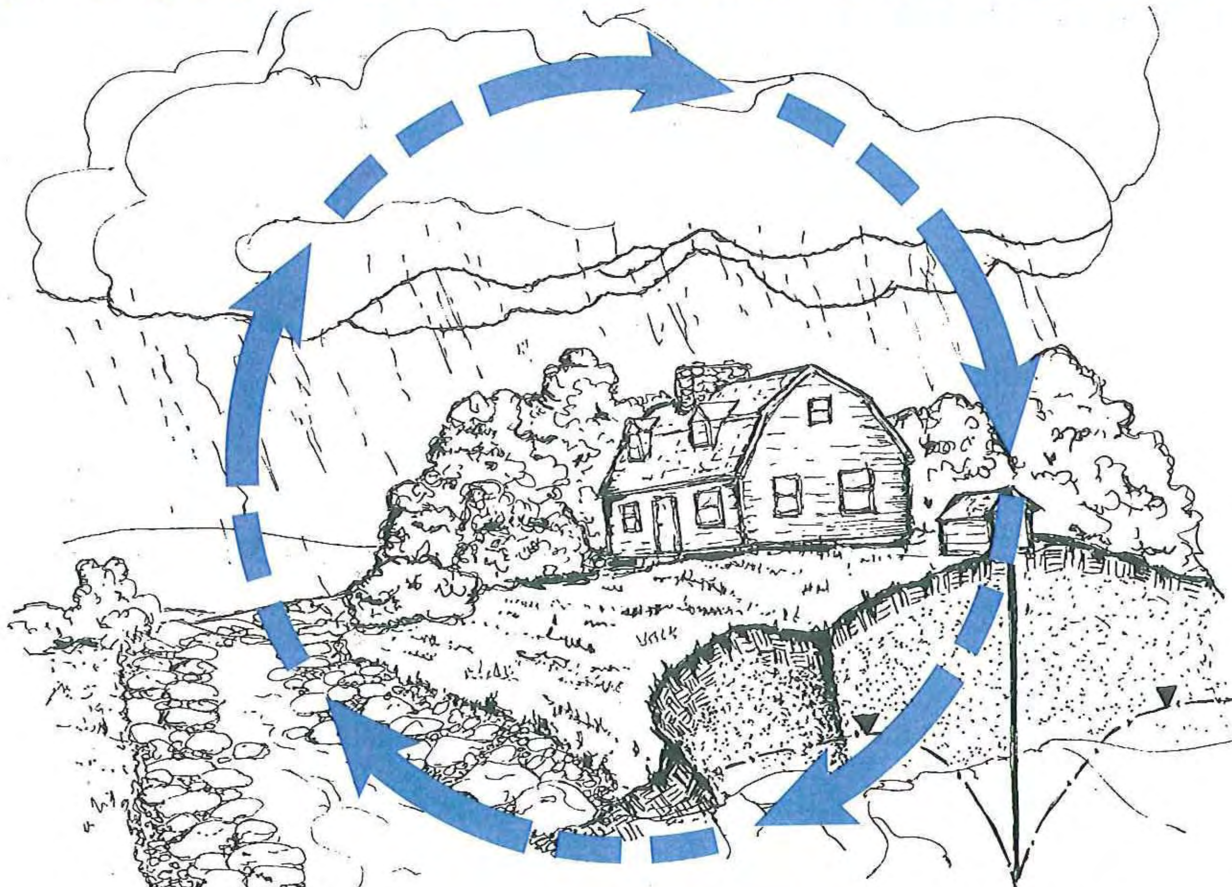
PROTECTING CONNECTICUT'S GROUNDWATER

A GUIDE FOR LOCAL OFFICIALS



By Robert Hust and James Murphy

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION
79 Elm Street
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Protecting Connecticut's Groundwater

A Guide for Local Officials

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Honorable John G. Rowland
Governor of Connecticut

Sidney J. Holbrook
Commissioner of the
Department of Environmental Protection

Robert Smith
Chief, Bureau of Water Management

Thomas Morrissey
Director, Planning and Standards Division

Robert Hust
James Murphy
Project Managers

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Introduction

Thinking About Groundwater

Water is a precious resource, essential to all life on earth. The state of Connecticut is blessed with abundant year-round precipitation, and large quantities of clean water are found in our streams, rivers, lakes and under the ground. Unlike some of the more arid regions of the country, Connecticut has seldom felt the impact of widespread water shortages, and its growth has not been significantly limited by a lack of water. We sometimes take our water supplies for granted, giving little thought to where they come from and how they may be affected by our actions.

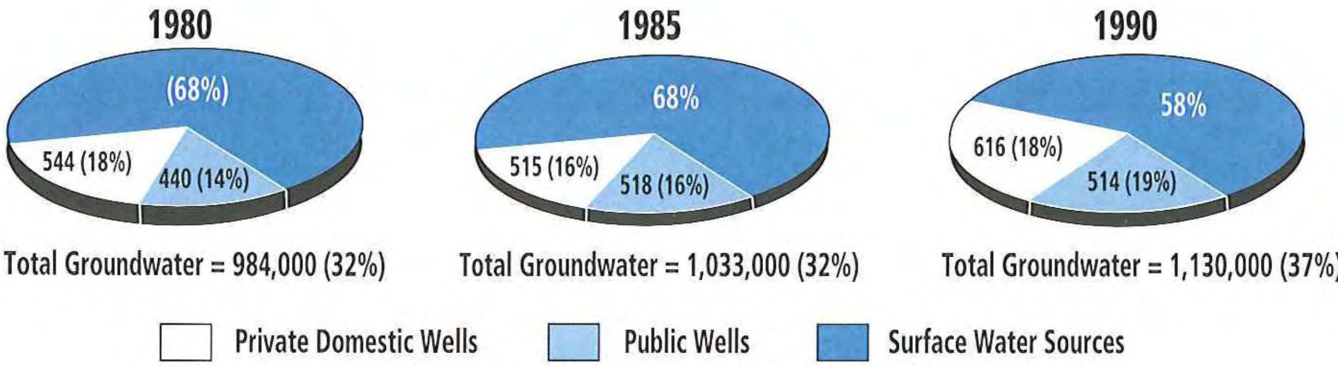
Today, however, there is a growing awareness that our water is not an infinite resource. Like our other natural resources, Connecticut's water requires careful stewardship if we are to continue enjoying an abundant and clean supply. As the population grows and we use our land more intensively, we increase the risk of polluting surface water and groundwater. In some areas of the state, groundwater is already too contaminated for drinking. More than 250,000 people have been affected by contaminated groundwater supplies, and groundwater contamination has been found in every town. Even where serious contamination has not been detected, land use development may represent such a threat to water supplies that it is difficult to ensure their continued protection.

...Over a third of Connecticut's residents depend on groundwater supplies from public or private wells, and the percentage is growing...

Over a third of Connecticut's residents depend on groundwater supplies from public or private wells, and the percentage is growing. Surface supplies, such as the large reservoir systems, have historically provided most of our public drinking water. But today, surface water supplies require costly treatment that may only be economically feasible for large sources of water. These systems also require the dedication of extensive land areas. As the state becomes more urbanized, communities have increasingly turned to public wells to meet the demand for water. Virtually all of the supply for future growth will have to come from groundwater sources, particularly in rural areas, which depend almost entirely on groundwater supplies.

Groundwater Use In Connecticut, 1980-1990

Population Served, in Thousands (% of total population)



Groundwater supplies pose some special protection problems. Many common and widespread land uses can pollute groundwater by releasing chemicals or wastes to the ground. Some contaminants are filtered out by soil, but many others are not so easily degraded or dispersed by soil, and can persist almost indefinitely. As a result, once groundwater is contaminated, it can be difficult to clean up and can pose long-term health hazards for well-water users. In wells that are not tested regularly, contaminants with no odor or taste may go undetected for a long time. When contamination is detected in a well, it may be extremely difficult to identify its source. And even after a pollution source has been removed, contaminants can remain in groundwater for many years. Because groundwater also plays a major function in the maintenance of surface water flow and quality, its protection is critical.

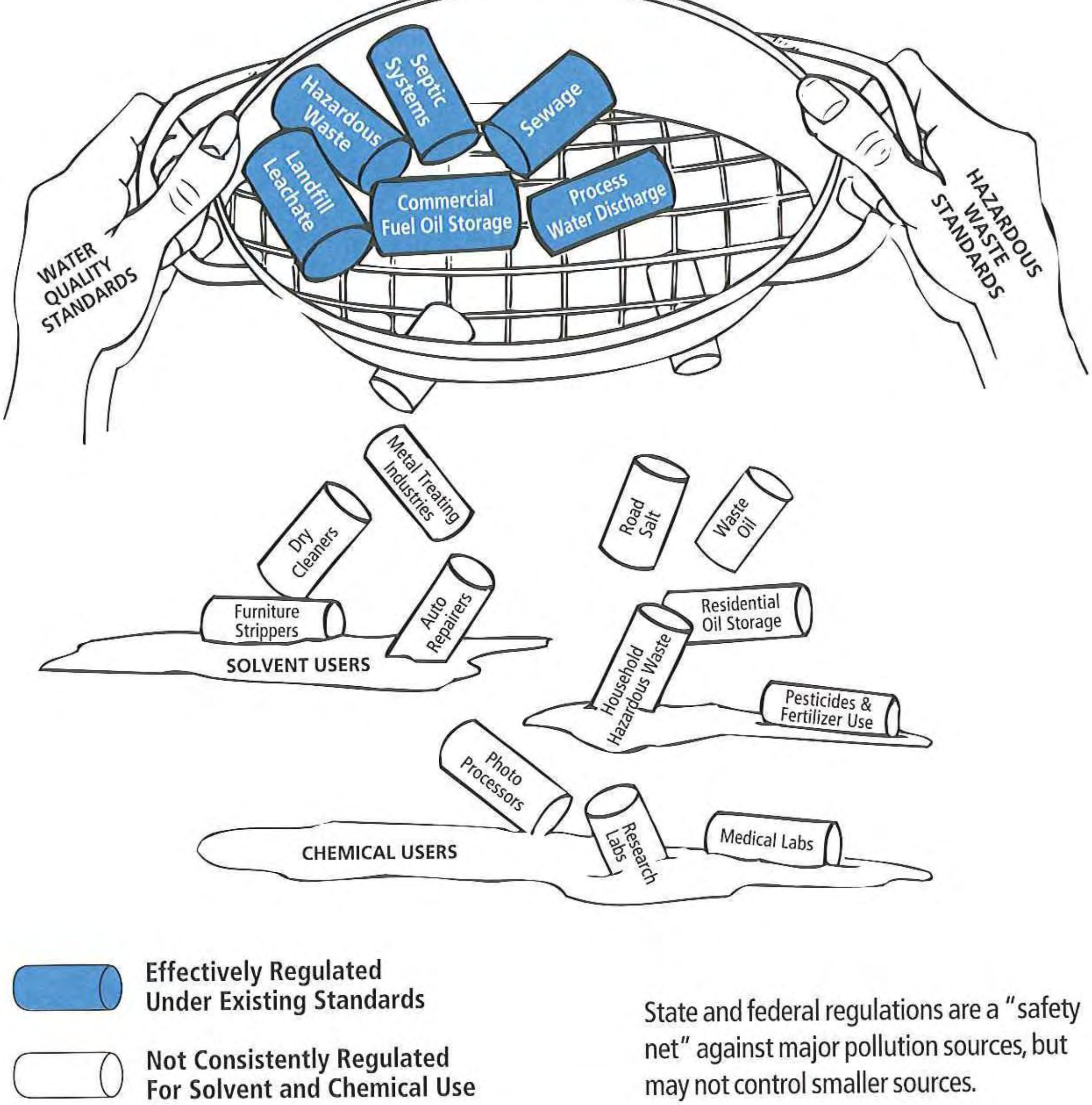
Preventing contamination is the single most effective way to protect our groundwater supplies. By recognizing where our groundwater comes from and managing land uses that place those resources at risk we can reduce and prevent groundwater contamination.

Sharing the Responsibility for Protecting Groundwater

During the 1980s, the State of Connecticut initiated several studies to address groundwater protection. Resources were inventoried, pollution sources identified, and management needs discussed. While there were many ways to approach needed management, proactive protection was clearly needed. It also became clear that cooperative involvement of both state and local governments was necessary for an effective program. Land use management, in which municipalities play a major role, was considered an important element which needed improvement.

Federal and state programs provide a "safety net" of permitting, monitoring, enforcement and remediation to protect groundwater against the most serious sources of contamination. Pollution hazards such as landfills, sewage, industrial wastes, and large underground fuel

What Is Regulated?



State and federal regulations are a "safety net" against major pollution sources, but may not control smaller sources.

storage tanks are effectively regulated. But state regulatory programs are a net, not a shield: many chemical users not consistently regulated at the state level — small businesses, farms, and other activities across the state — are also potential sources of groundwater pollution.

These hazards can only be effectively controlled by community action. State programs can assist municipalities by providing technical information, guidance, and enforcement action when needed. Recent state legislation, the Aquifer Protection Act, gives the state additional authority to control land uses affecting large public wells. But even in these areas, local communities will continue to have primary responsibility for managing activities that might pollute groundwater. Every community in Connecticut needs to examine its groundwater resources, and insure that protection needs are considered in land use planning and management.

How This Manual Can Help

The steps required to protect your community's groundwater depend on many factors: the sources of groundwater you rely on, the locations of wells, the water resources available for future use, and the types and distribution of land uses in your community. Your town may have public wells that are regulated under the Connecticut's Aquifer Protection Act, and this manual will help you understand that program and its limitations. Whether or not your town has regulated Aquifer Protection Areas, it is important to evaluate groundwater resources on a townwide basis to plan for the future and consider a program of active management of groundwater resources.

This manual will give you the tools to understand the need for groundwater protection in your community and to communicate its importance to other local officials and citizens. It will help you to...

- understand your groundwater resources and where your community's water supply comes from;
- recognize what kinds of activities and land uses threaten your water;
- evaluate the adequacy of protection provided by existing federal, state, and local regulations;
- identify additional protective measures needed in your community;
- ACT effectively to ensure that protection.

This manual has five principal sections: **Part I** provides basic information about the occurrence and movement of groundwater in Connecticut and how our wells tap this resource. **Part II** describes the problem of groundwater contamination and the human activities that can cause it. The last two sections deal with the issue of controlling this problem: **Part III** describes federal and state programs to protect groundwater, and **Part IV** discusses the regulatory and non-regulatory measures available to local communities to ensure that their groundwater resources are safe. **Part V** tells you how to go about developing a local plan. A special **Supplement Section** provides a sourcebook for local groundwater protection planning. It includes how to map and interpret groundwater information, examples and guides to help develop a community plan, and information sources, including state agency contacts and published references that may be useful in the planning process. Throughout the manual, you will find guidance on where to go for additional help in the "For More Information" tips that conclude each section. Refer to the Supplement for complete information on the references mentioned and how to obtain them.

The discussions in this manual introduce a number of technical terms (many are highlighted in **bold type**), some of which may be new to you. These terms are important to learn because they will help you understand your water resources and how to protect them, and because you will encounter them in other reading materials on groundwater, including state laws and regulations. The glossary to this manual will lead you to the section where many of these terms are defined or discussed.

For further help, the Connecticut Department of Environmental Protection (DEP) and the Department of Public Health (DPH) can provide information and technical assistance. The DEP Water Management Bureau and the Natural Resources Center stand ready to assist your community with resource information and guidance, and DPH can provide assistance on drinking-water issues. For information on contacting these agencies, see the list of state agency contacts in the Supplement.

Part I

Understanding the Resource: Basic Concepts of Groundwater

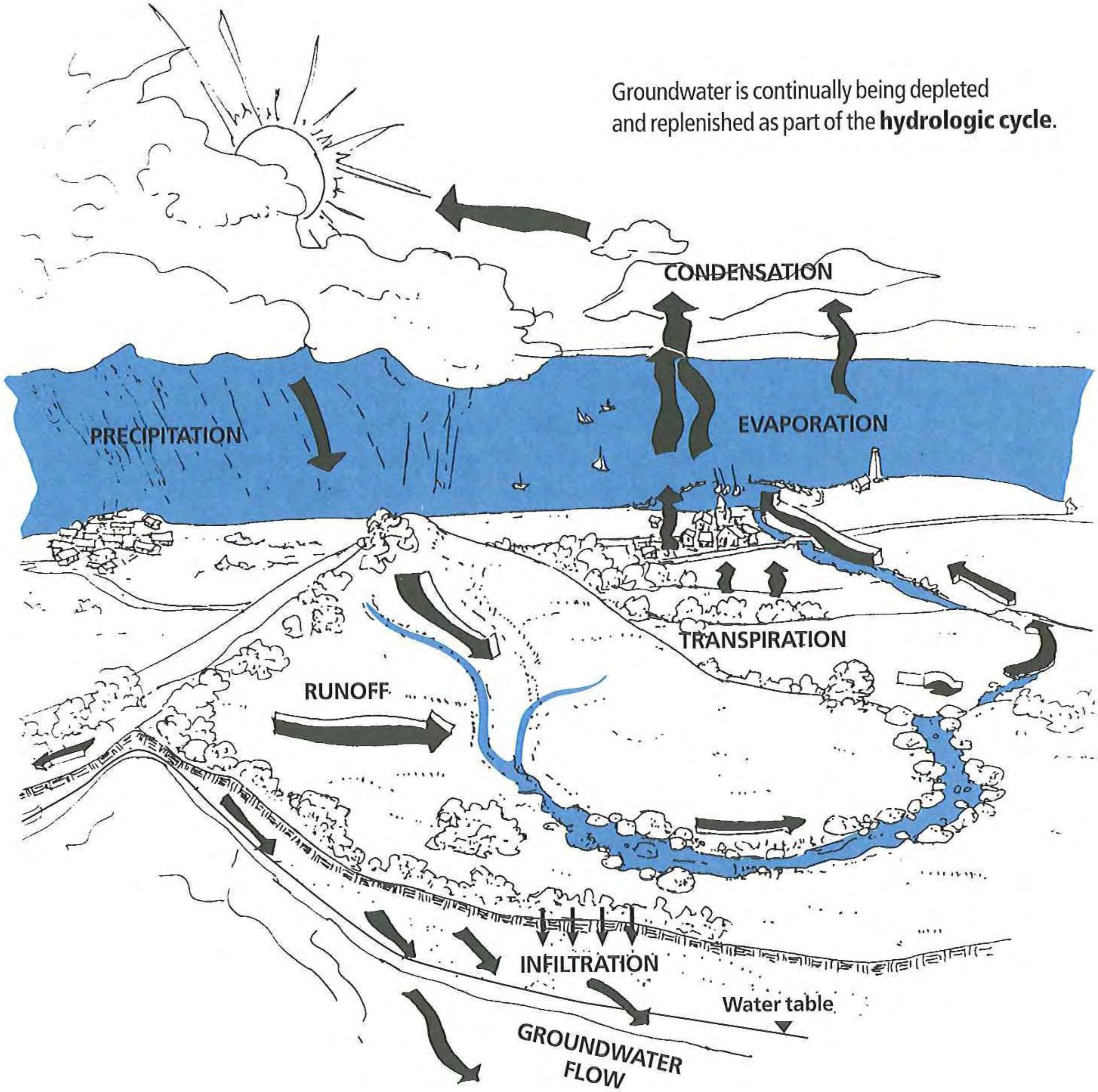
To understand how groundwater pollution occurs and how to prevent it, it is important to learn the basic facts about groundwater itself — what it is, where it occurs, and how it gets to our wells. **Groundwater** is the water that lies below the surface of the earth, filling the spaces or pores in soil and rock. The nature of the soil and rock that underlie our communities affects how groundwater moves and how much is available for human use. An understanding of hydrogeologic concepts will help to identify which areas in the community contribute water to our wells, thus providing a sound legal basis for protecting groundwater supplies through land use management. **Hydrogeology** is a complex science, but the basic concepts related to groundwater management are fairly simple.

The Hydrologic Cycle

The **hydrologic cycle** describes the occurrence and continuous movement of water through our environment. A "**water budget**," like a fiscal budget, can be developed to track water movement through this cycle. The "receipts" are the water coming into a 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 (these two processes collectively are 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 waterbodies, and groundwater stored beneath the earth's surface. Water is continually withdrawn (**discharged**) and deposited (**recharged**) to storage.

