Getting Up to Speed

THE WATER CYCLE AND WATER CONSERVATION

THE WATER WE'VE GOT IS THE WATER WE'VE GOT

The water available to planet Earth is the same water that has always been available and the only water that ever will be available. Because water covers three-quarters of the earth's surface, it might appear that there is plenty to go around. In reality, however, we have a limited amount of usable fresh water.

Over 97 percent of the earth's water is found in the oceans as salt water. About two percent of the earth's water is stored in glaciers, ice caps, and snowy mountain ranges. That leaves only 1 percent of fresh water that is readily available to us for our daily water supply needs. Our fresh water supplies are stored either beneath the ground, in soil or fractured bedrock, or in surface waters, such as lakes, rivers, and streams.

We use fresh water for a variety of purposes. Nationally, agricultural uses represent the largest consumer of fresh water, about 42 percent. Approximately 39 percent of our fresh water is used for the production of electricity; 11 percent is used in urban and rural homes, offices, and hotels; and the remaining 8 percent is used in manufacturing and mining activities.*

THE NEVER-ENDING JOURNEY

If you think about it, water never stays in one place for too long. Water is always on the move, traveling on a never-ending, cyclical journey between earth and sky. This journey is referred to as the **water cycle**, or **hydrologic cycle**. During its journey, water is continuously reused and recycled. It also changes form. It falls to the earth as rain, snow, sleet, or hail and **evaporates** from the earth back into the atmosphere as water vapor.

What form water takes and where it goes once it reaches the earth depends on where it lands. It might seep into the ground and move along slowly with the ground water to a nearby lake, stream, or estuary. It might sink into the ground, be taken up by a plant, move through the plant to its leaves, and evaporate back into the atmosphere (**transpiration**). It might land on a lake or pond and spend a season or two freezing and thawing—that is, changing from liquid to solid, and vice versa. It might land on a river or stream and continue on to the ocean. It might be heated by the sun, evaporate into the atmosphere, condense into tiny droplets, and become part of a cloud formation. Eventually, the water in the cloud falls back to the earth, and the journey begins again.

THE PEOPLE CONNECTION

While the total amount of water on earth remains constant, the availability of that water changes with weather (for example, drought or flooding), season, and human use. This problem is made worse in situations where communities use water from one location but release it into another place after it is used. In Massachusetts, for example, many communities in the Boston metropolitan area drink water from the Wachusett, Ware, and Quabbin Reservoirs located in central and western Massachusetts, but discharge that water as wastewater into Boston Harbor.

* Water use statistics from the "National Water Summary 1987—Hydrologic Events and Water Supply and Use." U.S. Geological Survey Water Supply Paper 2350.

If we understand that we have all the water that we will ever have, we can better appreciate why it is so important that we keep our water clean. The fresh water that is available for use by people, plants, and animals must be clean. And to this end, nature is very accommodating. The water that circulates between the earth and the atmosphere is continually restored and recycled thanks to Mother Nature's impressive bag of biological, chemical, and mechanical tricks.

But sometimes human carelessness bogs down the system, loading harmful and unhealthy substances into the system at a rate that exceeds its natural restorative capabilities. When harmful substances are discarded into the environment, they may very well end up as part of the water cycle. Nature can also stir up some environmental problems as a result of natural events such as volcanoes, earthquakes, and tornadoes.

When chemicals are released into the air from smokestacks, for example, they might well return to the earth with rain and snow or by simply settling. When harmful substances are discarded onto the land or buried in the ground, they might well find their way into ground water or surface water, which may, in turn, be someone's or some community's drinking water. In nature's water cycle, all things are connected.

In many ways, we, as a society, have had to learn about managing and caring for our water resources the hard way. By the early 1970s, many of our nation's water supplies had become foul-smelling and unhealthful. In 1972, recognizing that we could no longer turn our collective backs on the problem, Congress passed the **Clean Water Act**, thereby setting in motion the beginning of a concerted effort to rehabilitate the nation's degraded waters. Taking our cues from Mother Nature, we have over relatively few years developed biological, chemical, and mechanical technologies that effectively clean wastewater before it is discharged into waterbodies.

Keeping water clean is not just our nation's problem; it is a worldwide problem. Many other nations are trying to manage their water resources. Preventing water quality degradation from occurring in the first place is certainly the most cost-effective approach to water quality management. The water quality in some areas of the world has deteriorated to such an extent that the cost of turning the problem around has become prohibitive.

WHY CONSERVE WATER?

The issue of water conservation is not about "saving" water—it is about having enough clean water at any given time and place to meet our needs. Gifford Pinchot, an American conservationist and politician who served as chief of the U.S. Forest Service between 1898 and 1910, referred to **conservation** as "The wise use of the earth and its resources for the lasting good of men." The conservation of our water resources depends on our wise use of these resources. Such wise use, without a doubt, begins at home and in our community.

As we attempt to meet the water use needs of a growing population, issues of water quality and quantity will gain increasing significance in years to come. We cannot afford to take our water resources for granted—not even here in the water-rich Northeast. Droughts, for example, are natural occurrences that can cause water shortages.

But human activities can cause water availability problems as well. In some instances, communities have had to seek other sources of drinking water because their water supply well had been contaminated. For example, infiltration of gasoline from a leaking underground storage tank into a ground water supply well is all it can take to render a well field unusable. Once ground water becomes contaminated, it can take years or decades for it to clean itself naturally.

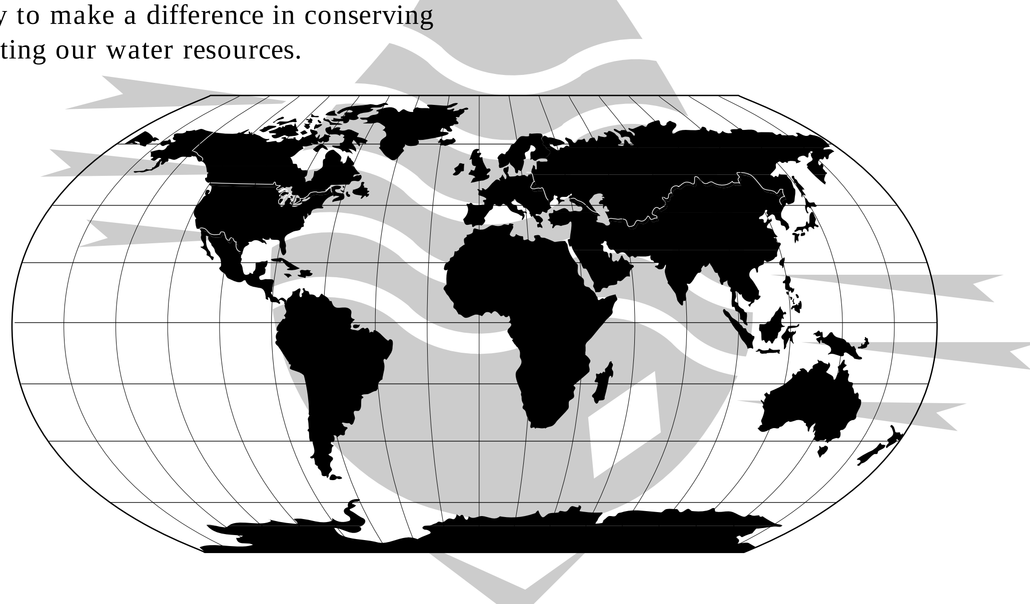
To some extent, we all share responsibility for ensuring the availability of a clean and healthy water supply. We can try to reduce contamination by keeping the water, the ground, and the air free of pollutants as much as possible. We can use just the amount of water that we need.

Industries can recycle their process water or pre-treat their wastewater so that it is easier to purify for drinking water and other purposes. Communities can educate residents about local water resources and work together to implement land use strategies that will protect and sustain water supplies into the future. They can develop plans to handle water shortages without waiting for a water emergency and can help residents dispose of harmful products properly by offering hazardous waste collection days. By behaving responsibly in our use of water, we can be sure that there will be enough clean water when we need it.

It is only recently that environmental issues and our interrelationship with the natural world have been integrated into school curricula. In this sense, teachers and students have become our environmental educators, getting the word out to families and friends that we all share the responsibility for protecting and maintaining our earth for current and future generations. This resource book is designed to help students recognize their own ability to make a difference in conserving and protecting our water resources.

KEY TERMS

- **Clean Water Act**
- **Conservation**
- **Evaporation**
- **Hydrologic Cycle**
- **Transpiration**
- **Water Cycle**



ALL THE WATER IN THE WORLD

Grades 7-9

OBJECTIVES

- Recognize that there is a lot of water in the world, but that not very much of it can be used for our drinking water and other water supply needs.
- Recognize that ground water is a very small percentage of the earth's water.
- Understand how important it is that we take care of our ground water.

INTERDISCIPLINARY SKILLS

Science, Math

ESTIMATED TIME

45 minutes

MATERIALS

- ❏ 5 gallons of water
- ❏ 5-gallon aquarium
- ❏ Measuring cup (24-ounce size would be best)
- ❏ Green food coloring
- ❏ Ice cube tray
- ❏ Ice pak
- ❏ Dropper
- ❏ 6-ounce see-through container
- ❏ Sand
- ❏ Activity handout

TEACHING STRATEGY

Part A - Aquarium Demonstration:

As you do this experiment, stress that the amounts represent relative quantities of different types of water, not actual amounts.

1. Put 5 gallons of water in an aquarium. Tell students to imagine that the container represents all the water in the world.
2. Ask students to guesstimate what proportion of this water exists on the earth as:
   - ocean
   - ground water
   - rivers
   - ice caps/glaciers
   - freshwater lakes
   - inland seas/salt lakes
   - atmosphere
3. Remove 18 ounces of the water from the aquarium with a measuring cup. Using green food coloring, color the remaining water in the aquarium. Tell the students that this water represents all the water on earth held in oceans. The water in the measuring cup represents all the water in the world that is not ocean water.
4. Pour 15 ounces of the water from the measuring cup into an ice cube tray. This water represents all the water held in glaciers and ice caps. This water is not readily available for our use. Since the amount of water held in the ice cube tray is comparable to that of an ice pack, place the ice pack in the aquarium to represent the total amount of water held in glaciers and ice caps.
5. The remaining 3 ounces represent the world's available fresh water. Of this amount, a fraction of an ounce is held in the world's fresh water lakes and rivers. Place this water (approximately one dropper of water) into a student's hand.

NOTES

6. The remaining water (approximately 2.5 ounces) is ground water. Pouring this remaining water into a cup of sand, explain that this is what is referred to as ground water and that this water is held in pore spaces of soil and fractures of bedrock. About one-third of New England's drinking water comes from ground water.

This Aquarium Demonstration was developed by Paul Susca, New Hampshire Department of Environmental Services, Water Supply Engineering Bureau.

Part B - Activity Handout: All the Water in the World

1. Ask students to complete the activity worksheet.
2. The answers to the drinking water percentages: O.419% total and 2.799% grand total.
3. Ask students if the numbers surprised them. Did they realize that such a small percentage of the water in the world is fresh?

Follow-up Questions

1. Why isn't all fresh water usable? *Some is not easy to get at; it may be frozen or trapped in unyielding soils or bedrock fractures. Some water is too polluted to use.*
2. Why do we need to take care of the surface water/ground water? *Water is very important for humans, plants/crops, and animals. If we waste water or pollute it, we may find that there is less and less of it available for us to use.*

Did you know...?

- **EARTH IS CALLED THE WATER PLANET.**
- **APPROXIMATELY THREE-FOURTHS (3/4) OF THE EARTH'S SURFACE IS COVERED WITH WATER.**
- **THE EARTH HAS DIFFERENT TYPES OF WATER:**

Oceans	97.2% of total water
Ice caps/glaciers	2.38%
Ground water	0.397%
Surface water (e.g., lakes, rivers, streams, ponds)	0.022%
Atmosphere	0.001%

ASSIGNMENT

Add up the percentages for water available for drinking water.

Ground water ____________

Surface water ____________

TOTAL ____________

Now add ice caps/glaciers ____________

GRAND TOTAL ____________

REMEMBER: Only a small percentage of water is suitable for humans to drink. Not all of the water in the ground and in lakes and rivers is easy to reach or clean enough to drink. Ice caps and glaciers are certainly hard to use for humans, plants, and animals. Some work is being done to take the salt out of ocean water (desalinate the water), but that is an expensive process.

This activity is adapted from *Water: The Resource That Gets Used and Used and Used for Everything.* Poster: Middle School Version. United States Geological Survey, Reston, Virginia. 1993.

HOW MUCH WATER DO YOU USE?

Grades 7-12

➤ OBJECTIVES

- Identify ways in which water is used.
- Analyse a family's water use with a focus on ways to reduce water consumption.

➤ INTERDISCIPLINARY SKILLS

Science, Mathematics, Critical Thinking

➤ ESTIMATED TIME

- Part A - 10 minutes to explain the chart; 30 minutes for follow-up discussion after the survey has been completed.
- Part B - 20 minutes

➤ MATERIALS

❏ Activity handout

TEACHING STRATEGY

Part A - Detective Work

1. Tell students that today's activity is designed to make them aware of how much water individuals and families use on a weekly basis.
2. Distribute the copies of the story, "The Case of the Mysterious Renters," and the survey. (Note: The story is designed to "liven up" the exercise. Teachers who feel that their students are too advanced for this story may choose to distribute just the water survey.)
3. Have students conduct the survey at home for a full week. Be sure students write down their hypotheses before completing their surveys.
4. Explain how to fill out the survey. Explain how to make tally marks each time the activity takes place. (It might be interesting, for extra credit, to compare weekday and weekend water use.)
5. After students have completed the survey, discuss the results.

Part B - Brainstorming About Water Conservation

1. Have students look at their water use surveys. Ask them to consider what their families could do to reduce the amount of water they use. How much water would that conserve? If everyone in the class followed that practice, how much water would it save in a year?
2. Give each student a copy of the "Water Conservation Tips." Look it over as a group to see how it compares with your list. Suggest that students take it home and post it in the bathroom or kitchen.

NOTES

Supplementary Activities

- Have students write an article for the school newspaper describing ways people can conserve water and why it is important.
- Have students write a brief newsletter for their parents reporting on the results of the survey. Honor those who used the least amount of water. Include water conservation suggestions.
- Have students conduct a survey of water conservation devices in their homes.

The Case of the Mysterious Renters

SCENARIO

Mrs. Jackson has called the water detectives to help her solve a serious problem. She has heard that the detectives have an excellent record for solving mysteries.

"What seems to be the problem?" asked one of the water detectives.

"Well," said Mrs. Jackson, "as you know, I rent out several apartments to college students. I never allow more than four students to stay in one apartment. But, in Apartment 319, I just know that there are more than four people. I just can't prove it."

One of the water detectives interrupted her with a question, "Have you ever tried making surprise visits?"

"Yes," she answered, "but every time I go there, four people or less are at home. Those college students come and go at all hours of the day and night. There is no way for me to keep track of how many students actually share the apartment."

"Very interesting," said one of the detectives. "I think we can help you, but first we'll need to see last month's water bill for the apartment."

"How will that help?" asked Mrs. Jackson.

"We'll be able to see how many gallons of water were used last month," said another water detective.

Mrs. Jackson found the bill. It revealed that last month the occupants used 15,000 gallons.

"Let's see," said one of the detectives. "Last month was September, which has 30 days. If we divide 15,000 gallons by 30 days, we know that they used 500 gallons a day."

"Yes," said Mrs. Jackson, "but is that a little or a lot?"

"We'll have to investigate and get back to you. We'll do a survey to find out how much the average person uses," said the detective.

With that, the water detectives left Mrs. Jackson with a promise to return soon with an estimate of how many people were sharing the apartment. The water detectives decided that they needed to do some research to determine how much water people use in one day. In order to come up with an estimate, they decided to find out how much water their own families use in one day. Here's how:

ASSIGNMENT

1. Record the facts of the case.

a. The people in the apartment used _______________ gallons of water in September.

b. September has ________ days.

c. The average number of gallons of water used per day was

_______________ gallons.

2. Form a hypothesis.

a. How many gallons of water a day do you think a person uses?

_______________ gallons

3. Fill out the water survey.

4. Record your conclusions.

a. How many total gallons of water did your family use in one day?

_______________ gallons

b. What is the average number of gallons of water used per person per day in your family?

_______________ gallons

c. Based on your results, how many people do you think are living in Mrs. Jackson's apartment?

____

d. Compare your answer with the answers of others in your class.

____

____

____

SURVEY:
How Much Water Do You Use?

▶ DIRECTIONS This is a survey to find how much water you use in your home during one full week. Place a tally mark in the Times Per Day column every time someone in your family does the activity.

Activity	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Weekly Total	Water per Activity*	Total Water Used
Toilet Flushing	+	+	+	+	+	+	=	______	x 5 gallons	= ______
Short Shower (5-10 minutes)	+	+	+	+	+	+	=	______	x 25 gallons	= ______
Long Shower (>10 minutes)	+	+	+	+	+	+	=	______	x 35 gallons	= ______
Tub Bath	+	+	+	+	+	+	=	______	x 35 gallons	= ______
Teeth Brushing	+	+	+	+	+	+	=	______	x 2 gallons	= ______
Washing Dishes with Running Water	+	+	+	+	+	+	=	______	x 30 gallons	= ______
Washing Dishes Filling a Basin	+	+	+	+	+	+	=	______	x 10 gallons	= ______
Using Dishwasher	+	+	+	+	+	+	=	______	x 20 gallons	= ______
Washing Clothes	+	+	+	+	+	+	=	______	x 40 gallons	= ______
								GRAND TOTAL		= ______

NOTE: *Another significant seasonal water use is lawn and garden watering. This survey deals with daily water use in the home, but most of us use additional amounts of water at school, at work, and other places throughout the day.*

* *These are estimated values.*

ASSIGNMENT

To find average use per person in your family, divide the grand total by the number of people in your family.

The answer is: _______________

FOLLOW-UP QUESTIONS

1. In your home, which activity happened most often?

___

___

___

2. Which activities use the most water each time they occur?

___

___

___

___

3. What other activities at home consume large amounts of water?

___

___

___

___

___

___

4. Why might your answer differ from that of your classmates?

___

___

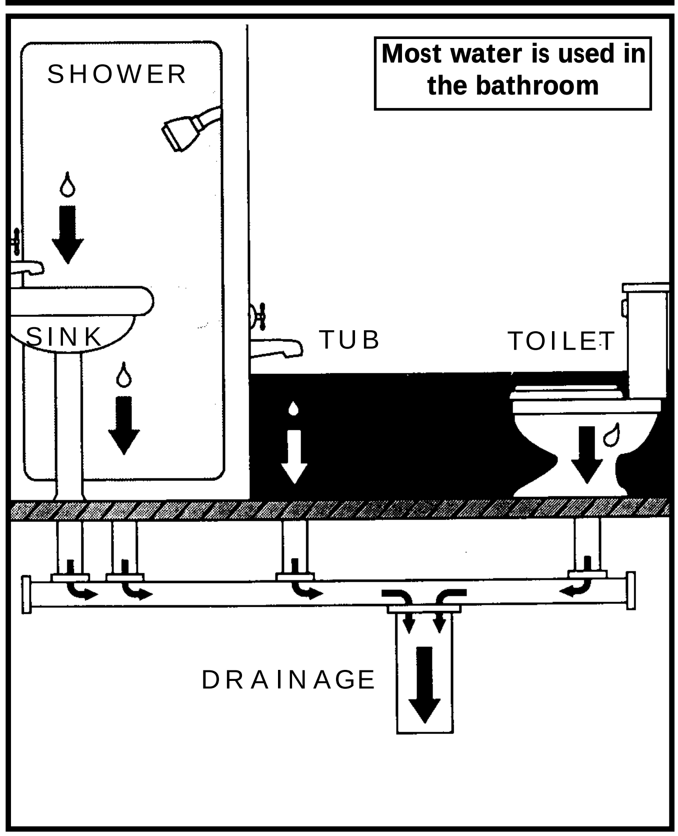
___

___

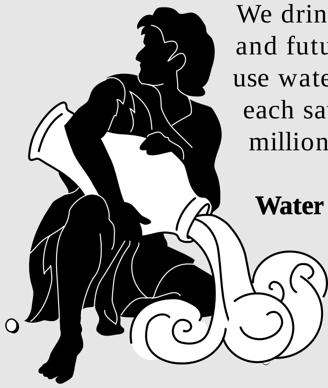
___

___

WATER USE IN THE BATHROOM



ALL WATER IS RECYCLED...



We drink the same water that Brontosaurus, Cleopatra, and George Washington did, and future generations will drink that same water. That's why it's important that we use water wisely and protect water supplies whenever and wherever possible. If we each save a small amount of water each day, our combined savings will add up to millions of gallons each year.

Water saved is money saved! Water conservation can save on water and sewer fees. Also, when you use less water, your fuel bills are lower. Even if you use well water, saving water reduces both electric costs and the waste load going into your septic system. Each day, as you drink water and use water, think of things you could do to help conserve and protect it. For starters, here is a list of household water conservation tips. What other tips would you add?

WATER CONSERVATION TIPS

Bathroom

Two-thirds of the water used in the average home is used in the bathroom, mostly for flushing toilets, showering, and bathing.

- ☑ **Turn off the water when you are not using it.** Don't let it run while you brush your teeth or shave.
- ☑ **Flush the toilet less often**. Put used tissues, trash, hair, paper towels, etc. in the wastebasket instead of flushing them.
- ☑ **Fix leaks and drips**. This is often simply a matter of changing a washer.
- ☑ **Retrofit older plumbing fixtures with flow-reducing devices.**
- ☑ **Take shorter showers**. Less than 5 minutes is adequate; any longer is recreation.
- ☑ **Take baths**. If you like to linger, a partially filled tub uses less water than a shower.

