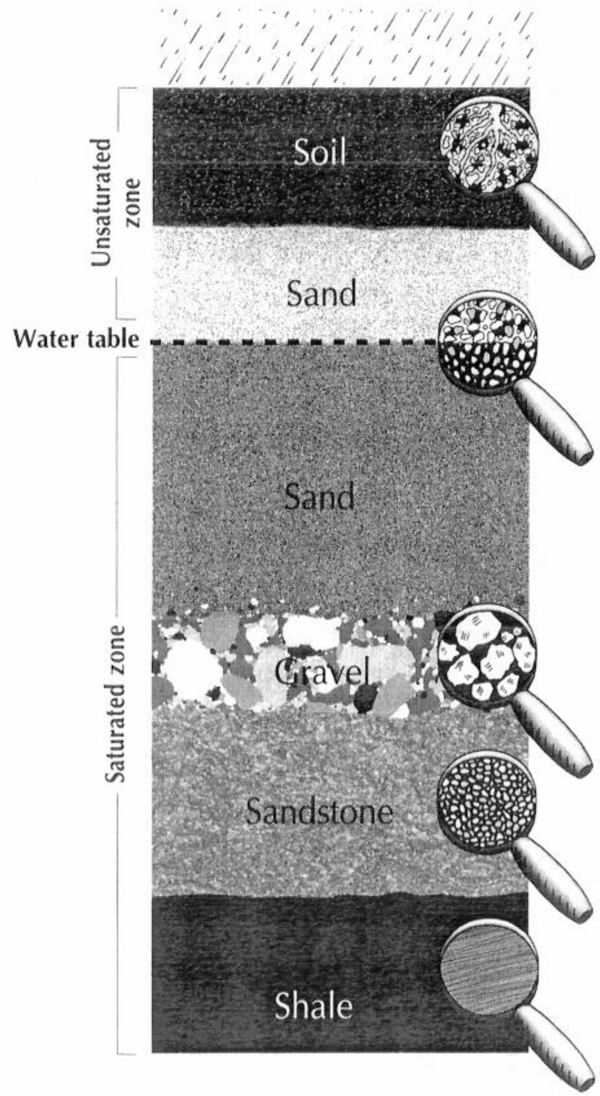
Imagine drinking water that's been stored in rocks and dirt! When people drink water from a well, they're drinking water that's been stored deep underground. Groundwater isn't stored in big underground lakes or rivers, but in the tiny spaces between particles of soil, sand, and rock.

Picture a glass filled halfway with water. The surface level of the water in the glass is the **water table**. Below it, the glass is filled with water. Above it, there's no water.



The same thing happens underground. If you started digging a hole in the ground, you'd dig down through soil, sand, and rocks. Eventually, water would appear at the bottom of your hole. You've reached the water table — the surface level of the water that's stored underground. Beneath the water table every single space in the ground is completely filled with water. Above it, there might be water in some of the spaces, but other spaces contain air.

Water Underground



1. Rainwater falls to the ground. Water that stays on the surface and collects in rivers and streams is called runoff.
2. Some of the rainwater soaks into the soil where some of it may be absorbed by the roots of plants.
3. Gravity pulls the water even further downward. The water trickles through the tiny spaces between particles of sand.
4. The **water table** is the dividing line between the **unsaturated zone** and the **saturated zone.** The area above the water table is unsaturated because the spaces in the material contain a mixture of water and air. The area below the water table is saturated because water fills all the available spaces. **Groundwater** is water that's stored in the saturated zone.
5. Water fills the spaces between the pieces of gravel.
6. Water seeps into solid rock like sandstone. Sandstone is made from grains of sand that have been cemented together. Water can fit inside the small spaces between the particles of sand that make up the rock.
7. Shale is a solid rock that often has no spaces in it. Water can't travel through shale, so it collects above it.

What is groundwater?

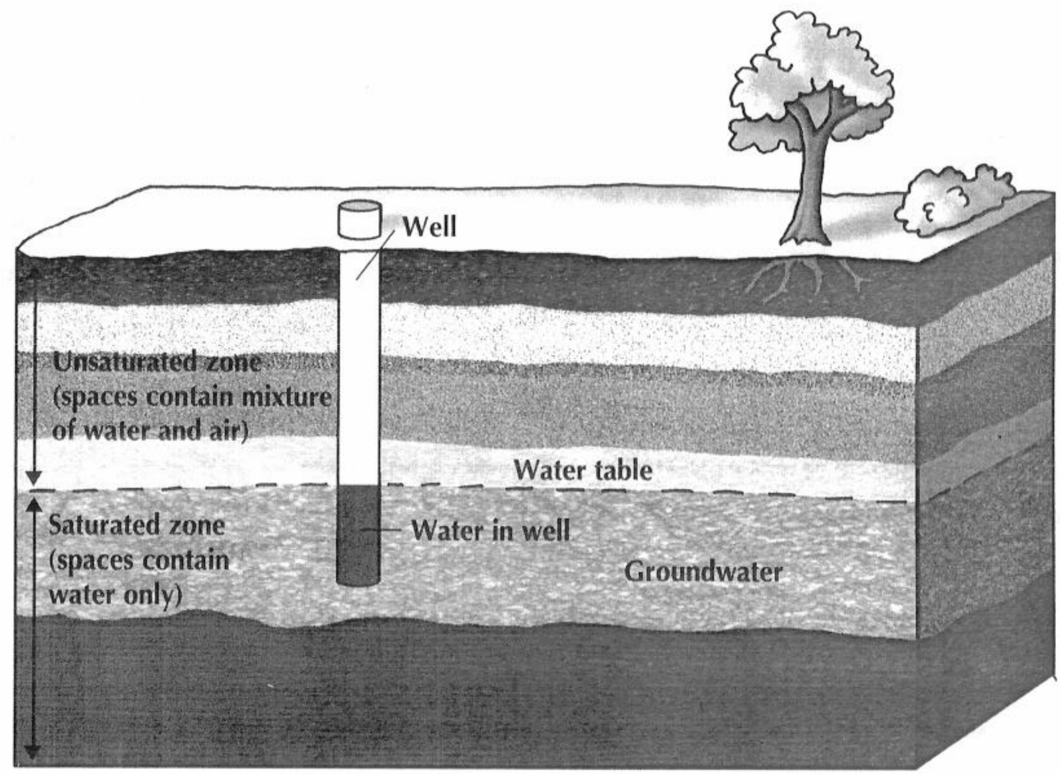
The Saturated Zone

Imagine spilling a soft drink on the floor and then trying to wipe up the spill with a paper towel. At what point does the paper towel stop working? If you believe the advertisements on TV, you could clean up the spill with one paper towel. But in real life, a paper towel only works until every available space in the towel is filled with liquid. At that point, when the towel is dripping wet, you'd need another paper towel to finish the job.

Something is **saturated** (SATCH-ur-ay-ted) when every available space is filled with liquid. A sponge that is dipped in a bucket of water is saturated. It can't hold any more water because the spaces in it are already full of water. Something is **unsaturated** when some or all of the spaces inside it contain air. A sponge that has been dipped in water and then squeezed out is unsaturated. Some of the spaces within the sponge still contain water, so it feels damp, but it could hold more water.

