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ABSTRACT

This collection of 10 activities is designed to give students a better grasp of concepts relating to groundwater, aquifers, and hydrology. Activities can be conducted as a demonstration (especially for younger students) or as a laboratory activity for students in higher grades. The guide contains an introduction for teachers and students, a materials list, 10 activities, and a glossary. The first activity, Pre-Lab Construction, sets up the materials for the following activities which all utilize soda bottles and simple materials like sand and food coloring. The remaining activities cover the topics of marking guides, the hydrologic cycle, porosity, permeability, parts of an aquifer, the recharge zone, the discharge zone, sedimentary rock and core sampling, solubility, pollution plumes, and chemical changes in groundwater. Activities can be conducted in sequence or individually and are reproducible for the teacher. (LZ)

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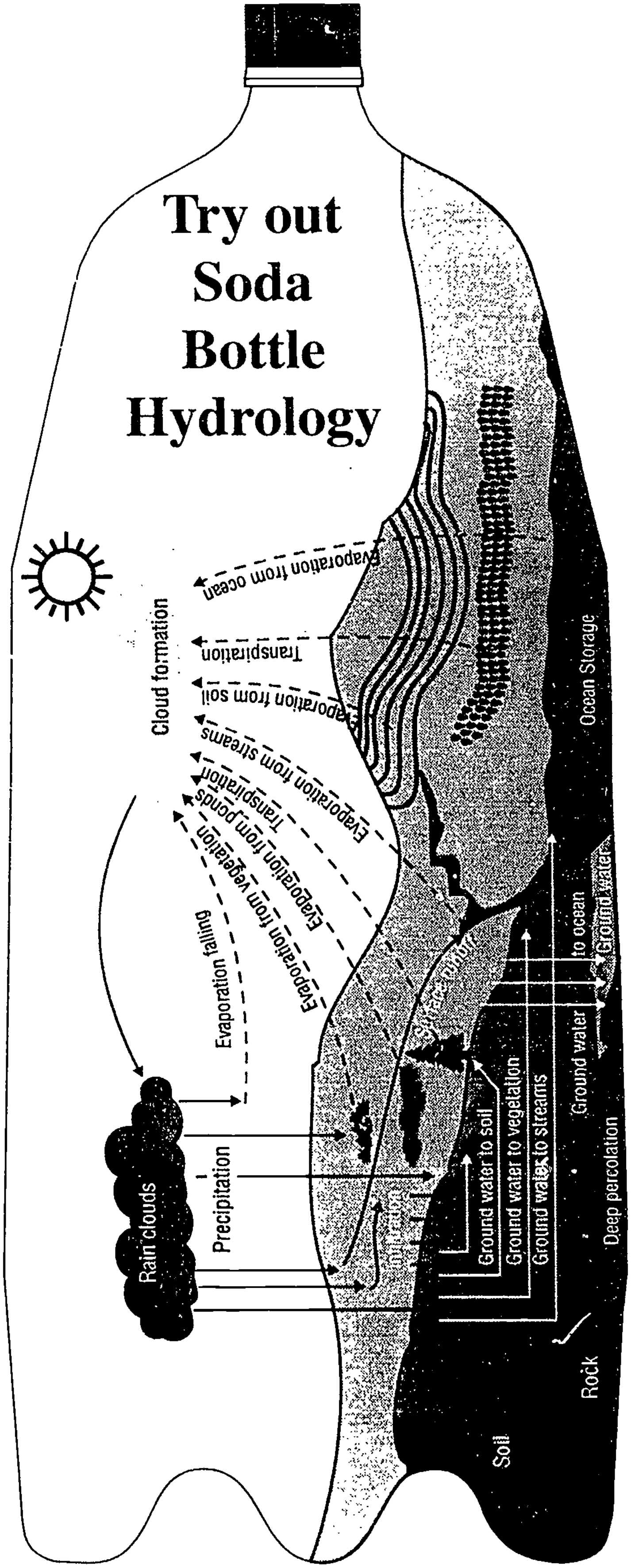
Try out Soda Bottle Hydrology



Attention Science Teachers

classroom activities with water

Hydrology is the study of water. The hydrologic cycle or water cycle is the endless recycling process water goes through on Earth. Heat from the sun makes water evaporate. The water vapor rises into the atmosphere, where it cools and condenses forming clouds. The clouds release water through precipitation (rain, sleet, snow, etc.). The water falls onto the ground and into the ocean. Some of it is absorbed into the ground and some of it runs along the surface to the ocean. Then the water starts to heat up again and goes through the cycle again.