Kitchen and Laundry

- ☑ **Use appliances efficiently.** Run full loads in the dish or clothes washer or, if your appliance has one, use a load selector.
- ☑ **Buy a water saver**. Select new appliances that are designed to minimize water use.
- ☑ **Clean vegetables and fruit efficiently**. Use a vegetable brush to expedite cleaning.
- ☑ **Use garbage grinders as little as possible**. Start a compost pile or give leftovers to a dog, cat, chicken, horse, etc.
- ☑ **Keep a bottle of drinking water in the refrigerator**. Avoid running the tap just to cool water for drinking.

Lawn and Garden

- ☑ **Water the lawn and garden only when necessary**. Early morning or evening are the best times. Let grass grow higher in dry weather. Mulch your trees and plants. Avoid watering drive-ways and sidewalks.
- ☑ **Deep-soak your lawn**. Allow the moisture to soak down to the roots where it does the most good. A light sprinkling evaporates quickly.
- ☑ **Plant drought-resistant trees and plants**. Many beautiful trees and plants thrive with less watering, particularly native species.
- ☑ **Wash your car sensibly**. Clean the car with a pail of soapy water and use the hose only for a quick rinse.

Getting Up to Speed

NEW ENGLAND'S GROUND WATER RESOURCES

THE ZONES

Water that falls to the earth in the form of rain, snow, sleet, or hail continues its journey in one of four ways: It might land on a water body and, essentially, go with the flow; it might run off the land into a nearby water body or storm drain; it might evaporate from a water body or land surface; or it might seep into the ground. Water that seeps into the ground moves in a downward direction, passing through the **pore spaces** between the rock and soil particles in what is known as the **zone of aeration**, or **unsaturated zone.**

Eventually the water reaches a depth where the pore spaces are already filled, or saturated, with water. When water enters this **saturated zone**, it becomes part of the **ground water**. Ground water is essentially everywhere at varying distances below the surface of the earth, wherever there are spaces, pores, or cracks in the soil or rock for it to fill. The process whereby precipitation or surface water infiltrates the soil and replenishes the ground water is called **ground water recharge**.

The top of the saturated zone is called the **water table**. The water table may be very close to the ground surface, which is often the case in New England when it is next to a surface water body, or it may be as much as 200 to 600 feet deep, which is the case in many areas of the southwestern United States.

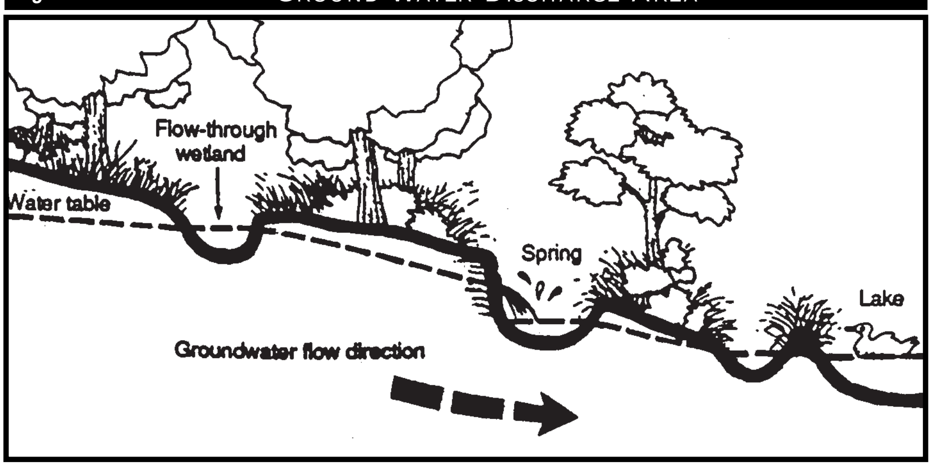
The saturated zone is underlain by **impermeable** rock or soil (e.g., a clay layer), which prevents further downward movement of water. When the water reaches this impermeable area, it begins to collect in the overlying soil pore spaces or rock fractures, thereby creating the saturated zone, or ground water area.

GROUND WATER DYNAMICS

Ground water is very much a part of nature's hydrologic cycle. Like water on the earth's surface, ground water tends to flow downhill under the influence of gravity and eventually discharges, or flows out of the ground, into streams or other surface water-dependent areas, such as wetlands. In New England, it is common to see ground water emerging from a hillside as a spring or seeping out of a road cut. During winter months, the ground water often freezes into long icicles as it seeps out of the rocks.

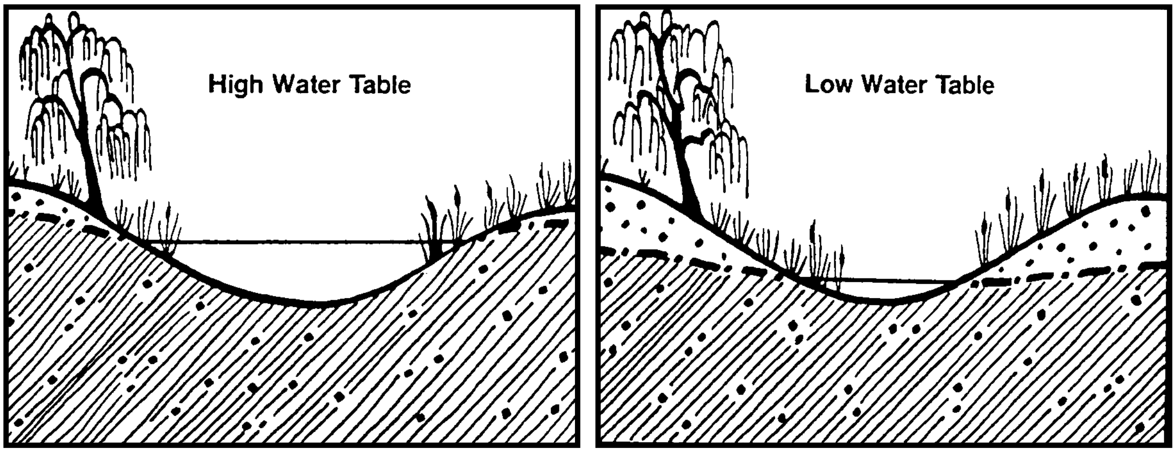
In such **discharge areas** (see Figure 1), the water table is at or near the land surface. In fact, most

Figure 1 GROUND WATER DISCHARGE AREA



Source: Lyle S. Raymond Jr. *What is Groundwater?* Bulletin #1. Cornell University. July 1988

Figure 2 WATER TABLE LEVELS



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

streams in New England keep flowing during the dry summer months because ground water discharges into them from the saturated zone. It is only when the water table falls below the level of the stream bed that a stream may dry up completely. Under certain conditions the flow may be reversed and the surface water may recharge the ground water.

Compared with water in rivers and streams, ground water moves very, very slowly—from as little as a fraction of a foot per day in clay, to as much as 3-4 feet per day in sand and gravel, to tens of feet per day in bedrock formations.

The speed at which ground water moves is determined by the types of material it must flow through and the steepness of the gradient from the recharge area to discharge area. Water moves more easily through the large pores of sand and gravel, for example, than through material that contains fine silt and clay.

The water table doesn't remain at the same level, or depth, all the time. The rise and fall, or **fluctuation**, of the water table occurs seasonally and is a natural part of the ground water system. In late winter and early spring, melting snow and rain infiltrate the soil, causing ground water levels to rise. The water table typically reaches its annual high level at this time. By late spring and into the summer months, when water is typically taken up by growing vegetation, little ground water recharge occurs, and the water table lowers. Ground water is recharged again during the fall rains after the growing season. In the winter, the ground is frozen and very little precipitation enters the ground water. In the spring, the snow melts, the rain falls, and the cycle begins anew.

The water table also responds to cyclical periods of drought and heavy precipitation that can last for several years (see Figure 2). For example, from 1979 to 1981, much of New England experienced a drought. The water table dropped steadily during those years. By the end of that period, the water table in many places was several feet lower than normal. In 1982, the drought ended when heavy rains fell and the ground water levels began to rise again. By early 1983, the water table was so high that many cellars that had never been wet before were flooded with ground water.

Surface waters also have a very dynamic relationship with ground water. Depending on the level of the ground water table, streams either receive ground water discharges, called **gaining streams**, or lose water to the adjacent ground water, called **losing streams**. In New England, where ground water levels are often relatively close to the ground surface, streams tend to receive ground water discharges. In this situation, the level of water in the stream is the same as that of the water table. This is true for wetlands, ponds, and lakes as well. More than half of the total flow of some streams during dry periods may derive from ground water discharge.

Ignoring the natural fluctuations in ground water levels can lead to expensive problems. For example, septic systems, drainage systems, and foundations designed and built for ground water conditions during drought conditions, when the water table is very low, can be flooded when the water table returns to more normal levels. In New England, the average depth to ground water ranges from 8 to 20 feet.

Our Water Budget

A **water budget**, similar to a household financial budget, can be developed to track water movement through the hydrologic cycle. The "receipts" are the water coming into the drainage basin, or **watershed**, and consist of the **precipitation** that falls within the basin as rain or snow. The "disbursements" consist of water vapor released by evaporation or by transpiration from green plants (collectively called **evapotranspiration**) and the water that is carried away into streams and rivers as **runoff**. Finally, the "savings" consist of surface water stored in lakes, ponds, and other water bodies, and ground water stored beneath the earth's surface. Water is continually withdrawn (discharged) from these storage areas and deposited (recharged).

The water budget within a drainage area depends not only on the water received as rain and snow, but also on how rapidly water leaves the basin. Topography, geology, soils, vegetation, and land use can all affect the rate of water storage and loss. Much of the precipitation that falls on steep slopes or on **impervious** surfaces, such as roofs and pavement, flows over the surface of the ground as runoff to streams that eventually carry it out of the basin. Rain falling on flatter, unpaved areas, however, can **infiltrate** into the soil. Vegetation can intercept precipitation as it falls to the earth and slow runoff so the water has a chance to infiltrate. the water budget is also affected when water is withdrawn from one basin and then discharged into another basin after it is used (e.g., when water is piped out of one basin to a wastewater facility, where it is treated and then discharged into a different basin.)

Drawing Water From A Well

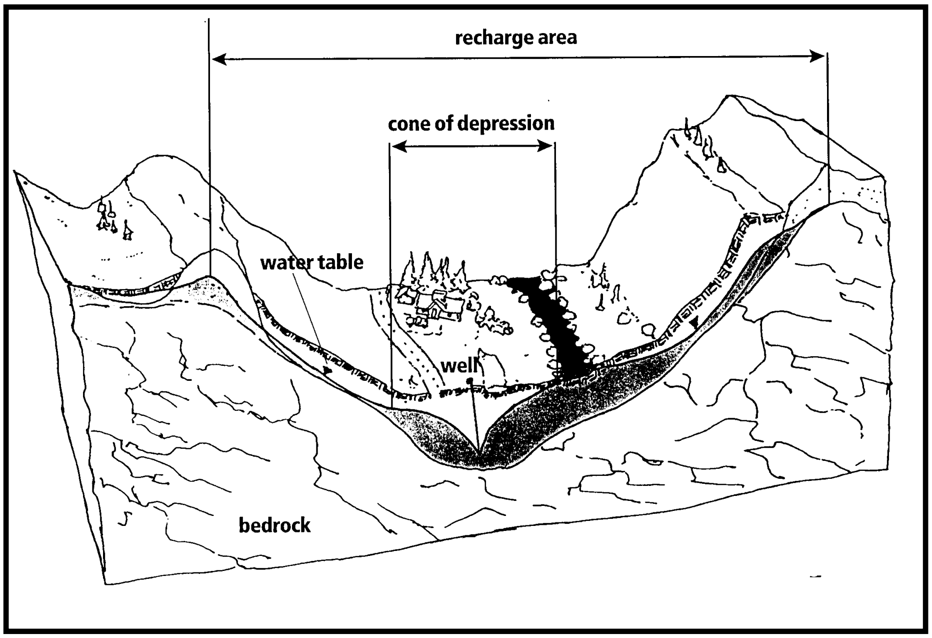
When people use ground water as a water supply source, the water is withdrawn from the ground by way of a **well**. Wells tap ground water as it flows through surficial deposits or cracks and fractures in bedrock. In almost all wells, the water must be pumped from the ground water to the surface.

Pumping depresses the water table around the well, forming a **cone of depression** (a low-pressure zone in the shape of an inverted cone), causing water to flow toward the well from all directions. The cone of depression can range from tens or hundreds of feet in radius for small bedrock wells to several thousand feet for high-volume public wells that draw water from sand and gravel aquifers. (See Figure 3.)

Not all ground water can be drawn into wells. To yield significant quantities of water, wells must be located in aquifers. An **aquifer** is a water-bearing soil or rock formation that is capable of yielding enough water for human use. All the spaces and cracks, or pores, between particles of rock and other materials in an aquifer are saturated with water. In bedrock aquifers, water moves through cracks, or **fractures**. Some types of bedrock—such as sandstone—can absorb water like a sponge; other types of bedrock—such as granite—do not. They hold water only in their fractures. The part of the aquifer that contributes recharge to a well is called the **zone of contribution**.

As wells pump out ground water, they reduce the amount of water in the ground water system,

Figure 3 WELLFIELD RECHARGE AREA



Source: Hust, R. and J. Murphy. *Protecting Connecticut's Groundwater: A Guide for Local Officials.* CTDEP. Hartford. 1997

causing the water table to fluctuate over time. Ideally, the amount of water withdrawn from a well will be balanced by the amount of recharge entering the system by way of rain, snow melt, or surface water body.

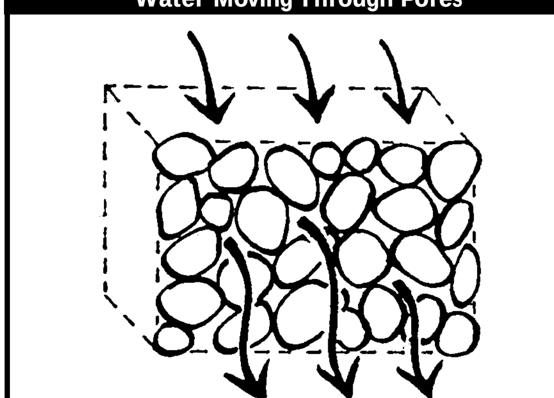
The **porosity** of a material determines how much water it will hold—the more pore space, the more water. Porosity is expressed as a percentage of the total volume of a material. For example, the porosity of a certain sand might be 30 percent; that is, 30 percent of the total volume of the sand is pore space and 70 percent is solid material. It means that 30 percent can be filled with water, or more than 2 gallons of water per cubic foot!

The ability of a material to transmit water is called it's **permeability** (See Figure 4). Permeability is a function of the size and shape of the soil particles, the amount of pore space between the particles, and whether or not the pore spaces interconnect. In consolidated rock, such as granite, permeability depends on how well the fractures in the rock are interconnected. In an unconsolidated material, such as sand and gravel, permeability depends on the size of the pore spaces between the grains of material.

Porosity and permeability are related, but they are not the same thing. A material can be very porous and hold a large volume of water but not be very permeable. For example, clay may be twice as porous as sand, but a pumping well will not be able to pull the water from the pores between clay particles fast enough to supply the well. Very small pore spaces create a resistance to flow that reduces permeability. The best aquifers are both porous and permeable.

When evaluating a ground water system in terms of its suitability as a water supply aquifer, hydrogeologists commonly use the term **hydraulic conductivity**, which is a function of permeability. It is important to understand the concept of perme-

Figure 4 PERMEABILITY: **Water Moving Through Pores**



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

ability/hydraulic conductivity because it is one of the key factors used to determine whether ground water can actually be drawn into a pumping well. The three primary factors that determine how much water can be withdrawn by a well are the steepness of the slope of the water table, the hydraulic conductivity, and the thickness and extent of the aquifer.

WHERE ARE OUR AQUIFERS?

■ In Bedrock

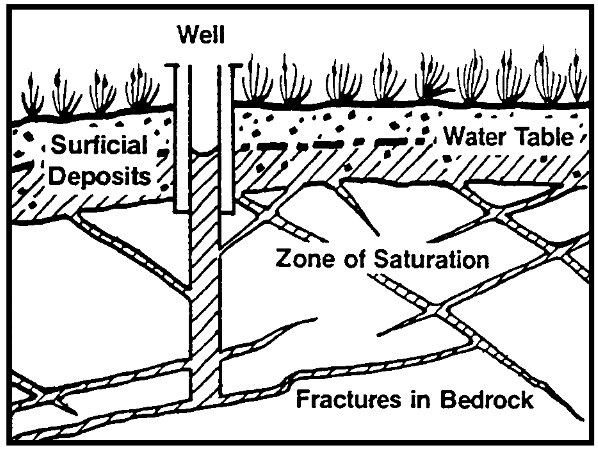
Solid rock can't yield water. Ground water in rock is mostly found in cracks, fractures, or in channels created when water enlarges the fractures in certain carbonate rocks (such as limestone).

Bedrock (see Figure 5) is the rock that lies beneath all the **unconsolidated materials** (soil and loose rocks) on the surface of the earth. It is the earth's crust. (In New England, bedrock is commonly called ledge.) If a well is drilled into bedrock fractures that are saturated with water, bedrock can serve as an aquifer.

In most of New England, however, bedrock is not highly fractured. Fractures generally occur within the first 100 to 150 feet of the surface, and they tend to be rather small, with few interconnections. Consequently, wells that intercept rock fractures can usually yield only enough water for private, domestic supplies. However, there are some highly fractured zones known as faults, where yields in the range of 200,000 to 400,000 gallons per day (gpd) have been developed, primarily for industrial use.

In western Massachusetts and parts of Maine, there are a few areas where bedrock is composed of limestone, a soft carbonate rock. Over time, water can form solution channels in this rock by dissolving the surface of the fractures along which it flows. The solution channels can become very large. They can hold and transmit enough water to provide a sustained yield to large wells. For instance, ground water found in solution channels in limestone is the major source of drinking water in other parts of the country (e.g., Florida).

Figure 5 BEDROCK AS AN AQUIFER



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

■ In Surficial Deposits

Most people would refer to **surficial deposits** as soil, but geologists call the sand, gravel, soils, rocks, and other loose material that lie on top of bedrock surficial deposits. Porous, permeable surficial deposits make good aquifers. Some surficial deposits are porous and permeable. Most are not. What makes the difference?

Most surficial deposits are **heterogeneous**. They consist of a wide variety of material types and sizes. In these deposits, almost all of the spaces between the large material are filled with smaller particles. For example, the spaces between pebbles and large stones may be filled with sand, and the spaces between the grains of sand may be filled with clay. This leaves few pore spaces for ground water storage and makes it difficult for water to move through the pores. Thus, deposits that are a mixture of types and sizes of materials are not usually porous and permeable enough to serve as aquifers.

In other surficial deposits, particles are similar in size and do not fit closely together. This creates many interconnecting pore spaces that can hold water. Some of these deposits contain very fine-grained silt and clay. They are porous but not permeable because the pores are too small to transmit water easily. In some surficial deposits of similar-sized particles such as coarse sand, the pores are large and water can flow through them easily. These deposits are both porous and permeable and are excellent aquifers.

Large-Volume Wells Need Large Sources of Water

The capacity of an aquifer to produce water is determined by the amount of porous, permeable materials that are present and the quantity of water that is available in that material. These factors can be determined for specific aquifers by geologic studies and pumping tests.

To supply a large public well, there must be enough water in storage in the aquifer or a nearby source such as a river or a lake that is connected hydrologically with the aquifer. Often, several wells are needed to supply all the water required by a municipality, but even small public wells are considerably larger than private wells serving single households. A small public well might yield 100,000 gpd, while a private well serving a single home might yield only 500 to 1,000 gpd.

Though most areas contain aquifers that are adequate for private, domestic wells, public wells must be located in aquifers that are large enough to sustain a consistently high yield over a long period of time. Aquifers that are large enough to supply public wells are found only in locations with certain geologic and hydrologic conditions. Protecting them for future use is of great importance.

Your Water Source?

Water supplies are derived from either private or public water systems. A **private water system** is defined by the federal **Safe Drinking Water Act** as a well that provides water for less than 15 service connections or a well that serves less than 25 people. Private water systems are not regulated by the Safe Drinking Water Act. These systems include rural homeowners and farms.

A **public water system** is one that has 15 or more service connections or that regularly serves at least 25 people for 60 or more days per year. Public water systems can be either publicly or privately owned and are subject to minimum water quality standards specified by the Safe Drinking Water Act. Common examples of public water systems include community wells, a well serving a school (with more than 25 students and employees), and wells used by trailer parks. Public water systems derive their water from either surface water (e.g., reservoirs or rivers) or ground water sources.

