GROUNDWATER BASICS

Description
Students learn about aquifers and movement of contaminants in groundwater by watching a demonstration of a groundwater model.

Student Outcomes
Students will:
- Observe a demonstration of a working groundwater model.
- Learn basic concepts and terminology associated with hydrogeology.
- Study groundwater movement and how contaminants move through aquifers.
- Understand that groundwater is a valuable and limited resource.
- Learn about how humans impact groundwater.

Student Products
- *Reading for Understanding Questions*
- *Groundwater Vocabulary Quiz*
- *Groundwater Model Demonstration*

Prerequisites
None

National Standards
Subject Area Standards Covered: *Geography, Language Arts, Science, and Social Studies.*
See Appendix D for the complete list of national education standards.

Teamwork Skill
Check to make sure everyone understands.

Activity Timing

Time Estimate	Two 50-minute Class Periods
30-60 min	Prep Time: photocopying; organizing materials
Homework	Background Reading and *Reading for Understanding Questions*
Day 1	Leaky Drum Demonstration and Vocabulary Quiz
Day 2	Groundwater Model Demonstration (or *Groundwater Video*)

Materials

- Hydroville Journal
- Groundwater model or the *Groundwater* video by Todd Jarvis, Institute for Water and Watersheds, Oregon State University (see ordering information in *Getting Started* section).
- TV/VCR or DVD player

For one Leaky Drum Demonstration:

- 400 mL glass beaker
- 125 mL clear glass marbles - flower arranging beads work well (~100 marbles)
- Hot water
- Coffee filter (basket style)
- Scissors
- 150 mL coarse, multi-purpose sand
- Tea bag (preferably a dark-colored tea, e.g. Red Zinger)

Teacher Information

For more information, refer to the Background Reading *Groundwater Basics*.

Terminology

Conduit flow
Contaminant plume
Diffuse flow
Discharge area
Drawdown
Hydraulic gradient
Hydrogeologist
Hydrogeology
Recharge area
Saturated zone
Unsaturated zone
Water table
Wellhead Protection Area (WHPA)

Suggested Lesson Plan

Getting Started

1. Obtain a groundwater model or a video that describes an aquifer system and groundwater contamination.
   - The video*,* ***Groundwater Model,*** was produced by the Hydroville Curriculum Project in collaboration with Todd Jarvis from the Institute for Water and Watersheds at Oregon State University in May 2007. The DVD is approximately 20 minutes long and covers an aquifer system, groundwater movement, contaminant plumes, and groundwater protection. It is available closed-captioned. To obtain a copy, e-mail hcp@oregonstate.edu or call 541-737-8105.
   - Groundwater models are available at:
     a. Fisher Scientific or Project Wet for $300 - $700. You might want to apply for a grant to obtain a groundwater model for your school.

b. On loan from your local public works department, watershed council, extension office, or your state's Water Resources Department.

2. Set up the "Leaky Drum" demonstration five-ten minutes before class begins. It will take about 15-20 minutes for the tea to move through the sand into the "aquifer" (represented by the glass marbles). The "Leaky Drum" demonstration shows how contaminants can leach into soil and into an aquifer and is intended to be used along with the Journal Prompts. Refer to Figure 1.
   a. Fill a 400 mL glass beaker about 1/3 full with clear, glass marbles.
   b. Add enough **hot** water to cover marbles.

      Note: Add hot water as you add materials to the beaker. If you wait to add the water after you have added all the materials, you will have very large air bubbles trapped in the marbles and the demonstration will not work very well.
   c. Trim a coffee filter to fit the diameter of the beaker. Lay coffee filter on top of marbles. (The coffee filter prevents the sand from falling down in between the glass beads. It is NOT an impermeable layer.)
   d. Add about half of the coarse sand to the beaker.
   e. Add hot water to saturate sand.
   f. Place tea bag on surface of sand (tuck in corners so they are not visible from outside of beaker).
   g. Add the remaining sand to about one inch from the top of the beaker.
   h. Add enough water so there is standing water above the sand (about ¼ inch). This represents the surface water.

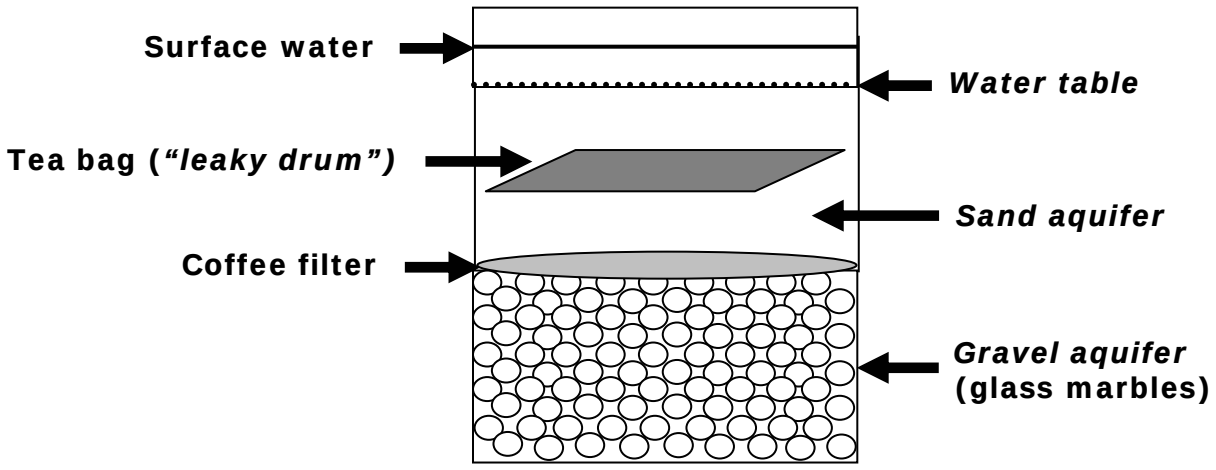


Figure 1. The setup for the leaky drum demonstration.