So what does all this have to do with groundwater? Underground, water isn't stored in big caves or rivers, but in the tiny spaces and cracks between particles of sand, soil, and rocks. The area where groundwater is stored is called the **saturated zone**, because all the spaces are filled with water. The top of the saturated zone is the **water table**. It forms a dividing line between the saturated zone that's filled with water, and the unsaturated zone above it that contains a mixture of water and air.

When people dig wells, they're getting water from the saturated zone. When you put a straw into a glass of juice, the juice fills the inside of the straw. The same thing happens underground. A well drilled down past the water table fills with water from the saturated zone around it.



What is groundwater?

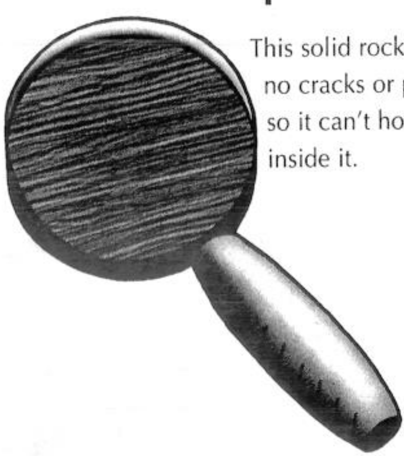
Rocks That Hold Water

Think about all the billions of gallons of fresh water contained in lakes, streams, and rivers all over the world. Sixty times that amount of water is stored underground. But underground, water isn't stored in lakes and rivers like it is on the surface. Instead, it's stored in the small spaces between grains of sand and soil. It can even be stored in the tiny little spaces inside solid rock.

The empty spaces within soil, sand, rock, or any other material are called **pores**. A material's **porosity** is a measurement of how much empty space there is inside it. The more empty space, the more water can fit inside it. Sand has a high porosity because there are lots of small spaces between the particles of sand. All those tiny spaces add up to a lot of space.

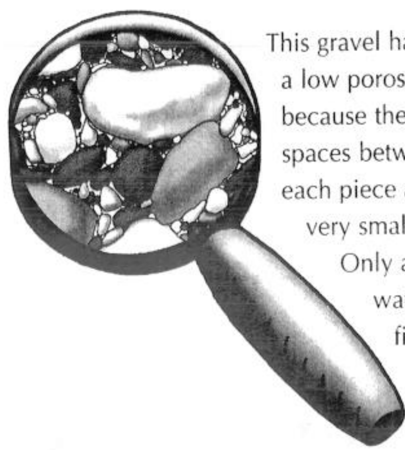
Solid rock can also be porous. Sandstone is a rock that is made from particles of sand that were buried deep underground and slowly cemented together over thousands of years. Even though sandstone is a solid rock, it's a little like Swiss cheese. There are tiny spaces between the sand grains that make up the rock, and water can fit into those spaces. Because the spaces are smaller, the porosity of sandstone is a little less than that of loose sand. Many other kinds of solid rock, like mudstone, siltstone, and limestone are formed with small pores that can hold water. Over many years some rocks can develop small cracks (or **fractures**) that water can fit into. Even though they weren't originally formed with pores, these rocks are porous because they can hold water in the spaces inside them.

Not porous



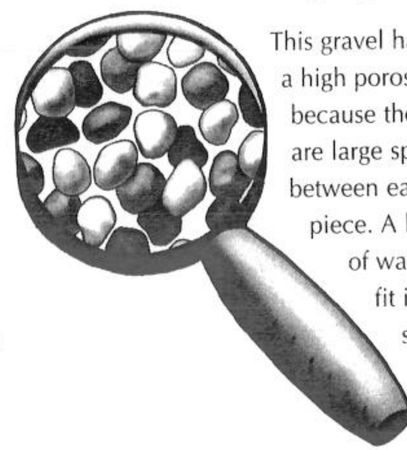
This solid rock has no cracks or pores, so it can't hold water inside it.

Low porosity



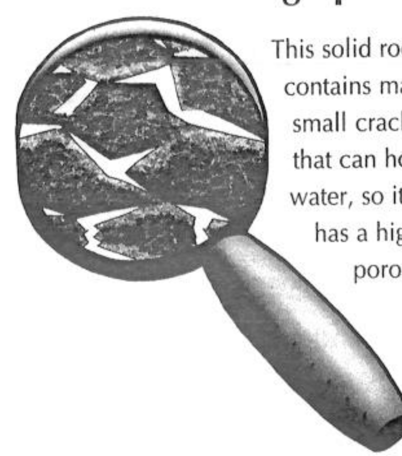
This gravel has a low porosity because the spaces between each piece are very small. Only a little water can fit into the spaces.

High porosity



This gravel has a high porosity because there are large spaces between each piece. A lot of water can fit in the spaces.

High porosity



This solid rock contains many small cracks that can hold water, so it has a high porosity.

Science Seekers

Safe Water

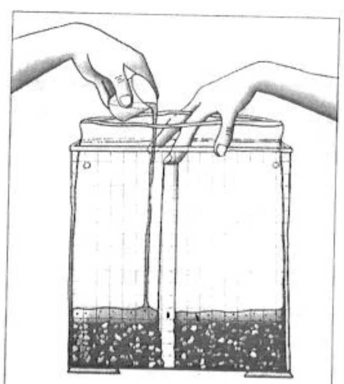
What is groundwater?

Investigation 1

Science La

What You Need

- newspapers
- plastic bag (reclosable)
- Science View tank
- clear Science View grid
- narrow plastic tube (15 cm long)
- plastic cup (1-oz)
- gravel
- damp sand
- potting soil
- water
- colored pencils
- straw
- paper cup

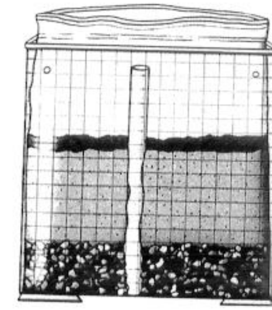


Well, Well, Well...Water!

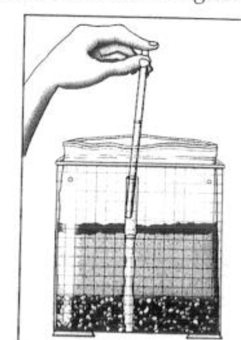
People use water from several kinds of sources. Surface water such as lakes and rivers can provide people with water for drinking and watering crops. People also dig wells to get at groundwater, which lies beneath Earth's surface. In this Science Lab, you will build a model of a groundwater system to investigate how water is stored underground, and how people can access groundwater.

What To Do

1. Spread newspapers over your work area.
2. Open the plastic bag and put it into the Science View tank. Hang the clear grid on the pegs on one side of the tank.
3. Place the clear plastic tube into the bag in the middle of the tank. (It should line up with the eighth or ninth column of grid squares from either side.) The tube will represent a well in your model.
4. Cover the top of the tube with your finger. This will keep materials out of the well as you add them to the tank. Holding the tube in place with your finger over the top, add three 1-oz cups of gravel to the bag, pouring an equal amount on either side of the tube. Gently shake the tank so the gravel layer is about the same depth (3–4 grid squares) all the way across the bottom.
5. Keeping your finger over the top of the tube, add four 1-oz cups of damp sand to the bag, two on each side of the tube. Gently shake the tank until the sand is about the same depth all the way across.
6. Add one cupful of potting soil to the bag, sprinkling soil on both sides of the tube. Gently shake the tank until the soil covers all the sand.