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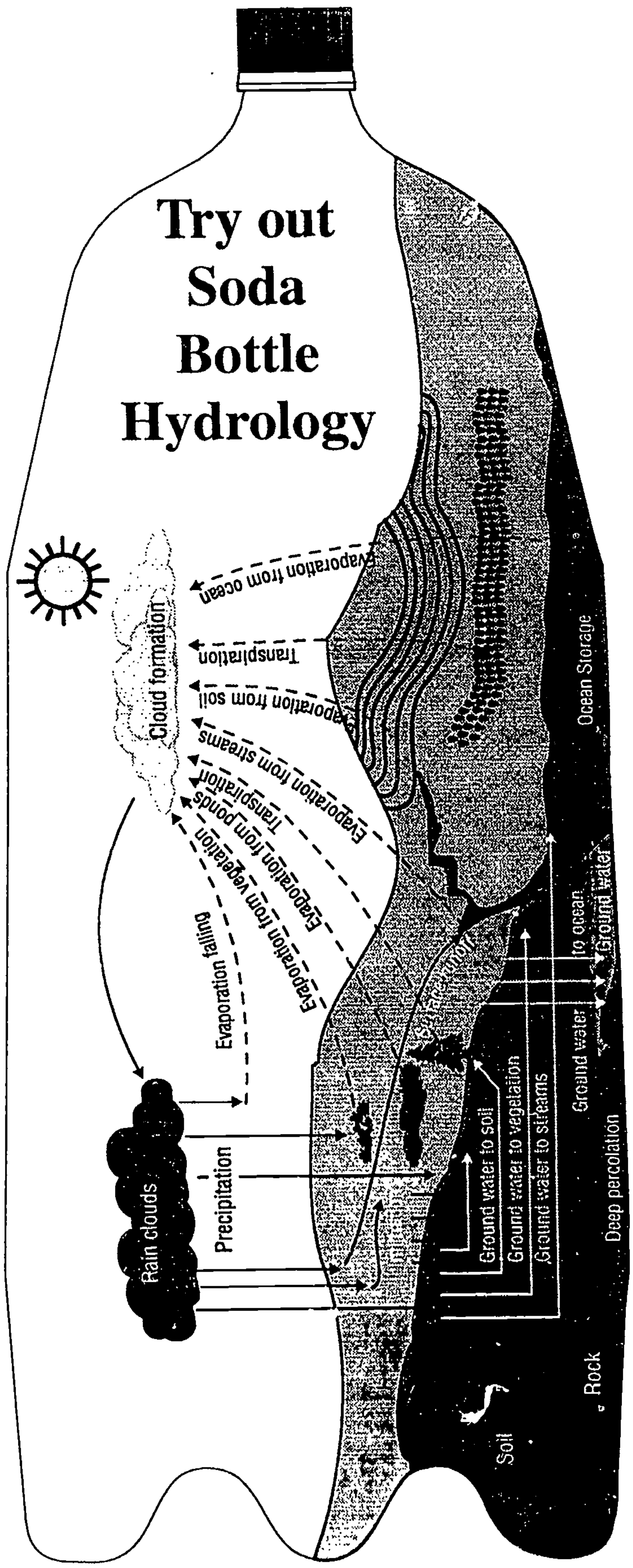


Attention Science Teachers

classroom activities with water

Table of Contents

Teacher's Introduction

The following activities are designed to give students a better grasp of concepts relating to **groundwater, aquifers**, and **hydrology**. The first activity, Pre-Lab Construction, sets up the materials for the following activities. Activities can be conducted in sequence or individually; feel free to improvise or expand at any level, and feel free to make copies of all or part of this booklet. The suggested materials on page 2 are commonly available at drug, hardware, and grocery stores. They are listed in the order they are used in the activities. Depending on what grade level you teach, and your class objectives, these activities can be used individually or collectively. They can be conducted as a demonstration (especially for younger students) or as a laboratory activity by students in higher grades. Younger students may have difficulty performing the experiments without making a mess.

Students who will perform the activities can collect clear plastic two-liter soda bottles at home about two weeks before the class begins these activities. For the activities to work best, students should collect only clear bottles with formed (not attached) bottoms. The bottles need to be stabilized for the activities to work well without making a big mess. This can be done with a ring stand and a clip or rubber band. Also, each activity must be started with dry sand.

Sand can be purchased at hardware stores. Ask for "play sand," the sand used in children's sand boxes. It has less dust, is inexpensive (usually about $3 for 50 pounds), and can be put in sand boxes after the activities are completed. You can use dirt, small rocks, limestone, marbles, or even cat litter instead of play sand. For students to learn about porosity and permeability, different kinds of cat litter can be compared. Construction sand should not be used because it can sometimes harbor an infectious skin disease.

Student's Introduction to Soda Bottle Hydrology

This booklet contains activities to help you better understand concepts relating to **groundwater**, **aquifers**, and **hydrology**. The first activity, Pre-Lab Construction, must be done before any of the other activities can be done. Your teacher will talk to you about getting the supplies you need.

Hydrology refers to the study of water. In this booklet we will be studying groundwater. Groundwater makes up only 0.61% of the Earth's total water supply but accounts for approximately 5% of the earth's total fresh water supply. When it rains some of the water flows down into the ground into regions called **aquifers**, which are porous rock structures that hold water (sometimes for thousands of years). Water under the ground is not pure and it dissolves small amounts of soil and rock.

We tend to take the abundance and purity of our water for granted, but we shouldn't. There is not an endless source of fresh water, and some scientists fear we could run out of it someday. Pollution and contamination of both surface and **groundwater** reduce the amount of clean, fresh water available. Common pollution sources include: chemical fertilizers, pesticides, waste discharge, leachate from toxic waste dumps, accidents, leaking underground gasoline/fuel storage tanks, and illegal dumping.

Since Americans use an average of 325 liters or about 85 gallons of water a day, it is very important to understand where our water comes from and how it gets there. The activities in this book will give you a glimpse at the fascinating world of water.

Materials List

- 2 Clear Plastic Two-Liter Soda Bottles
- Plastic Film Canister
- Metric Ruler
- Permanent Marker Pen
- Marking Guides Sheet (page 7)
- Scissors
- Rubber Bands
- Nylon Screen (10 cm by 10 cm)
- Play Sand (different colors if available)
- Water
- Stopwatch
- Water-based Marker Pen
- Food Coloring
- Ice
- Nail (large)
- Pan (or dish)
- Clear Tape
- Candle
- Clear Plastic Drinking Straws
- Lime (horticultural, from the local hardware/garden store)
- Clear Plastic Cup
- Liquid Dish Soap
- Plastic Spoon
- Dropper
- White Vinegar
- Clear Rubbing Alcohol
- Indicators: Laxative Tablets (containing Phenolphthalein)
- Boric Acid (powdered: from local drug or hardware store)

Materials

2 Clear Plastic Two-Liter Soda Bottles
Permanent Marker Pen
Rubber Band
1 Plastic Film Canister
Marking Guides Sheet
Nylon Screen (10 cm X 10 cm)
1 Metric Ruler
Scissors

In this activity you will create the bottles—model bottle/collection bottle—you will use for all the other activities.