Tips from Teachers

- Use the Leaky Drum demonstration as a problem-solving model. Students try to solve the location of the source of the contamination.
- Have students come up with ways to remediate aquifers, i.e., clean the water, remove the buried waste, etc.

3. **Homework:** Assign Background Reading: *Groundwater Basics* and Worksheet 1: *Reading for Understanding Questions.*

Day 1. Leaky Drum Demonstration and Vocabulary Quiz

Doing the Activity

1. Display the "Leaky Drum" demonstration in front of the class. Before introducing the Journal Prompts, explain to the student that this beaker represents a groundwater model. **Do not** tell students about the buried tea bag ("leaky drum").

2. Assign **Journal Prompt-9 (TM-1):** After each question, have a class discussion incorporating the new terminology and groundwater concepts from the background reading.
   a. Draw a diagram of the groundwater model in the beaker in your Hydroville Journal, and then answer the rest of the questions.
   b. On your diagram, label the following parts: gravel aquifer, sand aquifer, surface water, and water table.
   See Figure 1.
   c. How does an aquifer become filled with groundwater?
   Discuss how rain and surface water recharge aquifers and form groundwater.

3. If the tea bag has not discolored the water at this point, save **Journal Prompt-10 (TM-2)** for the wrap-up at the end of class.
   a. Why is the beaker becoming discolored? Propose a hypothesis of why this occurred.
   Answers will vary.
   b. How would you test your hypothesis?
   Answers will vary, but could include sampling water, digging monitoring wells, dig up, etc.
   c. What is the source of the discoloration? Where is it coming from?
   Answers will vary.
   d. What are possible sources of groundwater contamination in a real aquifer?
   Groundwater can be contaminated by gasoline spills, illegal dumping, leaking landfills and underground storage tanks, run off of fertilizer, etc.

4. Discuss homework, *Reading for Understanding Questions* (WS-1).

5. Assign *Groundwater Vocabulary Quiz* (WS-2) and correct in class. It is important that the students are familiar with the vocabulary BEFORE watching the video.

Tips from Teachers

- Extra credit option: create a water facts poster from information from the groundwater model video.

Day 2. Groundwater Model Demonstration (or *Groundwater* video)

Doing the Activity

1. Hand out *Groundwater Model Demonstration* (WS-3). Review the questions with the students or have them pre-read the worksheet. Students should answer questions on the worksheet as they watch an actual groundwater model demonstration or the video of a groundwater model. If you use your own model, you will need to adapt the questions accordingly.

   Note: The video has menu stops for each section on the worksheet. Stop the video at each part and discuss questions with the students.

2. Demonstrate a groundwater model or show the video *Groundwater* which is about 25 minutes long. The message to get across to students throughout this activity is to protect groundwater because it is a valuable and limited resource. In addition, once contaminated, the cost to clean up the groundwater is very expensive.

3. Use *A Cross-Section of an Aquifer System* (TM-3) to label parts of an aquifer, contaminant plumes, and discuss conduit flow and diffuse flow.

Wrap-up

1. Complete questions from Journal Prompt-10 if not completed.

2. Collect worksheets or have students put them into their Hydroville Journals.

Assessment

The following student products can be used for assessment:

Individual

- *Reading for Understanding Questions* (WS-1)
- *Groundwater Vocabulary Quiz* (WS-2)
- *Groundwater Model Demonstration* (WS-3)

Resources

See the Hydroville Water Quality Curriculum Web Resources webpage for current links:
http://www.hydroville.org/links/wq_resources.aspx

Teacher Keys

Reading for Understanding Questions **(WS-1)**

1. Why is groundwater important?
   Most of the world's total supply of drinkable water is groundwater. It is primarily used for farming and food production, but it is also crucial for business and industry.

2. What is hydrogeology? How do hydrogelogists study something that is not visible (underground)?
   Hydrogeology is the study of the distribution and movement of groundwater in soil and rocks beneath the Earth's surface. Hydrogeologists often develop groundwater models from information collected from wells to determine what an aquifer might look like.

3. Define the following terms in your own words or draw an illustration.
   a. Water table
      The top of the groundwater level above the saturated zone.
   b. Drawdown
      Lowering of the groundwater from the "static" water level by pumping.

4. What is the difference between a saturated zone and an unsaturated zone?
   The saturated zone is the part of an aquifer in which all of the pore spaces are filled with water. The unsaturated zone is below the land surface (above the water table) where the pore spaces are only partially filled with water.

5. Describe how groundwater is recharged in an aquifer and how it moves to discharge areas. Use the terms recharge, discharge, and hydraulic gradient in your explanation.
   An aquifer is recharged when water seeps into the saturation zone from rainfall, snow melt, etc. Groundwater moves down a hydraulic gradient to discharge areas, such as local springs, lakes.