The water budget within a drainage basin depends not only on the water received as rain and snow, but also on how rapidly water leaves

Groundwater is continually being depleted and replenished as part of the **hydrologic cycle.**



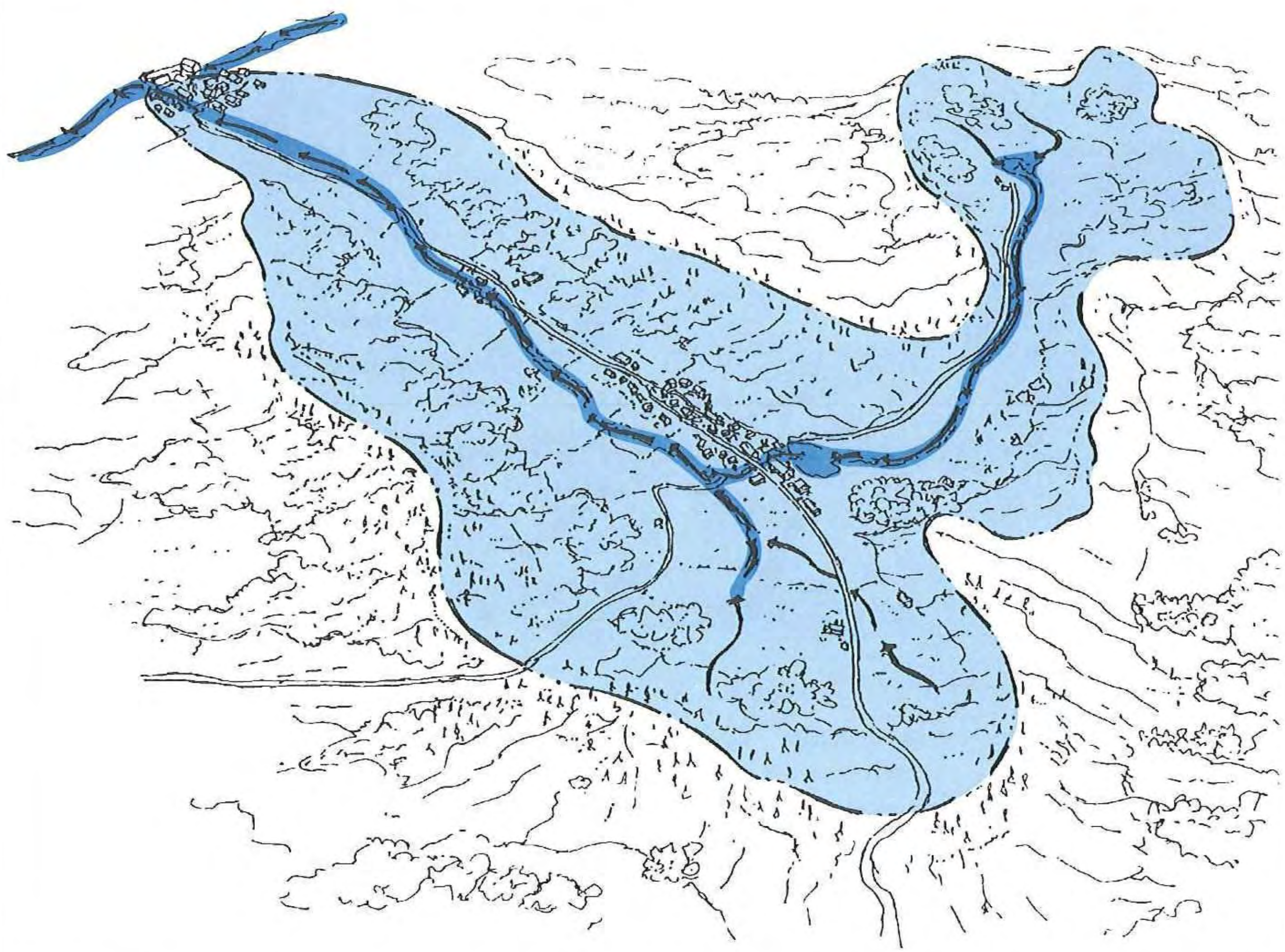
the basin. Topography, geology, soils, vegetation and land use can all effect the rate of water storage and loss. Much of the precipitation that falls on **steep slopes** or on **impervious surfaces**, such as roofs and pavement, flows over the surface of the ground as runoff to streams that eventually 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 earth, and slow runoff so the water has a chance to infiltrate.

Water that infiltrates the soil may be taken up by living plants to later be transpired, it may adhere to soil particles, or it may move downward between soil grains and through cracks or fractures in bedrock. The area

Predicting the Flow of Water – The Watershed

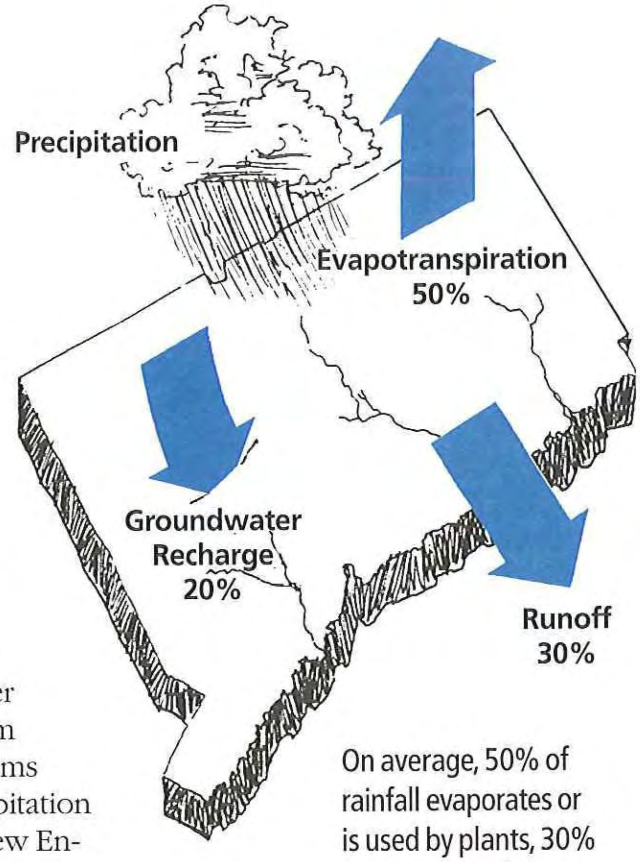
In Connecticut, groundwater flow is generally predictable enough that flow patterns can be organized into natural hydrologic land units commonly called **drainage basins** or **watersheds** (geographic areas over which water flows). A drainage basin is most directly understood by thinking of it as a large bathtub. The rim of the tub is the height of the land surrounding a stream or lake (hilltops), while the watershed outlet, the lowest point in the basin, is the drain. All the water in a basin arrives as rainfall or snow. This same water will eventually exit as either water vapor transpired by plants or directly evaporated from the surface, or as runoff, leaving in a stream (the basin outlet), just as bathtub water flows down a drain.

Just as surface water within a basin will move through streams, rivers, wetlands or lakes to reach the basin outlet, so will the flow of groundwater within a basin. Responding to the force of gravity, groundwater will move downward from hills into valleys, discharging directly into wetlands, rivers and lakes. When the water table intercepts the ground surface, a spring or stream will appear.



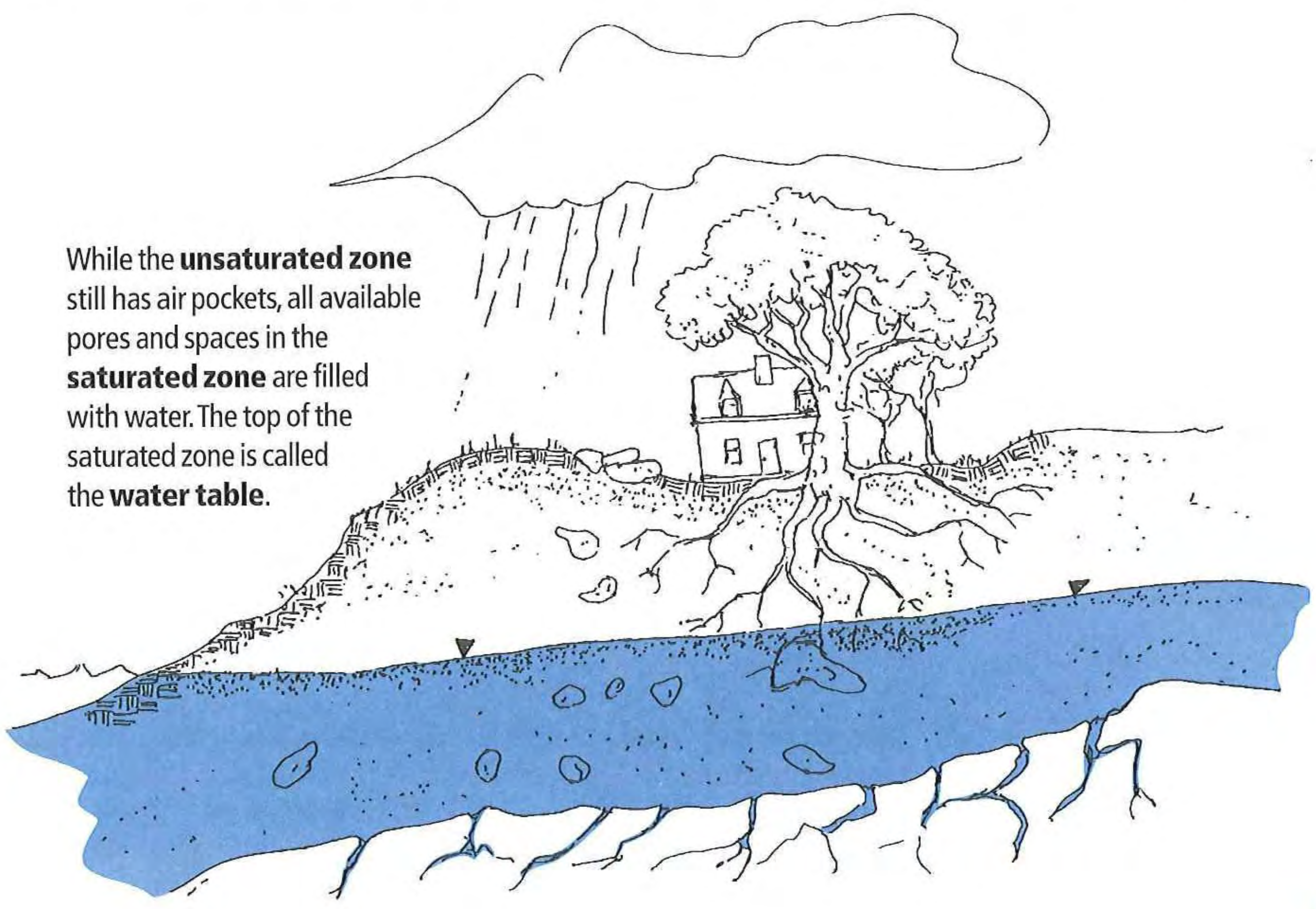
The shaded area above shows the boundaries of this watershed. Because of the terrain, precipitation falling outside the shaded area would collect in neighboring watersheds.

just below the ground surface is called the **unsaturated zone**, where the pore spaces are filled with both air and water. Some water continues to move downward through the unsaturated zone, until it reaches the **saturated zone** where all the available pore spaces are filled with water; the top of this saturated zone is called the **water table**. Precipitation that reaches the water table recharges groundwater.



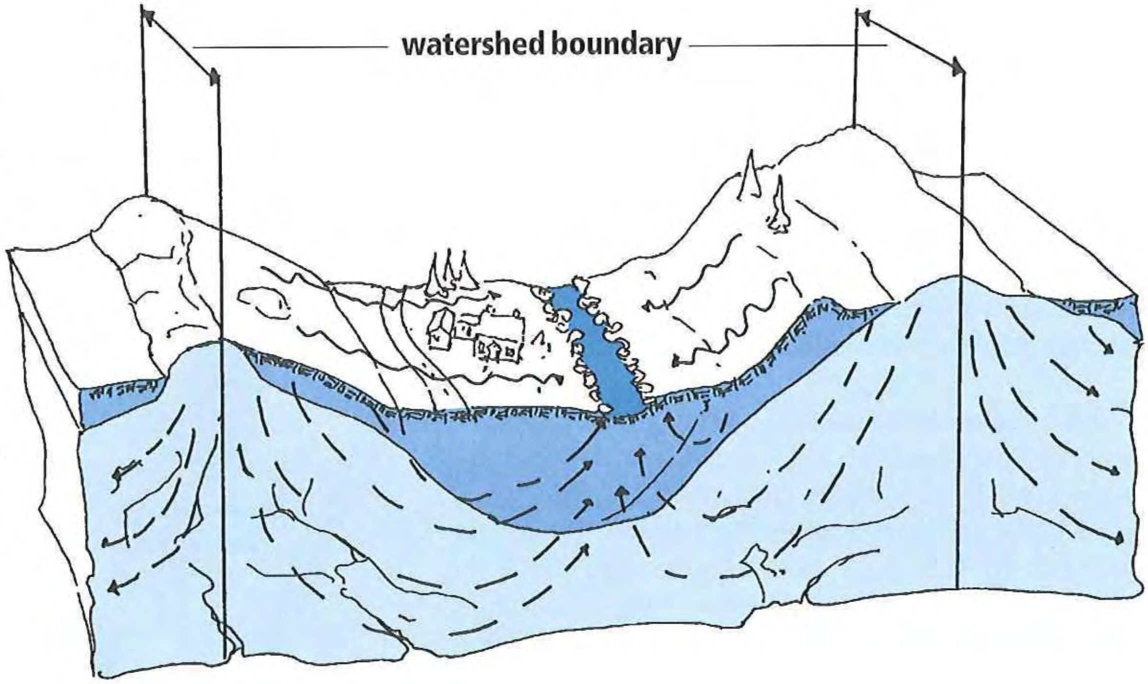
On average, 50% of rainfall evaporates or is used by plants, 30% runs off as surface water, and 20% goes underground.

Like water on the earth's surface, groundwater tends to flow downhill under the influence of gravity, and eventually discharges, or flows out of the ground, into streams or other surface waters, such as wetlands. In such discharge areas, the water table is at or near the land surface. This groundwater discharge sustains stream flow even during periods when there is little recharge to the watershed. It is only when the water table falls below the level of the stream bed that a stream may dry up completely. In southern New England, streams may dry up during the summer months. Although precipitation tends to be evenly distributed throughout the year in New England, during the summer months green plants return large amounts of water to the atmosphere through transpiration, thus lowering the water table, and potentially drying up streams.



While the **unsaturated zone** still has air pockets, all available pores and spaces in the **saturated zone** are filled with water. The top of the saturated zone is called the **water table**.

Water flows from areas of high head such as hilltops to areas of low head such as a river. Because it must move through soil or rock, however, groundwater flow is usually very slow, on the order of an inch to several feet per day



What is an Aquifer?

Groundwater is essentially everywhere at varying distances below the surface of the earth, wherever there are spaces, pores and cracks in the sediments or rock for it to fill. Any geologic formation (sediments or rock) that can yield a usable amount of water is called an **aquifer**. The amount of water an aquifer yields is directly related to the physical characteristics of the geologic formation and the amount of recharge received by the aquifer.

The size and number of the spaces in soil or rock (**porosity**) determines the storage capacity of the aquifer, while the connection between the spaces (**permeability**) determines how readily groundwater can flow through it. Porosity and permeability are related but are not the same. An aquifer can hold large amounts of water but transmit it very slowly. For example, clay may be twice as porous as sand, but because the pores are so small, water will not flow fast enough to supply a well. The best aquifers are both porous and permeable.

Water at any point below the water table has a certain amount of energy associated with it, called **hydraulic head**, which is a result of its relative elevation, velocity, and pressure. Groundwater moves from areas of high head (hilltops, for example) to areas of low head (valley bottoms, for example). Differences in hydraulic head from one place to another create a **hydraulic gradient**, or slope to the water table. Because natural hydraulic gradients tend to be very low, groundwater flow is usually very slow, on the order of less than an inch to several feet per day.

The steepness of the hydraulic gradient, the rate at which water can be transmitted through the aquifer (hydraulic conductivity, a function of the permeability), and the area through which groundwater flow is occurring (the thickness and extent of the aquifer) determine how much water can be withdrawn by a well.

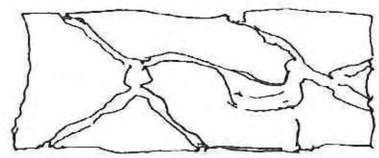
The aquifers from which we draw groundwater can be **bedrock (consolidated material)**, where water fills cracks and fractures or other spaces in rock, or **surficial deposits (unconsolidated material)**, where it fills the spaces between the particles of soil and broken rock that lie over solid bedrock.

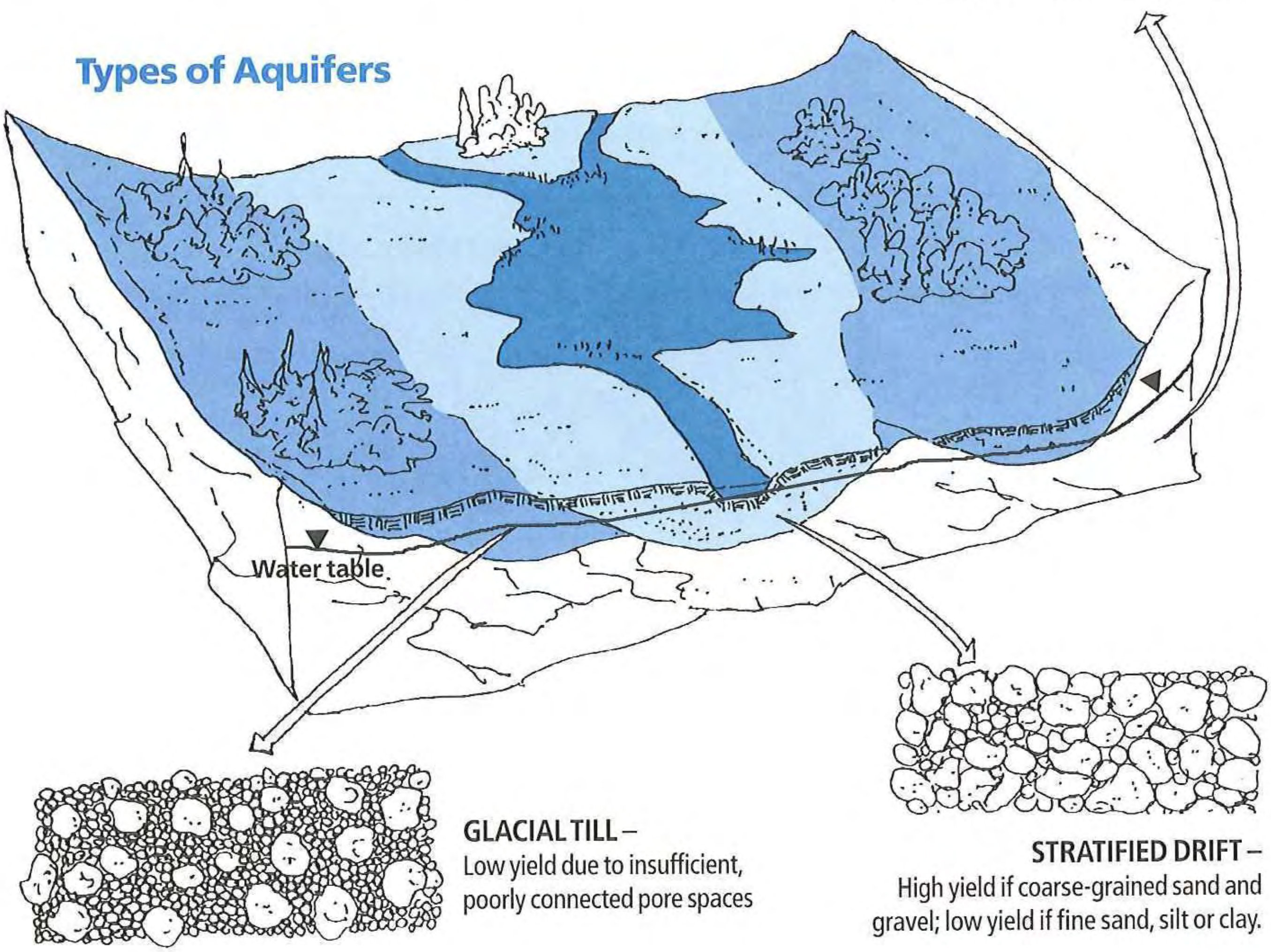
Connecticut's Aquifers

Most of Connecticut is covered by material that was deposited by glaciers that repeatedly advanced and retreated across our landscape until about 10,000 years ago. These ice sheets, which were up to a mile thick, flowed ponderously across the land, scraping soil and boulders from ridges and scouring sediments from valleys. The water storage capacity of Connecticut's unconsolidated aquifers is related to the way the glaciers deposited these sediments, known as drift.