Procedure:

1. Remove the labels from the bottles.

2. Select a bottle to become the model bottle with the bottom cut off and one to become the collection bottle with the top cut off.

3. Cut out the marking guides on the next page.

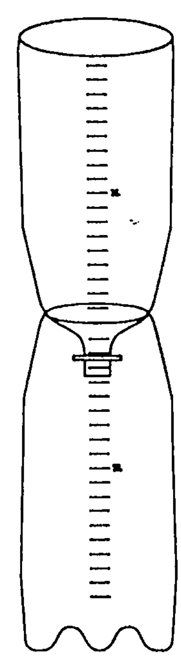
4. Place the cut out marking guides against the bottles, and using a permanent marker pen, label the bottles with the volumes on the marking guides.

5. On the collection bottle, cut off the top of the bottle 4 centimeters below the ring.

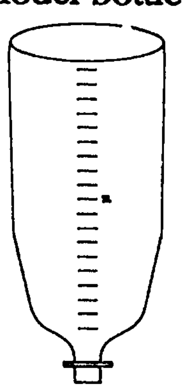
6. On the model bottle, cut off the bottom, 5 centimeters up from the bottom. (Note: save the bottom of this bottle for later activities.)

7. Fold or wad up the nylon screen and insert it into the neck of the model bottle.

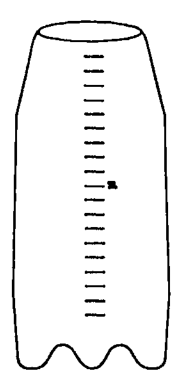
Standard set-up



Model bottle



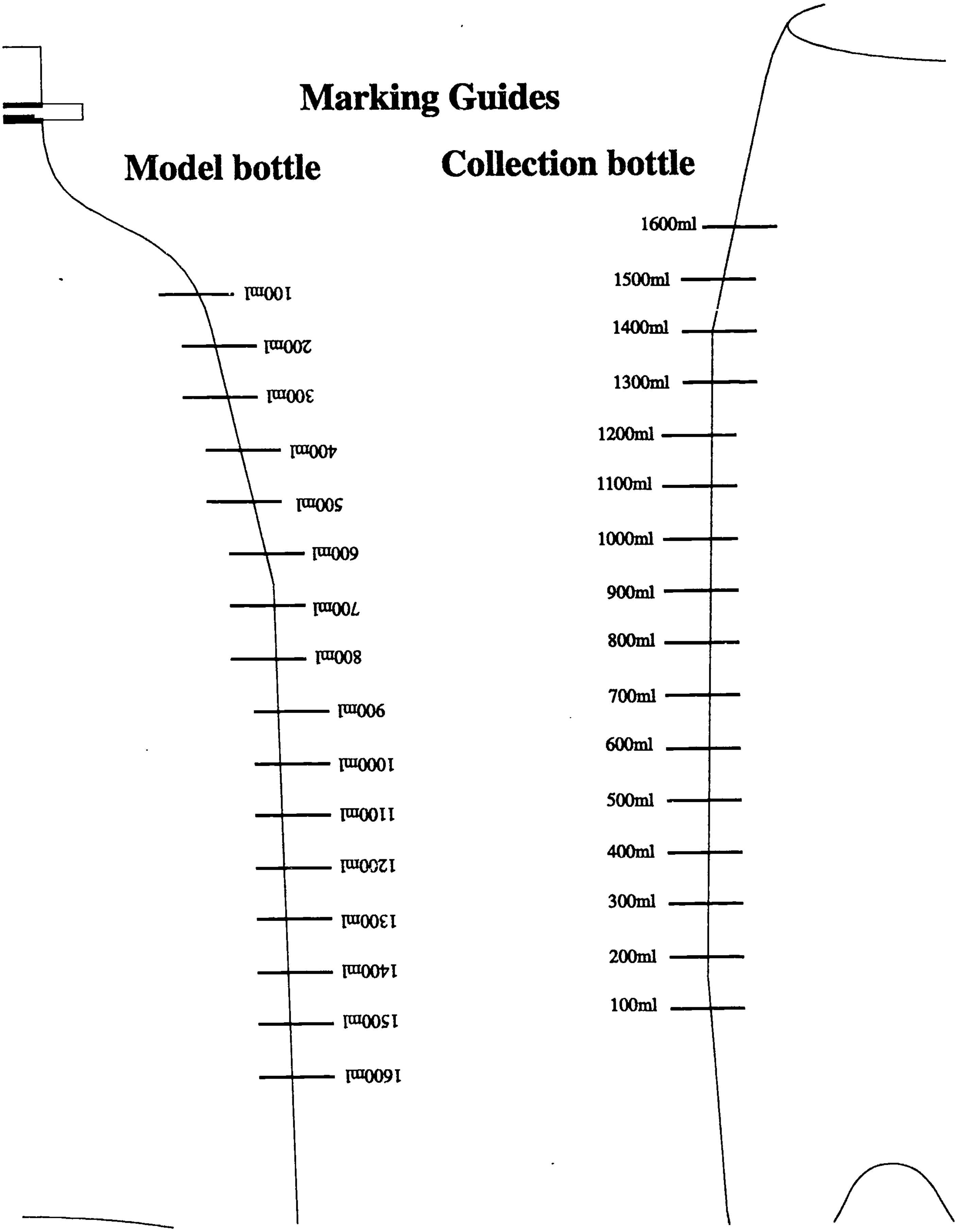
Collection bottle



Marking Guides

Model bottle

Collection bottle



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ACTIVITY 1

THE HYDROLOGIC CYCLE

Materials:

Sand Water Ice Model Bottle Water-based Marker Pen Bottle Bottom

Background:

Scientists call the constant endless movement of water from the atmosphere to earth to groundwater to river to ocean the **hydrologic cycle**. How long it takes water that falls from the clouds to return to the atmosphere varies greatly. Scientist predict it would take nine days to replace all of the atmospheric water and 37,000 years to replace all of the water in the ocean. In this activity we will create a **hydrologic cycle**.