6. What are three sources of groundwater pollution that may be a problem in your community?
   Answers will vary.

7. List three ways your community and you can prevent groundwater contamination.
   - *Monitor land use*
   - *Restrict certain activities near the well field area*
   - *Protect the land surface above the groundwater from chemicals and remove hazardous materials, such as leaky tanks*
   - *Properly plug abandoned wells or wells that are no longer maintained or used*
   - *Educate community members to help protect groundwater by using and disposing of chemicals properly*

***Groundwater Vocabulary Quiz* (WS-2)**

1. I
2. C
3. G
4. F
5. A
6. D
7. H
8. K
9. B
10. J
11. L
12. E

Groundwater Model Demonstration (WS-3)

PART I: Introduction

1. How much of the world's population is relying on groundwater for its drinking water? *50%*

2. What are other uses for groundwater?
   Irrigation and industry, such as the computer industry and the bottled water industry.

3. Where does bottled water come from?
   Bottled water comes from springs, groundwater, and surface water that have been processed in water treatment plants.

4. What does a hydrogeologist study?
   A hydrogeologist studies the geology of the earth, rocks, and sediment, as well as the movement of water through rocks.

PART II: A Cross-Section of an Aquifer System

For questions 5-7, refer to the diagram A Cross-Section of an Aquifer System in the Teacher Key.

PART III: Groundwater Movement

8. How does water move through a sand and gravel aquifer compare to a fractured rock aquifer? Fill in the table below:

Well #	Shallow or Deep Aquifer?	Private or Public Well?	Type of Aquifer
4	*shallow aquifer*	*Private ("domestic")*	*sand*
1	*deep aquifer*	*Public ("municipal")*	*fractured rock*

9. What are a couple of differences between private (domestic) wells and public (municipal) wells?
   Private wells are generally shallower and pump about 10-100 gallons/minute. Public wells are often deeper and pump a larger volume of water than a domestic well.

10. What are the effects on the groundwater when wells are pumped?
    There is drawdown of the water table and in other wells that are close by or far away.

Groundwater Model Demonstration **(WS-3) – continued**

PART IV: Contaminant Plumes

11. On the diagram, *A Cross-Section of an Aquifer System*, draw the **contaminant plume** from the leaking underground storage tank (UST) before pumping and after pumping Well 4.
    Refer to the teacher key for the diagram A Cross-Section of an Aquifer System.

12. On the same diagram, draw the path of the dye (contaminant) that was injected into Well 1.
    Refer to the teacher key for the diagram A Cross-Section of an Aquifer System.

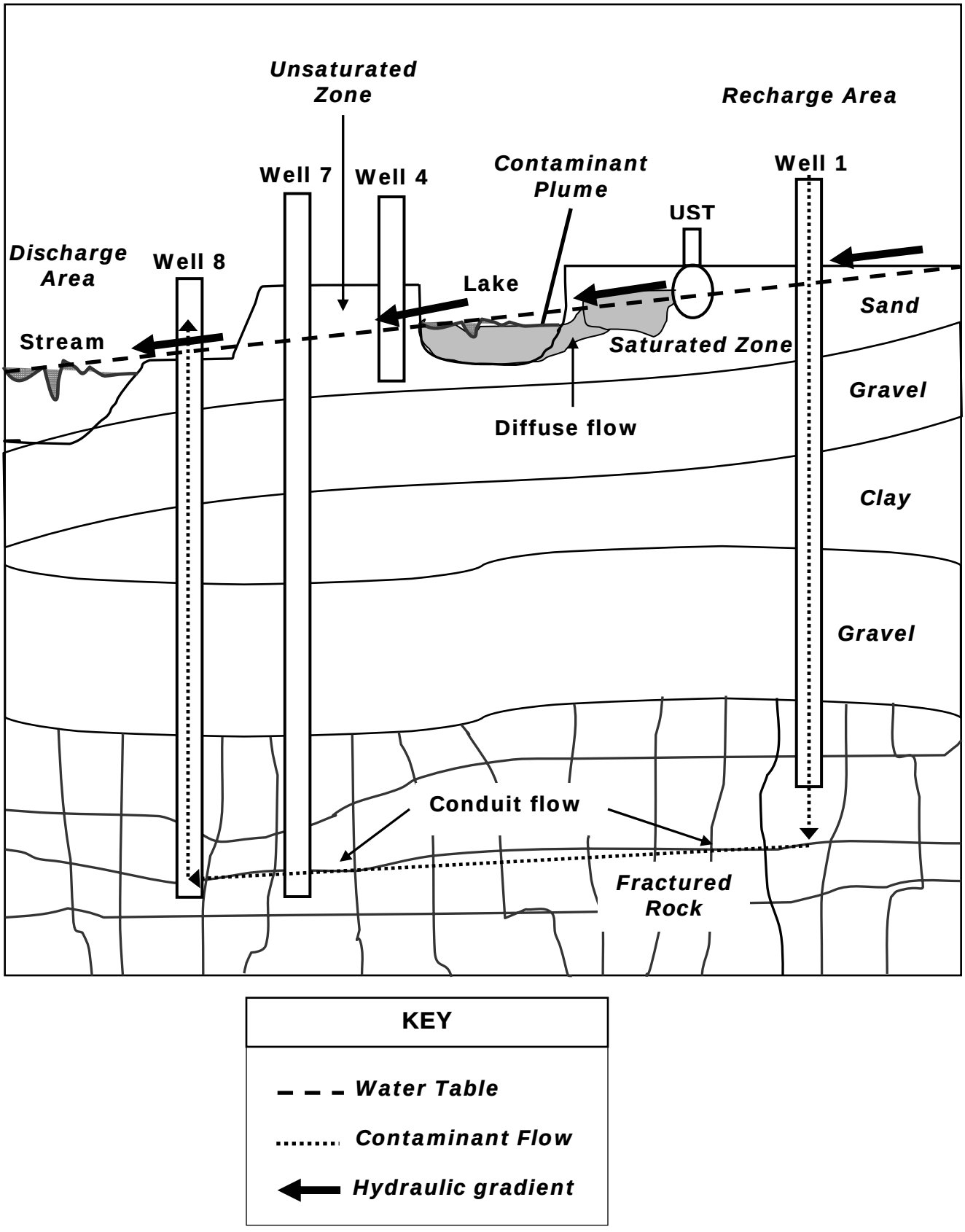
13. How does pumping of wells affect the movement of contaminants?
    Pumping a well increases the movement of contaminants from the source and into other wells.