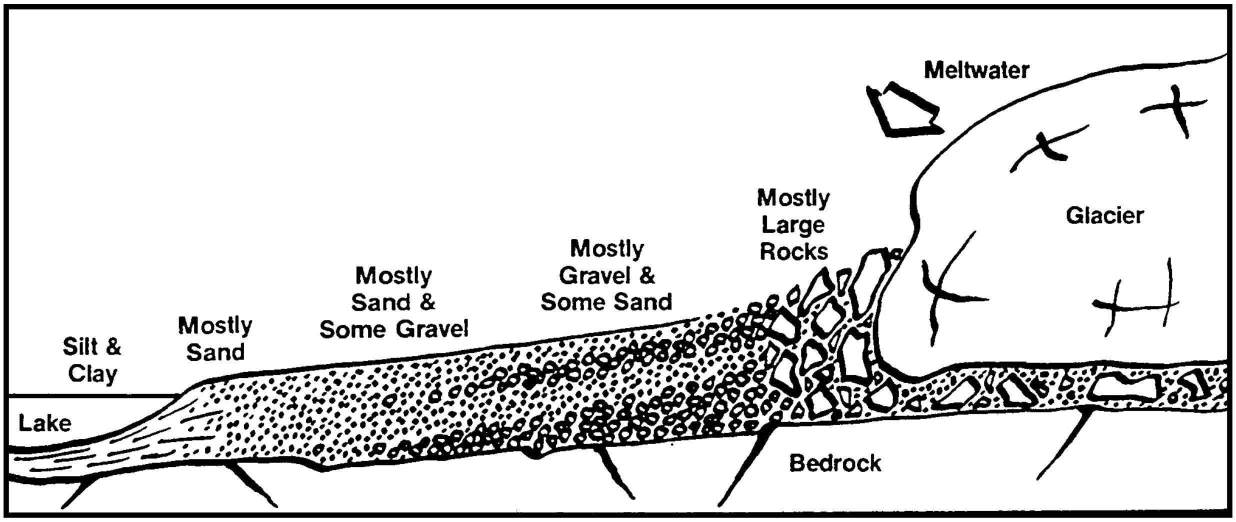
Glaciers Created Our Aquifers

In New England, porous, permeable surficial deposits were created by melting glaciers. Most of New England was covered by continental glaciers a number of times in the past 2 million years. Each glacier moved down over the region from the north, carrying with it large quantities of rocks and soil that it had scraped and plucked from the bedrock as it moved across the land surface. When the last glacier finally melted about 11,000 to 13,000 years ago, it redeposited this material as glacial debris. The region's surficial deposits are mostly glacial debris, topped with a thin layer of soil that has formed since the last glacier melted.

■ Stratified Drift: A Good Aquifer Material

Some glacial debris was carried away by torrents of water that flowed off the melting ice in meltwater streams. At the front of the glacier, these streams flowed so fast that they could transport glacial debris of all sizes except large boulders. As the meltwater moved further away from the glacier, it slowed down. The slower-moving water could no longer carry pebbles and gravel, so that debris settled out. Further along, when the water slowed more, sand grains settled out. Still further downstream, the water reached a lake or the ocean, and slowed completely. By this time, only very small particles remained suspended in the moving meltwater stream (see Figure 6).
When the water stopped flowing after it entered

Figure 6 GLACIAL MELTWATER STREAMS



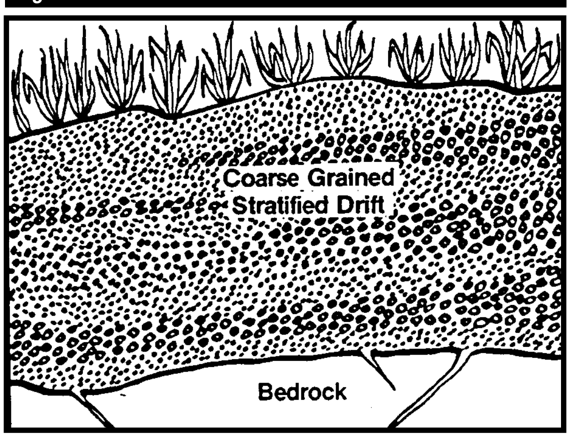
Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

the lake or ocean, the small particles settled out to form very fine deposits of silt and clay on the bottom of the lake. Thus, as they moved away from the glacier, the meltwater streams sorted the rock fragments they carried into separate layers of gravel, sand, and fine sand. These sorted deposits are called **stratified drift (**see Figure 7).

■ Glacial Till: A Poor Aquifer Material

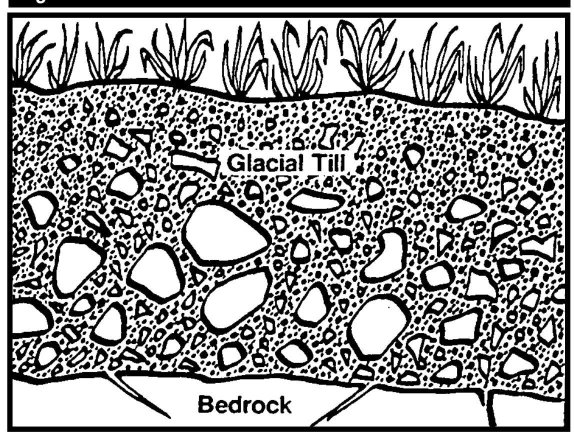
Most glacial debris was plastered onto the landscape as the last glacier advanced. Some slumped off the glacier into piles, was left up against the sides of valleys, or was formed into spoon-shaped hills called drumlins, when the glaciers moved over the debris. These types of glacial debris are called glacial till. They consist of an unsorted mixture of all sizes of soil and rock fragments and are usually not very porous or permeable. Therefore, public supply wells are not located in glacial till (see Figure 8).

Figure 7 STRATIFIED DRIFT



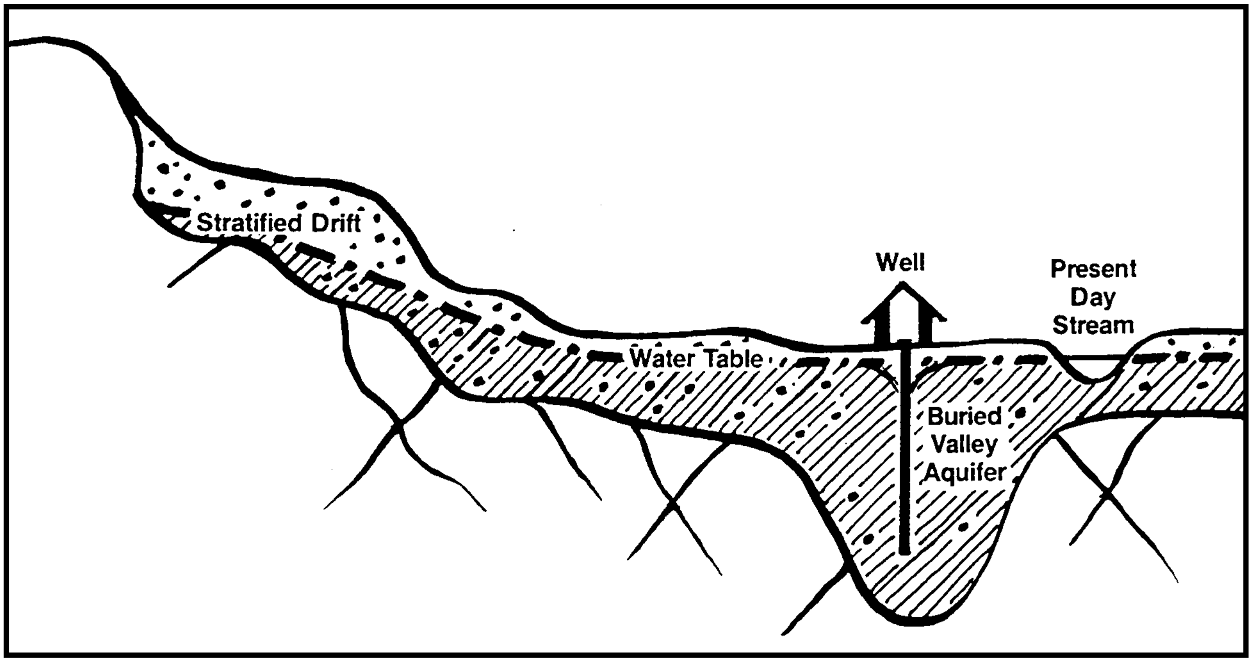
Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

Figure 8 GLACIAL TILL



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

Figure 9 BURIED VALLEY AQUIFER



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

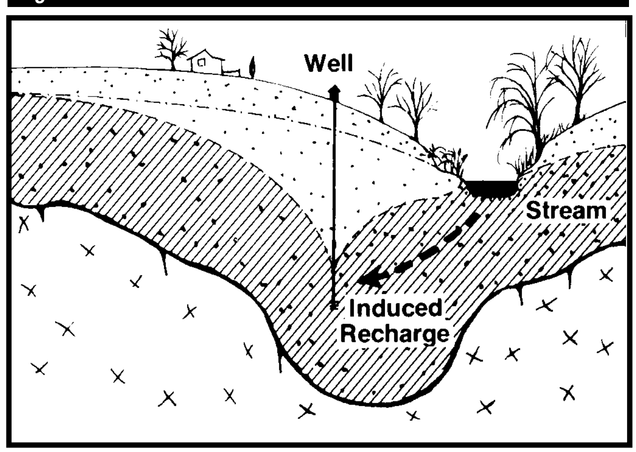
WHERE ARE THE GOOD PUBLIC WELL SITES?

■ Ancient River Valleys

In much of New England, meltwater moving away from the front of the glaciers flowed into existing river valleys. These valleys had been carved into the bedrock over millions of years by the rivers that drained the continent. In these ancient streambeds, the glacial debris settled out of the meltwater as stratified drift in the process described previously. Some of these ancient streambeds contain more than 200 feet of porous, permeable stratified drift. These buried valley aquifers (see Figure 9) are the sites of the majority of the larger public supply wells throughout New England.

Most public wells are located in buried valley aquifers that are connected hydrologically with a nearby river or stream. The pumping well may lower the water table below the level of the river, drawing water from the river into the well. This phenomenon is called **induced recharge** (see Figure 10). If this action takes place, however, it is important that wetlands and endangered plants and animals are not compromised and that surface water being withdrawn into the well is of adequate quality.

Figure 10 INDUCED RECHARGE



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #2. January 1993.

Most ancient streambeds correspond to present-day river and stream valleys, but the courses of a few rivers have changed since the glaciers melted. In those places, the aquifer is not located under and alongside the present river. Other small tributary streams have completely disappeared, leaving behind valleys filled with stratified drift. Geologic investigations can locate these ancient buried valleys, and the aquifers can be tapped for water supply.

■ Outwash Plains

In southern New England, glacial meltwater also formed excellent aquifers, but not in ancient river valleys. The last ice sheets to cover Massachusetts ended there. When they melted, the meltwater carried glacial debris from the front of the ice in a myriad of small parallel streams. Eventually, the stratified drift from the meltwater streams formed broad surfaces called outwash plains. These excellent aquifers differ from valley aquifers in that they are generally spread out over a larger area, but usually have no large sources of induced recharge.

Outwash plains and many valley aquifers are large enough to supply public wells. Smaller, coarse-grained stratified drift deposits can be aquifers for private domestic wells. Coarse-grained stratified drift deposits also readily absorb precipitation and thus commonly serve as important recharge areas.

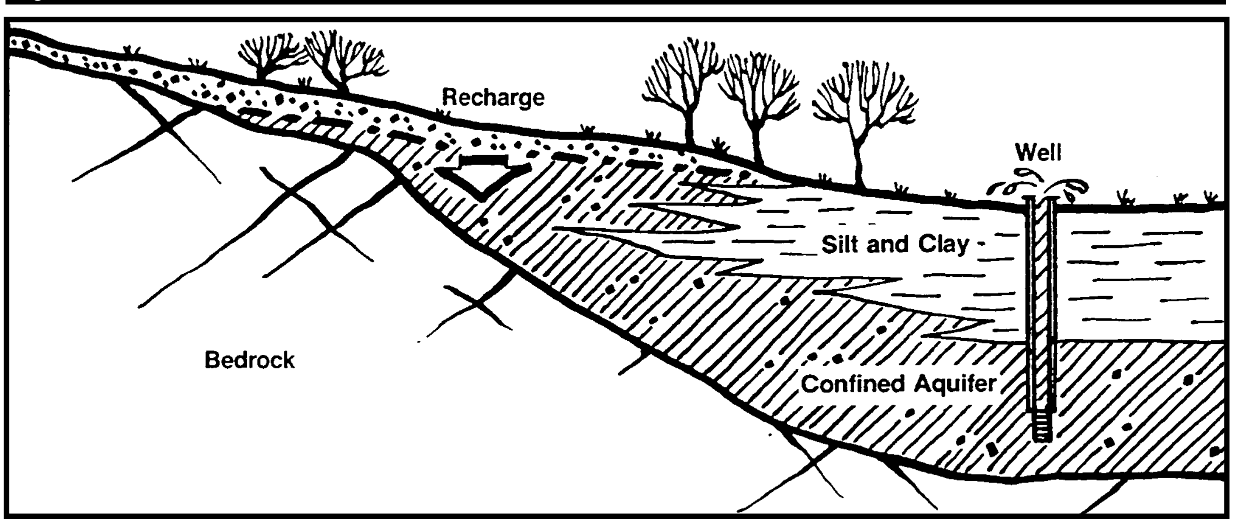
■ Confined Aquifers

The aquifers described so far are unconfined, or water table, aquifers. The top of this type of aquifer is identified by the water table. Above the water table, in the zone of aeration (or unsaturated zone) interconnected pore spaces are open to the atmosphere. Precipitation recharges the ground water by soaking into the ground and percolating down to the water table. The majority of the public wells in New England, and many private wells, tap unconfined aquifers.

Some wells in New England, however, are located in **confined aquifers**. These aquifers (see Figure 11) are found between layers of clay, solid rock, or other materials of very low permeability. Little or no water seeps through these confining layers. Recharge occurs where the aquifer intersects the land surface. This recharge area may be a considerable distance from the well.

In confined aquifers, often called artesian aquifers, water is under pressure because the aquifer is confined between impermeable layers and is usually

Figure 11 CONFINED VALLEY AQUIFER



Source: Massachusetts Audubon Society. *An Introduction to Groundwater and Aquifers.* Groundwater Information Flyer #1. January 1993.

recharged at a higher elevation than the top confining layer. When a well is drilled through the top impermeable layer, the artesian pressure will cause the water in the well to rise above the level of the aquifer. If the top of the well is lower than the recharge zone of the aquifer, water will flow freely from the well until the pressure is equalized.

HOW DO YOU FIND AN AQUIFER?

Since aquifers are tucked away beneath the surface of the ground, how do we figure out where they are located? Historically, many people used water dowsers—people who use divining rods—to locate underground water supplies. Today, we have acquired the scientific and technical wherewithal to more accurately locate ground water supplies.

In New England, soils were often laid down in several layers over time. Therefore, surface soils are not always good indicators. It helps to use several sources of information to identify aquifers. The best place to begin is by finding out what natural resource maps—local soils maps, topographic maps, surficial geology maps, bedrock geology maps—are available for the area in question. (See the "Revealing Stories—Resource Maps Tell All" activity and the "Resource File" for more information about map availability.)

To better understand regional soils, local health departments usually require that well logs be completed and submitted when drinking water wells are installed. In this case, well drillers (experts hired by local landowners or a community to install a well) must describe changes in the soil profile as they drill beneath the ground. This information is recorded in a document called a "well log." This information is useful because it allows hydrogeologists to better understand changes in the surficial deposits below the ground.

Another clue to consider is whether bedrock outcrops or ledge are common in the area. This may indicate shallow soils in the region.

"Getting Up to Speed" for section B, "New England's Ground Water Resources" is adapted from Massachusetts Audubon Society's *Ground Water Information* Flyers #1 and #2.

KEY TERMS

- **Aquifer**
- **Bedrock**
- **Cone of Depression**
- **Confined Aquifer**
- **Discharge Area**
- **Evapotranspiration**
- **Fluctuation**
- **Fractures**
- **Gaining Stream**
- **Ground Water**
- **Ground Water Recharge**
- **Heterogeneous**
- **Hydraulic Conductivity**
- **Impermeable**
- **Impervious**
- **Induced Recharge**
- **Infiltration**
- **Losing Stream**
- **Permeability**
- **Pore Spaces**
- **Porosity**
- **Precipitation**
- **Private Water System**
- **Public Water System**
- **Runoff**
- **Safe Drinking Water Act**
- **Saturated Zone**
- **Soil**
- **Stratified Drift**
- **Surficial Deposits**
- **Unconsolidated Materials**
- **Unsaturated Zone**
- **Water Budget**
- **Water Table**
- **Watershed**
- **Well**
- **Zone of Aeration**
- **Zone of Contribution**

PREDICTING GROUND WATER FLOW

Grades 9-11

OBJECTIVES

- Be able to draw a ground water contour map.
- Have a basic understanding of how to predict the direction of ground water flow.
- Understand the interrelated nature of ground water and surface water flow.

INTERDISCIPLINARY SKILLS

Science, Math

ESTIMATED TIME

45 minutes

MATERIALS

- ❏ Activity handout

TEACHING STRATEGY

Through the handout, students will learn how to draw ground water contours and will understand how ground water flow may be predicted. A teacher's copy of the correct ground water contour map is included with this activity. Be sure students have read "Getting Up to Speed" for this section and are familiar with the material in the activity "Revealing Stories—Resource Maps Tell All."

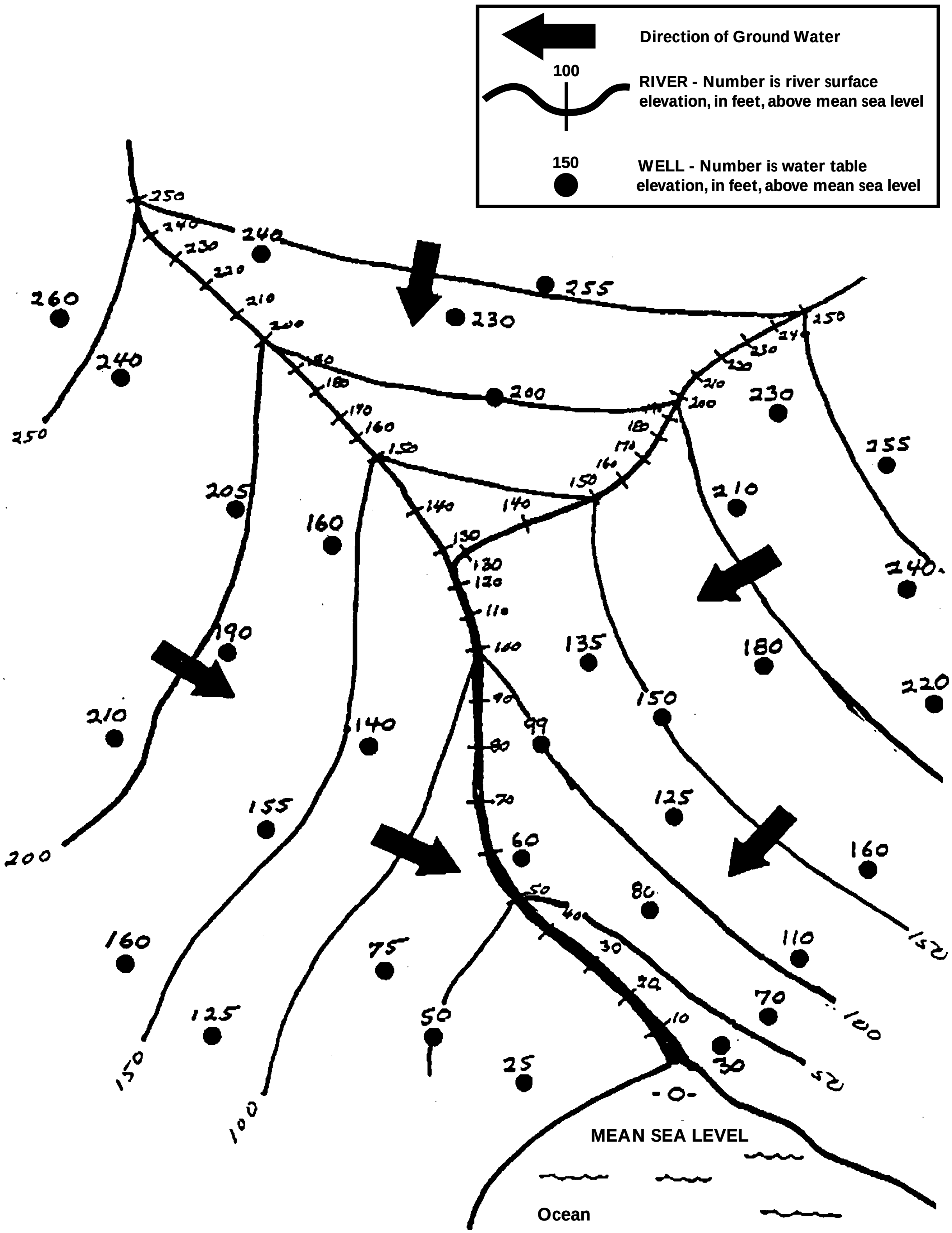
1. Distribute copies of the handout to each student.
2. Either lead students through the exercise as a class activity, or divide the students into teams to complete the assignment.

Follow-up Questions

1. Why should communities be aware of the direction of ground water flow? *By knowing the direction of ground water flow, communities can map out the land area that recharges their public water supply wells, streams, rivers, lakes, or estuaries and thereby take steps to ensure that land use activities in the recharge area will not pose a threat to the quality of the ground water and the resources dependent on it. Since contaminants generally move in the direction of ground water flow, communities can also predict how contaminants might move through the local ground water system.*
2. Why is it important to know if a stream in your community is a "gaining" stream or a "losing" stream? *Gaining streams receive much of their water from ground water, and the water level in the stream is generally at the same elevation as the water table in the adjacent aquifer. Water quality in the stream will be affected by the quality of ground water entering the stream. Because the water table elevation is approximately the same as the gaining stream surface elevation, both elevations may be used to construct water table maps and to predict ground water flow direction.*

   Losing streams lose water to the adjacent aquifer because the water table has dropped below the stream level. If there is no major source of upstream flow, the stream may dry up between storm events.

Contouring the Water Table



Predicting Ground Water Flow

NOTE: Read this entire handout before beginning the activity.