7. Your groundwater model is missing an important part — water! Make it rain by adding 75 mL water (about 2½ 1-oz cups) to the bag. Pour the water evenly over the whole model. Do not pour water into the well.
8. Let the model sit for about 10 minutes so the water can move throug the sediments. While you wait, do step 9.
9. Add the details of your groundwater model to the Groundwater Mod Diagram on the next page. Draw and label each layer and show its thickness in squares. Show the location and depth of the well.
10. When 10 minutes have passed, look for the water table in your model. It is the surface of the water that lies within the sediments in the tank. If you have trouble finding the water table, tilt the tank slightly from side to side. Watch for the surface of the water to move
11. When you have found the water table, use colored pencils to add the water table and the groundwater to the Groundwater Model Diagram
12. Now, you'll model the process of water being pumped from a well. A straw will represent a well pump. Insert the straw into the well, until it touches the bottom. Then place your finger over the end of the straw and lift the straw out of the well so that some water remains in the straw. Empty the straw into a paper cup by releasing your finger.



What is groundwater?

Groundwater Model Diagram

13. Continue removing water from the well until the well is empty. Then wait 5 minutes. Observe what happens in the well, and look for the water table. Compare the level of the water table now to the level before any pumping took place.

14. Pour the water from the paper cup back into the model.

15. Save the model for use in Investigation 3, and complete the What It Means section.

What It Means

1. Where is the groundwater stored in your model?

2. On the Groundwater Model Diagram, label the water table, saturated zone, and unsaturated zone.

3. Where does the water stop moving downward in your model? Why does it stop moving at that point?

4. Describe how the level of the water in the well compared with the level of the water table, both before and after you pumped water from the well. How did each change?

5. Based on your observations of the model, how can pumping from wells affect the water table?

How does groundwater get underground?

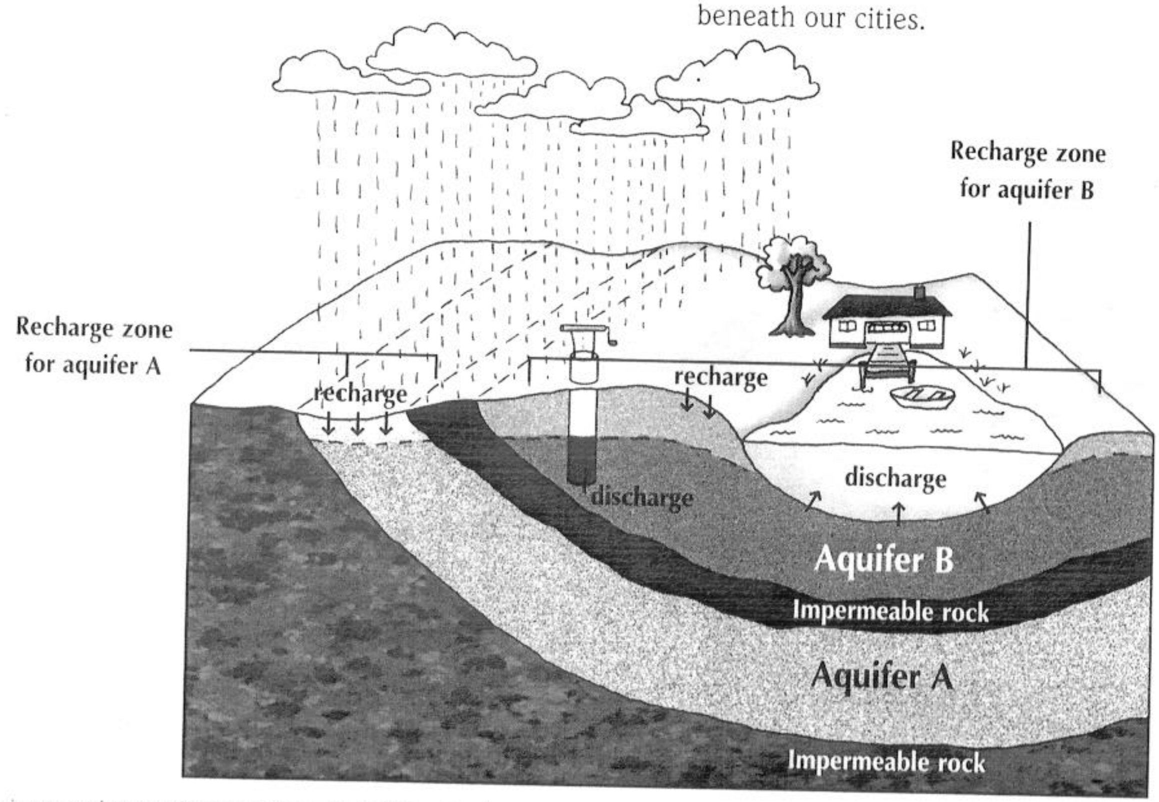
Recharge and Discharge

Think about the amount of water you use each day — you take a shower, flush the toilet, drink from a fountain. The clothes you're wearing and the dishes you eat from are washed in water. It all adds up. In fact, the average American uses between 80 and 100 gallons of water every day!

Every day the 10,000 people living in Fairview draw almost a million gallons of water from the **aquifer** (AH-kwi-fur) below. An aquifer is part of the saturated zone that contains enough groundwater for people to use as a water supply. Water from rain and melting snow helps replace water that's been removed from an aquifer. In fact, water from sprinkler systems, leaking underground pipes, or any liquid that soaks into the ground can become groundwater.

Water that soaks into the saturated zone is called **recharge**. The surface area of the land where water soaks into an aquifer is called the **recharge zone**. As water recharges an aquifer the water table rises, just like the level of water in a glass rises when you pour more water in. Luckily for us, the water table doesn't rise forever or we'd all be swamped. At some point groundwater is **discharged**, or released from an aquifer. Groundwater can be naturally discharged from an aquifer at a spring or geyser, in the bottom of a lake, stream, or river, or even at the bottom of the ocean. Groundwater is also discharged when people pump it out of the ground for drinking or irrigation.

In some places, the saturated zone is divided into separate aquifers by layers of rock that water can't travel through. Each aquifer has its own recharge zone above it. The recharge zone for an aquifer could be hundreds of square miles or a few city blocks. Humans have had a big effect on the recharge zones for some aquifers. Water can't soak through pavement, and instead washes into storm drains as runoff. By paving the ground, we reduce the size of the recharge zone for the aquifers beneath our cities.



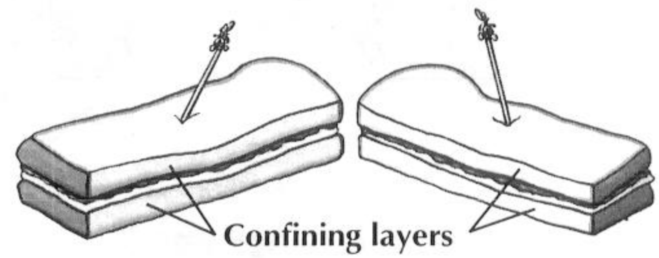
How does groundwater get underground?