14. Describe how contaminants move through a sand and gravel aquifer and how contaminants move through a fractured rock aquifer. Use the terms, conduit flow and diffuse flow in your explanation.
    In a sand and gravel aquifer, contaminants move by diffuse flow. The gasoline from the underground storage tank spread very slowly and contaminated the lake. Contaminants in a fractured rock aquifer move quickly through the fissures in the rock by conduit flow. This type of flow is less predictable than diffuse flow. When pumping occurred, the contaminant plume moved from Well 1 and entered Wells 7 and 8, and into the stream.

PART IV: Groundwater Protection

15. How can you protect the quality of groundwater?
    - *Know where your water comes from*
    - *Participate in hazardous waste collection day*
    - *Know where the wellhead protection areas are for your water sources*
    - *Recycle; don't dump motor oil on the ground*
    - *Talk about groundwater to the community*

A CROSS-SECTION OF AN AQUIFER SYSTEM



 **PAGES TO PHOTOCOPY†**

Note: Unless indicated, make one copy per student of all Handouts. For ease of photocopying, Transparency Masters appear first in the student pages.

Handouts and Transparency Masters

Day	What is Needed	Type*
HW	*Groundwater Basics*	BR
	Reading for Understanding Questions	WS-1
1	*Journal Prompt-9*	TM-1
	Journal Prompt-10	TM-2
	Groundwater Vocabulary Quiz	WS-2
2	*A Cross-Section of an Aquifer System*	TM-3
	Groundwater Model Demonstration	WS-3

* Type = Transparency Master (TM), Background Reading (BR), Worksheet (WS), Map (M)

JOURNAL PROMPT - 9

1. **Draw a diagram of the groundwater model in the beaker in your Hydroville Journal, and then answer the rest of the questions.**

2. **On your diagram, label the following parts:**
   - **gravel aquifer**
   - **sand aquifer**
   - **surface water**
   - **water table**

3. **How does an aquifer become filled with groundwater?**

JOURNAL PROMPT - 10

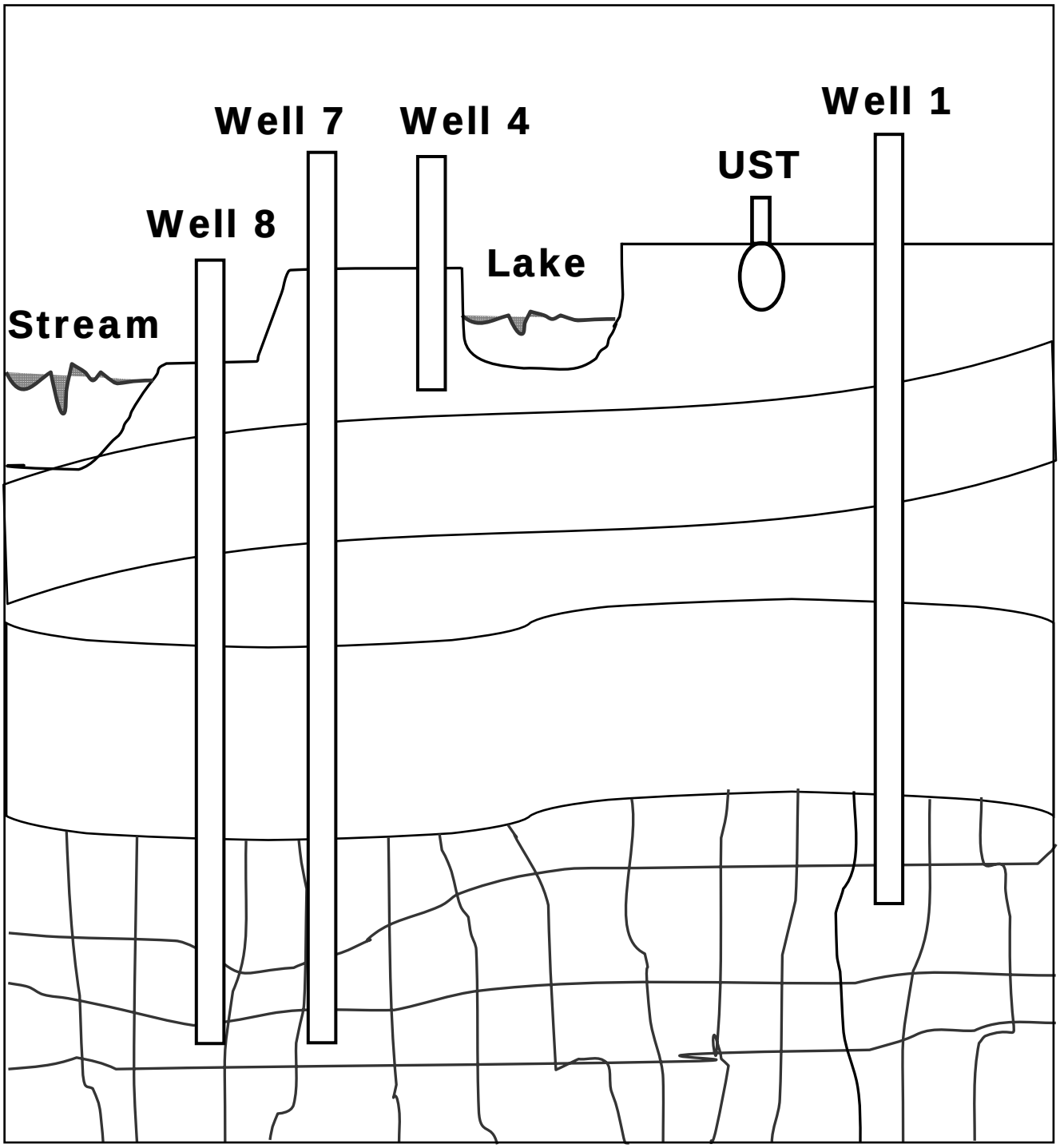
1. **Why is the beaker becoming discolored? Propose a hypothesis of why this occurred.**