Background

The water table is the surface of the saturated zone, below which all soil pores or rock fractures are filled with water. Ground water moves through the subsurface much like water on the ground surface, except that it travels a great deal more slowly. If the soil is mostly sand and gravel, ground water can move as much as five feet per day. But, more often than not, ground water moves at speeds of a few inches per day (or less).

Like streams and rivers, ground water moves from high areas to low areas. In this exercise, you will draw the contours of the water table to show how ground water moves beneath the ground, down the sides of a valley, to a river that flows to the sea. Before you begin this exercise, however, it is important that you understand three main principles.

First, ground water and surface water share a strong connection in New England. Have you ever noticed that streams continue to flow even when it hasn't rained for days? Where does the water come from? In most areas of New England, water is discharged to surface waters from ground water at the point where the water table intersects the surface of the land. In this situation, the surface water is called a **gaining stream** or **gaining pond**.

Second, because the water table is at the land surface adjacent to "gaining" surface waters, the elevation of ground water is generally the same as that of the river, especially between rain storms.

Third, ground water is assumed to flow at right angles to water table contours. This is because ground water moves downhill in the path of least resistance due to gravity. In this exercise, you'll use all three of these principles.

During this activity you will learn how to draw a water table contour map. Water table measurements that are taken at the same time of year can be used to develop a water table contour map to show the direction of ground water flow. Monitoring wells are typically used to determine the elevation of the water table. The elevation of the water table is determined at several locations throughout the area of interest. Like topographic map contours, water table contours represent lines of equal elevation. The difference between the maps is that water table elevations are measured in wells and at the river channel, not on the ground surface. Thus, just as surface water flow is downhill and perpendicular to topographic contours, the direction of ground water flow is also downhill and perpendicular to the water table contours.

Don't worry—drawing contours is easier than you think. Just follow these simple steps:

DIRECTIONS

ASSIGNMENT

1. Using the "Contouring the Water Table" worksheet, take a pencil (in case you make mistakes), and *lightly* draw in 3 or 4 arrows to show your prediction for the direction(s) of ground water flow.

2. Draw contours at 50-foot intervals. The pencil lines can always be inked-in later. Begin at 50 feet (the shoreline along the ocean will be sea level), then draw the other contours for 100, 150, 200, and 250 feet.

3. To get started, draw the 50-foot contour. Find the 50-foot elevation on the river. Draw a line from that point through the 50-foot elevation at the well just southwest of the river. Don't go much past the well, because there are no more data to tell you where to go!

4. Draw the contour on the other side of the river. When locating a contour between two points, you will have to **interpolate**—that is, figure out the proportional distance between the points.The 50-foot contour between the 30- and 80-foot elevations should be drawn closer to the 30-foot value (20 feet difference) than the 80-foot value (30 feet difference). You can do this by hand after a little practice, or measure it precisely with a ruler and calculator. For the other two wells, draw the contour exactly between the 30- and 70-foot elevations, because they are both 20 feet different from the 50-foot contour's value.

5. When you are finished, you will notice that the contours form V's with the river and its tributaries. That's because the river is a "gaining" river. It is receiving recharge from the aquifer. The contours show that ground water is moving down the sides of the valley and into the river channel. The opposite of a gaining stream is a "losing" stream. It arises when the water table at the stream channel is lower than the stream's elevation, or stage, and stream water flows downward through the channel to the water table. This is very common in dryer regions of the Southwest. In the case of a losing stream, the V will point downstream, instead of upstream.

NOTE: When making a water table map, it's important that your well and stream elevations are accurate. All elevations should be referenced to a standard datum, such as mean sea level. This means that all elevations are either above or below the standard datum (e.g., 50 feet above mean sea level datum). It's also very important to measure all of the water table elevations within a short period of time, such as one day, so that you have a "snapshot" of what's going on. Because the water table rises and falls over time, your map will be more accurate if readings are made before these changes occur.

Understanding how ground water flows is important when you want to know where to drill a well for a water supply, to estimate a well's recharge area, or to predict the direction contamination is likely to take once it reaches the water table. Water table contouring can help you do all these things!

FOLLOW-UP QUESTIONS

1. Why are communities interested in learning the direction of ground water flow?

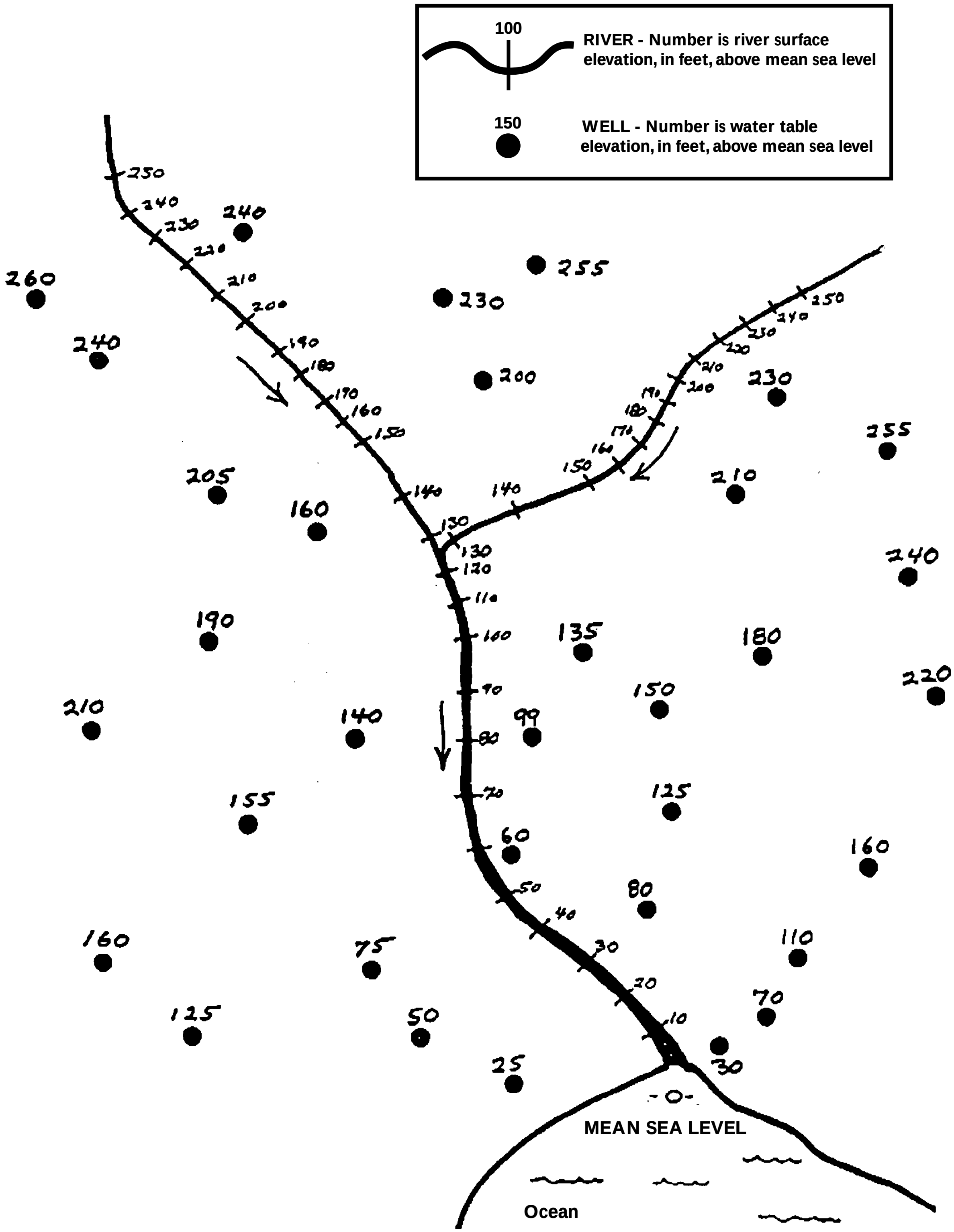
2. Why would it be important to know if a stream in your community is a **"gaining" stream** or **"losing" stream**?

3. Compare and contrast your predictions for ground water flow to your mapped ground water flow direction(s). Briefly explain and differences.

KEY TERMS

- **Gaining Stream/Pond**
- **Interpolate**
- **Losing Stream/Pond**

Contouring the Water Table



THE GREAT WATER HOOK-UP

Grades 7-12

OBJECTIVES

- Build a model of a water delivery system from source to user.
- Explore factors that need to be considered when designing a water distribution system.

INTERDISCIPLINARY SKILLS

Science, Social Studies, Mathematics, Economics

ESTIMATED TIME

2 hours (may be spread over 2 days)

TEACHING STRATEGY

1. Label boxes before class begins. (Suggestion: A few weeks before you begin the project, ask the students to collect cardboard tubes and boxes for the water distribution system.)
2. Distribute copies of the activity handout. Tell the students that they are water system designers. They have been asked to go to Small Town, New England, to design a new public water supply system. They must decide how to link all the homes and businesses to the water source so that everyone can get the water they need.
3. Have the class work as a group to design the delivery system. At random, give seven students the seven boxes that are labeled "school," "business," "industry," and "hospital." Wherever the students place the boxes will be their location in Small Town, New England. Assume that the chairs or desks in the classroom represent homes. (Reserve the 3 boxes that represent new buildings.)
4. Randomly select a location for the well. (This will be the starting point for the model.)
5. To avoid chaos, provide a large pipe that leads from the well. Have students begin building the distribution system from that point.
6. After the system is designed, have students determine the cost of the entire delivery system.
7. Have students scrutinize the design to see if any changes can be made to reduce the cost. Ask students to calculate the amount of money saved as a result of any design changes.
8. Randomly distribute the boxes marked "new school," "new business," and "new industry." If necessary, redesign the water system, and determine the cost of adding in these new users. Tell students that before a large water user is added to the system, communities must check to be sure there is adequate water to serve them.

MATERIALS

- ❏ Activity handout
- ❏ Large-diameter cardboard tubes (e.g., map tubes)*
- ❏ Medium-diameter cardboard tubes (e.g., wrapping paper tubes, toilet paper tubes, paper towel tubes)*
- ❏ Small-diameter tubes (rolled card stock or straws)*
- ❏ Ten boxes labeled: school (1 box); business (3 boxes); hospital (1 box); industry (2 boxes); new school (1 box); new business (1 box); new industry (1 box)

** If tubes are unavailable, roll up poster board or construction paper into different sizes. Tape or staple ends together.*

NOTES

9. After designing the water distribution system, help students develop a list of questions that community leaders should ask when designing a system. For example: How many homes, industries, schools, etc. must receive water? How much water do they need? How much water is available? Where will all the homes, businesses, industries, etc. be located? What will the system cost, and how will the community pay for it? How will the community change in the future? How can the community plan for these changes, and in the case of new industries, businesses, and schools, who should pay the costs?

10. Ask students what steps community leaders might take to reduce future costs (e.g., group similar types of users together [zoning], limit growth of the community).

NOTE: If this activity requires more than one class period, have students sketch the system at the end of each class and reassemble it when the class meets again.

Supplementary Activities

- Once the water distribution system is designed, discuss, as a class, how the community will pay for the system (e.g., loan, bond, one-time fee). Calculate the cost of the system for each user (assume the number of students in the class is the number of users), based on current interest rates (if appropriate). Negotiate a payment plan that is agreeable to your "water users." (This activity can used as a math/economics supplement.)
- If your community uses public water, have students research the water distribution system. Obtain a copy of the community's water distribution map(s) and invite your water supplier to come to class and discuss system planning, maintenance, and repair.
- Have the class add a wastewater collection system. Explain that Small Town is having problems with its septic systems and will soon need to build a wastewater treatment plant so that a wastewater collection (sewer) system can be hooked up to all the homes and businesses. Have students find a location where the wastewater can be treated and then discharged into a receiving river or stream. Figure out how to accomplish this great wastewater hook-up.
- Instead of using the piping costs provided in Part 2, relate the cost of the distribution system to the length of the system. To do this, have the students assign an overall scale to the piping system (for example, 1 inch = 10 feet). Based on this scale, assign a cost per linear foot of pipe (for example., $100 per foot (large), $50 per foot

NOTES

(medium), $25 per foot (small). You may even want to break it down further into separate installation and material costs. (Installation costs will be approximately the same per foot, whereas the larger pipe sizes will affect the materials cost per foot.) Have the students measure their proposed distribution system and then convert their results into feet and then into dollars.

Explain to the students that this is how real world construction costs are estimated. This type of exercise will help the students understand scales and conversions and, at the same time, add a planning component to the activity (e.g., the cost of developing away from the town center).

This activity is adapted from Massachusetts Water Resource Authority. *Water Wizards.* Boston: Massachusetts Water Resource Authority.

The Great Water Hook-Up

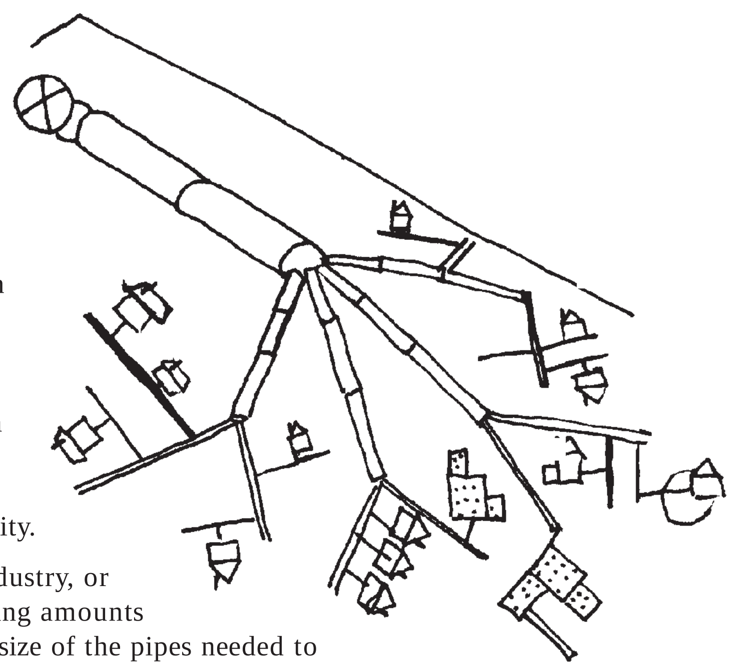
Background Information

Our **drinking water** comes from either ground water wells or surface water (e.g., river, lake, man-made reservoir). Ground water supplies are usually extracted by a pump, treated and disinfected when necessary, and delivered to homes and businesses through a network of pipes called a **distribution system**. Many people who live in rural areas have individual, on-site ground water wells with very simple piping systems; many other people who depend on ground water, but live in more populated areas, receive their water from large water supply wells through more complicated distribution systems.

Surface water supplies are withdrawn from rivers, lakes, and reservoirs through large intake structures. The water is disinfected and often treated or filtered to remove impurities before entering the distribution system. Surface water supplies often travel through many miles of underground pipes before reaching the faucets of people's homes and businesses.

In the water distribution system, the size of the pipe is a function of the amount of water that will typically pass through it. Thus, the largest pipe hooks into the source water supply (e.g., ground water well, reservoir, river); middle-size pipes serve larger water users (e.g., office buildings, hospitals, apartment buildings); and the smallest pipes serve individual residences.

PART 1



Scenario

Small Town, New England needs help in designing a new water delivery system. It has asked your firm, Water Hook-Ups, Inc., to do the design work.

Job Specifications

- The community relies on a large well to provide water to its residents, businesses, and institutions and needs a system to pump and deliver water from the well throughout the community.
- Each home, business, industry, or institution requires varying amounts of water. Therefore, the size of the pipes needed to provide water also varies. (Larger pipes provide more water.)

- You must follow these rules when laying pipes:

  1. Large pipes must hook up to the well. Large pipes will be used for the major water lines running through the community.
  2. The hospital and the industry use a very large amount of water and must be connected to a large water pipe or be served by a couple of medium-size pipes.
  3. The businesses and school use a lot of water but not as much as the hospital and industry. They must be connected to a medium-size pipe.
  4. Homes use less water than businesses and require a small pipe.
  5. Pipes can be connected only in descending order. That is, from the well, large pipes are connected to medium-size pipes, which are connected to small pipes. Also, from the well, large pipes can be connected to small pipes. However, once you lay a small pipe, you cannot add a medium-size pipe or large pipe on the end. That would cause a bottleneck.
  6. A large pipe can serve 3 medium-size pipes or 15 small pipes. Each medium-size pipe can serve 5 small pipes.
  7. Consider the need for future maintenance and repairs. If a section of pipe must be closed for maintenance, consider how you will provide water to the affected users (e.g., a loop versus a dead-end system).

Part 2: Your Job

ASSIGNMENT

1. Connect the pipes! Be sure that every home, business, industry, school, and hospital will receive water.
2. When you are done laying pipes, determine the cost of the project based on the following cost figures:

   Large pipe = $15,000 each
   Medium pipe = $ 5,000 each
   Small pipe = $ 1,000 each

FOLLOW-UP QUESTIONS

- How much did the whole delivery system cost?

  $ ____

Part 3: Delivery System Changes

1. Look at the delivery system you designed. Can you make any design changes to reduce the cost?

a. If so, briefly list those changes.

____

____

b. What is the cost of the redesigned system?

$ ____

c. How much did you save

$ ____

2. Help! Small Town is growing rapidly. The town wants to build a new school, a new business, and a new industry. (Your teacher will tell you where they are located.) Make changes in your design to serve these new needs.

a. How much did the changes cost?

$ ____

b. Who do you think should pay for those changes? Support your reasoning.

____

____

____

____

KEY TERMS

- **Distribution System**
- **Drinking Water**

This activity is adapted from Massachusetts Water Resource Authority. *Water Wizards.* Boston: Massachusetts Water Resource Authority

Getting Up to Speed

Ground Water Contamination

Ground water contamination is nearly always the result of human activity. In areas where population density is high and human use of the land is intensive, ground water is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute ground water. When ground water becomes contaminated, it is difficult and expensive to clean up.

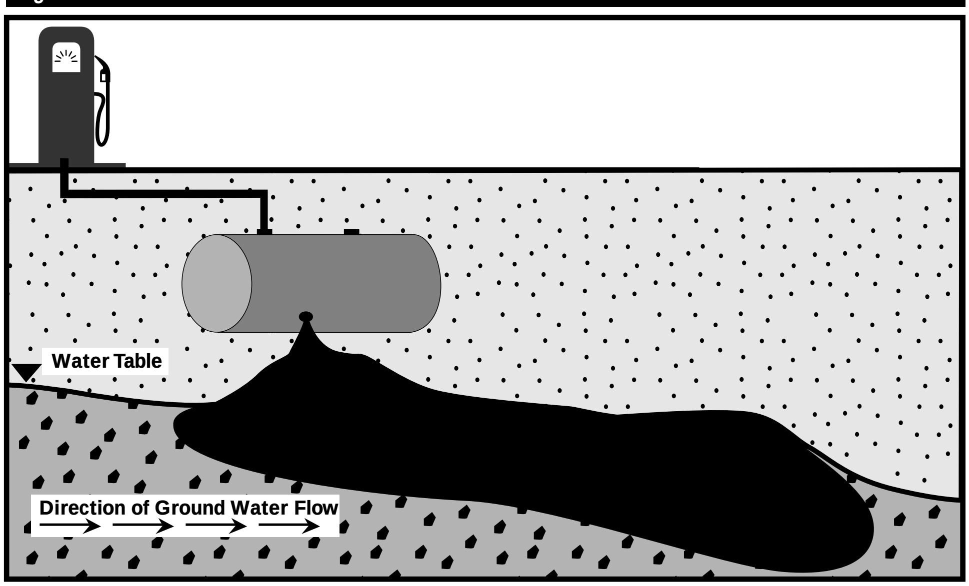
To begin to address pollution prevention or remediation, we must understand how surface waters and ground waters interrelate. Ground water and surface water are interconnected and can be fully understood and intelligently managed only when that fact is acknowledged. If there is a water supply well near a source of contamination, that well runs the risk of becoming contaminated. If there is a nearby river or stream, that water body may also become polluted by the ground water.

How Does Ground Water Become Contaminated?

Depending on its physical, chemical, and biological properties, a contaminant that has been released into the environment may move within an aquifer in the same manner that ground water moves. (Some contaminants, because of their physical or chemical properties, do not always follow ground water flow.) It is possible to predict, to some degree, the transport within an aquifer of those substances that move along with ground water flow. For example, both water and certain contaminants flow in the direction of the topography from recharge areas to discharge areas. Soils that are porous and permeable tend to transmit water and certain types of contaminants with relative ease to an aquifer below.

Just as ground water generally moves slowly, so do contaminants in ground water. Because of this slow movement, contaminants tend to remain concentrated in the form of a **plume** (see Figure 1) that flows along the same path as the ground water. The size and speed of the plume depend on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding ground water.

Figure 1 Contaminant Plume



Ground water and contaminants can move rapidly through fractures in rocks. Fractured rock presents a unique problem in locating and controlling contaminants because the fractures are generally randomly spaced and do not follow the contours of the land surface or the hydraulic gradient. Contaminants can also move into the ground water system through macropores—root systems, animal burrows, abandoned wells, and other systems of holes and cracks that supply pathways for contaminants.

In areas surrounding pumping wells, the potential for contamination increases because water from the **zone of contribution**, a land area larger than the original recharge area, is drawn into the well and the surrounding aquifer. Some drinking water wells actually draw water from nearby streams, lakes, or rivers. Contaminants present in these surface waters can contribute contamination to the ground water system. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer, often using water from storm runoff, irrigation, industrial processes, or treated sewage. In several cases, this practice has resulted in increased concentrations of nitrates, metals, microbes, or synthetic chemicals in the water.