Procedure:

1. Put the screen into the model bottle and put a cap on it.

2. Fill your model bottle with sand to the 1,000 milliliter mark.

3. Holding the bottle with your hand or a ring stand, slowly pour in 200 milliliters of water.

4. Let the water settle.

5. Turn the cut out bottle bottom upside down and insert it into the top of the model bottle, so you can add material to the bottle bottom.

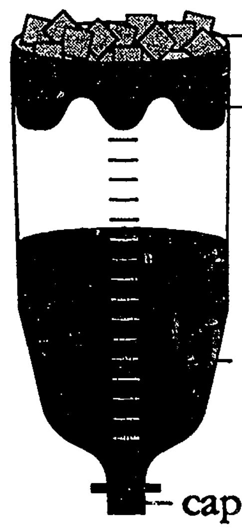
6. Put some crushed ice into the bottle bottom (which is at the top of the model bottle).

7. Set the bottle in a ring stand in sunlight or beside a strong lamp and observe.

8. With your marker, based on your observations and the descriptions above, label the groundwater model bottle with the following:
   Groundwater
   Surface water
   Evaporation
   Condensation
   Precipitation

9. Draw the water cycle on a piece of paper.

10. Clean up.



Materials:

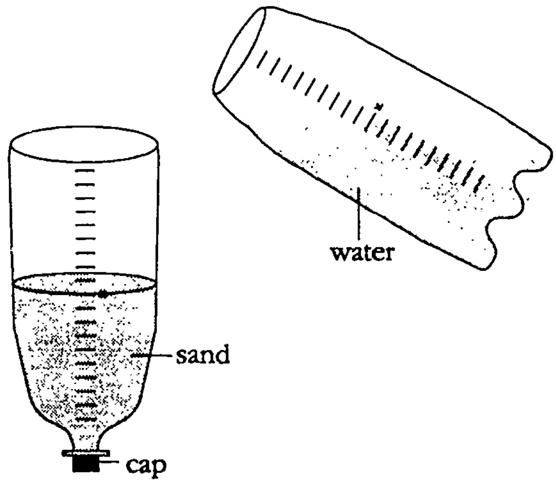
Sand Water Model Bottle Collection Bottle

Background:

Is something ever empty? If you take a glass from the shelf, is it empty or full of air? If you fill the glass with sand, is the glass now full or can you still put material (like water) into it?

Porosity refers to materials (like sand, rocks, marbles, or molecules) which have enough open spaces for water to move through. These spaces are called pores. Each material has a unique number of pores, or pore volume, which cause the water to move through it at different rates. In this activity you are going to measure the pore volume in a one liter sample of sand. The sand in these activities represents an **aquifer**. An **aquifer** is the porous rock structure that holds water underground. If we know the **porosity** of our aquifer and how big the **aquifer** is we can calculate the volume of water stored in that **aquifer**. In an actual **aquifer, porosity** will decrease with depth because overlying rock layers cause compaction.

Procedure:



1. Put the screen into the model bottle and put the cap on the bottle.
2. Fill your model bottle with sand to the 1,000 milliliter mark.
3. Fill the collection bottle with water to the 1,000 milliliter mark. This is the start volume.
4. Slowly pour water from the collection bottle into the sand in the model bottle until you can see water standing on the surface of the sand.
5. Read the current volume on the collection bottle and record it as the finish volume.
6. Remove the cap from the model bottle and let the water drain and the sand dry.
7. Clean up.

Data/Calculations:

Start Volume - Finish Volume = Pore Space Volume

1000 milliliters - _______ = _____ milliliters

Pore volume in a liter of sand is _____________.

(Pore volume/Total rock volume) X 100% = porosity (%)

(________/1000 ml) X 100% = _________%

Materials:

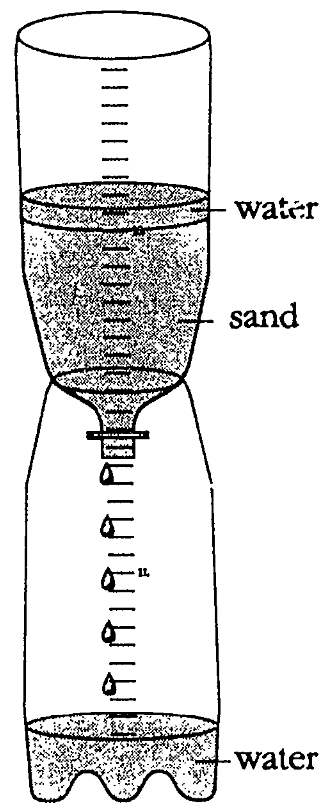
Sand Water Model Bottle Collection Bottle Stopwatch

Background:

How does water move through materials such as rocks? That question is answered, in part, by **permeability**. **Permeability** is the measure of how easily water can flow through a material (like rocks, soil, or an **aquifer**). We pump our drinking water from the **groundwater** in an **aquifer**, the layer of porous rock or soil under the earth's surface which collects water. As we pump water out of an **aquifer** more water will flow in to take its place during **recharge**. **Recharge** adds water to the **groundwater** system when rainfall, melting snow, surface water, or water from a creek or lake soak in through the soil and rocks. Since water flows slowly in rock, **recharging** the **aquifer** takes time. In this activity we will measure the **permeability** of water through sand to represent the movement of water in an **aquifer**.