Aquifers

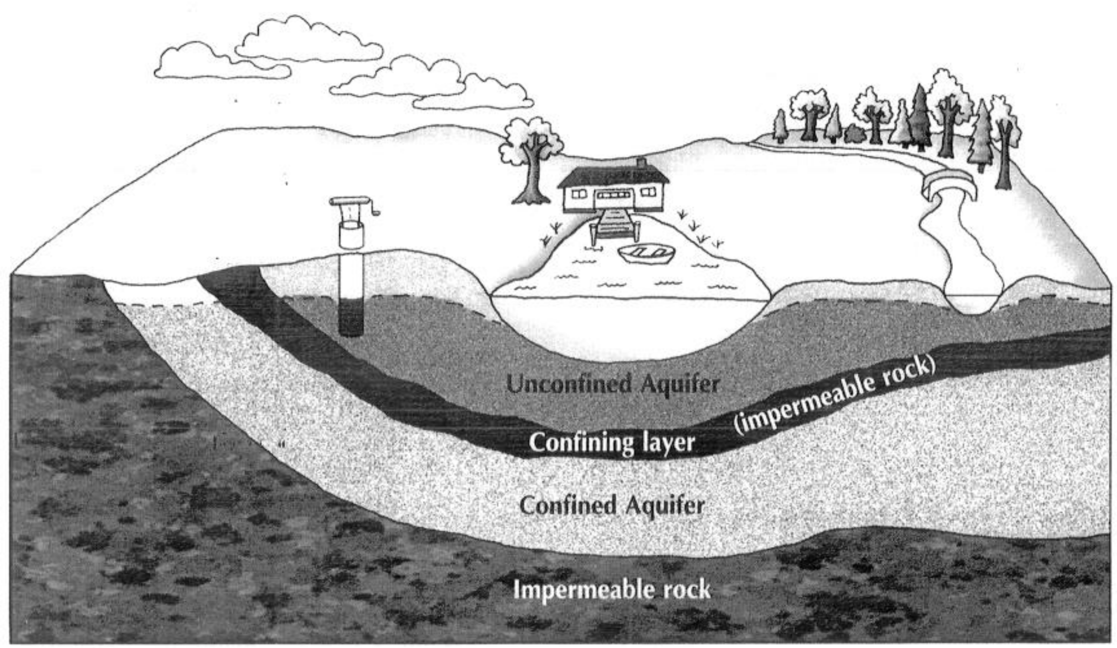
When you drink water from a well, you could be drinking water that's older than you are. During a rainstorm, the ground acts like a giant sponge, soaking up a lot of the water that falls on the ground. If you could look deep underground into the saturated zone, you'd find water from thousands of rainstorms. The water stays there, sometimes for hundreds of years, until it is **discharged**, or released from the ground at a spring, in the bottom of a lake or river, or from a well.

In some areas, the saturated zone stores enough water so that people can dig wells and use the water for drinking and for watering crops. The saturated zone is called an **aquifer** (AH-kwi-fur) if it holds enough water for humans to use as a water supply. Some aquifers are huge. For example, the Ogallala Formation is an aquifer underneath almost the entire state of Nebraska and several other states. Other aquifers might contain only enough water for a small town. All aquifers have a limit, though. Even a large aquifer could run out of water if people pump out more water than is added over time.

Underground, the saturated zone can be divided into separate aquifers by a layer of rock that water can't travel through, called a **confining layer**. In a peanut butter sandwich, the bread acts like a confining layer, keeping the peanut butter inside. In the saturated zone, a layer of rock that water can't travel through acts kind of like the bread in a sandwich, separating the water in one aquifer from the water in another.



Work with student C to figure out which rocks in Fairview act as confining layers.



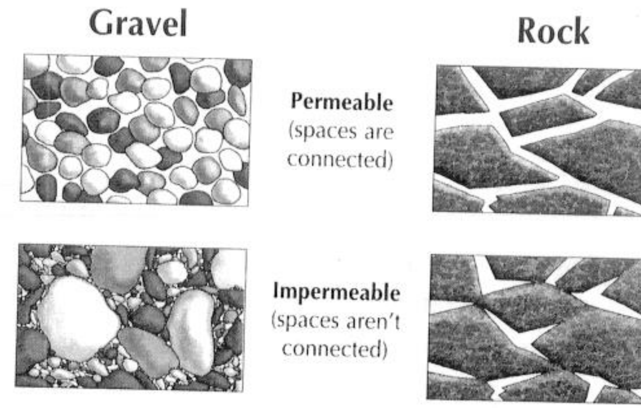
How does groundwater get underground?

Porosity and Permeability

What happened the last time you were caught out in a rainstorm? If you were lucky, you were wearing a plastic raincoat, so you stayed nice and dry. If not, the rain probably soaked through your clothes, making you cold and wet. This happens because cloth is **permeable** (PER-mee-ah-ble), meaning that it has small holes between the threads that let water soak through. Plastic protects you from the rain because it is **impermeable** — there are no holes for the water to travel through, so it just rolls off the surface.

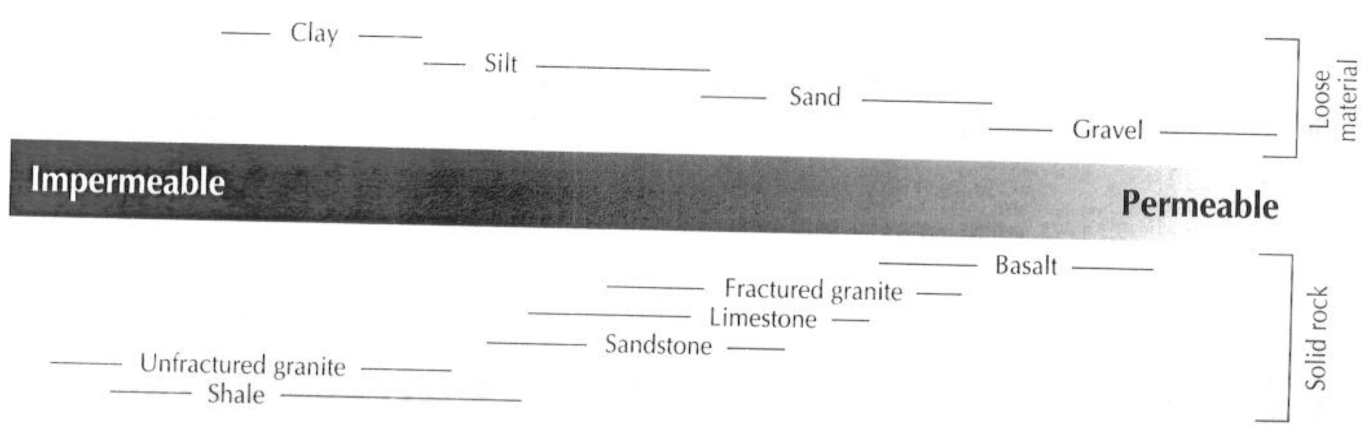
Underground, a **porous** rock contains tiny holes or cracks. But unless those spaces are connected, water can't flow through the rock. A permeable rock has spaces that are connected so water can flow through it. Water can't flow through an impermeable rock. An impermeable rock might not contain any spaces at all, or it might contain spaces that aren't connected. For example, an ice cube tray contains spaces that can hold water. But since they aren't connected, water can't move between the spaces in the tray.

All rocks have different amounts of porosity and permeability. Water can move quickly through a material like gravel, because the spaces between the pieces of gravel are large and well connected. Clay is a material that has a lot of empty space inside it — it has a high porosity. But the connections between those spaces are so small that water has a hard time moving through them, therefore, clay has a low permeability. That's why clay stays so wet. The water can't get out of the tiny spaces very easily, so it stays inside the clay.