Under certain conditions, pumping can also cause the ground water (and associated contaminants) from another aquifer to enter the one being pumped. This phenomenon is called **interaquifer leakage**. Thus, properly identifying and protecting the areas affected by well pumping is important to maintain ground water quality.

Generally, the greater the distance between a source of contamination and a ground water source, the more likely that natural processes will reduce the impacts of contamination. Processes such as oxidation, biological degradation (which sometimes renders contaminants less toxic), and adsorption (binding of materials to soil particles) may take place in the soil layers of the unsaturated zone and reduce the concentration of a contaminant before it reaches ground water. Even contaminants that reach ground water directly, without passing through the unsaturated zone, can become less concentrated by dilution (mixing) with the ground water. However, because ground water usually moves slowly, contaminants generally undergo less dilution than when in surface water.

Sources of Ground Water Contamination

Ground water can become contaminated from natural sources or numerous types of human activities. (See Tables 1 and 2 and Figure 1.) Residential, municipal, commercial, industrial, and agricultural activities can all affect ground water quality. Contaminants may reach ground water from activities on the land surface, such as releases or spills from stored industrial wastes; from sources below the land surface but above the water table, such as septic systems or leaking underground petroleum storage systems; from structures beneath the water table, such as wells; or from contaminated recharge water.

■ Natural Sources

Some substances found naturally in rocks or soils, such as iron, manganese, arsenic, chlorides, fluorides, sulfates, or radionuclides, can become dissolved in ground water. Other naturally occurring substances, such as decaying organic matter, can move in ground water as particles. Whether any of these substances appears in ground water depends on local conditions. Some substances may pose a health threat if consumed in excessive quantities; others may produce an undesirable odor, taste, or color. Ground water that contains unacceptable concentrations of these substances is not used for drinking water or other domestic water uses unless it is treated to remove these contaminants.

■ Septic Systems

One of the main causes of ground water contamination in the United States is the effluent (outflow) from septic tanks, cesspools, and privies.

Table 1 TYPICAL SOURCES OF POTENTIAL GROUND WATER CONTAMINATION BY LAND USE CATEGORY

Category	Contaminant Source	
Agriculture	Animal burial areas	Irrigation sites
	Animal feedlots	Manure spreading areas/pits
	Fertilizer storage/use	Pesticide storage/use
Commercial	Airports	Jewelry/metal plating
	Auto repair shops	Laundromats
	Boat yards	Medical institutions
	Construction areas	Paint shops
	Car washes	Photography establishments
	Cemeteries	Railroad tracks and yards
	Dry cleaners	Research laboratories
	Gas stations	Scrap and junkyards
	Golf courses	Storage tanks
Industrial	Asphalt plants	Petroleum production/storage
	Chemical manufacture/storage	Pipelines
	Electronics manufacture	Septage lagoons and sludge sites
	Electroplaters	Storage tanks
	Foundries/metal fabricators	Toxic and hazardous spills
	Machine/metalworking shops	Wells (operating/abandoned)
	Mining and mine drainage	Wood preserving facilities
Residential	Fuel oil	Septic systems, cesspools
	Furniture stripping/refinishing	Sewer lines
	Household hazardous products	Swimming pools (chemical storage)
	Household lawns	
Other	Hazardous waste landfills	Recycling/reduction facilities
	Municipal incinerators	Road deicing operations
	Municipal landfills	Road maintenance depots
	Municipal sewer lines	Storm water drains/basins
	Open burning sites	Transfer stations

Source: U.S. EPA, 1991a.

Approximately one-fourth of all homes in the United States rely on septic systems to dispose of their human wastes. Although each individual system releases a relatively small amount of waste into the ground, the large number and widespread use of these systems makes them a serious contamination source. Septic systems that are improperly sited, designed, constructed, or maintained can contaminate ground water with bacteria, viruses, nitrates, detergents, oils, and chemicals. Along with these contaminants are the commercially available septic system cleaners containing synthetic organic chemicals (such as 1,1,1-trichloroethane or methylene chloride). These cleaners can contaminate water supply wells and interfere with natural decomposition processes in septic systems.

Most, if not all, state and local regulations require specific separation distances between septic systems and drinking water wells. In addition, computer models have been developed to calculate suitable distances and densities.

■ Improper Disposal of Hazardous Waste

Hazardous waste should always be disposed of properly, that is to say, by a licensed hazardous waste handler or through municipal hazardous waste collection days. Many chemicals should not be disposed of in household septic systems, including oils (e.g., cooking, motor), lawn and garden chemicals, paints and paint thinners, disinfectants, medicines, photographic chemicals, and swimming pool chemicals. Similarly, many substances used in industrial processes should not be disposed of in drains at the workplace because they could contaminate a drinking water source. Companies should train employees in the proper use and disposal of all chemicals used on site. The many different types and the large quantities of chemicals used at industrial locations make proper disposal of wastes especially important for ground water protection.

■ Releases and Spills from Stored Chemicals and Petroleum Products

Underground and aboveground storage tanks are commonly used to store petroleum products and other chemical substances. For example, many homes have underground heating oil tanks. Many businesses and municipal highway departments also store gasoline, diesel fuel, fuel oil, or chemicals in on-site tanks. Industries use storage tanks to hold chemicals used in industrial processes or to store hazardous wastes for pickup by a licensed hauler. Approximately 4 million underground storage tanks exist in the United States and, over the years, the contents of many of these tanks have leaked and spilled into the environment.

If an underground storage tank develops a leak, which commonly occurs as the tank ages and corrodes, its contents can migrate through the soil and reach the ground water. Tanks that meet federal/state standards for new and upgraded systems are less likely to fail, but they are not foolproof. Abandoned underground tanks pose another problem because their location is often unknown. Aboveground storage tanks can also pose a threat to ground water if a spill or leak occurs and adequate barriers are not in place.

Improper chemical storage, sloppy materials handling, and poor-quality containers can be major threats to ground water. Tanker trucks and train cars pose another chemical storage hazard. Each year, approximately 16,000 chemical spills occur from trucks, trains, and storage tanks, often when materials are being transferred. At the site of an accidental spill, the chemicals are often diluted with water and then washed into the soil, increasing the possibility of ground water contamination.

■ Landfills

Solid waste is disposed of in thousands of municipal and industrial landfills throughout the country. Chemicals that should be disposed of in hazardous waste landfills sometimes end up in municipal landfills. In addition, the disposal of many household wastes is not regulated.

Once in the landfill, chemicals can leach into the ground water by means of precipitation and surface runoff. New landfills are required to have clay or synthetic liners and leachate (liquid from a landfill containing contaminants) collection systems to protect ground water. Most older landfills, however, do not have these safeguards. Older landfills were often sited over aquifers or close to surface waters and in permeable soils with shallow water tables, enhancing the potential for leachate to contaminate ground water. Closed landfills can continue to pose a ground water contamination threat if they are not capped with an impermeable material (such as clay) before closure to prevent the leaching of contaminants by precipitation.

■ Surface Impoundments

Surface impoundments are relatively shallow ponds or lagoons used by industries and municipalities to store, treat, and dispose of liquid wastes. As many as 180,000 surface impoundments exist in the United States. Like landfills, new surface impoundment facilities are required to have liners, but even these liners sometimes leak.

Table 2 POTENTIAL HARMFUL COMPONENTS OF COMMON HOUSEHOLD PRODUCTS

Product	Toxic or Hazardous Components
Antifreeze (gasoline or coolants systems)	Methanol, ethylene glycol
Automatic transmission fluid	Petroleum distillates, xylene
Battery acid (electrolyte)	Sulfuric acid
Degreasers for driveways and garages	Petroleum solvents, alcohols, glycol ether
Degreasers for engines and metal	Chlorinated hydrocarbons, toluene, phenols, dichloroperchloroethylene
Engine and radiator flushes	Petroleum solvents, ketones, butanol, glycol ether
Hydraulic fluid (brake fluid)	Hydrocarbons, fluorocarbons
Motor oils and waste oils	Hydrocarbons
Gasoline and jet fuel	Hydrocarbons
Diesel fuel, kerosene, #2 heating oil	Hydrocarbons
Grease, lubes	Hydrocarbons
Rustproofers	Phenols, heavy metals
Car wash detergents	Alkyl benzene sulfonates
Car waxes and polishes	Petroleum distillates, hydrocarbons
Asphalt and roofing tar	Hydrocarbons
Paints, varnishes, stains, dyes	Heavy metals, toluene
Paint and lacquer thinner	Acetone, benzene, toluene, butyl acetate, methyl ketones
Paint and varnish removers, deglossers	Methylene chloride, toluene, acetone, xylene, ethanol, benzene, methanol
Paint brush cleaners	Hydrocarbons, toluene, acetone, methanol, glycol ethers, methyl ethyl ketones
Floor and furniture strippers	Xylene
Metal polishes	Petroleum distillates, isopropanol, petroleum naphtha
Laundry soil and stain removers	Hydrocarbons, benzene, trichloroethylene, 1,1,1-trichloroethane
Other solvents	Acetone, benzene
Rock salt	Sodium concentration
Refrigerants	1,1,2-trichloro-1,2,2-trifluoroethane
Bug and tar removers	Xylene, petroleum distillates
Household cleansers, oven cleaners	Xylenols, glycol ethers, isopropanol
Drain cleaners	1,1,1-trichloroethane
Toilet cleaners	Xylene, sulfonates, chlorinated phenols
Cesspool cleaners	Tetrachloroethylene, dichlorobenzene, methylene chloride
Disinfectants	Cresol, xylenols
Pesticides (all types)	Naphthalene, phosphorus, xylene, chloroform, heavy metals, chlorinated hydrocarbons
Photochemicals	Phenols, sodium sulfite, cyanide, silver halide, potassium bromide
Printing ink	Heavy metals, phenol-formaldehyde
Wood preservatives (creosote)	Pentachlorophenols
Swimming pool chlorine	Sodium hypochlorite
Lye or caustic soda	Sodium hydroxide
Jewelry cleaners	Sodium cyanide

Source: "Natural Resources Facts: Household Hazardous Wastes," Fact Sheet No. 88-3, Department of Natural Science, University of Rhode Island, August 1988.

■ Sewers and Other Pipelines

Sewer pipes carrying wastes sometimes leak fluids into the surrounding soil and ground water. Sewage consists of organic matter, inorganic salts, heavy metals, bacteria, viruses, and nitrogen. Other pipelines carrying industrial chemicals and oil brine have also been known to leak, especially when the materials transported through the pipes are corrosive.

■ Pesticide and Fertilizer Use

Millions of tons of fertilizers and pesticides (e.g., herbicides, insecticides, rodenticides, fungicides, avicides) are used annually in the United States for crop production. In addition to farmers, homeowners, businesses (e.g., golf courses), utilities, and municipalities use these chemicals. A number of these pesticides and fertilizers (some highly toxic) have entered and contaminated ground water following normal, registered use. Some pesticides remain in soil and water for many months to many years. Another potential source of ground water contamination is animal wastes that percolate into the ground from farm feedlots. Feedlots should be properly sited and wastes should be removed at regular intervals.

Between 1985 and 1992, EPA's Office of Pesticides and Toxic Substances and Office of Water conducted a National Pesticide Survey to determine the number of drinking water wells nationwide that contain pesticides and nitrates and the concentration of these substances. The survey also analyzed the factors associated with contamination of drinking water wells by pesticides and nitrates. The survey, which included samples from more than 1,300 public community and rural domestic water supply wells, found that approximately 3.6 percent of the wells contained concentrations of nitrates above the federal maximum contaminant level, and that over half of the wells contained nitrates above the survey's minimum reporting limit for nitrate (0.15 mg/L).

The survey also reported that approximately 0.8 percent of the wells tested contained pesticides at levels higher than federal maximum contaminant levels or health advisory levels. Only 10 percent of the wells classified as rural were actually located on farms. There is a higher incidence of contamination by agricultural chemicals in farm wells used for drinking water.

After further analysis, EPA estimated that for the wells that contain pesticides, a significant percentage probably contain chemical concentrations that exceed the federal health-based limits (e.g., maximum contaminant levels or health advisory levels). Approximately 14.6 percent of the wells tested contained levels of one or more pesticides above the minimum reporting limit set in the survey. The most common pesticides found were atrazine and metabolites (breakdown products) of dimethyl tetrachloroterephthalate (DCPA, commonly known as Dacthal), which is used in many utility easement weed-control programs and for lawn care.

■ Drainage Wells

Drainage wells are used in wet areas to help drain water and transport it to deeper soils. These wells may contain agricultural chemicals and bacteria.

■ Injection Wells/Floor Drains

Injection wells are used to collect storm water runoff, collect spilled liquids, dispose of wastewater, and dispose of industrial, commercial, and utility wastes. These wells are regulated by the U.S. EPA's Underground Injection Control Program. In New England, these wells may not be used to inject hazardous wastes from industrial, commercial, and utility operations. The injection wells used in this region are typically shallow and include sumps and dry wells used to handle storm water.

Floor drains were historically used by businesses to handle spills. Today, if a business operates or handles waste fluids that drain to a septic system, dry well, or floor drain, it is required to submit information regarding its operation to the U.S. EPA or its state environmental protection agency. Disposal wells that pose threats to drinking water supplies are prohibited and must be closed, connected to a public sewage system, or connected to a storage tank.

■ Improperly Constructed Wells

Problems associated with improperly constructed wells can result in ground water contamination when contaminated surface or ground water is introduced into the well.

■ Improperly Abandoned Wells

These wells can act as a conduit through which contaminants can reach an aquifer if the well casing has been removed, as is often done, or if the casing is corroded. In addition, some people use abandoned wells to dispose of wastes such as used motor oil. These wells may reach into an aquifer that serves drinking supply wells. Abandoned exploratory wells (e.g., for gas, oil, or coal) or test hole wells are usually uncovered and are also a potential conduit for contaminants.

■ Active Drinking Water Supply Wells

Poorly constructed wells can result in ground water contamination. Construction problems, such as faulty casings, inadequate covers, or lack of concrete pads, allow outside water and any accompanying contaminants to flow into the well. Sources of such contaminants can be surface runoff or wastes from farm animals or septic systems. Contaminated fill packed around a well can also degrade well water quality. Well construction problems are more likely to occur in older wells that were in place prior to the establishment of well construction standards and in domestic and livestock wells.

■ Poorly Constructed Irrigation Wells

These wells can allow contaminants to enter ground water. Often pesticides and fertilizers are applied in the immediate vicinity of wells on agricultural land.

■ Mining Activities

Active and abandoned mines can contribute to ground water contamination. Precipitation can leach soluble minerals from the mine wastes (known as spoils or tailings) into the ground water below. These wastes often contain metals, acid, minerals, and sulfides. Abandoned mines are often used as wells and waste pits, sometimes simultaneously. In addition, mines are sometimes pumped to keep them dry; the pumping can cause an upward migration of contaminated ground water, which may be intercepted by a well.

EFFECTS OF GROUND WATER CONTAMINATION

Contamination of ground water can result in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, high costs for alternative water supplies, and/or potential health problems.

The consequences of contaminated ground water or degraded surface water are often serious. For example, estuaries that have been impacted by high nitrogen from ground water sources have lost critical shellfish habitats. In terms of water supply, in some instances, ground water contamination is so severe that the water supply must be abandoned as a source of drinking water. In other cases, the ground water can be cleaned up and used again, if the contamination is not too severe and if the municipality is willing to spend a good deal of money. Follow-up water quality monitoring is often required for many years.

Because ground water generally moves slowly, contamination often remains undetected for long periods of time. This makes cleanup of a contaminated water supply difficult, if not impossible. If a cleanup is undertaken, it can cost thousands to millions of dollars.

Once the contaminant source has been controlled or removed, the contaminated ground water can be treated in one of several ways:

- Containing the contaminant to prevent migration.
- Pumping the water, treating it, and returning it to the aquifer.

- Leaving the ground water in place and treating either the water or the contaminant.
- Allowing the contaminant to attenuate (reduce) naturally (with monitoring), following the implementation of an appropriate source control.

Selection of the appropriate remedial technology is based on site-specific factors and often takes into account cleanup goals based on potential risk that are protective of human health and the environment. The technology selected is one that will achieve those cleanup goals. Different technologies are effective for different types of contaminants, and several technologies are often combined to achieve effective treatment. The effectiveness of treatment depends in part on local hydrogeological conditions, which must be evaluated prior to selecting a treatment option.

Given the difficulty and high costs of cleaning up a contaminated aquifer, some communities choose to abandon existing wells and use other water sources, if available. Using alternative supplies is probably more expensive than obtaining drinking water from the original source. A temporary and expensive solution is to purchase bottled water, but it is not a realistic long-term solution for a community's drinking water supply problem. A community might decide to install new wells in a different area of the aquifer. In this case, appropriate siting and monitoring of the new wells are critical to ensure that contaminants do not move into the new water supplies.

Potential Health Problems

A number of microorganisms and thousands of synthetic chemicals have the potential to contaminate ground water. Drinking water containing bacteria and viruses can result in illnesses such as hepatitis, cholera, or giardiasis. Methemoglobinemia or "blue baby syndrome," an illness affecting infants, can be caused by drinking water that is high in nitrates. Benzene, a component of gasoline, is a known human carcinogen. The serious health effects of lead are well known—learning disabilities in children; nerve, kidney, and liver problems; and pregnancy risks. Concentrations in drinking water of these and other substances are regulated by federal and state laws. Hundreds of other chemicals, however, are not yet regulated, and many of their health effects are unknown or not well understood. Preventing contaminants from reaching the ground water is the best way to reduce the health risks associated with poor drinking water quality.

Regulations to Protect Ground Water

Several federal laws help protect ground water quality. The **Safe Drinking Water Act (SDWA)** established three drinking water source protection programs: the Wellhead Protection Program, Sole Source Aquifer Program, and the Source Water Assessment Program. It also called for regulation of the use of underground injection wells for waste disposal and provided EPA and the states with the authority to ensure that drinking water supplied by public water systems meets minimum health standards. The **Clean Water Act** regulates ground water that is shown to have a connection with surface water. It sets standards for allowable pollutant discharges to surface water. The **Resource Conservation and Recovery Act (RCRA)** regulates treatment, storage, and disposal of hazardous and nonhazardous wastes. The **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund)** authorizes the government to clean up contamination or sources of potential contamination from hazardous waste sites or chemical spills, including those that threaten drinking water supplies. CERCLA includes a "community right-to-know" provision. The **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** regulates pesticide use. The **Toxic Substances Control Act (TSCA)** regulates manufactured chemicals.

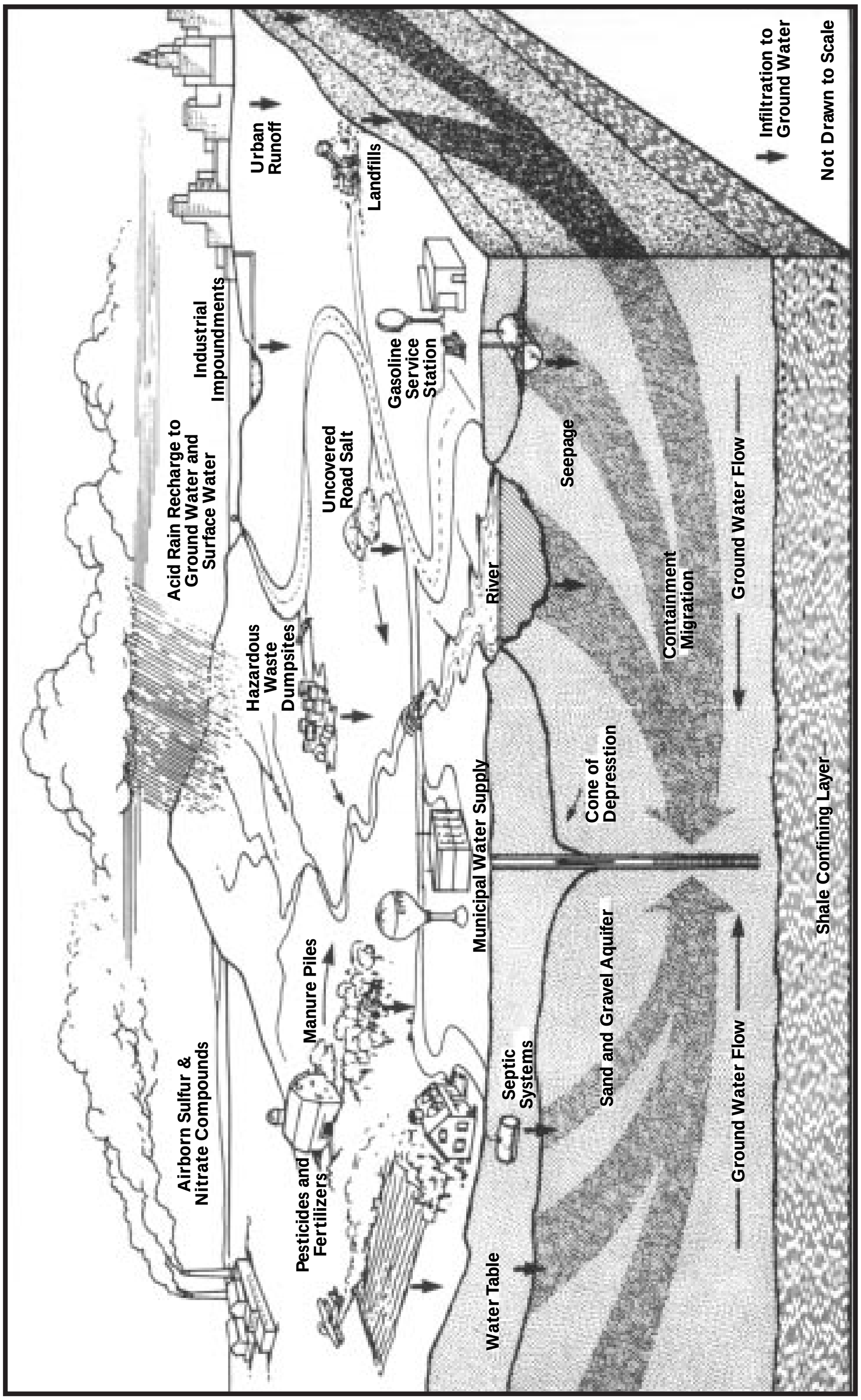
KEY TERMS

- **Clean Water Act**
- **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund)**
- **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)**
- **Interaquifer Leakage**
- **Plume**
- **Resource Conservation and Recovery Act (RCRA)**
- **Safe Drinking Water Act**
- **Toxic Substances Control Act (TSCA)**
- **Zone of Contribution**

"Getting Up to Speed" for section C, "Ground Water Contamination" is adapted from US EPA Seminar Publication. *Wellhead Protection: A Guide for Small Communities*. Chapter 3. EPA/625/R-93/002.