2. **How would you test your hypothesis?**

3. **What is the source of the discoloration? Where is it coming from?**

4. **What are possible sources of groundwater contamination in a real aquifer?**

A CROSS-SECTION OF AN AQUIFER SYSTEM



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Date_____Period_____

BACKGROUND READING: GROUNDWATER BASICS

(Adapted from the brochure, *Groundwater Basics* from The Groundwater Foundation at http://www.groundwater.org/gi/GWBASICS2.pdf)

A source of fresh water that is essential, but rarely understood or appreciated, is groundwater. Approximately 98% of the world's total supply of drinkable water is groundwater. In fact, half of the U.S. population depends on groundwater as a primary water source. Worldwide, groundwater is used for farming and food production, and it is also crucial for business and industry. People around the world are dependent on groundwater for life and work.

What does an aquifer look like?

The study of groundwater in soil and rocks beneath the Earth's surface is known as **hydrogeology**. **Hydrogeologists** often develop groundwater models from data collected from wells to determine what an aquifer might look like. (Remember, an aquifer is a geologic formation capable of storing and releasing water.) One useful model is a geologic profile or a cross-section which is like viewing the layers of a cake that has been cut in half. A cross-sectional view of the earth allows hydrogeologists to get a better understanding of groundwater in aquifers. Models are important to be able to understand how groundwater moves and how much groundwater is available in an aquifer.

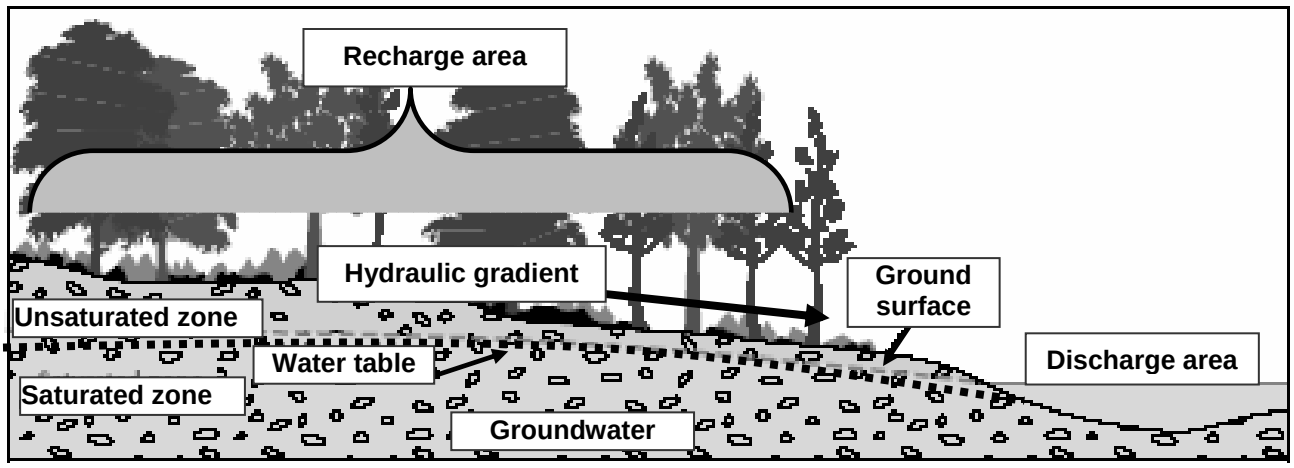

Image adapted from the U.S. Geological Survey

Figure 1. A cross-section of an aquifer system

Figure 1 is an illustration of a cross-section or profile of an aquifer. In order to think like a hydrogeologist, you need to imagine what groundwater looks like under the earth. Below the ground surface is the **unsaturated zone**. The soil in the unsaturated zone may be wet or dry depending on the amount of rain and snowfall and above ground temperatures. The dirt and rock in this zone contain air and some water and supports vegetation. Below this zone is the **saturated zone**. This is the area in an aquifer in which all pore spaces are filled with water. The **water table** is the term used for the top level of the saturated zone.

Name_____
Date_____Period_____

How does groundwater move?

Rain fall and snow melt that soak into the ground become groundwater. The area on the ground surface where water soaks in is called the **recharge area**. (See Figure 1.) It may take hundreds or thousands of years for aquifers to fully recharge. Groundwater moves from an aquifer's recharge area along a slope which is referred to as the **hydraulic gradient**. The hydraulic gradient influences the direction and rate of groundwater flow.