As the glaciers moved, they pushed and pulled material along, leaving behind a jumble of every size of particle from fine clay to huge boulders. This type of glacial deposit, called **till**, covers most of Connecticut. On ridge tops, it lies in a thin layer over bedrock, becoming thicker downslope. Because the small particles fill in the spaces

BEDROCK – High yield if large spaces or cracks; low yield if few interconnected cracks.





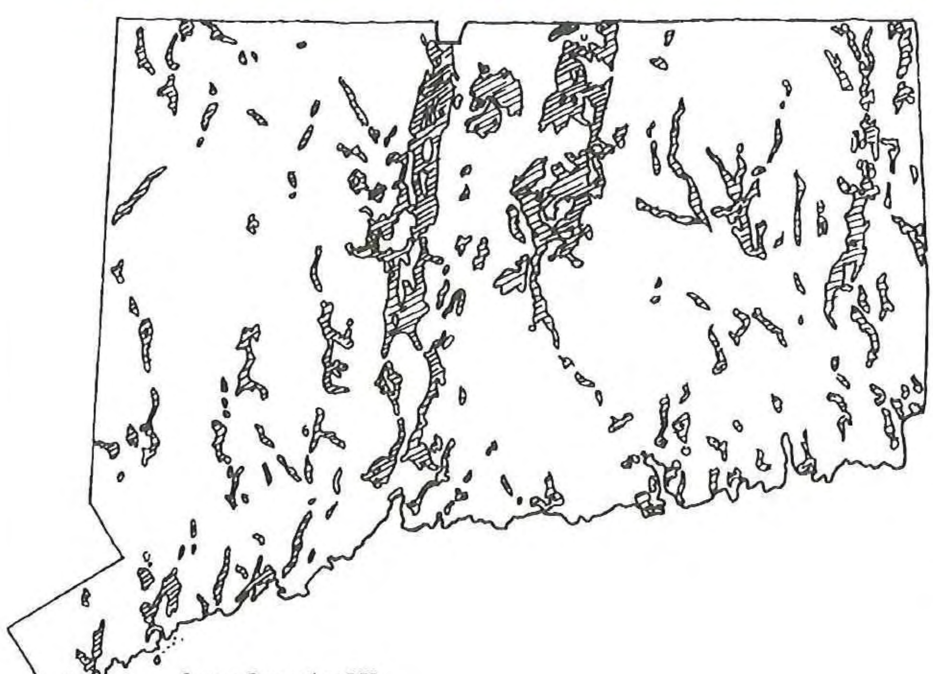
between larger ones, till allows little movement of water. In many areas, the glacier's weight packed this material down to form a compact layer of till, commonly known as **hardpan**, which is nearly impervious to water.

When the glaciers began to melt, the sediments they accumulated were carried away in streams of meltwater. Like all sediment deposited by running water, these particles were sorted by size. The larger particles (gravel and coarse sand) were carried downhill by rapidly moving waters and deposited in narrow, high gradient stream valleys. Finer particles (silt and clay) remained suspended in flowing streams to be deposited later in the still water of lakes, swamps, and the floodplains of wide, low gradient valleys. These meltwater sediments, deposited in layers of similar-size particles, are called **stratified drift**.

Stratified drift aquifers are our most productive sources of groundwater, some yielding millions of gallons a day. Most high-volume public wells tap large, thick deposits of coarse grained sand and gravel in the major river valleys.

Stratified drift aquifers can store great quantities of water, which moves readily through the large pore spaces between the coarse particles. Thin, isolated deposits of coarse-grained stratified drift store much smaller amounts of water. Fine-grained stratified drift deposits, like those of former glacial lakes, are not as productive because water cannot move readily through the small pores spaces.

Major Stratified Drift Aquifers in Connecticut



Source: Connecticut DEP

Stratified drift aquifers are our most productive sources of groundwater, some yielding millions of gallons a day. Most high-volume public wells tap large, thick deposits of coarse-grained sand and gravel in major river valleys. Yet many communities without stratified drift aquifers rely on low-yielding but widespread bedrock aquifers for supply.

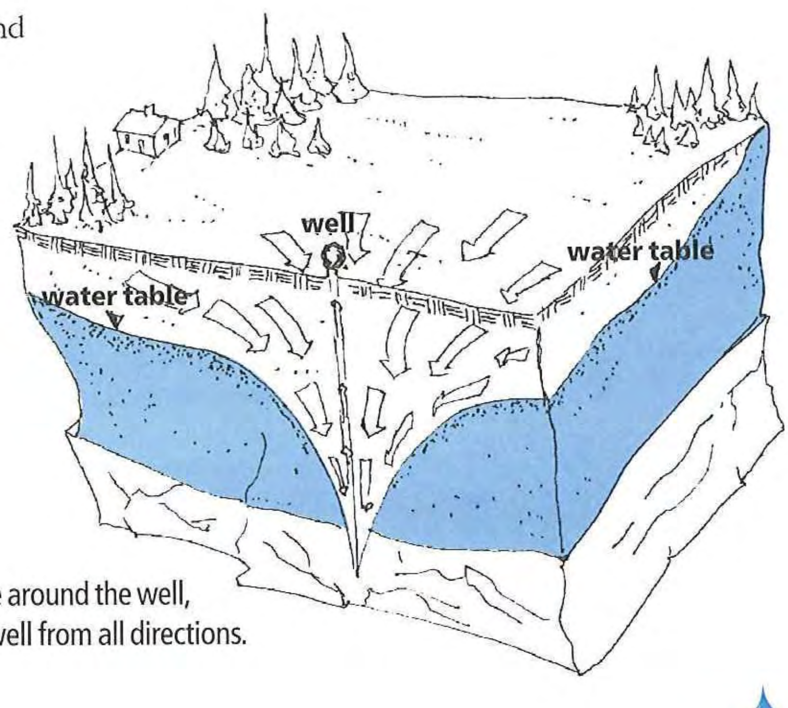
Since most of Connecticut is covered by till, many communities do not have stratified drift aquifers. Few wells draw water from till deposits, since they typically are thin (average 15' thick), yield only a few hundred gallons of water a day (less than a quarter of a gallon a minute) and may dry up during periods of drought. Most early dug wells were in till and provide an unreliable source of water for today's needs. Most private wells in Connecticut, and many small public wells, draw water from bedrock aquifers underlying till or thin stratified drift deposits. Their productivity can vary greatly, depending on the character of the rock. Rock that is highly fractured, like the traprock in parts of central Connecticut, may yield large amounts of water.

Sandstones, which underlie most of the central part of the state, vary in yield, depending on the size of their pores and spaces between layers. The crystalline bedrock that underlies most of eastern and western Connecticut has relatively few fractures, and wells tapping these aquifers generally have low yields (1-20 gallons per minute). In most cases, drilling a well will yield water, although it may not always be the desired amount.

How Wells Draw Water From Aquifers

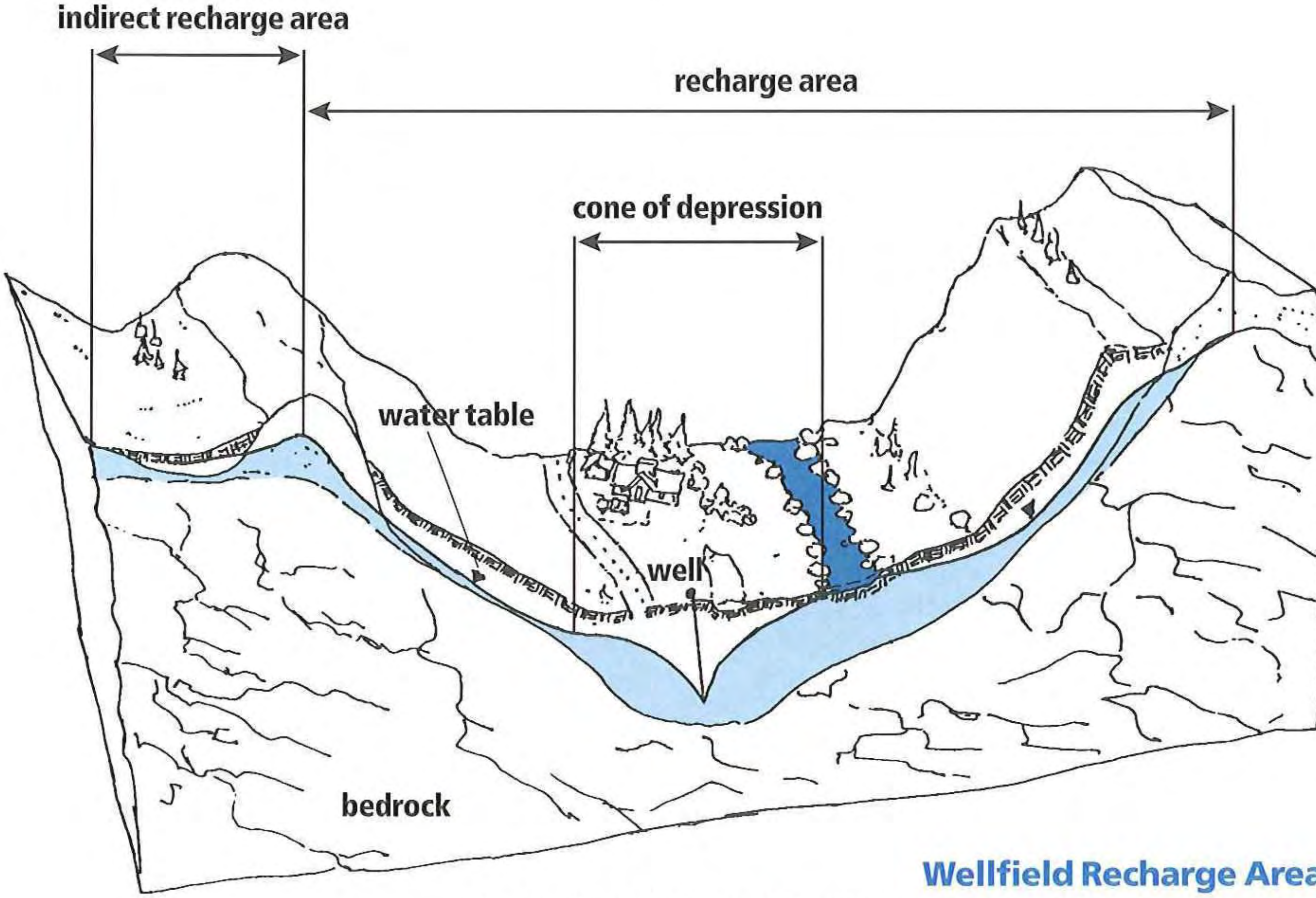
Connecticut wells tap groundwater as it flows through surficial deposits or through the cracks and fractures in bedrock. Wells penetrate the saturated zone below the water table, intercepting the groundwater before it reaches natural points of discharge such as lakes, swamps, springs, or streams. In rare instances, water under pressure, (between confining layers), may move upward when released, as it does in an **artesian well**. In almost all wells, however, the water must be **pumped** from the water table level 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 drawing water from sand and gravel aquifers.



Pumping Well — Cone of Depression

Pumping depresses the water table around the well, causing water to flow toward the well from all directions.



Wellfield Recharge Area

The area from which a well directly draws its water is the well recharge area.

The portion of the cone of depression from which groundwater is diverted to the well (sometimes referred to as the **area of contribution**), and upgradient areas from which groundwater flows directly into it, are collectively referred to as the **well recharge area**. Please note that in other publications different terms may be used to refer to these areas, or terms used somewhat differently, but the critical point is that this is the area from which the well draws its water. The size and shape of the wellfield recharge area depends on the aquifer characteristics and pumping rate.

In parts of the upper watershed of a wellfield, groundwater may continue to flow into the surface waters. These surface waters will generally reach the well only as a result of **induced infiltration**, when pumping lowers the water table under a nearby river or other waterbody so that surface water flows downward through the streambed into the aquifer. This watershed area is sometimes referred to as an indirect recharge area and contamination of the well from this area is much less likely.

Delineating Aquifer and Wellfield Areas for Protection

Effective protection of an aquifer or wellfield requires careful delineation of recharge areas in order to provide a sound basis for controlling pollution sources within these sensitive areas. One of the simplest methods for defining the land that recharges an area is to map the boundaries of the surrounding watershed. As described above, however, only a part of this area contributes groundwater directly to the aquifer or wellfield. Therefore, it may not be desirable or necessary to place stringent groundwater controls over entire watersheds.

The area from which a well draws water depends on hydrogeologic conditions in the aquifer and on the pumping rate of the well. A range of techniques can be used to delineate the land areas recharging a pumping well, depending on the information available and the degree of accuracy required. Accurate delineation can be difficult and expensive, but it is easier for public wells in stratified drift aquifers, in which groundwater flow is more predictable, than for bedrock wells. Therefore, the methods used to define protection areas should be determined in part by the type of aquifer, and known information about existing or potential wellfields:

...A range of techniques can be used to delineate the land areas recharging a pumping well, depending on the information available and the degree of accuracy required...

1. **Water supply wells.** Existing or proposed public water supply wells are discrete locations for which the pumping rate is generally known. The recharge areas for these known wellfields can be mapped to form a **Wellhead Protection Area (WHPA)**:

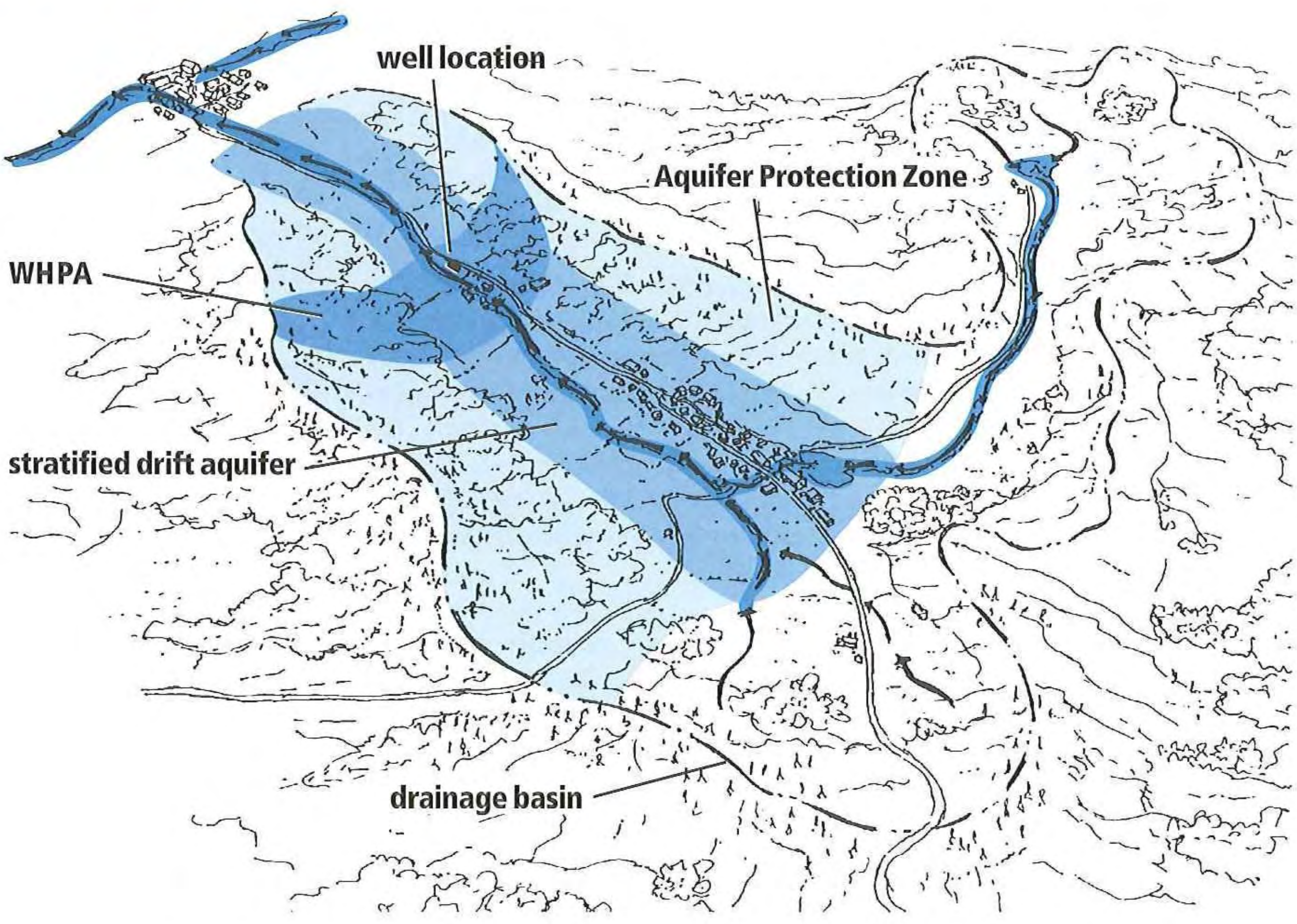
a. If the water supply well is in a stratified drift aquifer and serves more than 1,000 people, it comes under mapping regulations of the **Aquifer Protection Area Act**. The water company or municipality owning the well will be preparing (or already has prepared) mapping to define the recharge areas for the wellfield in this case. This mapping uses computer modeling based on extensive hydrogeologic data and field testing (Level A Mapping), and has a high level of accuracy. Once mapped, these areas will become a **State Aquifer Protection Area** (a special type of WHPA defined by state statute).

b. Other public water supply wells are not currently covered by the Aquifer Protection Area Act. The type of mapping done for the larger public wellfields under the Act is often not cost-effective for the smaller public wellfields. Instead, simpler approaches to delineate a WHPA can be utilized.

The simplest approach designates a fixed circle around the well for protection, using either an arbitrary radius or one that takes into consideration the geology of the aquifer and the pumping rate of the well. A simple circle, however, is not very accurate. For stratified drift aquifers in Connecticut, available hydrogeologic and topographic information permits a somewhat better estimate of the shape and size of the recharge area of a well with only a limited amount of field data.

Recharge areas for bedrock wells are much more difficult to determine, since the movement of groundwater in bedrock depends on the locations of fractures. If you imagine pouring a bucket of water onto a stone wall, you can see that there are many possible routes the water can take to get to the ground; it is difficult to predict the water's path. Contrast this to a bucket of water poured into a child's sandbox, which moves downward through the uniform pore spaces with little obstruction. This unpredictability makes it especially difficult to protect bedrock wells. Until new techniques are developed to better delineate the recharge areas of these wells, they can be defended by protecting the entire resource area or by undertaking the wellhead measures discussed above. State water quality programs also provide a layer of protection for these groundwater resources by limiting waste discharges. The State Public Health Code also requires a basic minimum separating distance around wells for sewage disposal and other waste sources (see Well Protection section).

Relationship Between Aquifer Protection Zones and WHPAs



The relationships between WHPAs, Aquifer Protection Zones, recharge areas and drainage basins are shown here. The Aquifer Protection Zone (recharge areas of the entire aquifer) will include WHPAs (portion of the aquifer recharging the well). A protection strategy may need to consider both WHPAs and the entire aquifer, depending on known existing or potential well sites.

2. **Potential public water supply aquifers.** Productive stratified drift aquifers should be protected for needed future public water supply development. The aquifer and the upgradient areas of stratified drift and till that recharge the aquifer can be delineated with reasonable accuracy using published geologic and topographic information, and a methodology developed by USGS in Connecticut. The potential aquifer and recharge areas can be designated an **Aquifer Protection Zone**, which would be broad, because specific well sites and withdrawals are not yet known.