Figure 2

SOME POTENTIAL SOURCES OF GROUND WATER CONTAMINATION



Source: Paly, Melissa and Lee Steppacher. *The Power to Protect: Three Stories about Ground Water.* U.S.E.P.A. Massachusetts Audubon Society and NEIWPCC.

"A CIVIL ACTION"

Grades 7-12

➤ OBJECTIVES

- Gain a new perspective from a compelling real-life story about people in Woburn, Massachusetts, who seek justice when their lives are turned upside-down as a result of exposure to contaminated ground water. Through an epic courtroom showdown, students will find out how the pieces come together (or don't come together) in a case where two large corporations are accused of causing the deaths of children.

➤ INTERDISCIPLINARY SKILLS

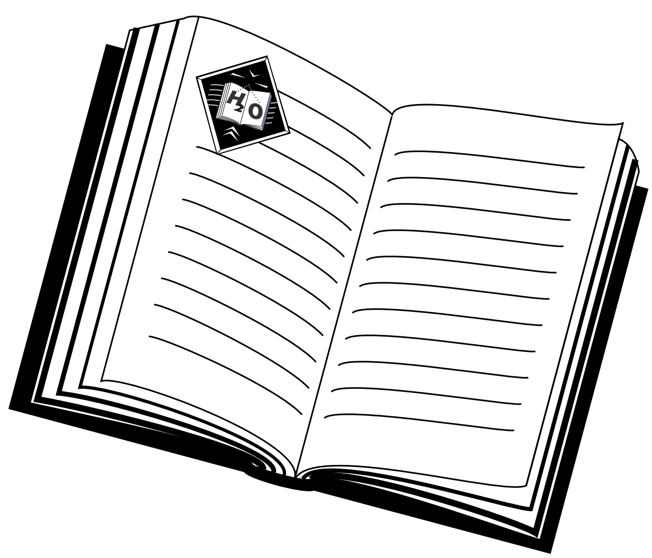
English, Earth Sciences, Social Studies

➤ MATERIALS

❑ Copies of the book *A Civil Action* by Jonathan Harr. Vintage Books, a division of Random House, Inc., New York. September 1996.

TEACHING STRATEGY

Have students begin reading this book at the beginning of this section or even earlier. Ideally, they should be prepared to discuss the book as a class when they have completed the ground water contamination activities at the end of this section. *A Civil Action* ties in well with the material in this section and should be more and more meaningful to the students as they learn about the fate and transport of contaminants and the determination of responsible parties. The book poignantly drives home the paramount importance of clean water in our lives. This activity could be coordinated as an English class reading assignment.



WHEN YOU WERE MY AGE, WHAT WAS THIS PLACE LIKE?

Grades 7-12

OBJECTIVES

- Discover the historical development patterns in a selected neighborhood, preferably one near a public water supply well or one dependent on private wells.
- Appreciate the cumulative effects of decisions over time. Students will begin to realize how decisions that communities make (or fail to make) today can affect the quality of life in the future.

INTERDISCIPLINARY SKILLS

Social Studies, Environmental Impact Studies, History, Communications (Interviewing Skills), Research Skills

ESTIMATED TIME

30 minutes to introduce assignment

15 minutes per team for oral reports

Allow students 2 to 3 weeks to complete the assignment, including research and interviews

TEACHING STRATEGY

1. To spark interest in this project, you may want to dig up copies of old newspaper articles announcing the development of a major landmark in the community (e.g., shopping center, housing project) and show it to the class. Ask the students if they recall land use changes in the community that took place as they were growing up.
2. Explain that the purpose of this exercise is to explore land use changes over time. By conducting research and interviews, the students will have an opportunity to learn about their community and how it has changed over the years. Then they will consider how those changes might have affected the community and its resources.
3. Select areas for study (e.g., whole community, section of town, one parcel of land) by the class. Preferably, select at least one area near a public well, in an area dependent on private wells, or an area near a river, wetland lake, or coastal water. Students should work in teams, with each team investigating a different area.
4. Have the teams identify individuals in the community who would be good candidates from whom to obtain information about the area (e.g., parents, grandparents, neighbors, town officials, historical society members). Once they have completed their list of possible interviewees, have the students contact these individuals by phone or in person to introduce themselves and schedule interviews.
5. Discuss interviewing skills in terms of preparing for and conducting the interviews.
6. Have the students brainstorm a list of possible questions to ask during their interviews. Remind them that most of the questions should be directed at discovering how land use has changed over time.

MATERIALS

- ❏ Paper/pen
- ❏ Tape recorder (optional)
- ❏ Video camera/VCR (optional)
- ❏ Camera (optional)
- ❏ Maps of selected areas (e.g., topographic, land use, road)

NOTES

Possible Questions

1. How long have you lived in this community?
2. Can you describe what this area was like over time (e.g., the past 50, 30, 25, 15, 10, 5 years)? How was the land used?
3. What did your parents/grandparents do for a living? Did they work in the town or somewhere else?
4. What roads existed when you were a child? What roads have been added? Widened?
5. Has the water quality in your well and in the nearest river, lake, or estuary changed over time? If so, in what way?
6. Has construction in the vicinity of the community's water supply well increased during your lifetime? If so, where and in what way?
7. With respect to conducting the interviews: One way to help people remember the changes in the area is to provide them with copies of articles and pictures from old newspapers to spark conversation. A topographic map of the area also provides a reference point for the interview. By comparing older USGS topographic maps with newer ones, students and interviewees will be able to note changes in development density, roads, and so on. Older versions of these maps can sometimes be found at local planning departments, libraries, or historical societies and then copied. Town planning offices generally have existing land use maps as well, and may also keep older versions. Students may want to bring tracing paper to the interview so that they can sketch out overlays of past road patterns and land uses with the help of the interviewees.
8. Have each team make an oral report to the class on what was learned through the interview. Have the students discuss how land use changes may have affected ground water and surface water quality in the area and how these changes may have affected the community's water supply (e.g., increased or decreased water demands, improved or decreased water quality, potential for contamination of the ground and surface water).
9. Explore this question: What can we learn from the past that could be applied to today's land use decisions?

Alternate Teaching Strategy

Divide the class into teams of 3-4 students. Have some teams pursue information about land use in the past (as described above). Have one team find out about local ordinances that affect land use. (See supplementary activity #2.) Have one team of artistic students work on the mural. (See supplementary activity #3.) Have one team prepare a pop-

NOTES

ulation density map. (See supplementary activity #4.) Have one team collect current articles on land use. (See supplementary activity #5.) Assign any of the other supplementary activities as needed.

Supplementary Activities

1. Record interviews on tape or video. Transcribe the interviews in a book form, including an introductory text and an evaluation of what has happened in the area. Alternatively, produce a video that documents the land use history of the area through interviews and narrative. Both approaches should zero in on the effects of land use decisions on water quality and water supplies.
2. Research and report on local ordinances that may have affected local development (e.g., a subdivision, zoning, wetlands). These ordinances may designate areas in a community where different land uses (e.g., business, industry, residential) can locate. There may also be special regulations to protect the community's water supply (often called a ground water management district, wellhead protection area district, aquifer protection district, or water supply district). Are these measures adequate? Discuss current land use decisions. (Consider interviewing your local planning office or local water supplier.)
3. Prepare a wall mural that shows "before" and "after" scenes as described by the interviewees and as discovered through primary research. (Option: Make a collage of old and current photographs.)
4. Using United States census records or local census records, prepare population density maps for the area 50 years ago, 25 years ago, and today.
5. Collect articles about land use issues (e.g., new businesses, malls, landfills, apartments, septic system problems) from current newspapers. Discuss how the decisions being made today may have an impact on the environment in the future.
6. Explore the impact of various land uses (e.g., landfills, highways, parking lots, agriculture) on other aspects of the environment besides water quality (e.g., air quality, forestry, wildlife habitats).
7. Contrast current land uses with early land uses by Native Americans and European settlers. How have the changes affected the demand for and the quality of water?
8. Attend a public meeting where land use decisions are being discussed (e.g., planning board, zoning board, conservation commission, wetlands board).

This activity is adapted from Massachusetts Coastal Zone Management and Massachusetts Marine Educators. "Land Use/Oral Histories," *Charting Our Course: The Massachusetts Coast at an Environmental Crossroads.* Boston: Massachusetts Coastal Zone Management. C-8.

Getting Up to Speed

PROTECTING GROUND WATER

As you have worked your way through this ground water program, we hope that you have gained an understanding and respect for the role that ground water plays in this interrelated and interwoven composition that is the Earth. For too long, our ground water resources have been out of sight and out of mind, and, as is often the case, our wake-up call has come in the form of accumulated ground water pollution crises.

Over the past few decades, we have learned some important lessons. We have learned, for example, that because it is located deep in the ground, ground water pollution is generally difficult and expensive to clean up. We have learned that it is much easier and less expensive to protect aquifers from pollution and harmful development than to find new water supplies or restore ground water quality after it has been contaminated. We have also learned that governments, industries, businesses, and individuals can all benefit from working together to protect this invaluable resource. In fact, ground water protection requires the active cooperation of all of the above.

In this final section of *That Magnificent Ground Water Connection*, we will zero in on what we as a society and as individuals can do to protect our ground water resources. For starters, educating children and young adults, as this curriculum does, is a critical step in the process. Once we all understand the value of our water resources, how the water resource system works, and how our actions can affect water quality, we can begin to work together to protect these resources now and for generations to come.

Federal and state governments play the "big picture" roles in ground water protection. Federal laws and U.S. Environmental Protection Agency regulations authorize or mandate many programs to protect ground water and help provide funding. In general, the states have responsibility for implementing ground water programs that are, at a minimum, consistent with federal requirements. States also have responsibility for developing ground water management plans that are based on their hydrologic conditions and water needs. State agencies implement ground water protection through permit programs, technical assistance, monitoring, and enforcement.

But the greatest means of protecting ground water is at the local level, where potential pollution sources must ultimately be managed, where most land-use decisions are made, and where water resources can benefit from community vigilance and stewardship. At the local level, individuals can easily get involved and make a difference. As anthropologist Margaret Mead said: "Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has."

As high school students, it won't be long before you will assume the responsibilities that go with being an adult. As adult members of your community, there are many ways in which you can make a difference on issues that matter to you—by voting; serving on various boards, commissions, or legislative bodies; organizing citizens groups and volunteer efforts; or taking part in citizens groups and volunteer efforts. If good intentions are to become realities, they must be translated into actions...effective actions. In the following reading you will learn about how citizens can get involved in protecting important natural resources in their community. This reading focuses on protecting ground water resources.

A Strategy For Protecting Ground Water Resources In Your Community

Ground water protection is a significant undertaking that may, indeed, affect many people for many reasons. It pays to have a well-planned strategy! Here's a plan of attack that has worked well in many communities:

STEP 1. Get People Involved

At the local level, the first step in developing any resource protection program is to form a community planning team. Since your ultimate goal is to have a ground water protection program that everyone in the community will support, it is important that the planning team represents as many diverse interests in the community as possible—town officials, community activists, residents, businesses, water suppliers, special interests.

STEP 2. Determine What Should Be Protected and Why

Once the team is formed, it should set about identifying its goals and objectives. The first important question that must be answered is: What ground water resources need to be protected and why? That is, is the goal to protect the drinking water supply? Is the goal to preserve critical resources such as wetlands, lakes, rivers, or coastal estuaries?

Communities may have varying reasons for wanting to protect their ground water. Your team will need to look at the local ground water resources in terms of identifying their functions and then protecting those functions based on present and future needs. For example, one community may want to protect its ground water supply by delineating and protecting the wellhead protection area, (a recharge area that supplies a municipal well(s) with water). Another community may want to protect its surface water supply by protecting all of the source water that flows into that surface water body, including, of course, the ground water. Another community may want to protect its estuarine areas by managing activities in its ground water recharge areas—the land areas that provide ground water recharge to the estuary.

After a community decides why it is protecting its ground waters, the next and perhaps most difficult task will be to identify ground waters which must be protected and determine what that protection area encompasses. Because ground water is not easily seen, many communities do not know where their most valuable ground waters are located or in which land areas polluting land-use activities will directly affect these ground waters.

Ideally, we should strive to protect all ground water and take precautions, whenever and wherever, to prevent pollution. In reality, however, we must often choose our battles, and direct our energies where the desired result will be most effective. In time, through education, our environmental vigilance will be enhanced. In the meantime, we must make choices.

If the protection goal is directed at ground waters that contribute to the community's wetlands, the protected area might include the land area where ground water recharges the wetland. If surface water protection is the goal, then the protected area might include the entire watershed that contributes to the community's streams and rivers. Here are the major types of protection areas used by communities:

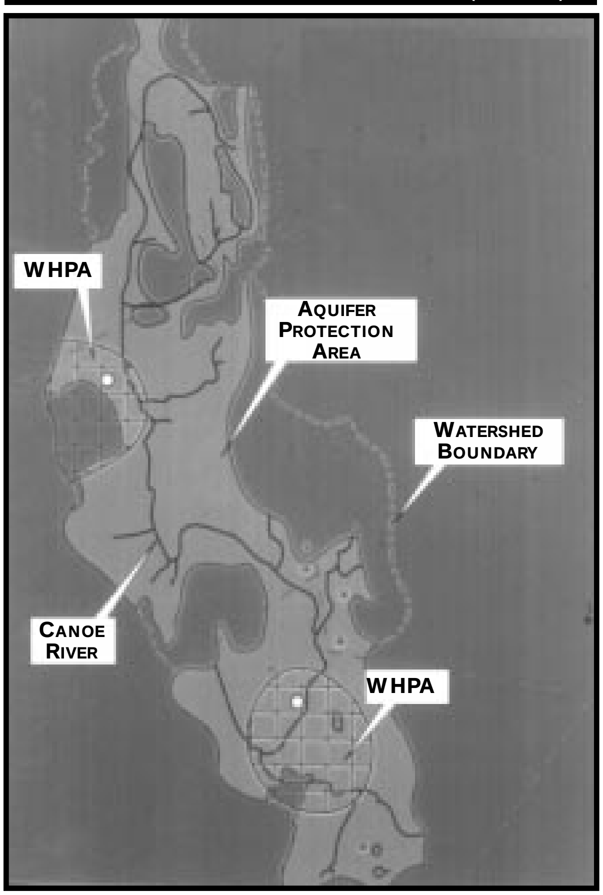
■ **Surface watersheds** are best used to protect surface waters and the ground waters that support them. A watershed is typically much larger than the area that supports a town's aquifers or drinking water wells. The advantage of using a watershed boundary to protect ground water resources is that it can be delineated fairly easily and at low cost.

■ **Aquifer protection** areas are used to protect potential community drinking water sources. The cost and difficulty in identifying these areas varies according to the amount of available information.

Communities that depend on private wells for drinking water may wish to identify and protect all of their aquifers, inasmuch as all landowners are dependent on the water on their properties for drinking water. In a case where a community has large supply wells, only a portion of an aquifer may be supplying water to the well. In this case, protection of the entire aquifer may provide more protection than a community feels it needs.

■ **Wellhead protection areas** are used to protect only the ground water that recharges a community's supply wells. If communities choose this method of protection, it is important that they determine their existing and future supply needs when identifying their wellhead protection areas.

Figure 1 AQUIFER VS. WELLHEAD PROTECTION AREA (WHPA)



If a community does not consider its future needs, it may not protect enough of its aquifers to support future development. In a case where a fairly inexpensive and inaccurate method is used to delineate the wellhead protection areas, the community may not truly understand which land areas may have an impact on its wells and may therefore achieve incomplete protection of critical ground water resources. Figure 1 provides an example of the different types of protection areas in a given community.

STEP 3. Collect Information About Your Ground Water Resources

The primary goals of most ground water mapping programs are to identify and map relevant watersheds, aquifers, wellhead protection areas, wetlands, and surface water areas. Much of the information you need to collect is already available in map form, but these maps may be at many different scales, making relationships hard to see. The best way to display these data is to purchase a topographic base map and then map the other information at the same scale on acetate overlays. The use of Geographic Information System (GIS) computer technology, if available to your community, allows you to easily view and evaluate mapped information.

Several types of maps that may be available for your community are described in the activity, "Revealing Stories—Resource Maps Tell All," and may be available in GIS form. These maps include the following:

■ Topographic Maps

These maps, prepared by the United States Geological Survey (USGS), use contour lines to show the elevation of the land surface at 10-foot intervals (or in newer maps, 3-meter intervals). By observing the contour lines closely, the map user can learn the shape of the land surface (topography). And, by connecting the points of highest elevation, watershed boundaries to rivers, streams, and coastal embayments can be mapped.

Topographic maps also show the location of major wetlands, rivers, roads, buildings, and other details.

■ Surficial Geologic Maps

These maps, prepared by USGS for portions of New England, are drawn by professional geologists who observe and interpret land forms and soil profiles. Permeable soils, indicative of good recharge areas, are usually identified on the map. The maps show only types of surficial deposits. They do not provide numerical data on soil permeability, nor do they identify aquifer recharge areas.

■ National Wetland Inventory Maps

National Wetland Inventory Maps, prepared by the U.S. Fish and Wildlife Service, are available at scales of 1:24,000 or 1:25,000 and show the location of medium and large-sized wetlands. Digital data may be available through the Internet for portions of New England.

■ Soil Maps

In communities where USGS surficial geology maps are not yet available, soil maps from the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service can be used to locate permeable soils that could be recharge areas. Soil maps have been prepared for much of New England. The maps show soil types on an aerial photograph. The soil survey report, which describes the soil classifications in terms of permeability and other characteristics, also includes a general soils map of the community. Both the USGS surficial geologic maps and the USDA soil maps show soil types within a few feet of the surface, but they do not contain information about deeper geologic deposits. This is a problem because one cannot assume that soils at deeper levels will be the same as those directly above. In fact, layers of different soils are common in New England.

■ Hydrologic Atlases

These maps, published by the USGS, are available for portions of New England and show the location of aquifers. The location of aquifers is estimated by examining surficial geology, depth to bedrock, and depth of the water table. It is important to realize that these maps show only aquifers that are considered favorable for ground water development for drinking water based on the geologist's interpretation. Actual well yield may differ from the estimated yield. Despite these limitations, the hydrologic atlases identify all the major aquifers within a given river basin. Thus, rather than hiring consultants to find an "undiscovered" aquifer, the USGS hydrologic atlas can be used to locate aquifer areas in a community.

■ Additional Sources of Information

Your community may already have a library of natural resource information. If you have a planning department, it would be the first place to look. Regional planning agencies often have an extensive collection of resource information. Some state environmental departments in New England have collected extensive information about the location and quality of aquifers, wetlands, and coastal recharge areas. Call your state ground water program (usually the program that implements the state's wellhead protection program), wetlands program, geologic survey, and coastal zone management program to determine what additional water resource information is available for your community.

STEP 4. Map Your Ground Water Resource Protection Areas

Once you have evaluated your ground water resource information and determined how that information will be applied to your community's ground water protection needs, you will need to transfer this information onto a separate Ground Water Resource Protection Areas **overlay map**. Depending on the amount of information available, the community may want to hire a consultant to map the resource protection area or seek assistance from the regional planning agency or state environmental agency. Assuming that this map is eventually adopted by the community, it will become an important land-use decision-making tool.

Communities use maps to identify a variety of land-use features, including zoning, existing land uses, water supply watersheds, wetlands, potential ground water supplies, and open space and recreation areas. When these maps are laid one on top of another, they provide local land-use decision makers with a critical body of information. You can use this overlay procedure to immediately identify areas where overlapping existing or intended land uses pose potential conflicts with ground water protection goals. Here are some examples of the kinds of ground water protection area maps that can be developed:

■ Surface Watershed Areas

Because any resource protection area will lay within one watershed or other, the first step of the ground water mapping process is to map the boundaries of the watershed in which the area(s) is located. Watershed boundaries (drainage divides) define the land area that drains surface water to a river, stream, pond, lake, or embayment. We are fortunate in New England because watershed boundaries generally correspond with ground water divides, so they can be used to identify the ground water basin as well as the surface drainage basin. (See the activity, "Watershed Basics," to find out how to delineate a watershed.)

■ Estuarine Protection Areas

In coastal communities where estuary protection is a concern, watershed maps and maps that show ground water recharge areas to estuaries can be used to establish estuarine protection area maps. The watershed maps allow communities to identify surface and ground water flow shoreward as well as land areas that could be potential sources of pollutant discharges, particularly stormwater runoff. Ground water recharge maps provide information on ground water discharge areas.