Procedure:

1. Put the screen into the model bottle.
2. Put one liter of sand into the model bottle and insert the screened end of the model bottle into the collection bottle.
3. Slowly pour water into the model bottle. Try to keep the water level 100 ml above the sand.
4. When water starts to come out of the model bottle and into the collection bottle, start timing.
5. Continue to add water to the model bottle, keeping all the sand wet.
6. When the collection bottle reaches 1,000 milliliters, stop pouring water, stop the timing and record the time.
7. Clean up.



Data/Calculations:

Permeability flow rate should be expressed as a volume per time (liters per minute).

$$\frac{\text{1 liter of water}}{\text{time for 1 liter to flow (minutes)}} \qquad \frac{\text{1 liter}}{\text{minutes}} = \_\_\_\_\_\_$$

PARTS OF AN AQUIFER

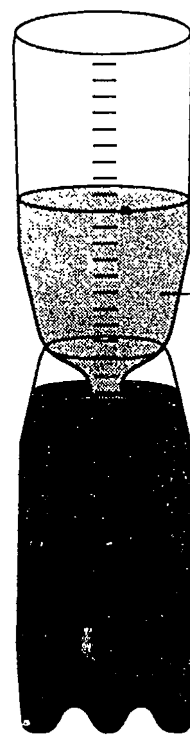
Materials:

Sand	Water	Model Bottle
Collection Bottle	Water-based Marker Pen	Food Coloring

Background:

Whenever water reaches the earth's surface, some of it goes into the ground where it flows through porous rocks. **Groundwater** is divided into layers called the **saturated zone** (full of water), the **water table** (the top of the **saturated zone**), and the **unsaturated zone** (everything above the **water table**). As water flows through the ground some water sticks to the surface of the rocks and soil in the **unsaturated zone,** but the pores in the rock or soil in this zone are filled with air. The water continues to flow down through the water table to the **saturated zone** where all the pores in the rock or soil are filled with water. In this activity we will use **capillary** action to lift water into our sand **aquifer**.

Procedure:



1. Put the screen in the model bottle.
2. Fill your model bottle with sand to the 1,000 milliliter mark.
3. Slowly pour approximately 1600 milliliters of water into the collection bottle.
4. Add food coloring to the water (about 6 drops of a dark color).
5. Place the model bottle in the collection bottle. If the opening of the model bottle is not in the water, remove it, add about 200 milliliters more water to the collection bottle, and re-place the model bottle in the collection bottle.
6. Observe.
7. With your water-based marker pen, based on your observations and the descriptions above, label the bottle with the following:
   Water table
   Saturation zone
   Unsaturated zone
8. Draw the parts of an **aquifer** on a piece of paper.
9. Approximately how much water was drawn up into the model bottle? (collection bottle start - collection bottle finish = **capillary** action volume)
10. Define <u>**capillarity**</u>.
11. Clean up.

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THE RECHARGE ZONE

Materials:

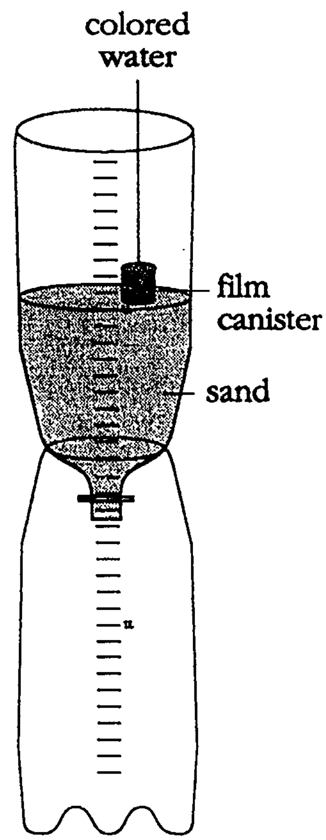
Model Bottle — Sand — Water — Plastic Film Canister (with bottom cut off)
Collection Bottle — Food Coloring — Water-based Marker Pen

Background:

Recharge zones (sometimes called green zones) are where water flows into the ground to become **groundwater** through the **recharge** system. **Recharge** adds water to the **groundwater** system when rainfall, melting snow, surface water, or water from a creek or lake soakes in through the soil and rocks. In a **recharge zone**, water flows downward through the **unsaturated zone**, **water table**, and **saturated zone** to get to the **aquifer**. In this activity we will observe the structure of the downward flow of water into an **aquifer**, which we will create using sand.

Procedure:

1. Put the screen into the model bottle and insert it into the collection bottle.
2. Fill your model bottle with sand to the 1,000 milliliter mark.
3. Cut the bottom off the film canister and insert it into the sand, next to the wall of the bottle.
4. Slowly pour colored water into the film canister.
5. Observe the flow of the colored water into the sand.
6. With your marker, draw the flow pattern of the water on the bottle .
7. On a piece of paper, draw the flow pattern you saw in the bottle.
8. Write down why you think it forms this pattern.
9. Clean up.