Water Supply Management

This overview of basic groundwater hydrogeology has highlighted a number of concepts needed to understand how to manage water resources wisely:

- Groundwater supplies are finite.
- Their quality and quantity can be affected by human alterations of our environment.
- Groundwater and surface water are interrelated and their flow patterns are organized into natural hydrologic areas called watersheds.
- Groundwater may be much more readily available in some areas than others depending on the kinds of geologic formations present.
- High-yielding stratified drift aquifers may exist in a community, and may be a very valuable and vulnerable resource.
- Existing community wells and potential aquifers should be considered in protection strategies.
- Wells drawing water from aquifers can be contaminated as a result of land use activities within their recharge areas.
- Though they tend to have low yields and may be more difficult to protect, bedrock aquifers that supply private wells or small public wells are equally essential.

The hydrologic cycle shows us that groundwater and surface water supplies are two aspects of a single resource. Pumping groundwater from wells and discharging it out of, or to other portions of, the watershed affects the water budget, lowering the water table and reducing the total amount of water in storage. This reduces the amount of water discharged naturally, so streams and rivers within the area of contribution of a well may have reduced flows during dry periods. Less water may then be available in streams and rivers for industry, sewage treatment, dilution of surface pollutants, and for recreation or other downstream uses. Lower stream flows can also adversely affect the fish and wildlife that rely on aquatic habitat.

Management of water resources to serve the diverse needs of Connecticut's population is a complex task. Later in this manual we will look at the many programs Connecticut has in place to plan and manage the use of its water resources. Basic to any water resources management program, however, is the need to use our water supplies wisely, to avoid wasting water, and to prevent pollution. The next section of this manual will discuss how groundwater can become contaminated, which is the basis for understanding what we can do to prevent contamination.

For More Information

Connecticut Water Resource Bulletins (for each of the 10 major drainage basins) provide technical hydrologic information for the state. These publications are the best source of groundwater resource mapping and information in Connecticut.

There are a number of other readily available publications that provide detailed information on groundwater hydrogeology. Two of the most useful are *Basic Ground-Water Hydrology*, by Ralph C. Heath (USGS, 1987) and *Handbook: Groundwater*, published by the U.S. EPA (1987). *Water in Environmental Planning* (Dunne and Leopold, 1978) provides an overview of both surface water and groundwater hydrology and how it is affected by human activity.

Methods for delineating recharge areas in stratified drift aquifers are described in U.S. Geological Survey publications. The method illustrated in this chapter is detailed in *Delineating Recharge Areas for Stratified-Drift Aquifers in Connecticut with Geologic and Topographic Maps*, by E.H. Handman (1986). Available from U.S. EPA is *Guidelines for Delineating Well Protection Areas* (1987).

For a general, and fascinating, discussion of the geological formations of our state, you may wish to read The *Face of Connecticut: People, Geology, and the Land*, by Michael Bell (1985).

Statewide mapping and summary information about the distribution and potential yield of aquifers are shown on *Groundwater Availability in Connecticut* (Meade 1978) and *Groundwater Yields for Selected Stratified Drift Areas in Connecticut* (Mazzafero, 1986).

Part II

What are the Risks? Sources of Groundwater Contamination

Groundwater pollution is nearly always the result of human activity. In Connecticut, where population density is high and human use of the land often intensive, our groundwater is especially vulnerable. Groundwater contamination has been found in every town in the state. Since 1979, over 1,400 Connecticut wells, public and private, have been discovered to be contaminated, affecting water supplies of over a quarter of a million people.

Virtually any human activity in which chemicals or wastes may be released to the environment, whether intentional or accidental, has the potential to pollute groundwater. In order to protect groundwater, we must understand the many variables associated with these contaminants and their potential fate in the environment, including:

- the type and amount of chemicals used or wastes generated;
- how these substances are used, stored, or disposed of;
- behavior of these substances in the environment;
- characteristics of the site, such as vegetation, soils, and geology;
- location of the site with respect to aquifers and wells; and
- the hydrogeology of the aquifer.

How Does Groundwater Become Contaminated?

Because the hydrologic cycle has many interconnected phases, all contaminants released into the environment — whether to air, land or water — have the potential to reach groundwater. Most groundwater contamination, however, results from spills, leaks or other releases on the surface of the land or just below it.

Some chemicals are broken down to harmless substances by exposure to light and air. Others, like gasoline, are volatile and **evaporate** quickly if spilled above the ground. Once a substance is below the surface of the ground, however, there is little opportunity for elimination, or **attenuation**, of the contaminant with the aid of light and air.

Fortunately, soil itself is a good treatment system for many pollutants, such as sewage wastes from properly installed and maintained septic systems. Soil acts as a filter for large particles such as bacteria and sediment. Soils with very fine particles (e.g., clay) and large amounts of organic humus are much more effective at trapping pollutants than coarse-grained sands and gravels typical of stratified drift. Contaminants can also be taken up by plant roots or broken down by microorganisms in the soil, a process called **biodegradation**, while others are physically or chemically bound to soil particles, through the processes of **sorption** or **ion exchange**. Metals, for example, which can be a serious problem in surface waters because of their toxicity to aquatic life, are readily bound to soil particles and so are not a common cause of groundwater contamination.

Other pollutants travel unaltered through the soil. Gasoline, for instance, flows rapidly downward through unsaturated soil. More viscous materials, like motor oil, move more slowly through the pores of the soil and may **persist** within the pore spaces, continuing to enter groundwater at a slow rate for many years. Substances that are highly soluble in water, such as salt, become dissolved in precipitation and move freely through the soil to groundwater.

Processes Affecting Environmental Fate of Contaminants in Soil and Groundwater

Attenuation Process ↓	Attenuation Value (Ability to Protect Groundwater)			
	Land Surface	Unsaturated Soils	Below Water Table	Bedrock Aquifer
VOLATILIZATION	high	low	none	none
CHEMICAL REACTION (oxidation, hydrolization, photodegradation)	high	high	medium	medium
DILUTION/DISPERSION	high	high	medium	low
BIODEGRADATION	low	medium	low	low
SORPTION/ION EXCHANGE	low	medium	medium	low

When a contaminant reaches the saturated zone and enters groundwater, it is likely to become a serious and persistent problem because there is little opportunity for further attenuation. Chemical breakdown processes requiring light and air are not active here, although a few substances, such as certain pesticides, may **hydrolyze** (react with water) to form less hazardous products; certain anaerobic microorganisms also can break down pollutants in the absence of free oxygen. The coarse soil particles of productive stratified drift aquifers are not very effective in removing pollutants by filtration or sorption. For the most part, then, once a pollutant reaches Connecticut's groundwater, the only significant mechanism of attenuation is **dilution** and **dispersion** by the flow of water through the aquifer.

...When a contaminant reaches the saturated zone and enters groundwater, it is likely to become a serious and persistent problem because there is little opportunity for further attenuation...

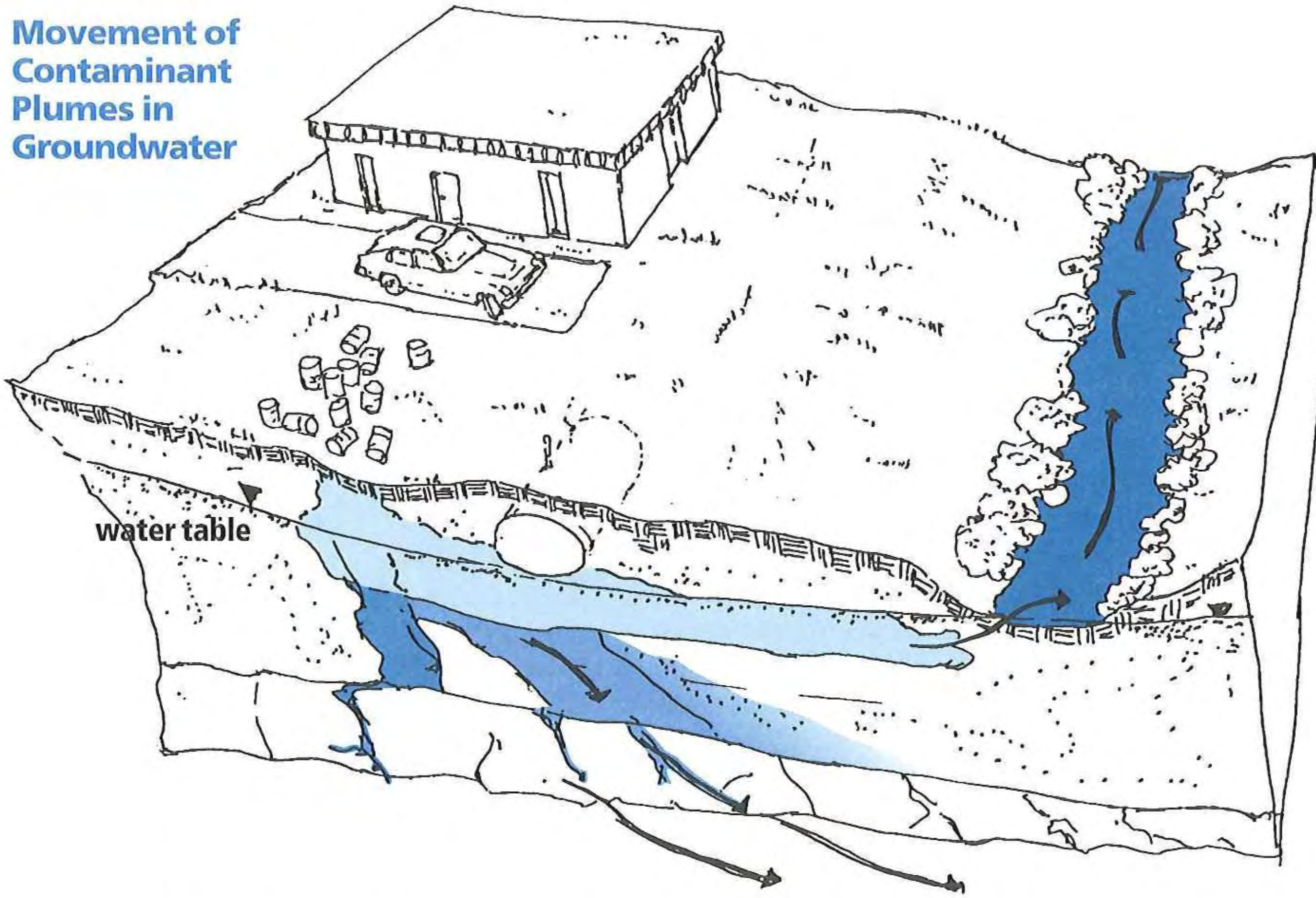
Though Connecticut does not allow the deep **injection wells** used in some states to dispose of industrial or mining wastes below the aquifer level, many shallower wells may unintentionally inject pollutants directly into drinking water aquifers. Stormwater drainage wells, disposal wells for industrial wastewaters, dry wells connected to floor drains in automobile service areas, septic systems and abandoned drinking water wells can all carry pollutants directly into groundwater if they are improperly used to dispose of hazardous materials.

Another potential but rare source of groundwater contamination is **induced infiltration**, which results from the pumping of wells. A well pumping large quantities of water from a sand and gravel aquifer can draw water from a nearby river or stream into the well. Few such incidents are known in Connecticut where rivers or streams present a significant threat to wellfields. In areas near the state's coast, overpumping of wells can cause salt water to be induced into wells, another infrequent source of contamination in Connecticut.

The relatively slow rate of groundwater flow does not allow much turbulence or mixing. A source of pollution will thus create a discrete **plume** of pollution extending from its source (such as a landfill or leaky storage tank) along the groundwater flow path to the point where the groundwater is either pumped from a well or discharged into a surface water body. The movement of the plume depends on the properties of the pollutant — its weight and whether it dissolves in water.

As a groundwater contaminant moves further from its source, it slowly becomes diluted, dispersed, and less concentrated. Consequently, at some distance from the pollution source, the groundwater may again be safe to use. This is the principal behind the Public Health Code's requirements for minimum separating distances between a public or private well and a septic system. It is also the reason for water utility ownership of land immediately surrounding public wells. In reality, however, this "safe" distance depends on the hydrogeology of the aquifer, as well as the type and concentration of pollutants. A simple minimum separat-

Movement of Contaminant Plumes in Groundwater



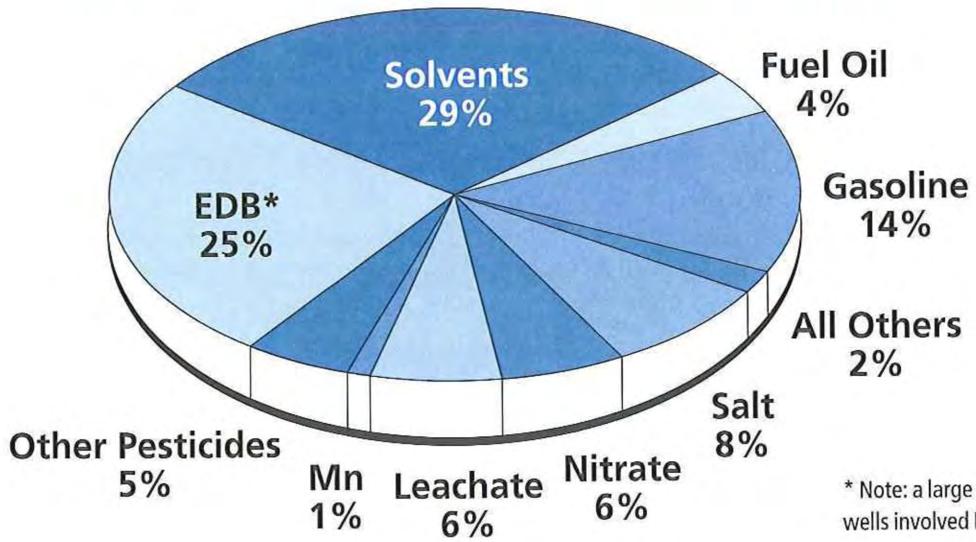
Pollution underground will create a discrete plume extending from its source (such as a leaky storage tank) along the groundwater flow path to the point where the groundwater is either pumped from a well or discharged into a surface water body. The movement of the plume depends on the properties of the pollutant, soil characteristics, and the groundwater flow path.

ing distance may not be adequate to protect wells from the varied pollution risks associated with many land uses.

What Contaminates Groundwater?

The most common causes of well contamination in Connecticut have been improper handling, storage, and disposal of solvents; leakage from petroleum storage tanks; application of pesticides; leachate from solid waste disposal sites; and improper storage of road salt. Many of these contaminants are controlled today far better than they were in the past. For example, most cases of pesticide contamination resulted from the use of ethylene dibromide, or EDB, a pesticide now banned. Landfills, underground storage tanks and road salt storage are regulated much more rigorously than they were a decade ago, as is the disposal of hazardous wastes. Yet new cases of groundwater contamination continue to be reported each year. Though some are the result of earlier land uses that left behind an environmental legacy, many are from recent, often accidental, releases by existing land uses.

Known Well Contamination By Type



* Note: a large percentage of pesticide contamination of wells involved EDB, a substance which is now banned.

The contaminants that can potentially affect groundwater are numerous, and they vary widely in their impacts. Some natural elements cause primarily aesthetic or practical problems that affect the taste, odor or appearance of groundwater but have no health affects. These include natural concentrations of dissolved minerals such as calcium that make water "hard," or iron and manganese that may precipitate to form dark specks in the water and discolor clothing washed in it.

Many human-induced contaminants, however, are known or suspected risks to human health. Acute health problems may result from bacterial or viral contamination of groundwater by sewage. Radionuclides such as radon, which may occur naturally in groundwater in some areas, are also a known health hazard. The most common and troublesome groundwater contaminants, however, are the organic and inorganic chemicals used in a wide range of human activities. With few exceptions, little is known about the long-term health effects that may result from consuming these substances at low levels in drinking water. Only a few of the more than 50,000 chemicals currently in commercial production have ever been studied to evaluate their long-term health effects. Drinking water standards have been set for a small number of substances that are known or suspected human health risks, but only public wells are monitored regularly for these substances. In private wells, which are seldom tested, contaminants may go undetected for a long time.

Contaminants react differently and have different impacts in the surface and groundwater environments. For example, a small amount of a volatile organic chemical discharged to a stream may rapidly volatize with little water quality impact. The same amount, discharged to groundwater can render a score of private wells unusable. On the other hand, a large amount of waste, high in Biochemical Oxygen Demand

(BOD), discharged to the ground, can be properly treated with little impact on groundwater. The same type and volume of waste delivered to a small stream can consume all the available oxygen resulting in a fish kill.

Types and Sources of Common Contaminants

Synthetic Organic Chemicals and Hydrocarbons

By far, the greatest share of groundwater contamination is caused by organic chemicals, mostly of man-made origin (synthetic organic chemicals or SOCs), along with refined hydrocarbons from naturally occurring sources such as petroleum. This group includes the toxic substances used as solvents in industries, businesses and homes; pesticides used on lawns and agricultural fields; refined liquid fuels, such as gasoline and heating oil; petroleum distillates used in industry; and oils of many types and uses.

...By far, the greatest share of groundwater contamination is caused by organic chemicals, mostly of man-made origin...

A few chemicals in this group, such as benzene and vinyl chloride, are known human carcinogens. Several other compounds, notably some of the chlorinated solvents, are suspected human carcinogens or are known to promote cancer in animal tests. For the great majority of these substances, however, little is known about their health effects. Drinking water standards have been established for only a handful of SOCs. These standards are often very low, less than 5 parts per billion (the equivalent of about one drop in a swimming pool). Because the "safe" concentrations are so low, even minute amounts of these chemicals in groundwater can threaten human health. What's worse, these chemicals are often **persistent** in soil and water and may affect groundwater for many years.

Landfill Leachate

Until recently, nearly all of the trash produced in Connecticut ended up in a landfill. Every landfill in the state generates leachate — smelly, polluted liquid created by precipitation seeping through the refuse. The composition of landfill leachate is highly complex, reflecting the variety of materials in our trash. Heavy metals, numerous organic decomposition products, and synthetic organic and inorganic chemicals are typically present.

Historically, landfills were located wherever land was inexpensive — in swamps, abandoned gravel pits, or on hilltops — with no thought as to potential future groundwater impacts. Over 120 wells have been contaminated by leachate from 19 of the state's 200 solid waste landfills, making many areas unsuitable as future public water supplies. Today, the siting of new landfills is restricted to areas where valuable groundwater resources will not be affected. Also, recycling and incineration of solid wastes are helping to reduce our use of landfills. Because landfills are now strictly controlled, we can plan accordingly to reduce the impacts of leachate.

Salt

Salt (sodium chloride, or NaCl) is highly soluble and can persist for a long time in groundwater. In very high concentrations, salt in drinking water can cause corrosion of pipes, pumps and fixtures, releasing toxic metal ions into the water. At such high concentrations, the salty taste is usually so noticeable that the water is undrinkable. But salt can increase health effects such as hypertension even in low concentrations that do not affect the taste of the water.

All of Connecticut's 169 towns, as well as the Connecticut Department of Transportation (DOT), use salt for winter road maintenance. Until recently, salt was frequently stored in open piles, where it could be dissolved by precipitation and leached into the groundwater. DEP has developed Best Management Practices (BMPs) for road salt storage and application to prevent groundwater contamination. At DOT facilities, salt is now stored within structures or beneath tarpaulins. Many municipalities have similarly improved their practices.

Salty groundwater contamination can also be caused by "backwash" from residential water softeners. Discharge of these salts to septic systems is illegal. Many users, however, are unaware that discharging water softener backwash can pose a risk to area wells.

Nitrates

Nitrogen is a major component of living tissue and a necessary plant nutrient. Nitrates are nitrogen salts that occur widely as a result of decomposition and other natural processes, but at high concentrations they affect the ability of the human circulatory system to provide oxygen, especially in infants. The principal sources of nitrate contamination in groundwater are animal manures, fertilizers and malfunctioning septic systems. Nitrates are highly persistent in groundwater.