■ Aquifer Protection Areas

It is difficult to determine the exact limits of aquifers and their recharge areas because ground water systems are dynamic. Although the geology of an area does not change perceptibly, the water table fluctuates. In addition, the porous, permeable materials that constitute aquifers do not end abruptly at a given point in the watershed; rather, they often blend into adjacent deposits.

Aquifer recharge areas usually include most of the land directly above the aquifer and also extend beyond the aquifer into the adjacent upland areas. If USGS surficial geology maps and USDA soil maps are available, they can be used to supply basic information on the location of permeable deposits. Depending on the amount and detail of existing information, additional soil data may be needed to map aquifer recharge areas. When a local ground water study is conducted by a consultant, existing information is often supplemented by field tests to verify the permeability of the soil at various depths.

■ Source Water/Wellhead Protection Areas

Source water protection areas are the lands necessary for protecting drinking water sources—wells, reservoirs, rivers. Surface water supply protection areas typically include the watershed upstream of the water intake. The term "wellhead protection area" is used to describe the area needed to protect ground water supplies. It is very important to know how much of an aquifer is affected by a well, because in addition to drawing water to the well, pumping will also pull any contaminants to the well that might be leaching from the land surface. Therefore, by defining the wellhead protection area as precisely as possible, you can focus your protection program on the land that is most critical and that affects the quality of your drinking water supply. By narrowing the focus of your protection program to those areas that have a direct impact on a resource, you are more likely to win support from your community as a whole for adopting protection strategies.

The process of wellhead delineation is extremely important, but it can also be difficult and expensive, depending on the needs of the community. Accuracy becomes important if management tools, such as land-use restrictions, are adopted to protect the water supply. In such cases, it is important to have a delineated wellhead protection area that can stand up to potential legal challenges by landowners. While there are some delineation techniques that the community can undertake itself, the more sophisticated techniques will probably require the town or water company to hire a ground water consulting firm.

Under the federal Safe Drinking Water Act, states are asked to develop Wellhead Protection Programs to enhance protection of the nation's drinking water supplies. All of the New England states have developed Wellhead Protection Programs and regulations or guidelines for delineation of wellhead protection areas for new and/or existing wells. Ground water planning teams should check the particular requirements and guidance materials applicable to their state before proceeding with the delineation process. There may be special assistance programs in your state to aid in the delineation process, as well as legal requirements you have to meet.

■ Wellhead Protection Areas for Bedrock Aquifers

Many communities in New England do not have high-yielding sand and gravel aquifers but depend instead on wells drilled into bedrock. Water is drawn from fractures within the rock, which may be difficult to identify and locate precisely. A bedrock geology map can, however, provide a general sense of the direction and size of the fractures in the bedrock, which may help to determine the land area where water actually enters the bedrock fractures. Unfortunately, there are no widely agreed-upon methods for delineating wellhead protection areas for bedrock wells.

■ Private Wells—Vulnerable Areas

If your community is served by private wells, it is important to identify vulnerable resource areas. While it may be difficult and unrealistic to draw a wellhead protection area around each individual well, there are other options.

If private wells are spread throughout the town, you may choose to identify the whole town as a protection area. If residential development is limited to a portion of town, then you may choose to delineate that area for more protection.

If you anticipate future growth, or if private well owners are experiencing water quality problems, it may be prudent to locate high-yielding areas for a future public water supply well, and take the steps to protect them to ensure that they will yield safe water in the future. To identify such areas, you can consult aquifer and surficial geology maps, or hire a consultant to do the necessary research.

STEP 5. Inventory Existing and Potential Pollution Threats to Ground Water Protection Areas

What happens on the surface of the land has the potential to contaminate the water below. Your team needs to determine which land-use activities pose a threat to your ground water protection areas. You need to know what kinds of materials are being used; how they are being handled, stored, and disposed; and where potentially harmful activities are located with respect to your ground water protection areas.

To get a handle on this information, you need to develop a map that shows land uses and activities within your resource protection areas. First, check and see if your community has a current land-use map. Otherwise, obtain a town/city assessor's map or a zoning map from which to create your exist-

Table 1

Relative Risks of Land-Use Activities

RISK PRIORITY

Moderate to High			Low	Very Low
Agriculture Airports Animal feedlots Auto-body shops Automotive repair shops Auto parts store Beauty salons Boat builders and refinishers Bus and truck terminals Car dealership Cemeteries Chemical manufacturers Concrete companies, asphalt, coal and tar Dredge disposal sites Dry cleaners Dumps Food processors Forestry Fuel oil distributors Funeral homes Furniture strippers Golf courses Highways Hospitals Hotels, motels	Industrial manufacturers Junkyards and salvage operations Land application of sludge Landfills Laundromats Logging operations Machine shops Marinas and boatyards Medical and research labs Metal and drum cleaning operations Metal plating operations Military facilities Mining Nursing homes Oil and sewer pipelines Paint shops Photographic processors Plant nurseries Printers, blueprint shops Prisons Public works garages	Railroad yards Repair shops (engines, appliances, etc.) Residential (moderate to high density) Restaurants Retail malls Road salt storage Rust proofers Sand and gravel operations Schools and colleges Service stations (gas) Shopping centers Snow dumps Stormwater management facilities Utility rights-of-way Utility substations, transformers Waste storage, treatment, recycling Waste transfer stations Wastewater treatment plants Wood preservers	Churches Field crops (non-intensive chemical and water use) Low-density residential Non-industrial office space	Forest land Open space Public parks Water utility owned land

Source: NEIWPCC. *Source Protection: A Guidance Manual for Small Surface Water Supplies in New England.* March 1996.

ing land-use base map. It always helps to double-check any of this information with a drive-by or walk-by survey. Aerial photos are also very useful. Once you have your existing land-use map, you can superimpose potential threats to resource protection areas onto the map. (Table 1 lists the types of land uses that typically pose a risk to both ground and surface waters.) You may want to identify general land-use types (for example, residential, agricultural, industrial, open space) on your map so you will know where to concentrate your efforts. Areas with industrial and commercial land uses will probably be the ones to focus on first.

Many of the land uses that might be a concern in your ground water protection area(s) may be already regulated, or at least registered, by a government program (for example, underground storage tanks, use and storage of hazardous materials, or transport and discharge of hazardous materials). Discharges to ground water are regulated by state environmental agencies through the issuance of ground water discharge permits. Superfund and other known hazardous waste sites are also registered with state environmental agencies.

You need to locate any facilities such as landfills, junkyards, sludge lagoons, and disposal areas by visual inspection or by contacting the solid waste division of your state environmental agency or your local health department. Residential development poses a host of potential threats from sources such as septic systems, road salt, lawn fertilizers and pesticides, improper disposal of hazardous materials, and stormwater. In terms of industrial and commercial development, those of greatest concern to ground water quality are the ones that use hazardous substances. Agricultural operations pose potential risk in terms of pesticide use and nutrient management.

Once you have inventoried your potential risks, you need to assess these risks in terms of which risks pose the greatest threat to your ground water resources. (See Table 1 on page D•7.)

STEP 6. Develop a Ground Water Resource Protection Area Management Strategy

After your team has established its ground water resource protection goals, identified and mapped ground water resource protection areas, and inventoried and rated or ranked the potential threats to these resources, your next step will be to develop a management strategy for these areas. Much of this work involves choosing mechanisms to control existing or future risks to your ground water resource areas. You may well discover that some mechanisms are already in place through federal, state, and local regulations and ordinances. But it is also likely that you will need to fine-tune protective measures to meet the needs of the site or even work with the community to implement new controls.

There are an infinite number of ways to structure your ground water protection program. What you choose depends on existing regulations in your state, the character of your community, your community's goals for future economic development, the kinds of threats you have identified, and the extent of your protection area. Also, you will have to consider how much your management program will cost, if there is a staff to implement and enforce it, and whether you have the legal authority in your state to do so.

In the section, "Your Ground Water Protection Toolbox," we list a variety of management approaches that have been used by communities throughout New England. Some of these options can stand alone, but most are like parts of a puzzle and work best when carried out in conjunction with other options as part of an overall protection program. There is not just one approach—each community must construct the mix of options that best suits its unique situation.

As members of a community ponder their management strategy, they should keep in mind the following questions:

- What sort of statutory authority does your state grant communities for controlling land use?
- What are the results of your inventory of potential threats, and what kind of current and/or future risks does your ground water protection area face?

- If you restrict future land uses in the ground water protection areas, are there other areas in the community that are more suitable for high-risk uses?
- Does your community already have, or will it support, a local zoning ordinance to protect ground water?
- If you have a zoning ordinance, are there portions of your ground water protection area that are zoned for dense residential development, industrial, or commercial use that are not yet developed?
- Does your town have staff with the time and expertise to undertake inspections, monitor ground water quality, and implement and enforce performance standards?
- Will voluntary programs be effective in ensuring that harmful activities do not occur?

STEP 7. Ensure That the Strategy Will Be Implemented

No strategy is "worth its salt" if it is not ultimately put into practice. Educating the public, and convincing individuals to care about their ground water resources, are the key to successful implementation and will be among your team's greatest challenges. The success of any program depends, to a great extent, on the involvement and awareness of the citizens in the community and, on how much support there is in the community for the adoption and implementation of the program. There are many ways to educate the public. Here are a few possibilities:

- Invite the local paper to cover your ground water protection team meetings so that it will keep the community up-to-speed on progress and issues. Encourage the paper to run a series of short articles about ground water—what it is, how it interrelates with the overall aquatic environment, how it becomes contaminated, and the ways to protect it.
- If there is a water company, ask it to insert information on ground water into the water bills.
- Teach the community about household water conservation practices and nontoxic alternatives to household products through the local paper and/or water bills.
- At key points in the resource protection process, sponsor a community meeting and invite state or local officials to explain why protecting ground water is important.
- Publish a newsletter that goes out to all residents and businesses in the community.

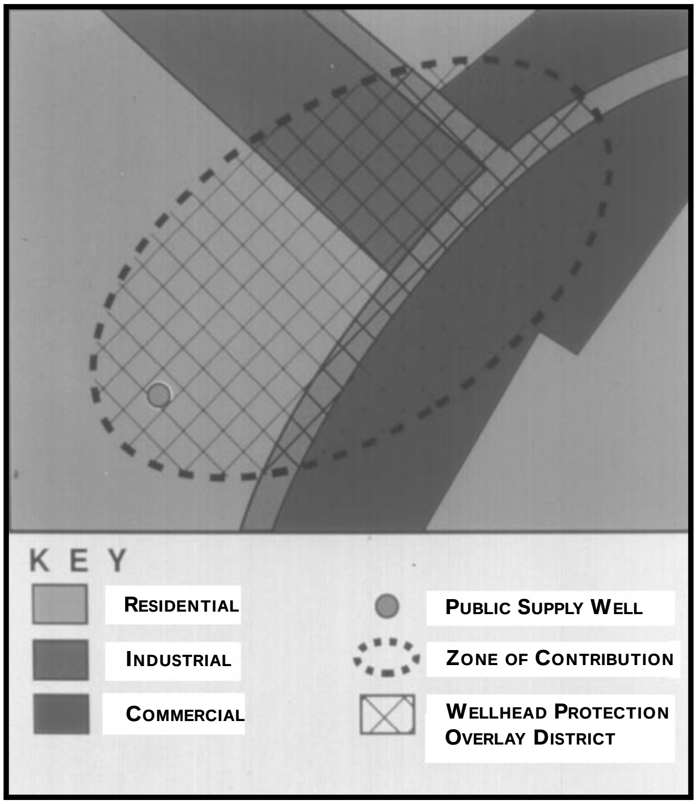
YOUR GROUND WATER PROTECTION TOOLBOX

Resource protection strategies can be implemented using a variety of tools that should consist of control measures and education and outreach strategies. Control measures may be both regulatory or nonregulatory. Regulatory controls at the local level generally involve the use of bylaws and ordinances designed to exclude or manage certain noncompatible land uses or activities in areas of concern. Nonregulatory controls are voluntary and do not involve the regulation of property. Here are some examples of both regulatory and nonregulatory resource protection tools.

■ Regulatory Tools

- **Zoning** is probably the most widely employed method of protecting ground water. Zoning is used to control the type of development allowed in a particular area and to separate incompatible land uses. Zoning typically controls future land-use, not the way already-developed land is used. Thus, if your resource protection area is currently undeveloped, an effective means for protecting ground water is to zone the area for land-use activities that pose little or no threat to the resource, such as low-density residential development, certain kinds of commercial use, or open space. Other uses may also be compatible if precautions are taken against the storage or use of hazardous substances. Some zoning techniques that are often

Figure 2 ZONING MAP



used for ground water protection are described below:

- **Overlay Zoning** supperimposes boundaries of the protection area on the zoning map. Preexisting zones are not actually changed; rather, new conditions are imposed on future development. (See Figure 2.)
- **Large Lot Zoning** limits water resource degradation by reducing the number of buildings and, therefore, septic systems within the critical resource area.
- **Cluster Zoning** increases the density of living units in a particular portion of a zone while allowing the remainder to be open space. This development approach tends to be less disruptive to the natural environment and aquatic ecosystems, in particular.
- **Special Permits** allow certain uses and structures upon the issuance of a permit or special exception. Special permits are usually granted only if safeguards are taken to reduce risk to the environment and if the use or structure is in harmony with the general purpose of the protected area.
- **Prohibition of Various Land Uses** (for example, gas stations, or industrial operations that handle, store, and transport hazardous substances) may be applied to the resource protection area.
- **Performance Standards** are based on the assumption that any given resource has a threshold, beyond which its ability to function deteriorates to an unacceptable level. This control method assumes that most uses are allowed in a designated area, provided that they do not or will not overload the resource of concern. It focuses additional regulations on specific impacts without burdening all uses in a zoning district and regulates land development impacts without prohibiting development.
- **Transfer of Development Rights** is used to transfer development from the resource protection area to locations outside that area. This mechanism allows a landowner to sell his or her right to develop the land as permitted by zoning, but maintain other rights associated with the land (e.g., ownership, existing use, open space).
- **Subdivision Regulations** focus less on land-use and more on engineering concerns such as street construction (for example, grade, width, intersection angles, stormwater control, drainage), utility placement, and traffic patterns of individual subdivisions. Subdivision controls are generally less effective for controlling potential environmental threats than zoning controls. Subdivision controls that address

drainage from roads and lawns and performance standards that address nitrogen and phosphorus loading associated with roads, lawns, and septic systems provide excellent means for keeping significant contaminants from entering the ground water.

- **Health Regulations** can be very effective in protecting ground water quality. These controls are usually contaminant source-specific (for example, septic systems, underground storage tanks, toxic and hazardous materials).

- **Wetland Bylaws** can greatly enhance water quality through the judicious regulation of proposed activities within wetland buffer zones. Specific steps that wetlands commissions may take include requiring vegetated buffer strips adjacent to wetland areas, imposing stringent controls on surface water discharges to wetlands, and restricting the use of fertilizers, pesticides, and herbicides in close proximity to wetlands.

- **Best Management Practices (BMPs)** are structural designs, nonstructural designs, or guidance for the operation of a specific business, industry, or land-use activity that prevent or control threats to ground water resources. The term "best management practices" applies to protective measures that have worked best over time. Through the use of BMPs, pollution from many land-use activities can be controlled. BMPs can be structural (for example, creating a **detention pond** to hold stormwater long enough so that many of the pollutants are removed by the soil and vegetation) or nonstructural (for example, establishing zoning ordinances that allow certain types of activities in certain areas, based on resource considerations). BMPs can serve as both regulatory and nonregulatory tools.

Nonregulatory Tools

- **Water Conservation Practices** Communities can provide the public with information, suggestions, and programs on conserving water resources. During severe droughts, some New England communities have instituted emergency water conservation measures (for example, limiting lawn and gardening watering). However, communities should also remind the public that water conservation is not only for emergencies—being water-wise should be everyday behavior. In cases where ground water or surface water is withdrawn from one drainage basin and used and then discharged into another, maintaining the **water budget** can become a serious concern for both the losing and the receiving basins.

- **Household Hazardous Waste Collection** If a large portion of your delineated area is residential, and particularly if it is unsewered, hazardous waste collection days can be an important way of reducing threats to your ground water protection area. Typical household hazardous wastes include:
  - Pesticides and herbicides
  - Paints and thinners
  - Solvents and degreasers
  - Septic system cleaners
  - Art supplies
  - Used oil and antifreeze

  These wastes, when disposed of in the trash, septic system, sewer, or backyard, can cause costly and sometimes irrevocable water quality problems. The organic chemicals used in these materials are some of the most common and persistent ground water contaminants. Household hazardous waste collection days can be organized by a community, a coalition of communities, or the state.

- **Recycling** Recycling programs can reduce the amount of toxins that might end up in landfills, incinerators, or backyards, or that might be flushed down sinks or toilets, where they can eventually leach into ground water and surface water.

- **Education and Outreach** You can conduct education programs and workshops to inform community residents about the importance of protecting ground water.

- **Land Donations** Landowners are sometimes able to donate a piece of land (as part of a development project or a developable parcel) either to the community or to a nonprofit organization such as the Nature Conservancy. Giving the land for preservation can provide the landowner with a variety of tax-saving and cost-share benefits.

- **Outright Sale of Land** Many communities are committed to the acquisition of selected parcels that are deemed so significant to the community's future that it is willing to purchase them outright, at market prices.

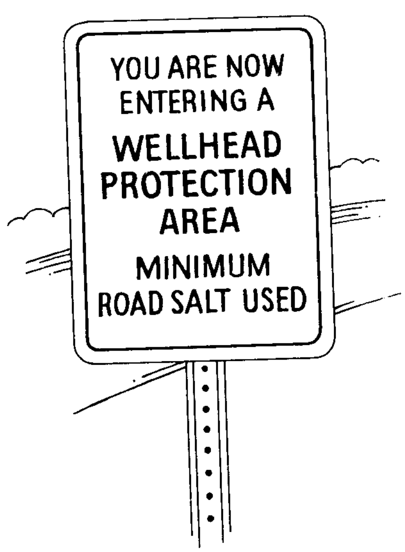
- **Tax Deferments** All New England states currently provide for some degree of real estate tax reduction for lands used, in general terms, for conservation.

- **Conservation Easements** An easement is a limited right to use or restrict land owned by a private landowner. The granting of a conservation easement by a community does not involve the transfer of ownership of the land; instead, it means giving up certain development rights of the property.

- **Protection Area Signage** Signs may be posted along roadways and property boundaries to educate residents and visitors about the location of protection areas. Signs may also include information about who to notify in the event of a hazardous material spill.

KEY TERMS

- **Best Management Practices (BMPs)**
- **Conservation Easement**
- **Detention Pond**
- **Overlay Map**
- **Water Budget**
- **Wellhead Protection Area (WHPA)**



DEVELOP A WELLHEAD PROTECTION PROGRAM

Grades 10-12

OBJECTIVES

- Learn about the tools communities may use to develop a wellhead protection program.
- Recognize that developing a community wellhead protection program is not easy and that, while it is important to protect drinking water supplies, it can be very difficult to develop a program that will gain support from the overall community.

INTERDISCIPLINARY SKILLS

English, Political Science, Law

ESTIMATED TIME

Two to three class periods

MATERIALS

- ❑ Activity handout
- ❑ "Protecting the Town Well Takes Some Doing"

TEACHING STRATEGY

In this activity, students will develop a wellhead protection program for a hypothetical community. While the community scenario is hypothetical, it is representative of situations that many New England communities face when embarking on a wellhead protection program. You may choose to have the students undertake this activity as a class or as teams. Students should read "Getting Up to Speed…Protecting Ground Water" before beginning this activity.

We recommend that you have students assume various roles in the community (e.g., gas station owner, photo lab owner or employee, beauty salon owner, restaurant owner, resident, environmentalist). In doing this, each student can bring the perspective of his or her role to the discussion. You may wish to point out that the relationships between businesses, environmentalists, and community leaders can be, but need not be, adversarial. Many businesses have taken pollution prevention to heart as a way of reducing supply costs, waste disposal costs, insurance costs, reducing regulatory paperwork, and being a good neighbor.

1. Distribute copies of the activity handouts and the reading.

2. Tell the students that they are residents of "Small Town" and are members of the town's Ground Water Protection Committee, which is about to begin developing a wellhead protection program for the community's public supply well. Students should keep in mind that this wellhead protection program must ultimately gain the support of the community as a whole to be effective.

Explain to the students that there is no "correct way" to protect a community's wells. Developing a best management program is dependent on the unique situation and limits (political, financial, physical, administrative) faced by the community. There really are no right or wrong answers in this exercise. As a homework assignment, have the class read the activity handout, the reading, and "Getting Up to Speed."

3. Hold a committee (class) meeting to discuss the information provided by the consulting firm hired by the Ground Water Protection Committee (as per the activity handout) and the considerations associated with developing a wellhead protection strategy—the area to be protected, potential threats to ground water, types of protection mechanisms, political and economic environment.

As part of this meeting, answer the three questions posed in the handout:

DEVELOP A WELLHEAD PROTECTION PROGRAM

NOTES

a. Does existing development in the wellhead protection area pose a threat to the town's well? If so, how?

Many land uses have the potential to jeopardize ground water quality. Ground water quality can be threatened by the improper use, handling, or storage of hazardous materials and the improper use of lawn and agricultural fertilizers and pesticides. Land uses where hazardous materials are typically used, such as gas stations and auto repair shops, pose an especially high risk of contamination because of the potential for repeated spills during their daily operation. Ground water availability can be strained because of excessive water use, particularly during periods of drought. Uses such as restaurants and hospitals tend to use large amounts of water. Watering of lawns and gardens during summer months without sufficient recharge (caused by drought or over withdrawal) places especially high demands on ground water supplies.

b. What, if anything, should be done to protect the town's well?