Permeability of Rock

The chart below shows the permeability of some rocks in relation to each other. Very few rocks are completely impermeable. But some have so few spaces that it takes water hundreds or thousands of years to move through them. Use this information to determine the permeability of the rocks in Fairview.



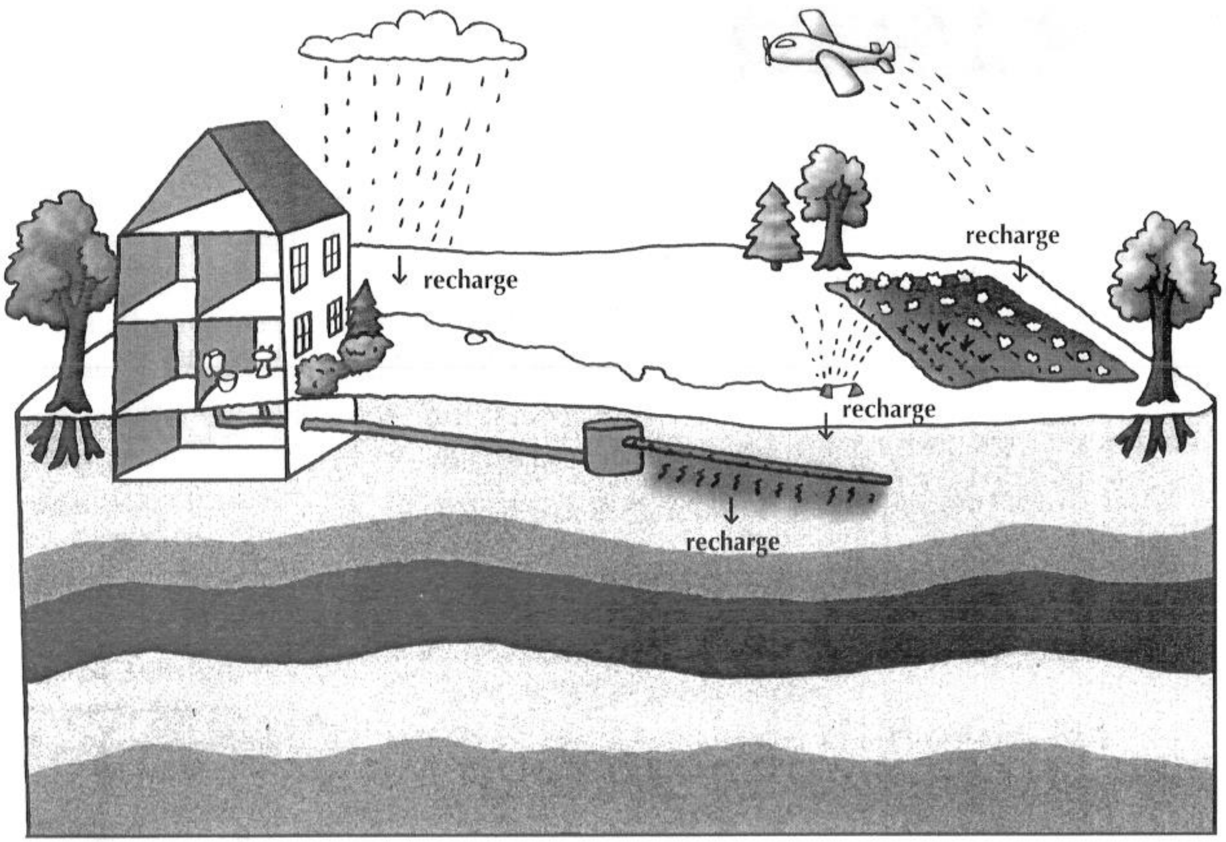
How does groundwater get underground?

What's in the Water?

The water that people drink from wells doesn't come only from rain that has soaked into the ground. Any water that strikes the ground could become groundwater. Water from a sprinkler, a spilled soft drink, even water from leaky underground sewer pipes could soak into the ground and trickle down to the saturated zone. Water that flows into the saturated zone is called **recharge**.

When water travels through soil, sand, gravel, and rock on its way to the saturated zone, it squeezes through some pretty tight spaces. As it does, small particles of pollution in the water "rub off" and stick to the solid material. Think of all the stuff that gets dumped on the ground every day — pesticides, fertilizers, detergents, not to mention waste water from our toilets, showers, and sinks. All this pollution makes its way down toward the saturated zone along with rainwater. On the way, dirt and rocks act like a filter, trapping the pollution.

Unfortunately, the ground can't always filter all the pollution out of the water. Sometimes the water is just too dirty and some pollution ends up in the aquifer. There are even some pollutants that can never be totally removed because they are too small — they flow right through the ground along with the water. This is how lead got into the groundwater in Fairview.



How does groundwater get underground?

What You Need

- paper cup
- water
- pipette (3 mL)
- wide plastic tube (30 cm long)
- plastic wrap (about 7 x 14 cm)
- ruler
- scissors
- 2 rubber bands
- dish
- plastic cup (1-oz)
- dry gravel
- paper towels
- dry sand
- piece of nylon stocking (about 7 cm long)
- clock or watch

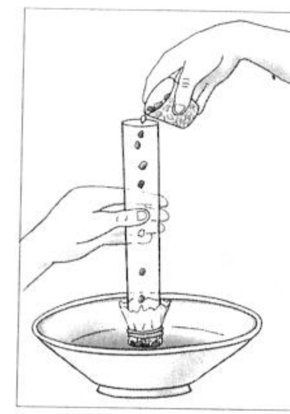
Porosity and Permeability

Groundwater is stored in the spaces between grains of loose material like sand and gravel (sediments) and in the tiny spaces inside some rocks. **Porosity** is a measure of how much space there is between the grains of a rock or sediment. **Permeability** is a measure of how easily water can move through a rock or sediment. For groundwater to travel through rocks or sediments, the material must be both porous and permeable. In this Science Lab, you will investigate the porosity and permeability of two materials, gravel and sand.

Part 1: Porosity

What To Do

1. First, make a prediction by writing either *gravel* or *sand* in the blank: *If I have the same amount of gravel and sand, I predict that the* ___________ *will have more pore space and will hold more water.*
2. Fill a paper cup with water and practice pulling 2 mL of water into a pipette. Squeeze the bulb, hold the tip underwater, then release the bulb. If the water comes up below the 2-mL mark, empty the pipette and try again. If the water comes up above the 2-mL mark, squeeze a few drops out until it reaches the 2-mL mark.
3. Use a double layer of plastic wrap and a rubber band to tightly seal one end of the wide plastic tube.
4. Set the plastic tube, sealed end down, in a dish. Fill the 1-oz cup with dry gravel. Make sure the gravel is level with the top of the cup. Pour the gravel into the tube, gently squeezing the sides of the cup. (To avoid spilling gravel, curl your hand around the top of the tube to make a funnel.)



5. Use the pipette to add 2 mL of water to the tube. Continue adding water 2 mL at a time to the tube, and count how many pipettes you add until the water just covers the top of the gravel. Record the number of pipettes in the Pore Space Measurements chart, then multiply by 2 mL to find the total amount of water that this sample of gravel holds.
6. Now empty the tube into the container provided by your teacher. Remove the plastic wrap and rubber band. Dry the tube with a rolled paper towel. If the plastic wrap is torn or messy, discard it.
7. Repeat steps 3–6 using dry sand instead of gravel. Record your measurements in the chart.