Treatment of Contaminated Groundwater: The Case for Prevention

Most contaminants can be removed from groundwater by various forms of treatment, but usually at considerable cost, time, and disruption. Some forms of contamination are relatively easy to remove. Bacteria, for example, can be killed by boiling or chlorinating water. Many hydrocarbons can be evaporated by exposure to air. Aeration is a treatment method used for many large public supplies contaminated by volatile organic compounds. Carbon filtration can also remove many of these compounds. Filtration units are available to treat individual faucets or household supplies. The effectiveness of such systems — which require regular maintenance — varies widely. Some contaminants, like nitrates and salt, can only be removed by expensive reverse osmosis units. Removing these contaminants in large amounts of water is not generally feasible.

When remediation is infeasible or prohibitively expensive, the only alternative may be to abandon a supply and find an alternate source of water — i.e., construct a new well in an uncontaminated aquifer or connect owners of contaminated private wells to a public water supply. In many cases of well contamination in Connecticut, the costs of remediation or development of an alternative supply have ranged from a few hundred thousand dollars to well over a million dollars. When these costs are considered along with the fact that contaminated wells may go undetected for a long time, it is clear that pollution prevention through controlling high risk land uses and activities is the most effective way to protect groundwater.

The cost of remediation or development of an alternative supply can be well over a million dollars.

Principal Groundwater Contaminants: Their Sources, Environmental Fate, Health Effects and Treatment Options

Contaminant (with examples)	Sources	Environmental Fate	Health Effects	Treatment Options
Solvents • naphthalene • toluene • benzene • tetrachloroethylene • trichloroethane • vinyl chloride	• industry • vehicle maintenance • metal parts cleaning, degreasing • drycleaning • furniture finishing • printing • gasoline additives • household products • improper disposal in septic systems • septic tank cleaners	**Surface:** Volatilize readily **Soil:** Resist biodegradation; breakdown products may be toxic **Groundwater:** very mobile and persistent; some are denser than water and move downward to bedrock	Vinyl chloride and benzene are known human carcinogens; some others, especially chlorinated solvents, are suspected carcinogens; can cause a range of other health effects, including central nervous system effects, irritation of respiratory and gastrointestinal systems.	Evaporation by aeration (public supplies); carbon filtration
Petroleum products • gasoline • motor oil • fuel oil	• vehicle maintenance • automobile service stations • heating fuel tanks • industrial machinery	**Surface:** light oils, gasoline volatilize readily **Soil:** low solubility, may persist in pore spaces and be leached into groundwater by precipitation for long period **Groundwater:** gasoline and light oils float on water table; heavy oils less mobile, move down to bedrock	Petroleum products can produce a variety of toxic effects, including central nervous system damage, irritation of respiratory and gastrointestinal system; benzene, a gasoline additive, causes leukemia in humans.	Same as solvents
Pesticides • chlorinated hydrocarbons (chlordane, EDB) • carbamates (Aldicarb) • organophosphates (Malathion)	• agriculture • lawn applications • pesticide manufacture, storage	Highly variable: chlorinated hydrocarbons tend to be very persistent, highly susceptible to leaching, and produce toxic breakdown products; other pesticides may be degraded to inert forms or bound to soil particles	Wide range of toxicity to humans; many pesticides are highly toxic, cause central nervous system damage, or are suspected carcinogens.	Some can be removed by carbon filtration or aeration
Nitrates	• agriculture (fertilizers and manures) • lawn care • septic systems • sewage treatment and collection systems	**Soil:** highly soluble, very mobile; can be taken up by growing plants **Groundwater:** very mobile and persistent	Nitrates react with blood hemoglobin, impairing ability to transport oxygen; infants can be fatally affected at relatively low concentrations.	Reverse osmosis (small quantities)

Principal Groundwater Contaminants: Their Sources, Environmental Fate, Health Effects and Treatment Options (cont'd)

Contaminant (and examples)	Sources	Environmental Fate	Health Effects	Treatment Options
Biologic pollutants • bacteria • viruses • parasites	• septic and sewerage systems • agriculture (manures)	**Soil:** bacteria and parasites readily removed by soil filtration	Bacteria cause gastrointestinal diseases (cholera, typhoid, enteritis, hepatitis); viral disease from groundwater uncommon, but no good lab tests available.	Disinfection by boiling, chlorination or other methods
Salt (sodium chloride)	• road salt storage and application • home water-softener backwash • salt water intrusion (near coast)	**Soil:** very soluble, highly mobile **Groundwater:** mobile and persistent	Excessive sodium intake has been linked with high blood pressure and hypertension.	reverse osmosis (small quantities)
Metals • lead • chromium • silver • mercury • aluminum • iron • manganese	• metal finishing and metal working industries • photo and x-ray processing • printing • painting • automobile radiator and body shops	**Soil and Groundwater:** metals readily removed by reactions with soil particles under neutral to basic conditions but soluble and mobile in acidic waters	Some heavy metals (e.g., lead, chromium) are highly toxic, cause developmental and nervous system effects; iron, manganese low in toxicity.	pH adjustment to neutralize water and filtration of precipitate
Acids/bases	• industry • photo processing • printing • painting • automobile radiator and body shops	**Soil and Groundwater:** mobile and persistent except in presence of natural pH buffers (e.g., limestone)	Acids and bases are rarely a significant health hazard in themselves, but they affect the solubility of toxic metals.	pH adjustment

Biological Pollutants

The most widespread source of disease-causing bacteria and viruses in groundwater is subsurface sewage disposal — commonly called the septic system. Though such contamination was once a serious problem, outbreaks of bacterial and viral disease from polluted wells are rare today because of improved septic system and well regulation. A septic system, if properly designed, installed and maintained, can effectively remove pathogenic organisms such as bacteria and viruses. However, a system which fails to allow for the percolation of sewage wastes through a sufficient amount of unsaturated soil may not effectively remove these organisms.

Bacteria are relatively large and are filtered readily by soil particles. A simple lab test reveals whether they are present in groundwater, so they can be monitored easily. Viruses are much smaller and can be more readily carried through pore spaces in soil. Also, their presence cannot be detected easily in the lab, so little is known about how frequently they are found in drinking water supplies.

Groundwater and Land Use

Almost any human use of land involves some handling of chemicals or produces wastes that can contaminate groundwater. Activities that use or store large quantities of chemicals or produce large quantities of wastes present the greatest risk, especially if they involve chemicals that can readily be carried into groundwater and that tend to persist for a long time in soil or water. A substance's use is important too: activities and processes in which chemicals or wastes can readily be spilled or leaked onto the ground — or below its surface, through underground tanks, septic systems or floor drains connected to drywells, for example — carry a higher risk than closed systems designed to minimize the possibility of releases to the environment.

The risks to groundwater associated with various activities is presented below. A more complete list of specific land uses, their potential hazards and controls is included in Section B of the Supplement.

Ranking Of Land Use Categories By Risk To Groundwater

- Water company-owned land
- Federal, state, local, private nature preserves
- Open space (passive recreation only)
- Private land managed for forest products
- Public parks and recreation areas

- Field crops — permanent pasture, hay, orchards
- Low-density residential (2-acre lots)
- Churches, municipal offices

- Agricultural production — vegetables, corn, dairy, livestock, poultry, nursery, tobacco
- Golf courses
- Medium-density residential (1/2- to 1-acre lots)

- Institutional uses — schools, hospitals, nursing homes, prisons *
- High-density residential (less than 1/2-acre lots, multifamily housing) *
- General commercial (discharging sewage only) *

- High-risk commercial — gasoline stations and automotive services, dry cleaners, photoprocessors, medical services, furniture strippers, junk yards, machine shops, radiator repair shops, printing *
- Industrial — manufacturing, processing, research facilities, chemical storage *
- Waste disposal — lagoons, landfills, bulky wastes *

* Risks to groundwater quality can be substantially reduced if these land uses are served by public sewers and if stringent material storage and handling regulations and waste minimization steps are implemented, including regular monitoring and inspection.

Groundwater Risks By Zoning Categories

Residential and Agricultural Activities *(Single and Multi-Family)*

Fertilizers — Use, Storage, Disposal
Fuel Oil Storage
Household Hazardous Materials — Use, Storage, Disposal
Pesticides — Use, Storage, Disposal
Septic Tank Additives
Septic Systems — Improper Siting, Design, Installation, Use, Maintenance
Stormwater Runoff
Waste Oil and Antifreeze Disposal
Water Conditioner — Discharges
Water Conservation — Lack of It

Commercial Activities *(Trades and Services)*

Aircraft Landing Fields
Agricultural Wastes
Asphalt Testing
Automobile — Dealers, Body Shops, Repair Shops, Service Stations, Washes, Undercoaters
Beauty Salons
Bulky and Mixed Municipal Waste Disposal
Colleges, Trade Schools
Concrete Molding
Dry Cleaners
Food Processing
Fuel Oil Distributors
Furniture Strippers
Golf Courses
Greenhouses and Nurseries
Hazardous Waste Treatment, Storage, Disposal
Junk and Salvage Yards
Lawn Care
Laundromats
Medical Facilities — Dental, Hospitals, Veterinarians
Nursing and Rest Homes
Photo Processing
Printers
Repair Shops — Appliances, Small Engines
Research Laboratories
Road Salt Storage
Septage, Sewage Sludge Spreading
Storage, Warehousing of Pesticides, Fertilizers, Chemicals
Transportation Terminals

Industrial Activities *(Manufacturing and Processing)*

Adhesives, Sealants
Batteries
Chemicals
Electrical Equipment
Electroplating
Explosives
Fertilizers
Glass
Instruments
Iron, Steel and Non-Ferrous Metals
Leather
Machine Shops
Metal Heat Treating
Paint and Ink
Paving and Roofing
Pesticides
Pharmaceutical
Plastic and Fiberglass Fabricating
Pulp and Paper
Rubber Goods
Smelting
Steam and Electric
Stone and Clay Products
Textiles
Wood Processing

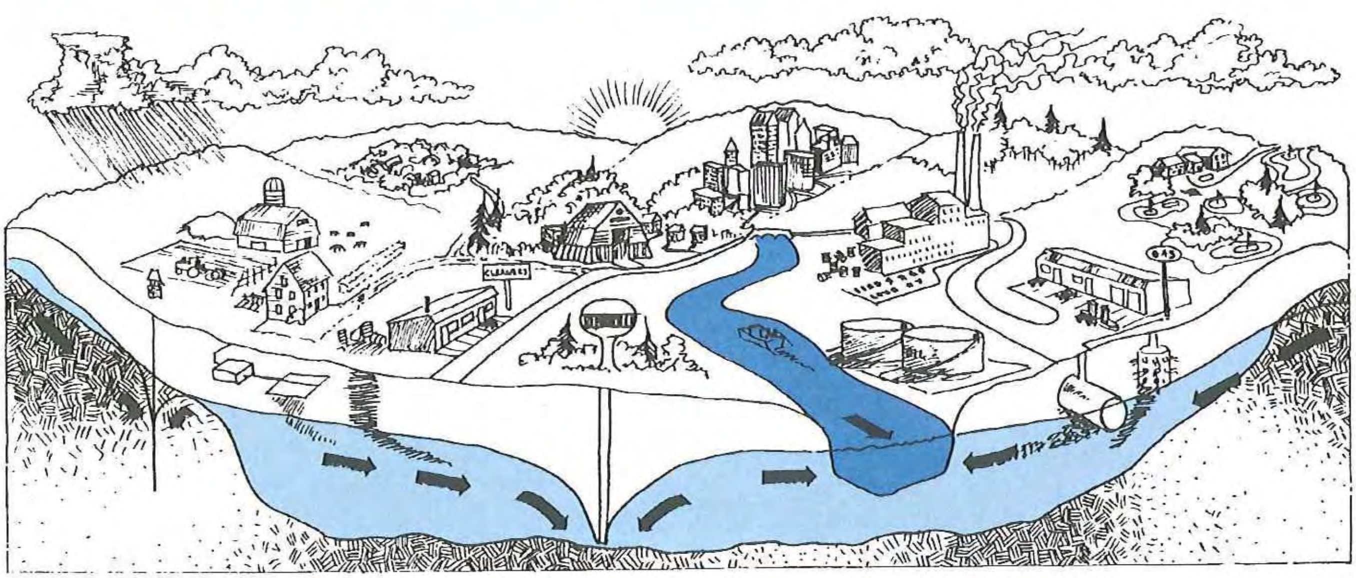
High Risk Land Uses

Land uses posing the highest risk of groundwater contamination include waste disposal sites, industries that use large amounts of chemicals or which may produce process wastewater, and certain types of commercial activities that involve regular use of substances such as solvents that present a significant threat to groundwater.

Waste disposal activities such as landfills, industrial wastewater lagoons and sludge piles have historically been a major source of groundwater contamination. A wide variety of contaminants can leach from these facilities directly into subsurface soil and water where there is little or no opportunity for attenuation. Waste disposal is now rigorously controlled through federal and state laws, and these facilities are generally prohibited on aquifers used for water supply.

Industrial uses are often associated with groundwater contamination because of the wide range of synthetic organic chemicals and other hazardous substances used or produced in industrial processes. Even though the use, storage, and disposal of these hazardous materials is subject to increasingly strict regulation, it is difficult to control accidental spills, leaking underground storage tanks, outdoor storage areas, and improper handling of chemicals or wastewaters. Public sewers can reduce some risk from wastewater discharges. Some industrial uses, such as assembly or warehouse storage of nonhazardous components, pose fewer risks of contamination. Nevertheless, once industrial use is established, it can be difficult to monitor and control changes in processes and materials or the types of industry that occupy industrial buildings.

Sources of Potential Groundwater Contamination



Source: Connecticut DEP

Virtually any human activity in which chemicals or wastes may be released to the environment has the potential to pollute groundwater.

Commercial facilities that pose a high risk to groundwater include automotive services, machine shops, dry cleaners, furniture strippers and printers. These establishments generally do some processing and use large amounts of solvents, including the very hazardous chlorinated solvents, that can escape to the environment through spills and leaks or by flushing into floor drains leading to dry wells, storm sewers or septic systems. Facilities such as automobile service stations that store gasoline or other fuels in underground tanks can present an especially serious risk because of the possibility that large amounts of contaminants may be released before a leak is detected. Many other types of commercial services, such as photoprocessors, medical and veterinary offices, laboratories, and funeral homes, use chemicals that can contaminate groundwater if they are washed down the drain into septic systems. The risk from many of these facilities can be substantially reduced if they are served by public sewers, use closed systems, and/or employ waste minimization techniques.

...The risk from many commercial facilities can be substantially reduced if they are served by public sewers, use closed systems, and/or employ waste minimization techniques...

Moderate to Low Risk Uses

High concentrations of human activity, characteristic of **urban land** and major **transportation corridors**, can pose a threat to groundwater because of the intensity of land use, the large areas of impervious surfaces, and the relative scarcity of vegetated areas that provide opportunity for natural removal of pollutants. High-volume motor vehicle traffic is associated with release of hydrocarbons and heavy metals, salt and potential spills of hazardous materials or contaminants in transit. General commercial use and high-density residential areas can entail significant risk to groundwater as a result of the intensity of human and vehicle activity.

Institutional uses can also pose a significant risk to groundwater, either because they involve hazardous chemical usage, like hospitals or school laboratories, or simply because they produce large amounts of domestic sewage, such as nursing homes and prisons. These risks can be largely eliminated if the institutions are served by public sewers or use closed loop systems and/or waste minimization; but where they are dependent on septic systems, careful controls are needed to prevent groundwater contamination.

Risks posed by **residential** uses are generally low, depending on their density, type of activity, and proper sewage disposal. Generally, residential developments with more than one housing unit per acre served by on-site septic systems and wells can be a concern for groundwater quality because it may be difficult to find soil conditions well suited to septic system construction and to provide adequate separation from private wells. If the density is very high, there may be cumulative effects from small amounts of contaminants (i.e., nitrates and phosphates) released from individual systems and other non-point sources. Even properly designed septic systems can contaminate groundwater if used improperly. Household hazardous wastes, certain home water treatment backwash, and the use of solvent-based septic system cleaners have caused well contamination. **Home occupations** that involve chemical usage, such as photographic studios, may pose special risks to groundwater through discharge of chemicals to septic systems or other improper disposal or storage practices.

...Risks to groundwater from residential developments can be reduced if they are served by sanitary sewers, but may be offset by accompanied increase in density...

Risks to groundwater from residential developments can be reduced if they are served by sanitary sewers, but may be offset by accompanied increase in density (see further discussion of septic systems and sewers). Underground tanks and associated piping for home heating fuel may be the highest residential source of groundwater contamination. A whole range of household hazardous substances, (used motor oil, solvents, lawn care chemicals) can also be a danger if improperly disposed of or otherwise misused.

Single-family homes on lots of more than 2 acres generally pose little risk to groundwater. Although large lots permit flexibility in locating septic systems in the most suitable soils and provide areas of open space, the character of the lot (buildable land) is more important. Well-designed cluster development can offer similar protection without decreasing overall density (see discussion under zoning). By clustering units on buildable land, substantial areas of permanent open space can be used to protect aquifer areas and other sensitive areas. Community septic systems can be placed where soils and groundwater conditions are most favorable, rather than located on individual lots. Pollutants such as stormwater, pesticides and fertilizers are generally reduced in cluster development because fewer roads and lawns are created.

Agriculture can cause groundwater pollution from the storage, handling and use of pesticides, manures and fertilizers. Certain activities, such as concentrated animal production or intensively grown crops or nursery stock, need careful management to prevent pollution. Other activities, such as organic farming, permanent pasture and hayfields, involve little pesticides and fertilizer use and pose correspondingly lower risks.

Pesticides vary widely in their ability to contaminate groundwater. Some are degraded quickly or are readily absorbed by soil particles, while others are more persistent. The quantity, timing, and manner of application can also affect their environmental fate. Pesticides have been responsible for more incidents of well contamination in Connecticut than any other type of chemical, but the great majority of these were caused by EDB, a crop fungicide applied directly to the soil, which is now banned.

Nitrogen in manures and fertilizers can cause nitrate contamination in groundwater. Most incidents of nitrate contamination have resulted from very concentrated nitrogen sources, such as intensive farming of livestock without adequate sanitary controls or improper storage of animal manure or chemical fertilizers. Even field applications of fertilizer, however, can cause contamination of groundwater if nitrogen is applied at a higher rate than can be used by the growing crops.

Open space uses, such as golf courses, that require substantial use of pesticides and fertilizers can also pose risks. Most recreational open space, such as parks and ballfields, can be managed less intensively and involves little risk. Natural open space, whether used for passive recreation (e.g., hiking), carefully managed forest production or as nature preserves, represents the lowest level of risk to groundwater. Such open space, especially if managed by or in cooperation with a water utility, provides one of the most effective approaches for protecting critical groundwater resources.

Sewage Disposal and Groundwater Quality

On-site sewage disposal systems, normally septic systems, are a commonly used method for disposing of domestic wastewaters in suburban and rural areas. Many residential, commercial and even some industrial facilities use septic systems. When properly located, designed, constructed, used and maintained, septic systems provide a very effective and efficient way to treat domestic sewage and protect water quality. The primary disadvantages of on-site systems is that proper land conditions are necessary and the system does require some care and maintenance. Although land area or lot size is an important factor, the "character" of the lot (soil, geology, hydrologic conditions) is what primarily determines a site capacity for sewage disposal.

Historically, problems with septic systems are a result of hydraulic overloading of a site (too much sewage for the site) and most failures from this result in surface water quality impacts. Groundwater quality impacts are primarily the result of misuse of the system by discharging wastes other than domestic wastewater, such as solvents, chemicals, or household hazardous wastes. Well water quality impacts may also be the result of very old development areas where minimum Health Code requirements were not met for system siting and design. Modern code requirements and strict administration of them has helped eliminate many of these concerns. It should also be noted that community septic systems and large (5,000 GPD) systems require State DEP permits, which demand intensive site hydraulic and pollution renovation analysis, as well as monitoring.

Public sewers help alleviate sewage disposal concerns, especially to solve problems from historic high density development with failing septic systems and to address disposal needs for planned urban areas. However, sewering areas will not address other non-point sources of pollution such as; stormwater, chemical spills and leaks, intensive lawn care, and other miscellaneous releases. In fact, the secondary effect of sewers may be to intensify the type and the density of land use which could increase non-point pollution sources and further degrade water quality. A recent USGS report which studied the effects of land use on groundwater quality verified this concern. For this reason sewering solutions may need to be accompanied by carefully planned land use regulations. Further discussion regarding sewers can also be found in the management section.