Groundwater moves very slowly underground following the hydraulic gradient. It may take days, years, or centuries for groundwater to reach a **discharge area**, an area where the groundwater is above the land surface. Lakes and springs are visible discharge zones. Less obvious is the groundwater seeping into wetlands or contributing to stream flows.

Hydrogeologists are concerned about the increasing demand for groundwater. At the current rate of use, more groundwater is consumed than the earth can naturally replenish. It may take hundreds of years for an aquifer to fully recharge. When the water table is lowered due to pumping, it is called **drawdown**. You may have observed this phenomenon if you ever drank a thick shake with a straw. As you drink from the straw, the liquid around the straw becomes lower than the "static" (resting) level. When this occurs in groundwater, the end result is a lowering of the water table. See Figure 2.

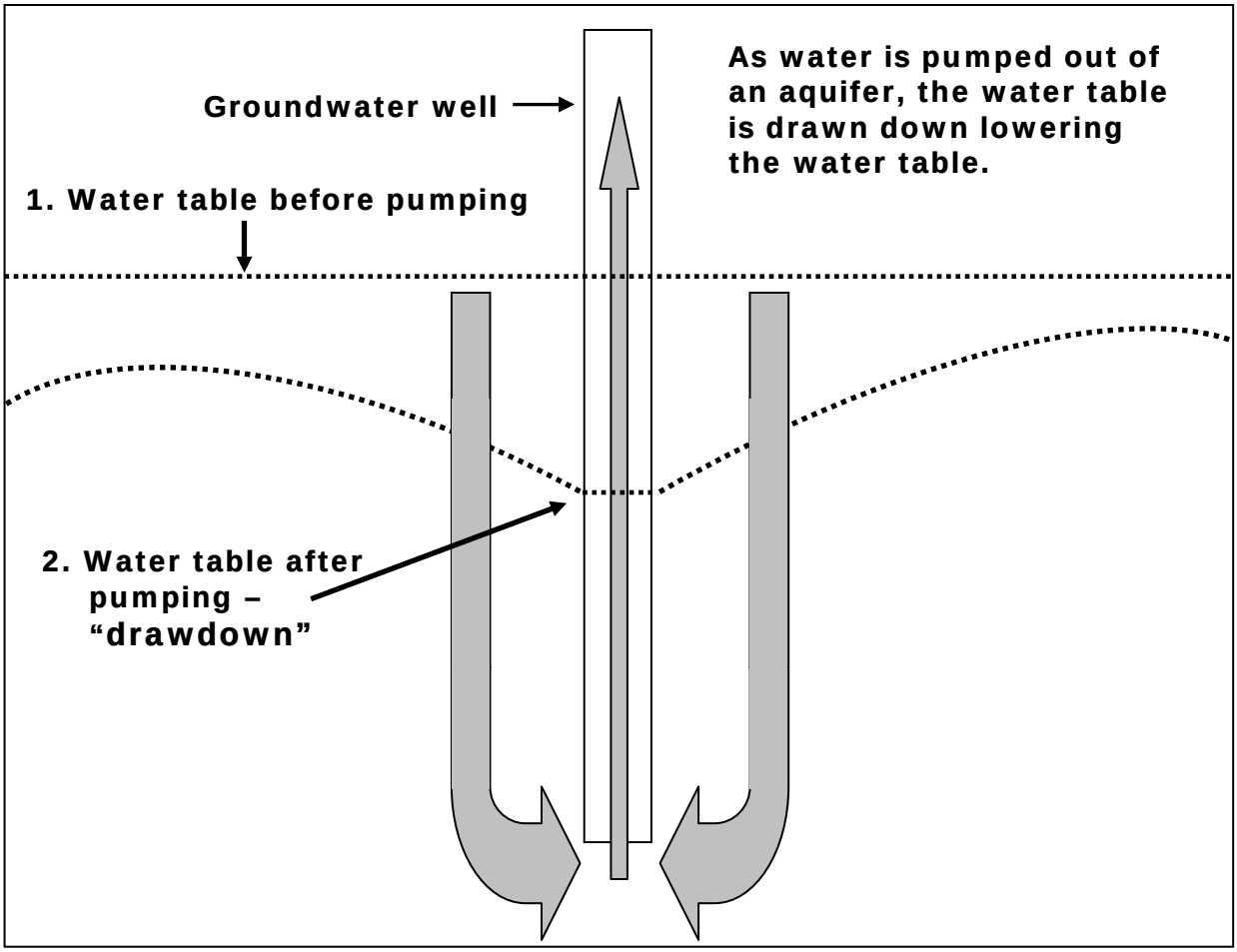

Figure 2. A cross-section showing drawdown of the water table

Name_____
Date_____Period_____

How is groundwater contaminated?

Due to its protected location underground, most groundwater is naturally clean and free from pollution. Unfortunately, any number of pollutants can enter the soil and rock, polluting the aquifer and eventually the well. Such contamination can pose a significant threat to human health. A mass of contaminants that spread outward from a pollution source is known as a **contaminant plume**. Hydrogeologists need to know the size of a plume and the direction it is flowing to predict what areas may be contaminated.

Sources of Groundwater Pollution

Bacteria are found in human and animal wastes, septic tanks, sanitary landfills, and garbage dumps.