Materials:

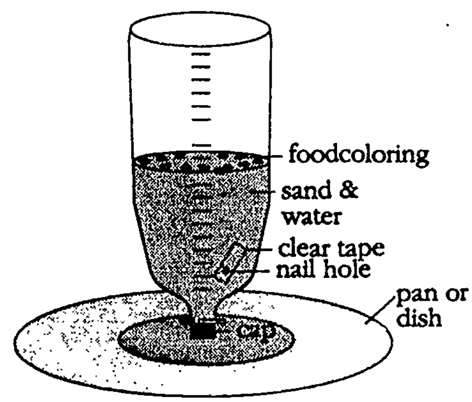
Sand	Water	Model Bottle	Food Coloring (yellow works well)	
Nail (large)	Pan	Clear Tape	Water-based Marker Pen	Candle

Background:

Sometimes water naturally flows out of the ground, like a spring or geyser; sometimes it is pumped out of the ground with a well. The area where water flows out of the ground is called a **discharge zone**. If the **water table**, the top surface of the **saturated zone** which separates it from the **unsaturated zone**, is to stay level the amount of water **recharged** (coming in to the ground) must equal the amount of water **discharged** (going out of the ground). In this activity we will create a **discharge zone** by putting a hole in the side of our model bottle (modeling an **aquifer**). We will be able to follow what is happening with the water by using food coloring as a **tracer**. A tracer is a material which helps us measure the direction of movement and/or the velocity of the water and potential contaminants which might be transported by the water.

Procedure:

1. Use a candle to heat the end of a long nail. Hold one end of the nail with a folded paper towel.
2. Use the hot nail to poke a hole in the model bottle at about the 500 ml mark.
3. Cover the hole with clear tape.
4. Put the cap on the model bottle.
5. Fill your model bottle with sand to the 1,000 milliliter mark.
6. Slowly pour water into the model bottle, until the sand is completely wet. If the sand were an aquifer, it would be considered full or "saturated" at this point.
7. Place the model bottle in a pan or dish.
8. Place drops of food coloring along the edge of the sand next to the bottle wall (6-8 drops).
9. Remove the tape.
10. Observe the flow of the colored water through the sand.
11. If the water isn't flowing, slowly add some more water to the sand.
12. With your marker, draw the water's flow pattern on the bottle.
13. On a piece of paper, draw the flow pattern you saw in the bottle.
14. Explain why you think it forms this pattern.
15. Clean up.



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SEDIMENTARY ROCK AND CORE SAMPLING

Materials:

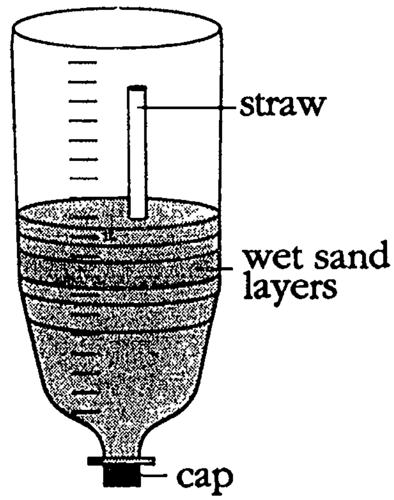
Sand (various colors) Clear Plastic Drinking Straws Model Bottle Water

Background:

Sedimentary rock is where aquifers are usually located. **Sedimentary rocks** form under water. Over 70% of the earth's surface is covered by **sedimentary rock**. Sand, silt or some other material is deposited and then gets compressed by the layers of material on top, making rock. This **sedimentary rock** forms in layers. Some layers are very **permeable** (like limestone), while others are only slightly **permeable** (like clay). Scientists who want to know what the rocks are like under the ground take a core sample—they drive a hollow tube into the ground and then pull it up and look at the rock and material in the tube. In this activity we will lay down layers of sand (to symbolize **sedimentary** material) and then take a core sample.

Procedure:

1. Put the screen into the model bottle and put a cap on it.
2. Pour in 500 milliliters of dry sand.
3. Add water to the model bottle until the water reaches the 1,000 milliliter mark.
4. If you don't have colored sand, add food colors to sand in separate dishes. Use at least three different colors.
5. Sprinkle in the different colors of sand one by one, alternating the colors until the sand reaches the 800 milliliter mark.
6. Uncap the model bottle and insert it into the collection bottle to drain.
7. Observe. On a piece of paper draw the layered design seen through the side of the bottle.
8. Slowly push a clear plastic drinking straw into the top of the moist sand, as deep as possible.
9. Cover the top of the straw with your finger and pull the straw out.
10. Observe the sand in the straw. On a piece of paper draw what you see in the straw.
11. Write down what you think about how or why the sand in the straw is different from the sand in the bottle.
12. Clean up.



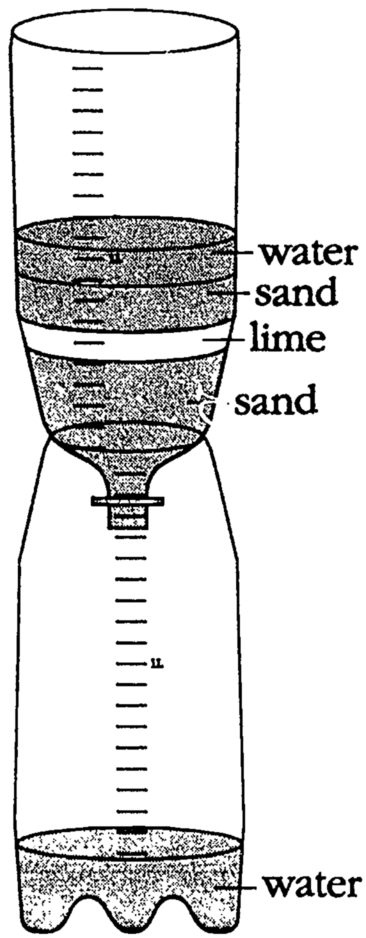
Materials:

Sand	Water	Clear Plastic Drinking Straw	Clear Plastic Cup
Model Bottle	Lime		

Background:

Solubility is a solid's tendency to dissolve. If the minerals making up rock, or materials put into the ground (like trash, fertilizer, pesticides, etc.), are **soluble**, then those materials will end up in **groundwater**. At some point, the **groundwater** cannot dissolve any more minerals because it is completely full or saturated. In this activity we will dissolve lime (a substance made from rock) into our **groundwater**. When the lime dissolves it cannot be seen, but that does not mean it is not there. We can test for the presence of lime in our water by running a chemical test. In this case all we have to do is blow bubbles (which contain carbon dioxide, which reacts with lime) into the water If lime is present, then a white precipitate will form, causing the water to turn cloudy.