How Can Risks to Groundwater be Controlled?

Since adequate and safe drinking water is essential to quality of life, protection of groundwater supplies should be given high a priority in determining how a community's land will be used. Although many mechanisms are available to control risks to groundwater, the most effective approach is pollution prevention.

Siting controls or prohibition of high-risk uses, however, may be appropriate only in the most sensitive areas. Severely restricting land uses over extensive areas is usually impractical. For bedrock aquifers, it is rarely possible to determine the specific recharge areas of individual wells adequately to justify severe restrictions on land use. Even in sensitive areas, prohibiting new high-risk uses will not solve the problem of controlling existing activities that are hazardous to groundwater.

...Land use prohibitions may be appropriate only in the most sensitive areas; other types of controls, such as Best Management Practices, are needed...

In these situations, other types of controls can be used to reduce risks to groundwater. Even industries and high-risk commercial facilities can substantially decrease the potential for groundwater contamination by following Best Management Practices (BMPs) or standards for the storage, use and disposal of hazardous materials. In some facilities, it may be feasible to make process changes that will reduce potential hazards by increasing the recycling and reuse of hazardous substances, or by substituting safer chemicals. In many cases, simple structural changes such as covered storage areas or containment can eliminate significant risks.

BMPs can also reduce groundwater hazards from agriculture. Proper manure storage and fertilizer application can control nitrate pollution. Pesticide hazards can be reduced by selecting chemicals that are readily degraded or removed by soil absorption. An integrated pest management (IPM) program can be instituted to ensure maximum effectiveness of pesticides.

The remaining sections of this manual provide specific information on the control measures available to reduce the risk of groundwater contamination. Part III describes the federal and state programs that are in place to help protect groundwater. Part IV focuses on how your community can select and implement control strategies that will meet its specific groundwater management needs.

For More Information

Groundwater Contamination in the United States (Pye, Patrick, and Quarles, 1983), one of the first publications to report on the extent and significance of contamination of this resource, discusses in detail the environmental fate and health impacts of contaminants in groundwater, as well as treatment options and their costs. Well-illustrated and readable, it presents a great deal of useful information in the form of charts, graphs, and tables.

A detailed evaluation of the health effects associated with contaminants in drinking water can be found in the National Academy of Sciences publication *Drinking Water and Health* (NAS 19, and subsequent supplements).

The Cape Cod Aquifer Management Project (CCAMP) has developed a valuable *Guide to Contamination Sources for Wellhead Protection*. This guidebook provides good summary explanations of attenuation processes and descriptions of major groundwater contaminants, their behavior in the environment and their health effects. It also describes 32 specific land use activities that have the potential to contaminate groundwater and recommends BMPs to control these risks.

The DEP Water Management Bureau has developed BMPs for many types of industrial and commercial facilities. The DEP document, *BMPs for the Protection of Groundwater, A Local Officials Guide*, which covers such widespread land uses as automobile service stations, dry cleaners and photographic developers, includes a description of the activity, the chemicals involved and associated risks, as well as detailed recommendations for facility design and chemical use, handling, and storage to minimize risks to groundwater. Available BMP guides are listed in section D of the Supplement.

A technical study of land use and groundwater quality, *Effects of Land Use on Quality of Water in Stratified Drift Aquifers in Connecticut* (Report 91-200), was conducted by the USGS.

Part III

The Groundwater Partnership: Federal, State and Local Roles in Protecting Groundwater

...Many of the conditions that threaten groundwater cannot be adequately controlled through federal or state programs. Local action is also needed...

Over the past two decades, the federal government and the State of Connecticut have created a growing network of programs to protect groundwater. Many Connecticut communities have also acted locally to protect their groundwater resources.

Groundwater protection requires active cooperation at all these levels. Federal laws and regulations of the U.S. Environmental Protection Agency (EPA) authorize or mandate many programs to protect groundwater and help to provide funding. The states have the major responsibility for implementing groundwater programs that are, at a minimum, consistent with federal requirements. States must develop plans based on their particular hydrologic conditions and water needs. State agencies implement groundwater protection through permit programs and other regulatory methods such as monitoring and enforcement .

Many of the conditions that threaten groundwater, however, cannot be adequately controlled through state or federal programs. Local action is needed to help manage the multitude of pollution sources, to make land use decisions that will protect groundwater, and to provide day-to-day vigilance for activities that can cause contamination. Local governments and citizen groups have a key role in education and in creating awareness within the community about groundwater issues.

As understanding of the importance of groundwater resources has grown, the focus of groundwater protection initiatives at all levels of government has shifted and expanded. Groundwater protection programs, like those for surface supplies, focused first on regulating and monitoring **drinking water use** to protect human health, identifying and setting **water quality standards** for critical drinking water resources, and **control of major pollution sources**, such as waste disposal facilities, in these critical areas. Monitoring water quality does provide limited protection, but detects contamination once it has occurred and may necessitate costly treatment and clean up. Because it has become clear that groundwater is uniquely vulnerable to certain types of persistent, long-term contamination, groundwater programs have in the past several years increasingly emphasized long-range **water-supply planning**, **pollution prevention**, and **land use management** to ensure an adequate supply of safe drinking water for our future.

Federal Groundwater Protection

The major federal laws directly affecting drinking water supplies are the **Clean Water Act** and the **Safe Drinking Water Act**. The first law stating a comprehensive national water protection policy was the 1972 amendments to the Clean Water Act, which were directed at eliminating the discharge of pollutants into waters of the United States. As defined in this law, "waters of the United States" do not specifically include groundwater. Many of the pollution prevention measures set forth in the Clean Water Act, however, help states to protect groundwater.

The Safe Drinking Water Act (SDWA), enacted in 1974, directed the EPA to establish drinking water standards and to delegate to the states the primary responsibility for enforcing the regulations and supervising public drinking water systems. To date, EPA has set Maximum Contaminant Levels (MCLs) for a number of substances in drinking water, and secondary standards, based primarily on aesthetic considerations (taste, odor, color), for a few others. The EPA is in the process of setting standards for some 59 additional substances, including many synthetic organic chemicals, as required by 1986 amendments to the SDWA. The SDWA also regulates the use of underground waste disposal wells, and created the federal "Sole Source Aquifer" program to recognize areas highly dependent on groundwater for drinking supplies.

The 1986 SDWA amendments also directed EPA to initiate far-reaching programs for groundwater protection. One of the most significant provisions is a requirement that all states develop "wellhead protection" programs to safeguard public wells. Federal groundwater protection programs continue to follow a strategy of building and enhancing groundwater protection at the state level.

Other major federal laws help to protect groundwater by controlling the manufacture, use, and disposal of hazardous materials. The **Resource Conservation and Recovery Act** (RCRA) regulates hazardous wastes to prevent contaminants from leaching into groundwater from landfills, underground storage tanks, surface impoundments and hazardous waste facilities. The **Comprehensive Environmental Response, Compensation, and Liability Act** (CERCLA) authorizes the government to clean up contaminated ("Superfund") sites. Its 1986 amendments, the **Superfund Amendments and Reauthorization Act** (SARA) establish a community "right-to-know" about the presence of hazardous materials and set forth reporting requirements for chemical users, as well as emergency planning provisions for the containment and cleanup of hazardous spills. The **Toxic Substances Control Act** (TSCA) authorizes EPA to control the manufacture and use of toxic chemicals. The **Federal Insecticide, Fungicide, and Rodenticide Act** (FIFRA) provides for control of pesticide manufacture and use. In addition to helping to prevent groundwater contamination, these laws, through their registration and reporting requirements, provide valuable information resources that communities can use in identifying and controlling groundwater risks.

Connecticut's Groundwater Management Programs

The Connecticut Department of Environmental Protection (DEP) is responsible for most of the state's groundwater protection programs. The Connecticut Department of Public Health (DPH) has specific responsibilities for protecting and regulating public water supplies; some of these responsibilities are delegated to the water utilities or to local or regional health districts under DPH oversight.

State groundwater programs can be grouped into four broad categories: **planning**, **monitoring**, **permits** and **enforcement**. The following pages summarize the program elements and legislative authority, and also provide an historical perspective on groundwater protection.

Statewide Groundwater Management Programs

- Drinking Water Standards
- Water Quality Standards And Classification
- Waste Source Controls
- Enforcement And Remediation
- Statewide Bans Of Toxic Substances
- Best Management Practices
- Victim Compensation
- Water Quality Management Planning
- Water Use And Allocation
- Water Supply Quality Monitoring
- Research
- Computer Management Of Resource And Use Date
- Technical And Financial Local Assistance
- Education
- State Aquifer Protection Area Program
- Nonpoint Source Pollution Management

Regional And Local Groundwater Management Programs

- Land Use Control
- Aquifer Identification
- Aquifer Protection
- Performance Standards
- Well Protection
- Household Wastes
- Monitoring And Inspections

Planning

- **Water quality standards (Conn. Gen. Stat. Section 22a-426)**: Establishes the State's Water Quality Standards Program. Requires DEP to adopt, and amend as necessary, standards for the water quality of the state. The Standards are intended to serve as clear and objective public policy statements for the management of the State's water resources. Groundwaters are classified by existing and potential use, considering competing demands for use ranging from water supply to waste disposal. The Standards also establish allowed discharges, and priorities for monitoring and enforcement actions.

Groundwater Classifications, Uses, and Discharges Allowed*

CLASS GAA

Existing or potential public drinking water supplies without treatment, base flow for surface waters.

Compatible Discharges: Restricted to discharges of human or animal origin, acceptable agricultural practices, backwash from public drinking water treatment, and other minor cooling and clean water discharges.

CLASS GA

Existing private and potential public drinking water supplies without treatment, base flow for surface waters.

Compatible Discharges: Those permitted in Class GAA areas plus septage disposal or disposal of wastes of predominantly human or animal origin. May receive substances of natural origins or materials that easily biodegrade and pose no threat to drinking water supplies.

CLASS GB

May not be suitable for potable use unless treated because of existing or past land uses, industrial process and cooling waters, base flow for surface waters.

Compatible Discharges: All the above plus it may be suitable for receiving certain treated industrial wastewaters when the soils are an integral part of the treatment system. The intent is to allow the soil to be part of the treatment system for easily biodegradable organics and also function as a filtration process for inert solids. Such discharges shall not cause degradation of groundwaters that could preclude future use for drinking without treatment, or prevent maintenance or attainment of adjacent surface water designated uses.

CLASS GC

May be suitable for certain waste disposal practice due to past land use or hydrogeologic conditions which render these groundwaters more suitable for receiving permitted discharges than development for public or private water supply. Down gradient surface water quality classification must be Class B or SB.

Compatible Discharges: All the above plus other industrial wastewater discharges that do not result in surface water quality degradation below established classification goals. The intent is to allow the soil to be part of the treatment process, if conditions in Connecticut's Water Quality Standards are met.

* Note: The State policy regarding the discharger's responsibility for ownership or other property rights to a groundwater discharge zone of influence, is implemented during the State's discharge permit review process. Such requirements apply to any discharge into any type of groundwater classification.

• **Well siting and separating distances (Conn. Public Health Code Section 19-13-B51)**: Authorizes DPH to approve siting of new water supply wells, and establishes standards and minimum well separating distances for sewage disposal and other sources of pollution.

• **Inventory of hazardous waste disposal sites (C.G.S. Section 22a-8a)**: This legislation required DEP to compile an inventory of any sites in the State which have been used for toxic or hazardous waste disposal and to submit a report on the findings to the Connecticut General Assembly.

• **Water utility plans (C.G.S. Section 25-32d and Section 25-32h)**: Requires Connecticut water utilities, both public and private, serving more than 1,000 people, to prepare and submit long-range water supply plans for review and approval by the Connecticut Department of Public Health (DPH). Also requires development and approval of regional water supply plans aimed at ensuring overall coordination of water supply development in the State.

• **Inventory of groundwater and surface water resources (C.G.S. Section 22a-351)**: This legislation enables DEP to participate in cooperative programs, such as its cooperative program with the United States Geological Survey, designed to collect hydrogeologic information to support the State's groundwater management program. The statewide data base developed under this cooperative program is utilized in developing groundwater classifications, and also provides resource data for permitting and enforcement issues.

• **An act concerning the protection of public water supplies C.G.S. Section 8-2, 8-23, 25-32f)**: This public act makes the Commissioner of the Department of Public Health a party to any municipal board and commission hearings concerning proposed changes in planning or zoning regulations that would affect public water supply. It also allows the Department of Public Health to appeal a local land use decision if it is deemed to have adverse impacts on public water supplies. Finally, the act requires municipal and land use commissions to consider protection of existing and potential public surface and groundwater supplies in their planning and zoning regulations.

• **Discovery and evaluation of hazardous waste disposal sites (C.G.S. Section 22a-133b)**: Required DEP to implement a program for continuing site discovery efforts initiated in 1979 and determining whether or not sites pose a threat to public health or the environment.

• **Disposal site inventory (C.G.S. Section 133c)**: Requires DEP to maintain an inventory and method of recording the status of disposal sites.

• **Inventory of contaminated wells and leaking underground storage tanks (C.G.S. Section 22a-134q)**: Requires DEP to compile an inventory of contaminated wells and leaking underground storage tanks and submit a report to the General Assembly annually.

• **Aquifer protection area program (C.G.S. Section 22a-354a to 22a-354bb)**: DEP is to implement a Wellhead Protection Program for the State's stratified drift aquifers. The program includes delineation of Wellhead Protection Areas, completion of land use inventories, adoption of land use regulations governing potential sources of contamination, and preparation of farm management plans. Legislation requires water utilities serving more than 1,000 people to delineate protection areas for wells in stratified drift aquifers using DEP mapping procedures.

• **An act concerning notice to water companies and health directors of storage of hazardous substances on certain watersheds (C.G.S. Section 29-307a,b.)**: Expanded the reporting requirements for employers who use, store, or produce hazardous materials to include local fire marshals. It also requires any hazardous substance information be provided to any water company that has wellfields or reservoirs within the watershed.

• **Statewide environmental plan (C.G.S. Section 22a-8)**: Requires DEP to formulate, and periodically update, a statewide environmental plan for the management and quality of the environment and the natural resources of the State. The plan must establish environmental goals and objectives and describe strategies for their achievement. This legislation gives DEP authority to develop and revise its "Environment/2000" plans.

Monitoring

• **Groundwater monitoring related to public water supply wells (C.G.S. Section 25-32)**: Requires regular testing of raw and finished water at public water supply wells by water utilities, with results sent to the Department of Public Health quarterly. This implements EPA's drinking water standards requirements by overseeing the approval, monitoring, and testing of public water systems.

• **Groundwater monitoring related to discharges to groundwater (C.G.S. Section 22a-430; C.G.S. Section 22a-5a)**: Legislation requires that a permit be issued before any person or municipality may discharge any substance into the waters of the State. The DEP may (and typically does) require periodic water quality monitoring as a condition for permit issuance.

• **Groundwater monitoring related to sources of groundwater pollution (C.G.S. Section 22a-5a and 22a-432)**: Gives DEP the authority to issue an order to take necessary steps to correct existing or potential sources of pollution. The DEP requires water quality monitoring to demonstrate compliance with that order.

Permits

• **Wastewater discharges (C.G.S. Section 22a-430, as amended by Public Act 84-21)**: This Act requires that a DEP permit be obtained for the discharge of any wastewater into the state's surface waters, groundwaters, or sewer systems, except that DEP has delegated authority for issuing discharge permits for small and moderately sized (less than 5,000 gallons of domestic sewage per day per septic system) to the DPH. The DPH has, in turn, delegated the authority to permit small septic systems (less than 2,000 gallons per day) to local health departments.

• **Solid waste landfills (C.G.S. Sections 22a-207 to 251)**: This requires that all solid waste disposal facilities obtain a permit from DEP in order to insure compliance with landfill operating requirements. A wastewater discharge permit is also required under Section 22a-430 CGS for a facility of this type.

• **Hazardous waste (C.G.S. Section 22a-114 to 133, 22a-449(c), 22a-454)**: DEP's Waste Management Bureau enforces regulations covering hazardous waste handling for generators, i.e., anyone generating in excess of 100kg of hazardous waste per month, and issues permits and enforces regulations that apply to hazardous waste treatment, storage and disposal facilities. Legislation also prohibits disposal of hazardous waste in a hazardous waste disposal facility unless specifically authorized in the statute.

• **Water diversions (C.G.S. Section 22a-365 to 378)**: Connecticut's Water Diversion Policy Act states that the diversion of more than 50,000 gallons per day of water from any surface or groundwater source requires a permit from DEP, as well as an impact study addressing groundwater quality problems resulting from diversion of contaminant plumes.

• **Agricultural operations (C.G.S. Section 22a-46, 66z & 430)**: Large-scale animal and agricultural operations require a waste water discharge permit from DEP due to the potential for non-point pollution from excessive organic nutrients.

Enforcement

• **Groundwater pollution abatement program (C.G.S. Section 22a-432; C.G.S. Section 22a-433; C.G.S. 22a-430(d))**: These three statutes give DEP its authority to issue orders to abate pollution of the waters of the state. Specifically, if DEP finds that any person or municipality is discharging to waters of the state either without a permit or in violation of a permit, an abatement order may be issued. If DEP finds that any person has established or is maintaining a facility or conditions which "reasonably can be expected to create a source of pollution to the waters of the state," DEP may issue an order to correct that potential source of pollution. When DEP issues an order, the owner and the operator are jointly and severally responsible for abating the pollution or correcting the condition. Enforcement of the state's groundwater discharge program, including its regulation of injection wells, is carried out under this legislation.

- **Enforcement powers (C.G.S. Section 22a-6(a)(3))**: Gives the Commissioner of Environmental Protection his or her overall powers, including the power to issue orders and seek injunctions to enforce environmental statutes, regulations and permits.

- **Threats to Water Supply Sources (C.G.S. Section 25-32g)**: Allows the Department of Public Health Commissioner to issue orders to abate immediate threats to sources.

- **Water supply orders (C.G.S. Section 22a-471)**: In 1982, Connecticut became the only state in the nation to establish the authority to order a polluter to provide potable drinking water to parties with contaminated groundwater. Immediate delivery of bottled water is required, along with the provision of treatment or an alternate water supply for long-term use, according to a plan submitted to and approved by DEP, in consultation with the State Department of Public Health. This Act was amended in 1985 to require the state take responsibility for making grants available to municipalities, and for providing temporary water and conducting engineering studies where no responsible party can be identified.

- **Remediation of hazardous waste disposal sites (C.G.S. Sections 22a-133e)**: Requires remedial action for all sites on the inventory of hazardous waste disposal sites and sites reported to the Department under the Property Transfer Act.

- **Property transfer program (C.G.S. Section 22a-34(a-e))**: The program governs the transfer of properties where hazardous waste has been generated, managed or disposed. When a transfer of such an establishment occurs, the owner or operator must submit a negative declaration if there has been no release of hazardous waste, or must certify that the owner or operator will contain, remove, or otherwise mitigate the effects of any discharge, spillage, uncontrolled loss, seepage or filtration of hazardous waste on-site. Remediation of identified sites is overseen by technical staff of the program, and is driven through the issuance of a Consent Order, Administrative Order or Court Stipulated Judgment.

- **Site discovery program (C.G.S. Section 22a-133b, 22a-133h)**: This series of legislation establishes the State's Site Discovery Program which is responsible for overseeing the discovery and evaluation of hazardous waste disposal sites, and establishment of procedures for the containment, removal and mitigation of hazardous wastes. The program acts to identify and alert DEP about violations of state statutes, regulations and permits, and the need for enforcement. All identified hazardous waste disposal sites are recorded on a state inventory. A toll-free telephone line is established to receive anonymous information from the public leading to the discovery of hazardous waste disposal sites.

• **Underground storage tank program (C.G.S. Sections 22a-449, 22a-432, 22a-433)**: DEP is required to adopt regulations for all non-residential underground fuel storage tanks. The regulations require tightness testing and replacement of unprotected steel tanks. Legislation authorizes DEP to order the abatement of pollution from leaking underground storage tanks.

• **RCRA corrective actions and closure (C.G.S. Sections 22a-449(d))**: Authorizes the development and implementation of programs and regulations necessary to enforce Subtitle I of the Resource Conservation and Recovery Act of 1976, as amended.