Pesticides and Fertilizers used by farmers to promote growth and reduce weeds and insect damage. These products are also used on golf courses, lawns, and gardens. Fertilizer runoff can add to nitrates.

Heavy Metals come from activities such as mining, industry, and construction can release large amounts of heavy metals into nearby groundwater sources.

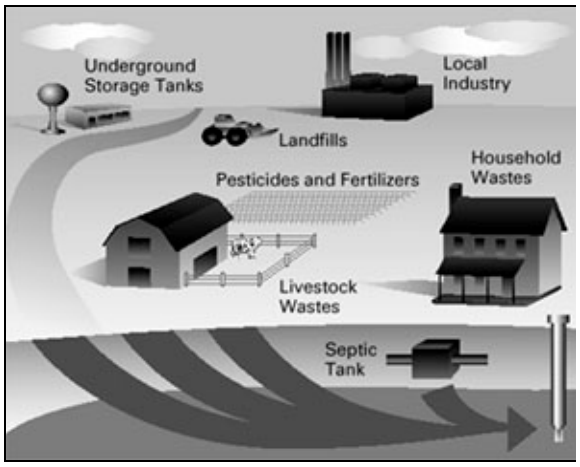

Figure 3. Above ground sources of pollution that can move into the groundwater

Industrial Wastes are produced by industrial plants, factories, and even small businesses such as gas stations and dry cleaners. Spills and improper disposal of hazardous chemicals can threaten groundwater including petroleum, chemicals, and other wastes stored in underground storage tanks (UST). Leaking tanks and abandoned wells on farm sites is another common occurrence.

Landfills and Waste Dumps can pollute. Modern landfills are designed to contain liquids that can leach into the groundwater, but rising flood water can cause the chemicals to flow over the barriers. Older dumps that lack liners may have a wide variety of pollutants that can seep into groundwater.

Household Wastes and improper disposal of many common products can pollute groundwater. These include cleaning solvents, used motor oil, paints, and paint thinners. Even soaps and detergents can harm drinking water.

Protecting Groundwater

Because aquifers are located underground, groundwater that is contaminated is extremely difficult and costly to clean up. Therefore, pollution prevention is the key to preserving groundwater quality. Individuals can help protect groundwater by using and disposing of chemicals properly and getting involved in monitoring and education activities.

Public water systems protect the land surrounding public wells or a well field (two or more wells) from potential pollutants. A **Wellhead Protection Area (WHPA)** restricts certain activities and monitors land use near municipal well fields to protect the groundwater in the aquifers. Other protection methods involve plugging abandoned wells and removing hazardous materials from leaky underground storage tanks.

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Name_____
Date_____Period_____

WORKSHEET 1: READING FOR UNDERSTANDING QUESTIONS

1. Why is groundwater important?

2. What is hydrogeology? How do hydrogelogists study something that is not visible (underground)?

3. Define the following terms in your own words or draw an illustration.
   a. Water table

   b. Drawdown

4. What is the difference between a saturated zone and an unsaturated zone?

5. Describe how groundwater is recharged in an aquifer and how it moves to discharge areas. Use the terms recharge, discharge, and hydraulic gradient in your explanation.

6. What are three sources of groundwater pollution that may be a problem in your community?

7. List three ways your community and you can prevent groundwater contamination.

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Name_____
Date_____Period_____

WORKSHEET 2: GROUNDWATER VOCABULARY QUIZ

Instructions: Match the correct vocabulary word with the definition.

A. Aquifer
B. Contaminant plume
C. Discharge area
D. Drawdown
E. Groundwater
F. Hydraulic gradient
G. Hydrogeology
H. Recharge area
I. Saturated zone
J. Unsaturated zone
K. Water table
L. Wellhead Protection Area (WHPA)

1. _____ The zone in a soil profile or geologic formation in which all pore spaces are filled with water.
2. _____ Areas where subsurface water is discharged to the land surface, and appears as lakes, streams, springs, and wetlands.
3. _____ The study of the distribution and movement of groundwater in soil and rocks beneath the Earth's surface.
4. _____ The slope of the water table that influences the direction and rate of groundwater flow.
5. _____ A water-bearing layer of rock or sediment composed of sands and gravel or sandstone or fractured limestone and yields usable quantities of water.
6. _____ The vertical drop of the water table in a well caused by groundwater pumping.
7. _____ The area on the ground surface where groundwater is replenished naturally when rainfall filters down through the soil or rock into an aquifer.
8. _____ The top of an aquifer below which the pore spaces are generally saturated; the groundwater level in an aquifer.
9. _____ A mass of contamination extending outward from the source.
10. _____ A soil or rock zone below the land surface (above the water table) in which the pore spaces are only partially filled with water.
11. _____ The area surrounding a drinking water well or well field which is protected to prevent contamination of the well(s).
12. _____ The supply of fresh water found beneath the Earth's surface, usually in aquifers, which supply wells and springs.

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Name_____
Date_____Period_____

WORKSHEET 3: GROUNDWATER MODEL DEMONSTRATION

Instructions: As you watch the groundwater model demonstration or video on the hydrogeology of an aquifer system, answer the questions on this worksheet.

PART I: Introduction

1. How much of the world's population is relying on groundwater for its drinking water?

2. What are other uses for groundwater?

3. Where does bottled water come from?

4. What does a hydrogeologist study?

VIDEO (STOP)

PART II: A Cross-Section of an Aquifer System

Label the following terms on the diagram *A Cross-Section of an Aquifer System* (Worksheet 3, page 3).