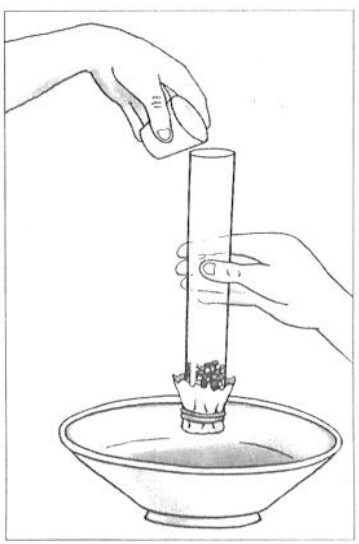
Pore Space Measurements

Sample	Number of pipettes to saturate	x 2 mL	= Total pore space in sample
Dry Gravel		x 2 mL	
Dry Sand		x 2 mL	

How does groundwater get underground?

Part 2: Permeability

What To Do



1. You need at least one partner for Part 2. Make sure you can see a clock or a watch that times seconds. Decide who will pour and who will time.
2. Cut a 7-cm length of nylon stocking. Stretch a double layer of nylon stocking over one end of the clear tube and secure it with a rubber band.
3. Set the tube, stocking end down, into a dish. Pour a level 1-oz cup of dry gravel into the tube.
4. Use a pipette to drip water into the 1-oz cup until it is filled to the 5-mL mark. Hold the cup in one hand. With the other hand, hold the tube over the dish.
5. Have your partner look at the clock or watch. When your partner says GO (and starts timing), pour the water into the tube. Your partner should get another 5 mL of water ready in the 1-oz cup.
6. When water starts to drip out of the bottom, say STOP to your partner. If water does not drip through the tube after 60 seconds, add another 5 mL of water. Add 5 mL of water every 60 seconds until water starts to drip from the bottom of the tube.
7. Record the total amount of water added and the time it took for the dripping to start in the Permeability Measurements chart.
8. Empty the tube into the container provided by your teacher. Rinse and dry the tube and the 1-oz cup.
9. Repeat steps 2–8 using dry sand. Record your measurements.
10. Clean up as directed and complete the What It Means section.

Permeability Measurements

Sample	Total water added (mL)	Time to start dripping
Dry Gravel		
Dry Sand		

What It Means

1. Which sample has more pore space, the gravel or the sand?

2. Which sample has larger pores (or spaces) between the grains, the gravel or the sand?

3. Which sample allows water to pass through more quickly, the gravel or the sand?

4. Which layer has greater porosity, gravel or sand? Which is more permeable, gravel or sand?

5. Based on your observations, why is one of the materials you tested more permeable than the other?

Where does groundwater go?

Groundwater Flow Direction

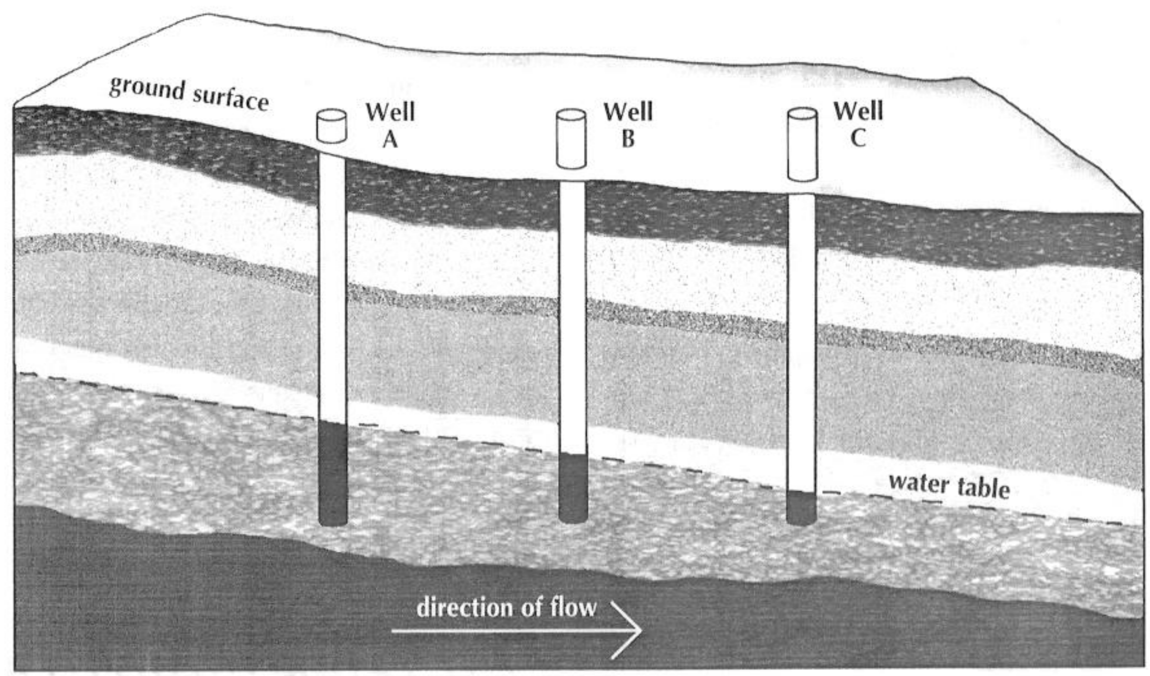
On Earth's surface, water is constantly moving downhill. Water from rain or melting snow collects in streams and flows down mountainsides into bigger rivers. The rivers flow over the land and out to sea.

The reason water flows downhill is the same reason why a ball rolls downhill, or why you can ski down a mountainside. Gravity, the force that pulls you and everything else toward Earth's center, is constantly pulling water downward. Groundwater is no different from water on the surface, although it moves much more slowly. Water in an aquifer is always being pulled downward by gravity.

Because groundwater is always moving, the water table underground isn't flat like it is in a glass of water. Underground, the water table slopes toward the direction in which the groundwater is moving. Scientists can "see" the angle of the water table by measuring the water level in special wells drilled in the ground. When scientists study the groundwater in an area, they drill many sample wells to measure the level of the water table in different places. Then they "connect the dots" to draw a picture of what the water table looks like underground.

Often, scientists enter this information into a computer model of the area they're studying. A model can help scientists draw a picture of the groundwater in a large area. Knowing how the angle of the water table from one place to another is a clue to which way groundwater is flowing.

The illustration shows three sample wells drilled into the ground. Water or pollution that soaks into the ground near well B will flow toward well C instead of toward well A. Using this information, work with student D to determine which way the groundwater in Fairview is flowing.



Where does groundwater go?

How Fast Does Groundwater Move?

The groundwater beneath our feet never sits still. It's constantly moving, but it moves very, very slowly compared to water on the surface. The speed at which groundwater moves depends a lot on the permeability of the material that the water is flowing through. All permeable material has connected spaces. In order to move, groundwater has to squeeze through these spaces. The bigger the connections between the spaces, the more quickly water can flow through them. In fact, groundwater flowing slightly downhill would take about 5 days to travel through a bed of gravel 100 meters thick. It would take 14 years for water to flow through the same amount of sand, and 137,000 years to flow through 100 meters of clay.