• **Storage and application of road salt (C.G.S. Section 22a-474)**: Requires DEP to adopt regulations dealing with the storage and application of road salt.

• **Delegation (C.G.S. Section 22a-432)**: This legislation allows the Commissioner of Environmental Protection to establish regulations delegating authority to qualified local officials to carry out activities such as performing inspections, obtaining samples, and issuing notices of violations.

Other Nonregulatory Programs

Many potential sources of groundwater contamination, such as the storage and use of chemicals in commercial establishments and homes, are far too widespread to be effectively regulated by the state. To better control these risks, DEP is placing increasing emphasis on prescriptive measures, education, technical assistance, incentives, and local community and business support to implement **pollution prevention practices**.

• **Best management practices (BMPs)**: An important DEP initiative has been the development of Best Management Practices: procedures or methods of reducing or eliminating releases to the environment. Industries are being required to implement these BMPs as a condition of their state discharge permit renewals. BMPs are also developed for many commercial facilities, such as dry cleaners, auto service, and machine shops; BMPs for agricultural operations have been developed in cooperation with the state Department of Agriculture and the University of Connecticut Extension System. Because many potential miscellaneous pollution sources are usually not covered by permit processes, widespread adoption of these BMPs will depend on education of chemical users and incentives for compliance, as well as on active support by local communities. Sections C and D of the Supplement include general BMPs and BMP guides available from the DEP Water Management Bureau.

• **Waste minimization and recycling**: In waste management programs, too, many initiatives are underway to reduce risks that are not adequately controlled by regulation. There is a growing focus on controlling small quantities of hazardous wastes through voluntary compliance. Industries and businesses are encouraged to reduce the quantities of hazardous wastes they generate, both through recycling and by changing processes to use less hazardous materials. The state has encouraged municipalities to sponsor household hazardous waste collection days. A permanent center has been established at the South Central Connecticut Regional Water Authority, and other regions are considering similar centers. Countywide agricultural collection days have been proposed to enable farmers to dispose of pesticides, and similar programs are being considered for commercial small-quantity generators of hazardous wastes.

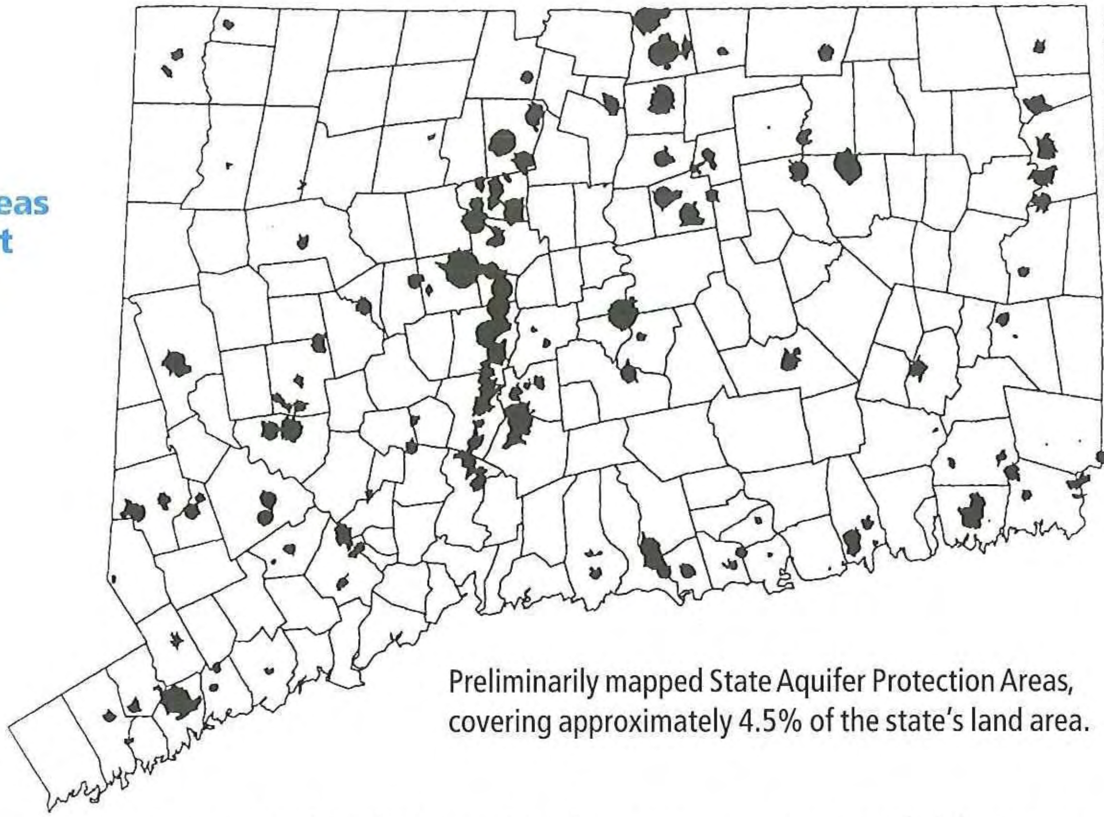
Land Use Controls

Decisions about how people can use their land have traditionally been left largely to local boards and commissions. Land use decisions, freighted with so many issues of personal freedom, economic well-being and quality of life, are generally best made by those who have local knowledge, interest and accountability within their own communities. Groundwater, however, can involve land use issues that may transcend individual communities. Pollution of drinking water has direct and widespread effects on public health, and its consequences can be so serious and so costly that they may exceed an individual community's ability to correct them. Furthermore, groundwater has no regard for political boundaries and must be managed from a resource perspective. Connecticut's "Aquifer Protection Act" increased the state's authority to control land use in certain significant aquifer areas, but this program covers only large public water supply wells in stratified drift.

• **Local Land Use Requirements**: Prior to 1985, protection of water supplies was one of many factors that could be considered by municipal planning and zoning commissions in their land use decisions. In that year, Connecticut planning and zoning law was amended to require that local zoning regulations and town plans of development consider the protection of existing and future public water supplies. Legislation also gave the Commissioner of Public Health the right to appeal municipal zoning decisions that would affect public water supplies and to issue orders to stop activities that create "imminent and substantial damage" to a public water supply. Subsequent legislation (Section 8-3i, CGS) gives public water utilities the right to review and comment on applications to zoning and other local boards within water supply watershed areas.

• **Aquifer Protection Area Program**: During the 1980s, DEP inventoried high and moderate-yield stratified drift aquifers in Connecticut, and identified water quality issues critical to protection of these groundwater supplies. As the state gathered information on these aquifers, it

Aquifer Protection Areas in Connecticut



Preliminarily mapped State Aquifer Protection Areas, covering approximately 4.5% of the state's land area.

became evident that special land use measures were needed for protection of these resources, particularly aquifer areas recharging large public water supply wells. In order to protect public water supplies, it was necessary to define the land area that contributes water to the wellfield, thus providing a legally defensible basis for the land use regulations. A series of state laws adopted in 1988 and 1989 require Connecticut water utilities to map the land areas overlying aquifers recharging certain stratified drift wells (those serving over 1,000 people) and provide a framework for land use controls in these wellhead protection areas, termed "Aquifer Protection Areas." These laws require state agencies, public water utilities and municipalities to work together to protect these areas.

• **Aquifer mapping**: All water utilities serving 1,000 or more people are required to map Aquifer Protection Areas for their existing and future stratified drift wells, delineating the locations of wellfields, and recharge areas. Two levels of mapping are required. The preliminary Level B mapping is based primarily on existing geologic information about known aquifer characteristics. The final Level A maps are based on extensive hydrogeologic information, test data and computer modelling, and are the final regulatory boundary. Aquifer Protection Areas are expected to cover less than 4.5% of the state's land.

• **Regulation of "Aquifer Protection Areas"**: Within designated "Aquifer Protection Areas," the state and towns share regulatory responsibilities. The towns must conduct a land use (pollution sources) inventory and must adopt land use regulations once the Aquifer Protection Areas are delineated.

The state land use regulations under this law will include Best Management Practices or standards for regulated activities and certain high-risk uses will be prohibited from locating in these areas. Agriculture will be regulated by DEP in conjunction with state farm agencies. DEP will develop a model municipal Aquifer Protection Area regulation and must review and approve the regulations adopted by towns. Water utilities provide technical assistance to the towns and will assist with inspections in the regulated areas.

• **Education and technical assistance**: DEP and other agencies, including large water utilities, have been charged with providing education, training and technical support to municipalities. Other aspects of the program will include a strategic groundwater monitoring plan, guidelines for land acquisition around public wells, an aquifer protection study of transportation concerns, and research directed at protecting other types of water supply aquifers.

What Should Local Communities Do to Protect Groundwater?

Even though an impressive array of state programs helps protect Connecticut's groundwater, communities play a critical role in the groundwater partnership. Your community can help assure it will have the safe drinking water it needs by acting at the local level — and that, of course, is the reason for this manual. Many options are available to you and different things will be suitable for different towns.

Mandated programs for Aquifer Protection Areas will most likely fall short of meeting your town's groundwater protection needs for several reasons:

- The town may not have stratified drift aquifers.
- Stratified drift aquifers or wellfields within the town may not be covered by the program.
- Much of the community's water may come from bedrock aquifers.
- All or part of the town may be served only by private wells.
- Even in areas that will become an Aquifer Protection Area, the town may need interim protection measures.

For these reasons, we urge ***every*** town to take stock of its groundwater resources, identify protection needs, and develop a town-wide groundwater management plan. Since the state's efforts are necessarily directed first to controlling major pollution sources and protecting the most critical resources, local communities should pay special attention to those activities that DEP cannot regulate effectively or enforce adequately. Residential heating oil tanks and small commercial tanks, for instance, are not covered by state underground storage tank regulations, but if these tanks leak they can cause significant groundwater pollution, as can improper municipal storage and handling of road salt. Perhaps most important, the state cannot reasonably regulate all use of hazardous chemicals in homes, businesses and small industries. Local communities are encouraged to join with state efforts to prevent groundwater pollution by bridging state program gaps.

If necessary, your community should consider adopting supplemental regulations for groundwater protection. Nonregulatory programs to build community awareness and an ethic of groundwater protection are also essential to create a consensus for action and to reduce risks not effectively controlled by regulation. By working through the inventory and planning process described in this manual, your community will be able to select and implement the regulatory and nonregulatory tools necessary to achieve its needs. The next section describes the array of local measures available to protect your community's groundwater.

For More Information

Federal laws and programs to protect groundwater are described in detail in the American Planning Association's publication, *Local Groundwater Protection* (Jaffe and DiNovo, 1987).

EPA's *Citizen's Guide to Groundwater Protection* provides a brief overview of these programs. Publications describing specific federal programs are also available from the EPA.

Information on permit requirements and other state regulatory and nonregulatory programs can be obtained from the responsible state agencies. A summary description of state programs and responsible agencies is included in section E of the Supplement to this manual. Information for towns affected by the Aquifer Protection Act is available from the DEP Water Management Bureau.

Several state reports discuss important groundwater resources and the critical need for protection efforts. They include: *Protection of High and Moderate Yield Stratified Drift Aquifers* (DEP 1987), and *Report of the Aquifer Protection Task Force* (1989).

Part IV

Tools For Local Groundwater Management

There are many ways to build a community groundwater protection program. No single method can fill the groundwater protection needs of every town. Your town may want to select a variety of measures that address your specific water supply concerns and use them to build an appropriate and effective program.

The basic building blocks of a local groundwater protection program are fairly simple. They include managing land use activities through **regulatory** measures, such as zoning and other town ordinances, and a variety of **nonregulatory** programs. Regulation is appropriate to address the most pressing threats of groundwater contamination, to provide maximum protection for the most sensitive aquifer areas, and to control specific activities that can pose very high risks. For these situations, regulations offer two advantages: they place the responsibility for protection of groundwater on the individual owner or user of land, and they provide legal authority for enforcing this responsibility. Their principal limitation is that regulations are effective only if they can be enforced, a task that will require adequate town staff.

Nonregulatory programs are needed to bridge the "enforcement gap," to address larger concerns that are a community responsibility, and to foster a voluntary commitment to protecting groundwater by the community as a whole and by its individual citizens. Regulatory measures can work in tandem with widespread voluntary participation to provide the groundwater protection your community needs.

Regulatory Measures: Planning and Zoning

Zoning is one of the most powerful and versatile tools communities have to control land use, and thus help protect groundwater. One of its major purposes is to protect the public health and welfare by preventing inappropriate or incompatible uses of land. Connecticut state law specifically charges local planning and zoning commissions with considering the protection of existing and potential public water supplies in their regulations and decisions.

Connecticut Towns with Local Groundwater Protection Regulations

Approximately one-third of Connecticut's 169 municipalities have enacted local regulations to protect their groundwater. The ordinances vary widely in their rigor, comprehensiveness, relationship to water supply, and in the scientific basis used to determine protection area boundaries. To date, towns that have groundwater protection regulations in place include:

Bozrah	Enfield	Killingworth	Ridgefield	Tolland
Canterbury	Essex	Litchfield	Salisbury	Wallingford
Cheshire	Farmington	Mansfield	Scotland	Waterford
Columbia	Granby	Middletown	Sharon	Westbrook
Cornwall	Groton	Newtown	Simsbury	Westport
Coventry	Guilford	North Haven	Southbury	Willington
Cromwell	Haddam	No. Stonington	Southington	Wilton
Danbury	Hamden	Old Lyme	Stafford	Windham
Durham	Hebron	Old Saybrook	Stonington	Woodbury
East Hampton	Kent	Plainfield	Thomaston	
East Lyme	Killingly	Redding	Thompson	

Zoning regulations specify prohibitions, conditions, or standards for land uses. The zoning permit process can also provide opportunity for detailed review of new land use proposals to ensure that they do not involve conditions that create a high risk to groundwater. In addition, most communities already have an enforcement capability through the zoning enforcement officer that can be used to ensure compliance with groundwater protection provisions of the zoning code.

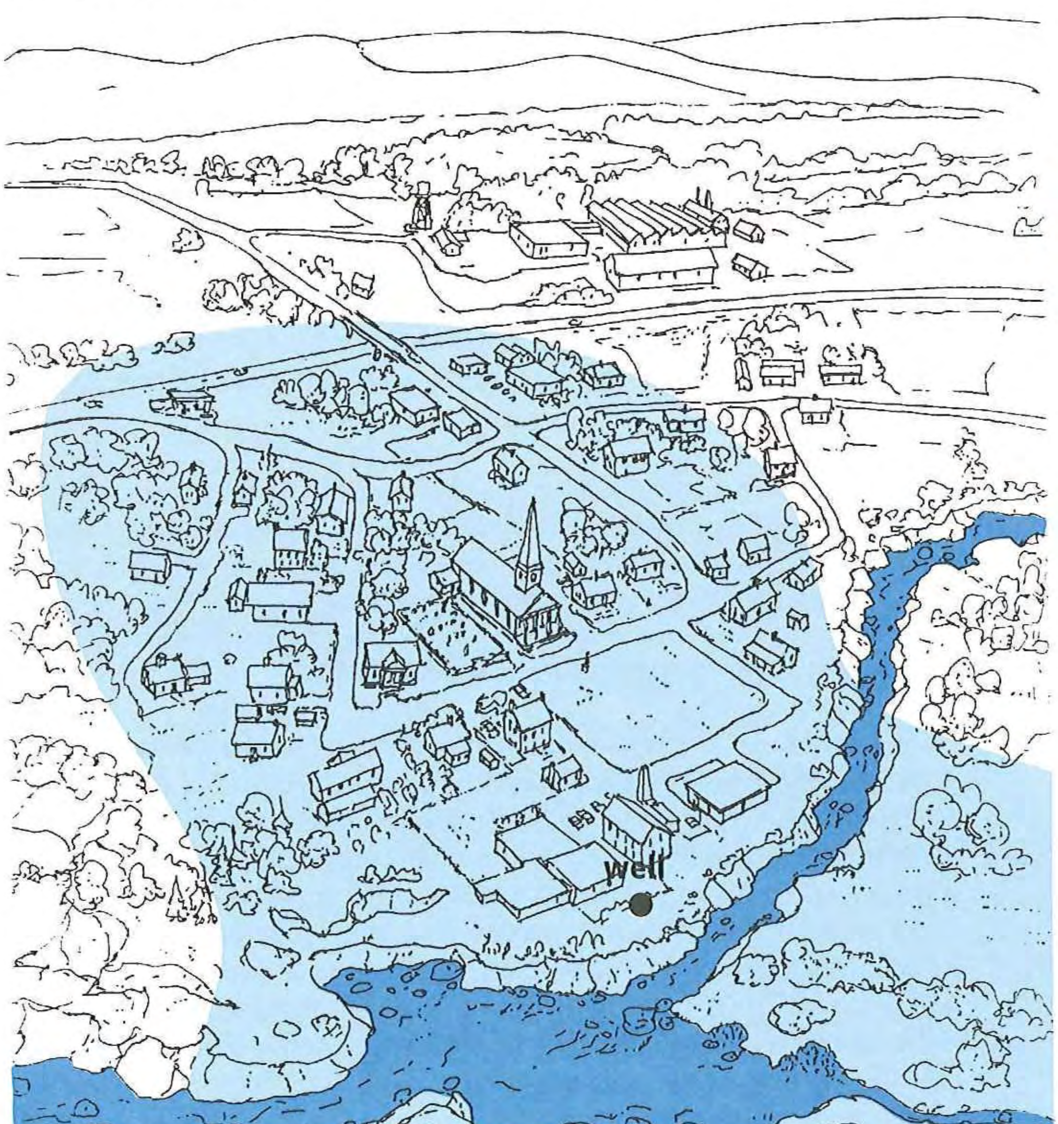
Before selecting and adopting zoning changes to help protect groundwater, however, the community should take a careful look at its Plan of Development. Connecticut towns are required to prepare and update these plans every 10 years. Although they have no direct regulatory force, PODs are intended to express the community's long-term goals. Zoning regulations should be a means for achieving these goals, and zoning changes must consider the adopted plan of development and will be much easier to defend if faced with legal challenges consistent with the plan.

Therefore, your town's plan of development should be amended to incorporate your groundwater protection goals and objectives. Since the plan of development is not regulatory, you are likely to encounter less resistance in this process than if you immediately set out to enact more restrictive zoning regulations. The plan provides a context for zoning changes that will help to ensure that all their implications have been considered. For example, if you decide to prohibit high-risk uses in sensitive groundwater areas, where (if anywhere) will you allow them? Incorporating water-protection goals into your plan of development also provides an additional opportunity for public education and consensus building before you embark on the potentially more controversial process of amending the zoning code, and it will put the community in a stronger position to meet any future legal challenges to its zone changes.

Zoning regulations provide several mechanisms that can be used to protect water quality. The zoning map divides the town into various zoning districts that differ in the types and intensity of uses that are permitted. **Use restrictions** specify the uses permitted in each zoning district; they may prohibit certain uses and allow others only after special review procedures to determine whether the specific proposal is appropriate for the location. Zoning regulations also control development density by setting minimum lot sizes and other **bulk requirements** such as setbacks from lot lines and maximum permissible coverage of the lot by buildings. These regulations can also be used to specify **design and performance standards** that control how specific uses may be implemented.

Aquifer/Wellhead Overlay Zone

One of the most effective ways to impose special use restrictions and other protective regulations within a sensitive aquifer area is the overlay



Protection Overlay Zone

zone. The overlay zone delineates the boundaries of aquifer and recharge area, or wellhead areas if known, on the town zoning map and specifies measures for their protection without changing the underlying zoning districts. Specified high-risk uses can be prohibited in the aquifer zone even if they are permitted in the underlying district. Zoning applications within the aquifer zone may be required to meet designated standards, undergo special review, or obtain an aquifer protection permit prior to approval. A model aquifer overlay zone regulation is included in Section D of the Supplement to this manual.

An aquifer overlay zone is most effective where significant groundwater resources exist, risk of groundwater contamination is high, and the boundaries of the sensitive area can be mapped accurately, such as high-yield stratified drift aquifers. Another possible approach is to designate two aquifer protection zones, providing the highest degree of protection and review within the recharge area of public supply wells or aquifers, and imposing less stringent restrictions on areas where there are scattered private wells.