5. Label the aquifer types on the diagram.
   - **Sand**
   - **Gravel**
   - **Clay**
   - **Fractured rock**

6. Label the groundwater movement terms on the diagram and draw a line representing the hydraulic gradient.
   - **Recharge area**
   - **Water table**
   - **Hydraulic gradient**
   - **Discharge area**

7. Label the saturated zone and unsaturated zone in an aquifer on the diagram.
   - **Saturated zone**
   - **Unsaturated zone**

VIDEO (STOP)

Name_____
Date_____Period_____

PART III: Groundwater Movement

8. How does water move through a sand and gravel aquifer compare to a fractured rock aquifer? Fill in the table below:

Well #	Shallow or Deep Aquifer?	Private or Public Well?	Type of Aquifer
4			
1			

9. What are a couple of differences between private (domestic) wells and public (municipal) wells?

10. What are the effects on the groundwater when wells are pumped?

VIDEO (STOP)

PART IV: Contaminant Plumes

11. On the diagram, *A Cross-Section of an Aquifer System*, draw the **contaminant plume** from the leaking underground storage tank (UST) before pumping and after pumping Well 4.

12. On the same diagram, draw the path of the dye (contaminant) that was injected into Well 1.

13. How does pumping of wells affect the movement of contaminants?

14. Describe how contaminants move through a sand and gravel aquifer and how contaminants move through a fractured rock aquifer. Use the terms, conduit flow and diffuse flow in your explanation.

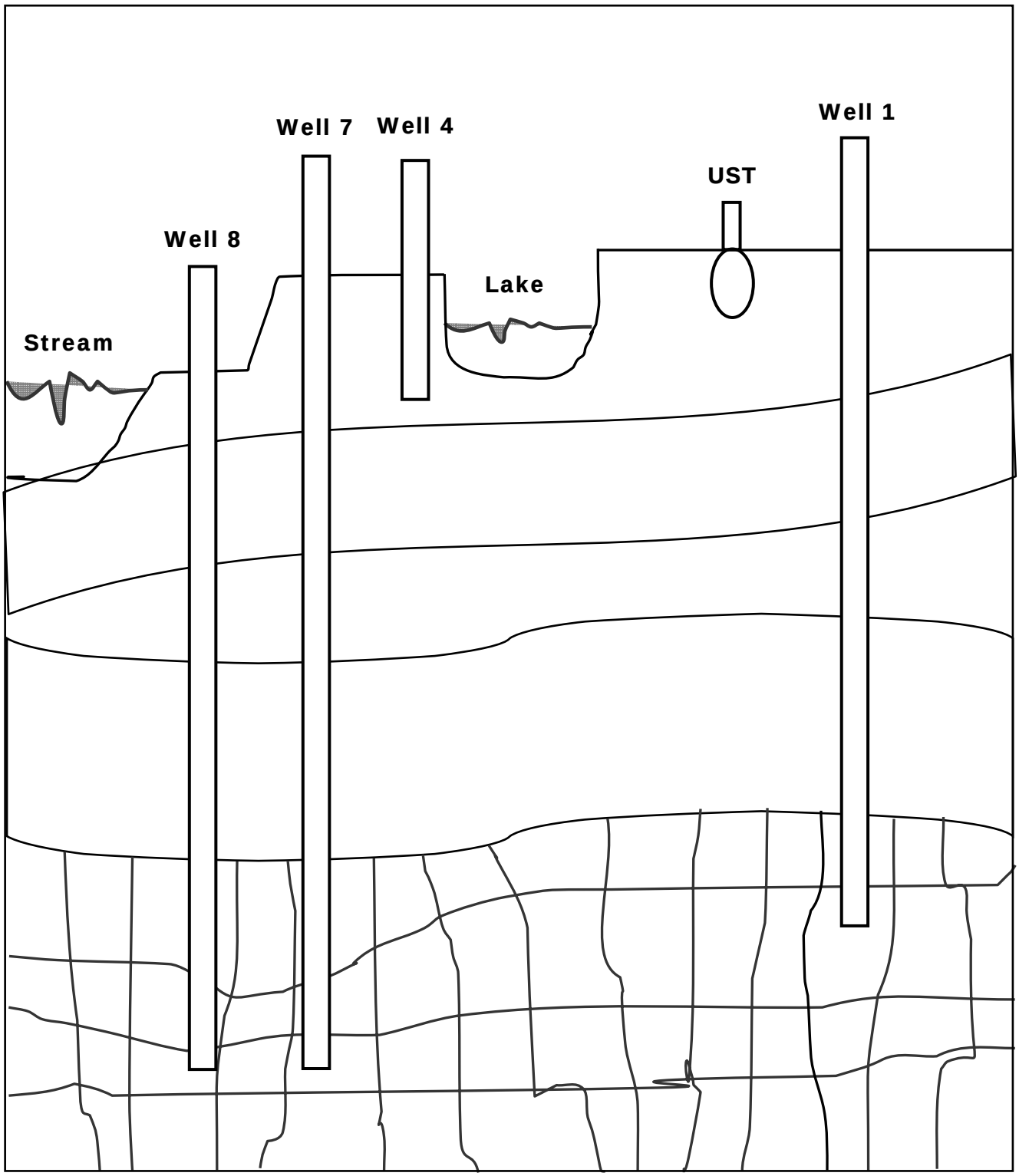
VIDEO (STOP)

PART V: Groundwater Protection

15. How can you protect the quality of groundwater?

Name_____
Date_____Period_____

A CROSS-SECTION OF AN AQUIFER SYSTEM



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