In this scenario, the town's drinking water supply is at risk from potential sources of contamination. Ideally, the town should work to minimize potential risks from existing and future land uses in the wellhead protection area in particular, and town wide, in general. Students should be familiar with information in "Getting Up to Speed…Protecting Ground Water" to gain some insight on steps communities can take to protect their water resources.

c. How can the town ensure that current and future land uses in the wellhead protection area will not present a threat to the well?

There is no way for any community to ensure that current and future land uses in its wellhead protection area(s) will be risk-free—accidents and carelessness happen. Communities do, however, have many tools available to them to reduce the risk of contamination. Refer to "Getting Up to Speed…Protecting Ground Water" and the reading for this section.

4. Based on the Ground Water Protection Committee's discussion, have the class or each team prepare a wellhead protection strategy for presentation at town meeting. Encourage students to think creatively. There are no right or wrong answers. When developing a protection strategy, communities must balance environmental protection with other goals, such as economic sustainability and quality of life, and must consider the political feasibility of gaining acceptance of the strategy. A plan is only worthwhile if it can be carried out.

5. If the activity is carried out by teams, ask each team to present its findings to the class. Students should assume the roles of various members of the community (e.g., business owners, landowners, homeowners) so that the committee hears many viewpoints.

Develop a Wellhead Protection Program

Directions

Read the following scenario:

Setting

You are a resident of "Small Town" and a representative of the town's Ground Water Protection Committee. Like many small towns in the United States, your town developed along a historic travel route. A well was installed approximately 30 years ago to serve the downtown area and a nearby residential neighborhood in the town.

Action

Because of recent incidents of ground water contamination in a neighboring community, your community hired a firm to identify (or delineate) the land area that supplies water to your well. This land area is called the wellhead protection area.

Existing Conditions

At the last Ground Water Protection Committee meeting, the firm presented its findings. Your committee learned that most of the downtown area is located in the wellhead protection area. (See attached land-use and zoning maps.)

- A range of land uses exists throughout the wellhead protection area, including:
  - Gas station
  - Photo lab
  - Restaurant
  - Hospital
  - Farm
  - Houses (sewered)
- Land uses located nearby but outside the wellhead protection area include:
  - Houses
  - Plastics manufacturing plant
  - Clothing store

Your Job

ASSIGNMENT

The Ground Water Protection Committee is meeting tonight to discuss the firm's findings. Tonight you will discuss three key questions and begin developing a wellhead protection plan.

Ground Water Protection Committee Agenda

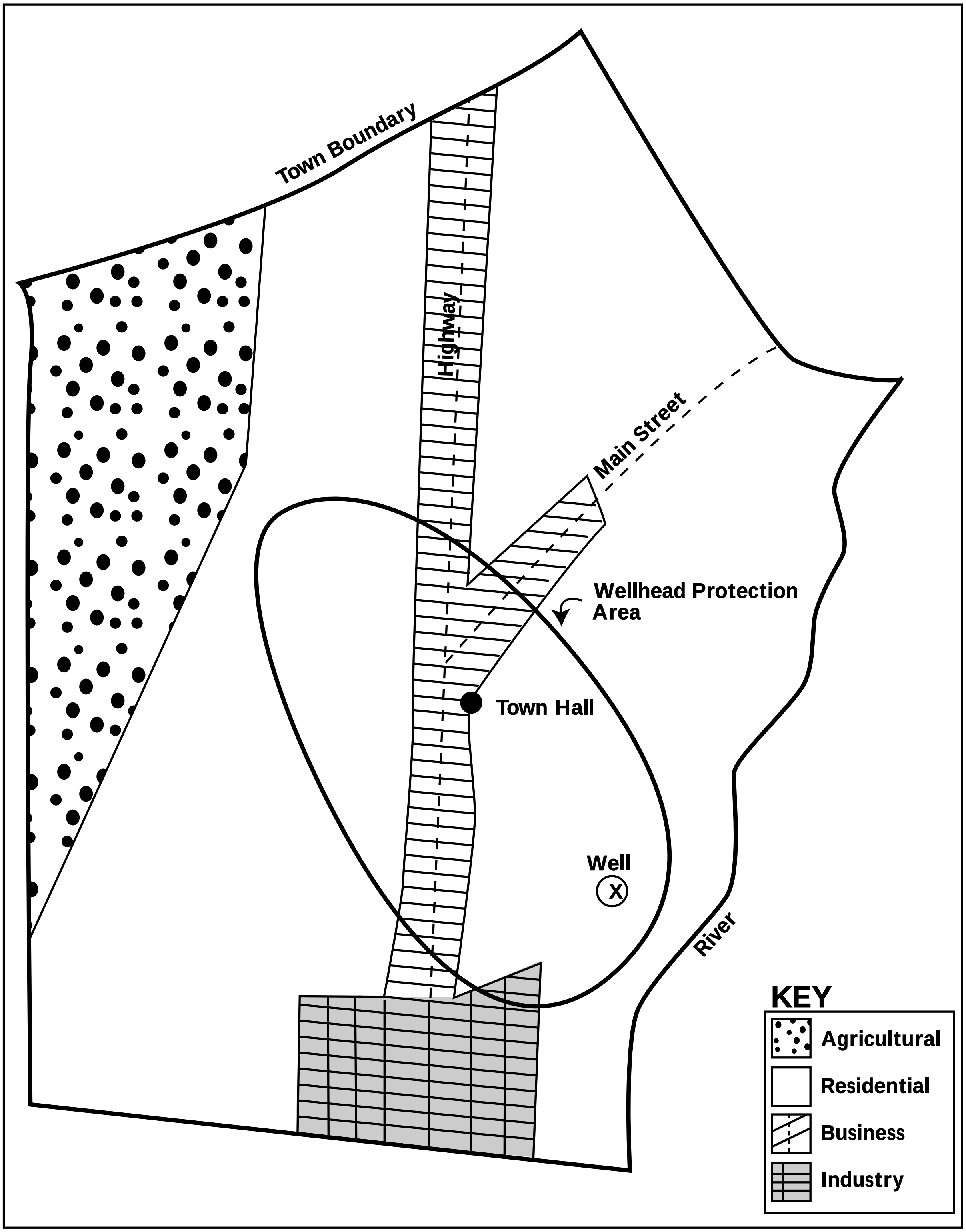
___________, 19__

1. **Introductions**
2. **The Committee will discuss the consultant's findings and will attempt to answer three major questions:**

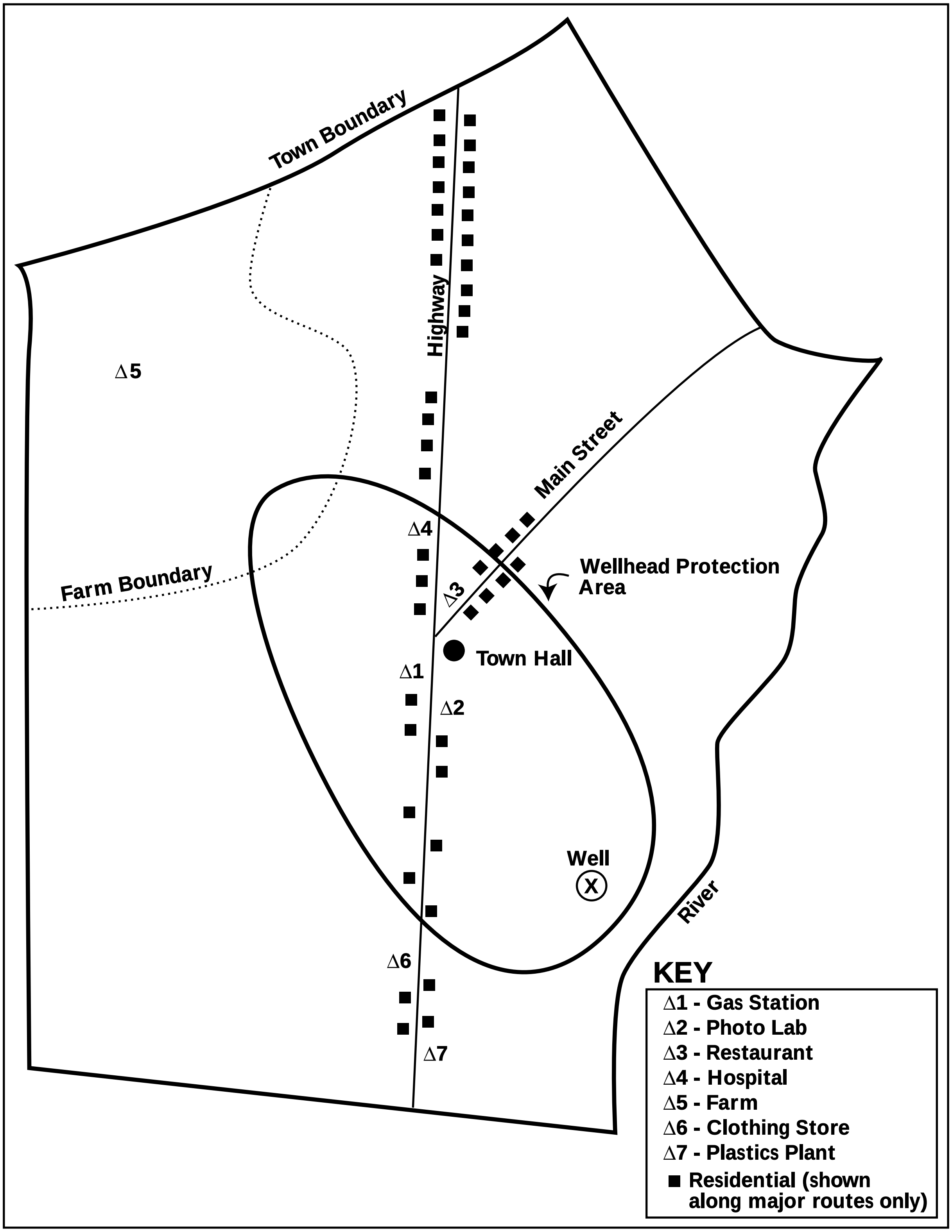
   - Does existing development in the wellhead protection area pose a threat to the town's well? If so, how?
   - What, if anything, should be done to protect the well?
   - How can the town ensure that current and future land uses in the wellhead protection area will not present a threat to the well?

3. **The Committee will begin development of a wellhead protection program for the well, in light of the consultant's findings and the answers to the above questions.**

Small Town Zoning Map



Small Town Land-Use Map



CLINTON WATER DISTRICT, CLINTON, MAINE

Protecting The Town Well Takes Some Doing

Is it worth losing your best friend to protect the town well? Just ask Ron Boivin, Water Superintendent for the Town of Clinton, Maine, who faced this question when his town attempted to implement wellhead protection measures to protect the town's only well. Located in Kennebec County amid gently rolling hills at the confluence of the Kennebec and Sebasticook Rivers, this tranquil dairy farming community of 3,350 in south central Maine has the highest number of active dairy farms of any town in the state.

A few years back, nitrates detected in ground and surface waters alarmed many residents, who began to suspect that local farming activities were to blame. The town had relied on a single well since 1946 for its drinking water supply. Discussion of protecting the land above this aquifer raised a number of land use issues, which frightened many of the town's farmers—Boivin's best friend among them.

"I was scared to death when this project started," says Boivin, who didn't know how his fellow town residents would react to the idea of imposing certain restrictions to protect the town's water supply. The Tapley Well, which supplies 100,000 gallon per day, is located in a partially developed downtown area.

"My best friend owns the farm that we originally thought was causing the nitrate levels in the water," Boivin explains. With no backup well online in the event of contamination, town officials were coming to realize that a second well was needed.

A Chance Meeting

While attending a Maine Water Works conventio in Portland in 1991, Boivin met Peter Garrett, a principal in the firm of Emery and Garrett Groundwater Inc., a hydrogeological consulting firm located in Waterville - the next town over from Clinton. Garrett was familiar with Maine's new EPA-approved Wellhead Protection Program, and was looking for an opportunity to apply it on the local level.

After listening to Boivin's concerns about protecting the town's water supply, Garrett suggested to Boivin that Clinton apply to a new EPA grant program for funds to study and map the wellhead protection area—the area of land that recharges the well. Inexperienced in the often-daunting process of filling out federal grant applications, Boivin convinced the town that their money would be well spent to hire Garrett to do it for them.

Garrett, in turn, made a convincing case to town officials that the most logical process for Clinton to follow would be to conduct a hydrogeological study of the existing well to determine the extent of land that needed to be protected before addressing the installation of a backup well.

EPA Awards Demonstration Grant

Garrett teamed up with Esther Lacognata, an environmental policy consultant, to prepare the grant application. Lacognata was a former Bureau Director in Maine's Department of Agriculture, and also had extensive experience in public participation and agricultural issues.

Garrett and Lacognata both felt that the grant application should focus on two primary principles of wellhead protection: demonstration of how to induce farmers to adopt Best Management Practices (BMPs) in public water supply watersheds; and emphasis on the importance of citizen involvement through the formation of an advisory committee.

In 1991, EPA awarded the Clinton Water District a $15,200 grant to develop a wellhead protection project that would consist of delineating the zone of contribution; identifying and proposing management options to control threats to ground water quality; and preparing a contingency plan in the event of contamination.

The consultant team was also hired to assemble an Aquifer Protection Advisory Committee that would provide input and oversee the plan. With strong leadership from the town's Selectmen and the Water District, the Town of Clinton contributed $18,250 to the project - a substantially higher sum than the minimum 5 percent match that EPA required for the grant.

The Advisory Committee Is Assembled

With dairy farmers accounting for almost half the land ownership in Clinton, both Garrett and Lacognata knew that the farmers' support was critical if the wellhead program was to have any chance of success. Garrett also recognized the importance of using Lacognata's public participation skills to help explain highly technical issues to the public, because, as he says, "many of the people who can do the technical work are often not very good at explaining it."

Source: NEIWPCC. *The Water Source.* Fall 1994.

Protecting the Town Well Takes Some Doing *continued*

It took some measure of persuasion to convince local water officials that a citizen's advisory committee, which would have substantial input into the wellhead protection plan, would be a good idea. One of the first tasks Lacognata tackled was to assist local officials in determining who should comprise the 10-to 12- member Aquifer Protection Advisory Committee.

To avoid the inevitable political squabbles that often arise in local government, Lacognata "pre-interviewed" members of the local water district and the comprehensive planning committee to seek their input on membership. The final Aquifer Protection Advisory Committee consisted of members of Water District staff, the Comprehensive Planning Committee, the Planning Board, local historians, business owners, and farmers.

Hydrogeological Study Yields Some Surprises

While Lacognata focused on generating public support for the project, Peter Garrett got to work conducting water sampling and pump tests to determine the direction and source of water supplying the well. At the time, Clinton was using a 300-foot fixed radius as a zone of protection around the well. However, Garrett knew from experience that a fixed radius bears little relation to what is actually happening beneath the surface. Poring over state maps that showed the well to be located in a shallow sand and gravel deposit, Garrett initially believed that the aquifer was too small to be supplying such a large amount of water. This concern lead him to believe that the two streams located on either side of the well were actually recharging the aquifer through a process known as induced filtration.

After reviewing the data, the recharge rates, and old pump test yields from the 1940s, Garrett surmised that the streams must have, at one time, supplied recharge to the aquifer. Old pump tests revealed that, indeed, more water had been pumped in the 1940s.

After much head scratching, Garrett observed that the stream bottoms were heavily silted over, probably as a result of changing crops over from hay to corn (plowing associated with corn crops loosens the soil and increases erosion runoff) in the 1950s. This siltation suggested that, at present, very little water was infiltrating the streambed. Also, water samples from both the well and the streams indicated differences in hardness, which, as Garrett hypothesized, "seemed to fit a model that would suggest that the water came from bedrock fractures."

With data in hand, Garrett mapped out a Primary and Secondary Wellhead Protection District that, much to the relief of area farmers, did not include their farms. The Primary District was the immediate area of drawdown around the well (called the cone of influence). The Secondary District, consisting of 638 acres, comprised the recharge area.

It is ironic to note that, although farming activities did not appear to be threatening the wellfield, the farm community did find itself subject to changes in farming practices. A state law, which was being implemented at the same time that the wellhead protection project was underway, required minimum setbacks from streams and other water sources. Best management practices, such as manure holding tanks, pesticides application controls, and riparian preservation corridors, are currently being implemented by farmers statewide.

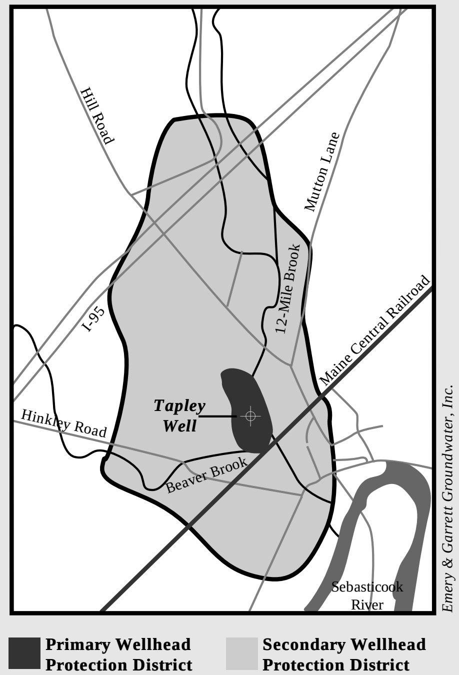
The Public In The Process

The first public meeting of the newly formed Aquifer Protection Advisory Committee attracted many farmers who were, according to Lacognata, "absolutely terrified" that the wellhead protection plan would impose new regulations and land use controls over their activities. "The first meeting was educational and confirmatory," says Lacognata. "Peter Garrett and I used a mock question and answer session to address the farmers concerns about what this would mean to them."

This question and answer technique had been used successfully by Garrett on other occasions to help take the pressure off the audience. By having Lacognata, who was not a hydrogeologist by training, ask Garrett to explain basic concepts that the audience might have been reluctant to ask, they created a more relaxed atmosphere at the meeting, which in turn facilitated discussion.

Other activities intended to

Primary and Secondary Wellhead Protection Districts for Clinton's Tapley Well



Protecting the Town Well Takes Some Doing *continued*

further public support for the project included a field trip to the pump station and monitoring well; a demonstration of a pump test; visual aids; and a demonstration by Garrett on how he had calculated the size of the wellhead protection area.

A New Wellhead Protection Ordinance

Enter Paula Thompson and Ron Cormier. Thompson, at the time a Senior Planner with the North Kennebec Regional Planning Commission, began to work with the Advisory Committee on developing a wellhead protection ordinance. Fortunately, Clinton had completed a Comprehensive Plan (a requirement of Maine's Growth Management Act) in 1989 that specifically required the town to address ground water and public water supply issues. A section in the new Land Use Ordinance was set aside for wellhead protection.

Working with the Planning Board, Thompson, and the Advisory Committee, Code Enforcement Officer, Ron Cormier set out to design an ordinance that was tailored specifically to the needs of Clinton. Using model ordinances from other states as a starting point for discussion, the group eventually proposed an overlay district that would prohibit certain high risk activities within the wellhead protection area.

With input from town officials and the public, the ordinance was tailored to give landowners considering activities in the wellhead protection area two options: to rebut the presumption of the boundary of the wellhead protection area, or to adhere to the performance standards that were developed for certain uses.

In the case of a challenge to the boundary, the burden of proof would fall on the landowner or developer to show that the intended activity within the Secondary Wellhead Protection District would not adversely impact the well. To overcome this presumption, a landowner would have to hire a hydrogeological consultant, whose work would also be reviewed by the Water District's hydrogeological consultant, to conduct in-depth studies to make their case.

Flexibility The Key To Success

By offering some flexibility in terms of what uses would be allowed in the Secondary Recharge Area, the town felt that opponents to the plan would have fewer grounds on which to object. According to Cormier, the ordinance process allows a landowner to work with town officials in a reasonable manner to determine if their intended use will impact the well. "Give us your plan, we'll talk about it," says Cormier.

Lacognata also agrees that flexibility was key to obtaining public support for the project. "We did design the ordinance for Clinton and it's conditions. Therefore, it may be more permissive than it might be someplace else," she explains.

Lessons Learned

Despite a current challenge to the wellhead ordinance by a local landowner, the participants have all felt that the Clinton project was successful in many respects. Ron Boivin found out that even highly technical subjects like wellhead protection can be made understandable. "If you explain it to people in language they understand, they react much better," he says.

The farming community, who initially balked at any talk of land use controls to protect the town's drinking water, also learned that the public participation process was an effective forum for airing their concerns and for understanding the issues.

Ron Cormier feels that 40 years in the land development business has taught him the critical importance of protecting municipal water supplies. "No water, no town. It's that simple," he says. He also credited the success of the project to strong leadership by the Planning Board and Selectmen, who made the decision to spend money on prevention activities to protect the long term interests of the town.

Peter Garrett feels that the true value of wellhead protection is "not simply arriving at a drawn line around a well." Rather, he says, information about the safe yield, water quality, thickness of the aquifer, and other data will allow for more intelligent and informed decision making.

The Clinton experience has reinforced Esther Lacognata's belief that wellhead protection is essentially a locally-based activity. "Wellhead protection cannot be forced from the top," she says. The project has also confirmed for her that the public needs to understand the "fundamental relationship between land use, water quality, and the need for sound scientific information as a basis for management decisions."

Paula Thompson says the Clinton project has taught her that you can't "overcommunicate" between parties. With continual turnover of local officials, many of whom are volunteers, the entire wellhead program and ordinance is but "one town vote away" from elimination. She stresses the need for a support system that both ensures continuity of understanding and intent and sustains the momentum evident at the beginning of the project. •