Procedure:



1. Put the screen into the model bottle.
2. Add 500 ml of clean dry sand to the model bottle.
3. Add 100 ml of lime.
4. Add sand to the 1,000 milliliter mark.
5. Put the model bottle over the clear plastic cup, so the cup can catch water coming from the model bottle.
6. Slowly pour water into the model bottle.
7. Collect water in the cup until it is about half full of "water."
8. Set the model bottle inside the collection bottle to drain.
9. Observe the color of the liquid in the cup.
10. Using the clear plastic drinking straw, slowly blow bubbles into the cup of water. be careful not to suck water up the straw.
11. Observe the results and write them down. Answer the questions below.
12. Clean up.

Color of liquid before bubbling: ___________________

Color of liquid after bubbling: ___________________

What happened to the water going through the aquifer?

ACTIVITY 9

POLLUTION PLUMES

Materials:

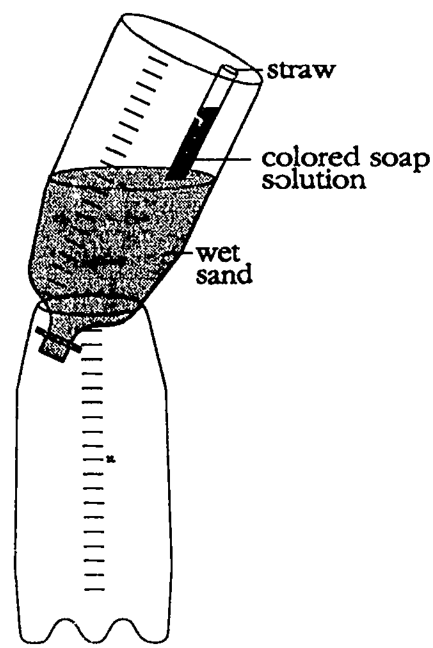
Sand	Water	Plastic Spoon	Model Bottle	Collection Bottle
Liquid Dish Soap	Dropper	Food Coloring	Clear Plastic Drinking Straw	
Clear Plastic Cup				

Background:

Pollution takes many forms and it affects us in many ways. Pollution can be caused by contaminants released into the **groundwater**. Septic tanks, cess pools, and injection wells intentionally empty substances into **groundwater**. If an underground oil or fuel pipeline broke, then fuel would accidently be released into **groundwater**. When you fertilize your lawn, some of those fertilizers go into **groundwater**. If someone had a gas station that closed, but there was still some fuel in the underground tanks, those tanks could rust and leak fuel into the **groundwater**. When a contaminant gets into the **groundwater** it will produce what is called a *plume*, an area of the water which is contaminated. A plume's shape is determined by what the contaminant is and the conditions around it. In this activity we will create a contaminant plume and diagram its shape.

Procedure:

1. Put the screen into the model bottle.
2. Fill the model bottle with sand to the 1,000 milliliter mark.
3. Place the model bottle into the collection bottle.
4. In the clear plastic cup mix about one teaspoon of liquid dish soap and five drops of food coloring.
5. Add water to the model bottle until all the sand is wet. If the sand were an aquifer, what condition does this represent?
6. Fill a drinking straw about half way with the soap/food coloring mixture.
7. Keeping your finger over the straw hole, insert it into the sand near the edge of the bottle.
8. Tip the model bottle so that the sand the straw is in is higher than the rest of the sand (see diagram).
9. Wait 10 to 15 minutes.
10. Scrape out a 100 ml layer of sand with a plastic spoon and then draw the "contaminant plume" by looking at the sand left in the bottle. (Label this line by the volume from the side of the bottle.)
11. Scrape out another 100 ml of sand and add this shape to your drawing.
12. Continue scraping out 100 ml volumes of sand and adding to your drawing until you can no longer see the plume.
13. Clean up.



CHEMICAL CHANGES IN GROUNDWATER

Materials:

Sand	Water	Model Bottle	White Vinegar	Clear Rubbing Alcohol
Cup	Lime	Collection Bottle	Laxative Tablets (containing Phenolphthalein)	
Dropper	Bottle Bottom			

Background:

There are many different kinds of **aquifers**. The water in an **aquifer** can react with the rock surrounding it. Some rocks don't react much, like sands; some react a lot, like limestones. When water passes through limestone the water becomes slightly basic (pH greater than seven). This is caused by ions coming out of the rock into the water. Some rocks contain sulfates. When water passes through sulfates the water becomes acidic (pH less than seven). When the **groundwater** changes in composition its behavioral properties also change. An acidic water may react with or cause other materials to dissolve that otherwise would not. Even rain has effects. If acid rain is present in an area, then the water entering the ground is already acidic and may react with the surrounding rocks and materials. In this activity we will check the pH (acid or base) of water as it passes through an **aquifer**. To check the pH we will use an indicator (phenolphthalein). A chemical indicator is something that changes color depending on its surroundings. Phenolphthalein is clear in acids and purple or pink in bases.

Procedure:

1. Make the indicator solution by putting 1 or 2 laxative tablets in half a cup of rubbing alcohol and stirring for a few minutes.

2. Observe the color of the indicator by putting a few drops in one section of the bottle bottom. Write the color in the data table on page 17.

3. Fill the model bottle with about 500 milliliters of sand.

4. Insert the model bottle into the collection bottle.

5. Pour some indicator onto the sand (about 1/4 a cup).

6. Add water until it starts to come out into the collection bottle.

7. Observe the color of the indicator/water by putting a few drops in another section of the bottle bottom. Write the color in the data table on page 17.