Another thing that affects how quickly groundwater flows is the angle of the water table. Imagine riding your bike down a hill. The steeper the angle of the hill, the faster you go. The same thing happens to water flowing through rock underground. The steeper the angle of the water table, the faster the groundwater flows.

One clue to finding out who polluted the water in Fairview is to calculate the amount of time it would take pollution from each site to reach the polluted well. When you go somewhere in the car, you can calculate how long the trip will take by dividing the distance you're going by the average speed at which you are traveling. For example, if you are going 120 miles, and driving 60 miles per hour, it would take you two hours to get where you're going. The equation would look like this:

$$\frac{\textbf{120 miles}}{\textbf{60 mph}} = \textbf{2 hours} \quad \textit{or} \quad \frac{\textbf{distance}}{\textbf{rate}} = \textbf{time}$$

You can calculate the time it would take groundwater to flow between two sites in the same way. Work with student C to complete these calculations.

The Center for Science Seekers is building a computer model of groundwater flow in Fairview. The computer needs data about the speed at which the groundwater is moving, which way it's flowing, and how far it has to travel. With this information the computer model can create a picture of how water is flowing beneath Fairview. Be ready to share the data you've collected with the Center.

Site	Distance ÷	Rate =	Time
Site A Ed's Gas Station	______ km	.218 (km/year)	______ years
Site B Tannery	______ km	.218 (km/year)	______ years
Site C Lead Mine	______ km	.218 (km/year)	______ years
Site D Landfill	______ km	.218 (km/year)	______ years

Step 1 – For each site use the scale on the diagram of Fairview and a ruler to determine the distance (in kilometers) between the site and the polluted well. Fill in the "Distance" column in the chart.

Step 2 – Divide the distance by the average rate at which the water is moving through the limestone. This will give you the amount of time it would have taken for pollution from that site to reach the well. Fill in the "Time" column in the chart. Also, record this information in the Field Notes section of your group's Fairview groundwater diagram.

Step 3 – For each site, compare the number of years it would have taken for pollution to reach the well to the actual number of years the site has existed. Based on this information, can you eliminate any of the sites as culprits?

Where does groundwater go?

Pollution in the Water

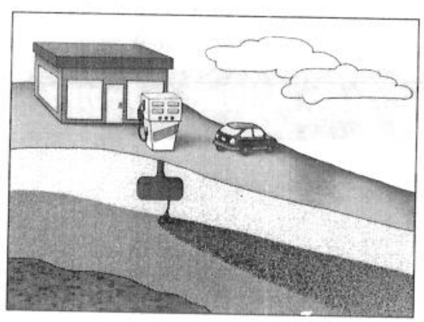
Imagine putting a drop of green food coloring in a glass of water. The water will turn green, but it is a lighter green than the food coloring was to begin with. If you poured the glass into a bathtub full of water, the water in the tub would be an even lighter green. And if you poured the water from the bathtub into a lake, you probably wouldn't notice any change in the color of the lake water. The green food coloring has become so **diluted** (dye-LOO-ted), or spread out, that you can't see it.

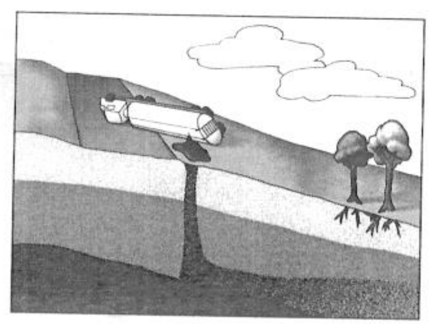
When pollution seeps into the groundwater in an aquifer, the whole aquifer doesn't suddenly become undrinkable. The pollution spreads out gradually, sometimes over many years. The pollution flows with the water in the aquifer, in the same direction and usually at the same rate. The way in which a pollutant spreads is called a **plume**. Imagine smoke coming out of a chimney or smokestack — the smoke forms a thick trail as it comes out of the chimney and gets carried away by moving air. As the smoke moves away from the chimney, it gets more and more spread out. A plume of pollution in an aquifer works in the same way. It starts out as a small trail, then gets picked up by moving groundwater and fans out, becoming more diluted.

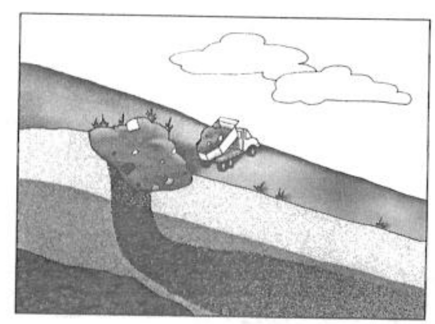
The key to figuring out where a plume of pollution comes from is to figure out the direction in which the water in the aquifer is flowing, and the speed at which it's flowing. Scientists do field research to find out this information. They drill sample wells in many locations to study the groundwater below. Then they input this information into a computer model. The model uses mathematical equations to determine how fast and which way groundwater — and the pollution in it — is flowing. The Center for Science Seekers is currently working on a computer model of groundwater flow in Fairview. They'll need some of your team's calculations from Investigation 3 to complete the model. Work with student B to determine how fast the groundwater in Fairview is flowing. Then be ready to send your data to the Center.

Pollution Plumes

Pollution in an aquifer flows in a plume, or trail, which slowly fans out as it mixes with the groundwater. Some pollution is heavier than water and sinks to the bottom of the aquifer. Other types of pollution, like gasoline, are lighter than water and float near the top of the aquifer. Pollution from landfills, called leachate, is watery and can easily mix with the groundwater in the aquifer.







Where does groundwater go?

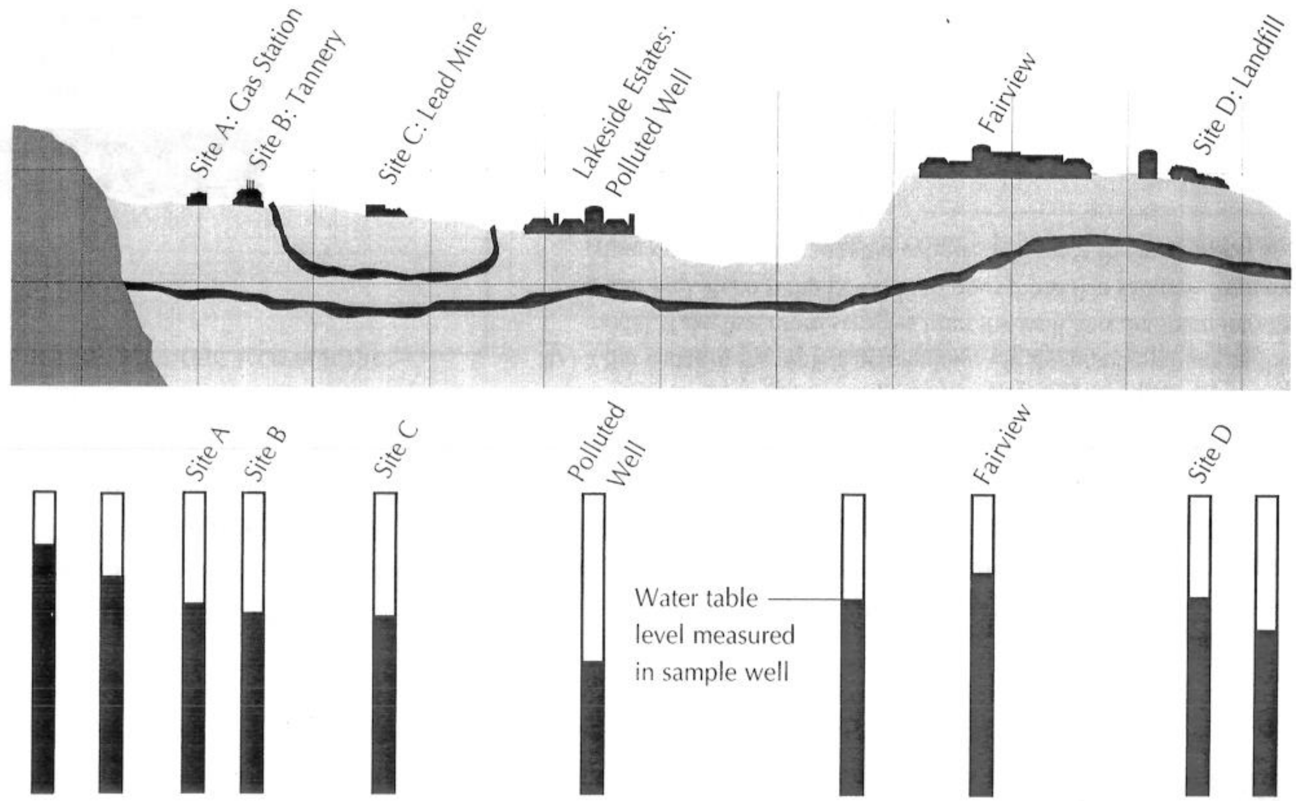
Measuring Flow Direction

Just like water in rivers and streams on the surface of the land, water under the ground is constantly moving. One important step in determining which way groundwater moves is to measure the angle at which the water table slopes. Since no one can actually look inside the ground to see the water table, scientists drill sample wells in the area they're studying. The sample wells show scientists where the water table is in each place. By looking at the results from many sample wells, scientists can "connect the dots" to draw a picture of the angle of the water table underground.

The Center for Science Seekers has collected results from several sample wells drilled around Fairview. Using this information, draw a picture of the water table in Fairview's groundwater system. Then work with student A to determine which way the groundwater in Fairview is flowing around each of the sites. Draw arrows on your group's diagram of Fairview's groundwater system to show which way water flows beneath sites A, B, C, and D. Which ones are flowing toward the polluted well? Which are flowing away from the polluted well? Record your observations in the Field Notes for each site.

Fairview Sample Well Results

Work with student A and use this information about the level of the water table in different places around Fairview to find out which way the groundwater is flowing around each of the possible pollution sites.



Where does groundwater go?

What You Need

newspapers

groundwater model (from Investigation 1)

paper cup

straw (in addition to straw already in model)

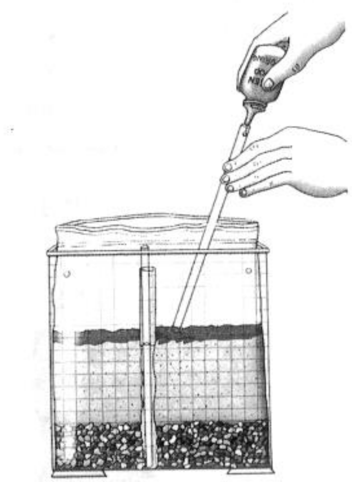
food coloring

clock or watch

pipette

water

graduated cylinder



Pollution Plume

What happens to a pollutant between the time it is spilled on the ground and the time it appears in well water? In this Science Lab, you will use food coloring to pollute the surface of the groundwater model you made in Investigation 1. You will observe and describe the formation of a pollution plume as rainwater washes the spill into the aquifer, and you'll measure the time it takes for the pollutant to reach the well in your model.

What To Do

1. Cover your work surface with newspapers to catch drips and spills.
2. Make sure your groundwater model is complete. It should have a clear plastic tube (representing a well) that reaches most or all of the way to the bottom, and a straw pump that fits inside the well.
3. Using the straw pump, take some water out of the well. Put the water into the paper cup. If the water is colorless you are ready to begin. Write "colorless" for sample 0 in the Pollution Plume Observations chart. If the water is colored, follow the Clean-Up Procedure on the following page.
4. Rest one end of a second straw on top of the soil in the tank, about halfway between the well and the edge of the tank.
5. Put five drops of food coloring in the top end of the straw. Let the food coloring run down the straw into the soil, then remove the straw. Record the time.
   Time when pollution was added to model: ______________
6. Use the pipette to make it rain on the food-coloring spill. Squirt two pipettes full of water directly on top of the food coloring.
7. Use the straw in the well to take five samples of water from the well. Put all five samples together into the paper cup. Record the color of the samples in the Pollution Plume Observations chart, then pour the water from the paper cup into a graduated cylinder.
8. Observe how the pollution in the model looks and record your observations in the Comments column of the chart.
9. If the water in the well is getting low, use the pipette to rain on the model. Take five more samples from the well and put them into the paper cup. Record the color, then pour those five samples from the paper cup into the graduated cylinder. Observe the model and record your observations.
10. Until the water in the well changes color, keep taking samples five at a time, recording observations, and raining on the model as needed. When the water changes color, go to step 11.
11. When you first see color (pollution) in the well water, record the time.
    Time when pollution first appeared in well water: ______________
12. Pour any water from the paper cup into the graduated cylinder. Record the amount of water in mL.
    Water taken from well until pollution showed: ______________ mL
13. Add four pipettes full of water to the model. Take five more samples of water from the well with the straw. Put the water into the paper cup. On the chart, note how the color of the well water has changed. Leave the water in the paper cup.
14. Follow the Clean-Up Procedure on the next page to clean the model. Take turns with your partners. When you are not working with the model, use the time to complete the What It Means and Advising the Team sections.

Where does groundwater go?

Clean-Up Procedure

To clean pollution from the groundwater model, do the following:

- Use the straw to take water out of the well. Empty it into the paper cup.
- Keep the level of water in the well high by adding water to the model with the pipette.
- Work steadily. Take turns with your partners. Continue adding water to the model and removing water from the well until the well water is clear again.

Stop working when the water from the well is clear, or when you have 10 minutes of lab time left. Use the graduated cylinder to measure the polluted water from the paper cup and record the measurement.

Amount of polluted water in paper cup: ____________ mL

What color was the last sample of well water? ____________

Pollution Plume Observations

Sample	Color	Comments
0		
5		
10		
15		
20		
25		
30		
35		
40		

What It Means

1. Describe the shape and movement of the pollution plume you observed.

2. Was the polluted groundwater flowing toward the well or away from the well?

3. How long, in minutes, did it take for pollution to appear in the well? (Subtract the time you recorded in step 5 from the time you recorded in step11.):

4. If each minute of time in your model represents 6 months of time passing, how many months passed before pollution from the spill appeared in the well water? ____________

5. How much water was taken from the well after the spill, but before the well water was contaminated? (You recorded this amount in step 12.) ____________ mL

6. During the Clean-Up Procedure, how much polluted water did you take from the well before the well was clear again, or before you had to stop? ____________ mL
Was this enough water to completely clean the groundwater?

7. Was there a lot of groundwater recharge or only a little groundwater recharge during the time it took for the well water to become clear again? Explain.

Advising the Team

Which of the possible contamination sites can you rule out as the source of the lead contamination in Fairview? Support your answer using your lab results.