8. Add about 50 milliliters of lime to the collection bottle, and cover with sand to the 1 liter mark. This creates a limestone aquifer.

9. Pour the indicator/water back into the model bottle, and add water until some indicator/water comes out.

10. Observe the color of the indicator/water by putting a few drops in another section of the bottle bottom. Write the color in the data table on page 17.

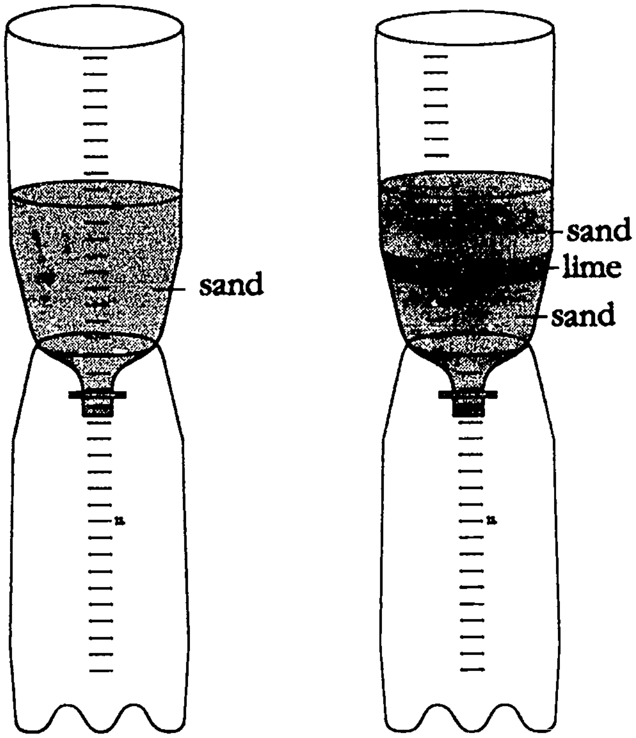
11. Check to see if your indicator /water is basic by taking a small sample of the indicator/water (in the bottle bottom) and adding to that a few drops of white vinegar (acetic acid). See if a color change occurs.

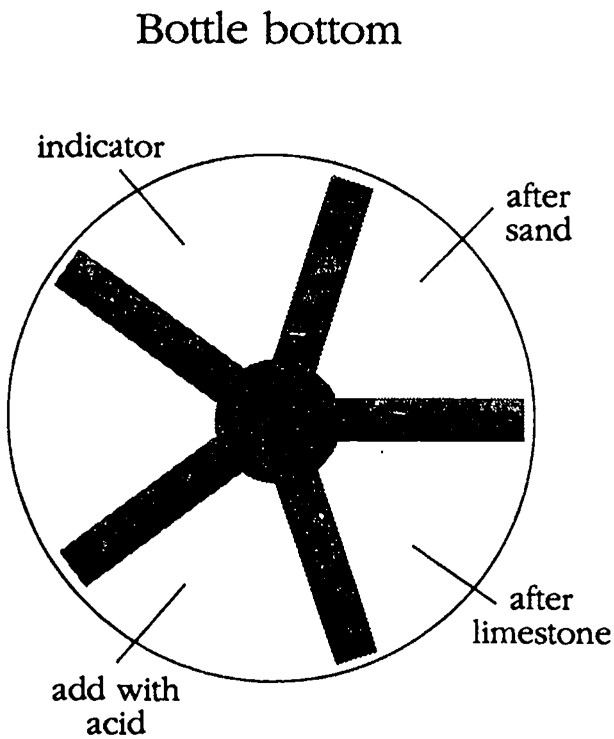
DATA TABLE	
	COLOR OF INDICATOR/WATER
Before pouring into sand	
After pouring through just sand	
After pouring through "limestone"	
After adding acid to a small sample	

12. You can make an acidic **aquifer** by using *boric acid*, which you can get from a drug store or hardware store. Repeat steps 3, 4, 6, and 8, using boric acid instead of lime in step 8 to create an acidic aquifer. Pour the indicator/water from the limestone **aquifer** through the acidic (boric acid) **aquifer** and note the changes.

13. Answer the question below and clean up.

What happens to water as it flows through the ground?





Glossary

Aquifer	the underground porous rock structure which holds water.
Condensation	transition of a substance from vapor to liquid.
Discharge	way in which groundwater flows out of the earth's surface (springs, geysers, wells, etc.)
Evaporation	the conversion of a liquid into a vapor.
Groundwater	water within the earth that supplies wells and springs.
Hydrologic cycle	the earth's endless recycling of water from the atmosphere, to and through the ground, to the ocean, and back into the atmosphere.
Hydrology	the study of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere, particularly with respect to evaporation and precipitation.
Infiltration	a gradual penetration by scattered units.
Leachate	the liquid that has been percolated through soil or another medium.
Percolation	the slow passage of a liquid through a filtering medium, such as water downward through the soil.
Permeability	the measure of how fast and easily water flows through materials such as soil or rocks.
Porosity	the measure of how much open space, pores, a material has for water to move through.
Precipitation	the water/moisture deposit on the Earth of hail, mist, rain, sleet, or snow.
Recharge	water coming into the groundwater system, such as rain soaking into the ground.
Saturated zone	the area below the water table where open spaces are filled with water.
Sedimentary rock	rocks made from compressed sediments (such as sand, silt, or other deposits).
Solubility	the measure of a solid's tendency to dissolve.
Surface Water	natural water that has not penetrated much below the surface of the ground.
Transpiration	the emission of watery vapor from the surfaces of leaves or other parts of plants.
Unsaturated zone	the area between the ground surface and water table.
Water table	the top surface of the saturated zone which separates it from the unsaturated zone.