Rezoning

In some cases, it may be desirable to change the underlying zoning district. This approach may be needed when a sensitive aquifer area is already zoned for a highly inappropriate use, such as industry, and other areas are available. With an aquifer protection overlay that prohibits high risk uses, land use in an industrial zone may be extremely restricted. Rezoning to a residential, limited commercial, or mixed-use zone, for example, can provide land use opportunities compatible with groundwater protection.

Zoning changes to protect public wells may increase the pressure to locate high-risk uses in areas with private wells. When an aquifer overlay zone is adopted, the town may want to rezone other areas to provide the best locations for necessary high risk uses.

Large-lot Zoning and Buildable Land

Another type of zoning modification that may help to protect groundwater is increasing lot sizes to decrease the density of use. In residential areas not served by public water and sewers, large lots (two acres or more) may be appropriate where soil conditions dictate. Other zoning tools that are more helpful include prorating lots by excluding areas of unsuitable soils and wetlands from the calculation of minimum lot size, referred to as buildable land criteria. In nonresidential areas, an additional means of controlling density may be to establish a standard for maximum coverage of the lot by impervious surfaces, including parking lots and roads, or to require that a minimum percentage of each lot remain in vegetated open space.

Cluster Zoning

In many circumstances, cluster zoning is a more conducive than large-lot zoning for groundwater protection. "Cluster zoning" here refers to provisions in the zoning regulations that allow units to be constructed on smaller lots, provided that a portion of the property remains in open space; it does NOT mean increasing overall density permitted on a parcel, although in some cases a small density bonus may be included as an incentive to developers to use cluster design. Unlike zoning for larger lot sizes, cluster zoning does not reduce the number of units that can be built on a given piece of property, and therefore does not negatively affect land values.

Clustering may make it possible to place construction where it is least likely to impact groundwater resources, and to locate wells and sewage treatment systems in the most suitable areas, in some cases by using community rather than individual septic systems and wells. Good cluster subdivision designs can greatly reduce the length of roads serving a development and the amount of lawn that may be treated with pesticides and fertilizers, while preserving large areas of natural vegetation that provide the greatest protection to groundwater and reduce development costs. Cluster regulations can be more difficult to administer, however.

Cluster zoning is generally applicable to subdivision development on fairly large parcels of land. It may be desirable to make clustering mandatory in certain areas, unless waived by the zoning commission, or to include incentives to design cluster rather than conventional subdivisions. Most important, if cluster zoning is intended as a method of protecting water quality, that objective should be stated in the regulation, and site plans should be reviewed critically to determine whether adequate protection measures are included in the proposal.

Design and Performance Standards

Zoning regulations can incorporate specific standards to prevent contamination of groundwater. These may specify structural measures to be incorporated in the design of a facility, such as requiring that chemical storage areas be roofed and enclosed to contain leaked or spilled material. Alternatively, they may specify required performance criteria, such as requiring a system capable of preventing ground- and surface-water contamination. A combination of these standards usually is the best approach. Section D of the Supplement includes an example of recommended design and performance standards for aquifer protection.

Permitting Procedures

The procedure for granting zoning permits in aquifer areas or town wide can make groundwater protection a decision criterion. In sensitive areas proposed uses could be reviewed on a case-by-case basis to evaluate how it may affect groundwater.

Some uses are typically subject to **site plan review** by the planning and zoning commission to verify that they meet specific requirements. This type of review is appropriate when the review criteria can be stated in terms of very specific design standards.

When the planning and zoning commission must exercise a greater degree of judgment, however, as in determining whether a specific use is appropriate for a particular location, a **special permit** could be required. The special permit procedure gives the commission more discretion in deciding whether to grant a permit based on whether it meets stated zoning objectives and criteria.

Zoning permits are ordinarily required for new construction, and hence provide limited control over changes of use in a building once it is occupied. Some towns have addressed this problem by requiring **change of use permits** within aquifer areas.

Subdivision Regulations

These regulations provide for the manner in which land can be divided for building purposes. Groundwater protection can be included in the public health and environmental provisions of these regulations including measures for adequate sewage disposal, adequate and safe water supply, stormwater management and open space dedication for sensitive areas.

Transfer of Development Rights

Some towns have zoning provisions that permit transfer of development rights (TDR). This allows developers to develop noncritical lands at higher densities by transferring permitted development rights from more sensitive areas, which are then permanently protected. The system can be very flexible for uses the landowner and the easement holder agree upon. Administration can be cumbersome.

Local Ordinances

While planning and zoning controls can effectively reduce groundwater risks from newly proposed facilities, other techniques are needed to deal with existing facilities and uses. In addition, ordinances can regulate certain uses townwide, not just in a specified groundwater protection zone, particularly if much of the town gets its water from bedrock wells.

Because health districts or local health departments have environmental health responsibilities, it may be logical for them to implement groundwater protection ordinances. The health code gives the health director broad powers to inspect and issue orders to abate health risks from potential groundwater pollution, particularly for small commercial or industrial activities not effectively regulated at the state level.

Activities that a town might control through ordinances include the storage and handling of hazardous materials, underground storage tanks (especially residential and small commercial tanks not covered by state regulations) and the protection of private and small community wells. Some model ordinances are included in section D of the Supplement.

Any ordinance should state its purpose, specify the requirements or standards, and include penalties for violation. Enforcement issues should be considered when developing an ordinance. What town department will be responsible for inspections, approvals and follow-up on violations? Will there be sufficient local resources to enforce the ordinance once it is adopted? The fire marshal should be consulted regarding any ordinance dealing with flammable liquids such as gasoline or fuel oil.

Hazardous Materials

A local hazardous materials ordinance can be an important component of local groundwater protection programs. Present state and federal regulations do not completely control the storage or handling of hazardous materials as virgin products, and controls over low-volume generators of hazardous wastes are limited. Because of the great number of facilities that use hazardous materials, state agency regulation of all of these facilities is not feasible.

Local regulations, however, can provide a substantial degree of protection through a hazardous materials ordinance, either townwide or restricted to specific aquifer areas. The ordinance should include a definition of what hazardous materials are being regulated, generally by citing federal or state definitions of hazardous materials. The ordinance may specify storage and spill containment requirements for hazardous materials meeting state and federal hazardous waste storage standards. The ordinance can also require that facilities use appropriate Best Management Practices in the handling and use of hazardous materials. DEP has developed specific BMPs for a wide range of facilities, from manufacturing to agricultural operations, including many small commercial activities that involve chemical usage. The Water Management Bureau of DEP can review a proposed hazardous materials ordinance before it is adopted.

Enforcement mechanisms may include a registration requirement and the submission of "as-built" plans. Education and inspections are essential components of a successful hazardous materials ordinance.

Underground Storage Tanks

The underground storage of fuels and hazardous materials is a major threat to groundwater quality. Federal and state regulations govern the design and monitoring of large commercial underground fuel tanks. Currently unregulated by DEP, however, are residential heating oil tanks, smaller commercial tanks, and underground tanks for non-petroleum based chemical storage. Well contamination problems have resulted from underground tanks and transmission lines.

Considering Local Options for Unregulated Tanks

DEP's underground storage tank regulations do not cover all types of tanks or uses, including:

- Chemical liquids not classified as oil or petroleum (some are regulated under the federal CERCLA)
- Residential use tanks — heating oil storage of *any* size tank stored underground serving
  - single-family homes
  - rented dwellings
  - condominiums
- Non-residential use tanks less than 2,100 gallons in size used for on-site heating or stationary power production where *not* for resale or waste oil storage
- Residual fuels (viscous liquids which do not flow at temperatures less than 60-degrees Fahrenheit (No. 6 fuel oil)

In sensitive aquifer areas, it is generally encouraged to prohibit the installation of any new underground storage tanks, except for replacing existing tanks that would present a fire hazard if located above ground. The fire marshal should be involved in any modification of fuel storage requirements. Where prohibition is not feasible, underground tanks can be regulated by setting standards and requiring a registration and monitoring program similar to the state underground fuel regulations. A registration requirement could at least provide the town with an inventory of the type of materials being stored, where they are buried, and the types and ages of tanks.

Well Protection

As discussed in Part III, the state's Aquifer Protection Area Program requires new protection measures for public water supply wells in stratified drift serving over 1,000 people. Other public wells (all those in bedrock and those in stratified drift serving less than 1,000 people) and private wells are protected primarily by the state Water Quality Standards and the Public Health Code which governs the siting, construction, testing and monitoring of wells. The Public Health Code requires fixed radius setbacks from on-site sewage disposal systems and other sources of pollution to protect wells from the basic pollutants related to sewage. The required setback distances vary to some extent with well withdrawal rates and permeability of the soils. The setbacks do not, however, afford much protection for the wells from pollutants unrelated to sewage, such as hazardous materials and chemicals.

Regulatory tools such as zoning or ordinances may be used to better protect wells by setting more stringent setbacks, restricting high risk activities (such as underground fuel storage) within setbacks, or requiring additional monitoring. Hydrogeologic studies can determine the land

Public Health Code Well Separating Distance

Well Withdrawal Rate	Separating Distance*	Special Provision
under 10 gal. per minute	75 feet	(1) Separation distances shall be doubled where the soil has a minimum percolation rate faster than one inch per minute (also see Standard VIIIA). (2) Separation distance shall be increased as necessary to protect the sanitary quality of a public water supply well.
10 to 50 gal. per minute	150 feet	
over 50 gal. per minute	200 feet	

* minimum distance for sewage disposal system or other potential source of pollution

area that contributes water to a well (see "wellheads" in aquifer mapping section). Though not a reasonable requirement for every domestic well because of the costs of such a study, the use of simple hydrogeologic mapping techniques for public or community water supply wells — measuring the pumping rate of the well, aquifer permeability and topography (essentially, Level B Aquifer Protection Area mapping) — may better define areas for protection. This type of delineation is more feasible in stratified drift aquifers than bedrock. Reliable hydrogeologic information is encouraged before placing stringent restrictions on land use around wells.

Most public wells are tested on a somewhat regular basis, while private wells are only required to be tested for general potability prior to being approved for use. Additional protection can be provided by giving local authority to test wells for a wider range of possible contaminants (such as hydrocarbons), or by requiring periodic testing (once a year). This is particularly appropriate in areas of heavy industrial use (also see monitoring section). The DEP Water Management Bureau can provide recommendations on additional testing parameters or additional well setbacks.

Nonregulatory Programs

Some programs necessary for groundwater protection require a public commitment by the town. In addition to public education, such programs may include water quality monitoring, household hazardous waste collection, modifications of salt storage and use practices, extensions of sewer and water service, and acquisition of land in sensitive aquifer areas.

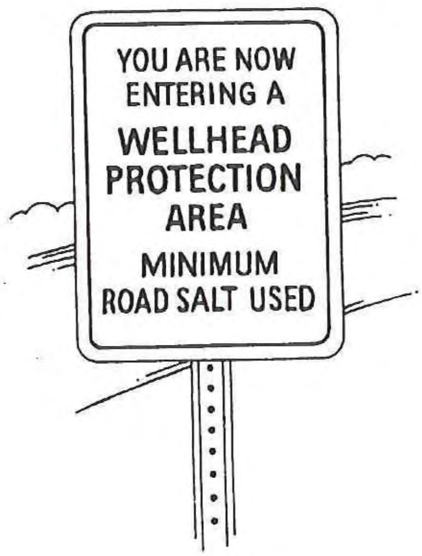
■ The First Step: Public Education and Participation

Public education is the cornerstone of every community groundwater management program. It is a key part of groundwater planning, essential to bringing about the adoption of needed regulation, and necessary to generate understanding of new regulatory requirements. It is also the means of promoting voluntary action to protect groundwater in the many activities throughout the community that cannot be regulated effectively.

...Public education is the cornerstone of every community groundwater management program...

The planning process itself provides an incomparable opportunity for community education. After the plan is adopted, you can keep this momentum going as you build your groundwater protection program, develop regulations and generate funding and support for nonregulatory programs.

You have seen in this guide that groundwater issues are often complex and far-reaching. In building a groundwater management program, you will need to communicate a great deal of information to your community. Some of the issues to cover in public educational activities include:



- a basic understanding of the community's groundwater resources and how they can be contaminated;
- proper handling, use, and disposal of chemicals, including household hazardous wastes;
- underground fuel storage;
- alternatives to toxic chemicals used by households, farms and businesses;
- proper septic system use and maintenance;
- water conservation measures;
- the content and rationale of proposed or newly adopted groundwater protection regulations;
- posting signs to identify sensitive aquifer or wellfield areas;
- protection of private wells.

One of the first and most critical targets for these information programs is, of course, local officials. Elected officials, volunteer board members and town staff will be directly involved in building your groundwater management program and in setting an example of good water protection practices. Eventually, educational outreach efforts should bring this message to the local business community, homeowners and the general public throughout town.

There are many avenues for public education. Media coverage is essential: invite reporters to your planning meetings, write a feature story on your community's water supply for the local paper, distribute press releases about milestones in your groundwater protection program. Public meetings and educational programs are also invaluable, such as special-focus workshops for small businesses or farmers on handling of toxic chemicals.

Regular communications are critical. You may want to set up an exhibit or distribute information on groundwater protection in the library or town hall; put up road signs to let people know when they are entering aquifer areas; or do a townwide mailing to distribute information of special importance. If the town is served by a public water utility, ask them to distribute information on groundwater protection as inserts in water bills.

Local civic groups such as the League of Women Voters, Rotary, Garden Club, or Land Trust may be willing to sponsor meetings or other educational programs, and they can be an important source of voluntary energy and commitment. Youth organizations like the Scouts may also take on projects. And get information into the schools: a science unit on groundwater protection will create greater knowledge and awareness of groundwater issues in the coming generation, and is an opportunity for children to carry home literature and ideas that can influence their parents' behavior.

An ongoing educational program will do more than disseminate information about specific groundwater protection issues — it will help to make water consciousness a fact of life in your community. Public education should be a continuing priority in building your groundwater management program: every plan, regulation, ordinance or publicly funded program needing community support is a further opportunity for community learning.

Although some of these programs may be costly to implement, they can be the most effective way to achieve key groundwater protection goals. Undertaking such programs is a strong and clear signal that the community is committed to protection of its water resources. They offer an opportunity to generate support for water protection efforts and help to convince landowners in sensitive aquifer areas that the community is willing to share the financial burden of protection. A demonstrated commitment to groundwater protection can be one of your town's strengths in seeking funding through state and federal programs. Cleaning up an aquifer that has become contaminated is likely to involve much greater public expenditure and give the community little choice about whether and how much to spend.

Monitoring: Groundwater, Land Use

Your information may reveal that water quality in some areas is at risk or already contaminated. If supply wells are in use in such areas, the local health department could consider a private well testing program to insure that water quality is acceptable. Monitoring wells installed between a public water-supply well and potential sources of contamination can be an effective way of discovering problems before they get to the water supply. Such "strategic monitoring" is required under the Aquifer Protection Area Program for large wells. Some towns have

Potential Contaminants to Monitor			
Land Use/Activity	**General Potability, Including Bacteria, Chemical and Physical Quality**	**Volatile Organic Compounds (includes most hydrocarbons)**	**Pesticides**
Fuel Storage		✔	
Road Salt	Chlorides, sodium		
Industry/Heavy Commercial Services	✔	✔	
Agriculture	bacteria, nitrate		✔
Septic Systems	✔		
Landfills	✔	✔	✔
Septage Lagoons	✔	✔	

required as a condition of aquifer zone permits that businesses install monitoring wells on their property and have them tested regularly. However, siting and constructing monitoring wells requires considerable hydrogeologic expertise, and is required only when necessary. Your town should work with your water utility to determine what kind of monitoring system will most effectively protect its public wells. Refer to the general guide for monitoring above. Any proposed monitoring program should be coordinated with the Water Supplies Section of the Department of Public Health or the Water Management Bureau of DEP, particularly regarding types of contaminants to sample and testing frequency.

Monitoring activities can be more useful than monitoring the groundwater. A regulatory or non-regulatory program could be developed to inspect and monitor "high risk activities," helping businesses become aware of commercial/industrial activities that threaten groundwater quality and the Best Management Practices they can take to address these problems. Critical resource areas could be specially targeted for regular monitoring or inspections.

Household Hazardous Materials

Many ordinary household activities, from cleaning to car maintenance, furniture finishing to lawn care, involve the use of hazardous materials. Motor oil, gasoline, pesticides, fertilizers, paint strippers and thinners, and household cleaning agents are among the hazardous products used in and around the home. Surplus or discarded products poured into septic systems or dumped "out back" can cause dangerous and costly contamination of groundwater.

Many Connecticut communities have reduced the risk of such contamination by organizing household hazardous waste collection days, either individually or in cooperation with neighboring towns. The collection event should be located at an accessible site and well publicized. The hazardous wastes brought to the site must be collected by a reputable, licensed waste management firm and transported to a legal disposal site, just as industrial wastes are. The collection should be repeated periodically, preferably once a year, so that residents can count on having a safe, legal disposal option available.

One group of 17 Connecticut towns, in cooperation with the South Central Connecticut Regional Water Authority, has developed the state's first permanent household hazardous waste collection center. The center, located in New Haven, is open every weekend from spring through fall to accept household hazardous waste from residents of participating towns. A licensed waste management firm staffs the center when it is open, packs wastes for safe storage at the center, and hauls away filled containers for disposal. Access to a household hazardous waste disposal facility on a regular basis has substantially increased the amount of these wastes collected from residents of the towns, compared to the one-day collections previously used.

The publicity that surrounds a household hazardous waste day collection provides an excellent opportunity to educate householders about the chemicals they use. Even if no collection is scheduled, this information should be part of the town's groundwater education program. Consumers/residents should be urged to avoid hazardous products whenever possible, to store them safely, follow instructions carefully and dispose of wastes safely.

Agriculture

If agriculture is a significant part of the economy and character of your town, you may want to coordinate with the DEP, University of Connecticut Extension System, and the Soil and Water Conservation District to develop a program covering agricultural practices. Such a program could incorporate BMPs for use of pesticides and other chemicals and storage of manure and fertilizers. Agricultural operations could prepare a management plan to minimize potential threats to groundwater. Under the Aquifer Protection Area Program, specific requirements will apply to certain agriculture. A wide range of management practices for agriculture is provided in *Manual of BMPs for Agriculture* (DEP, 1993).

Salt Storage and Use

Municipal salt storage and use are a significant but controllable source of groundwater pollution. The implementation of Best Management Practices consistent with DEP guidelines can reduce the likelihood of problems. Storage of road salt and salt-sand mixtures in sensitive aquifer areas should be avoided. A program of reduced salt use or substitution of alternative deicing agents in these areas should be considered. As part of the town's education efforts, roadside signs can be used at the boundaries of aquifer protection areas to inform motorists that minimum road salt is used in these areas.

Sewer and Water Service

In order to solve problems or meet planning goals, a town may find it necessary to provide sanitary sewers or public water service. In areas where there is a concentration of contaminated wells, or wells at high risk of contamination, connection to a public water supply may be a more economically feasible option than cleaning up the aquifer or protecting it for water supply. Public sewers can help to reduce some of the groundwater risks from existing heavy industrial and commercial use or high density residential development, but they should not be regarded as a substitute for preventing pollution. Public sewer service will not remove other major groundwater quality threats such as chemical storage and handling, and may actually further degrade quality by intensifying land use type and density. See further discussion in the Groundwater and Land Use section.

Land Acquisition and Conservation

Dedicating land in critical aquifer areas to water supply use provides the greatest degree of groundwater protection. Water utilities are required by state law to have full control over land in a 200-foot radius around a public well pumping more than 50 gallons per minute. While this distance may prevent bacterial contamination, it is inadequate to protect these wells from other types of contamination. Aquifer Protection Area regulations may provide for additional land acquisition around large public wells, helping to protect against mobile and persistent contaminants like organic chemicals.

Protecting the entire recharge area of a well through public or utility ownership is rarely feasible, but any land within the recharge area that can be controlled in this way represents a permanent reduction in potential risk to the water supply. Often land within critical aquifer areas can also help meet other open-space needs of the community — greenways for passive recreation, scenic beauty, preservation of natural areas and protection of water quality in rivers and lakes. As part of its Plan of Development, every community should develop a plan for conservation of open space, with protection of significant aquifers as one of its criteria for acquisition of land.

In addition to having an explicit open space plan, it is important for a community to demonstrate a financial commitment to land acquisition. Setting aside funds on a regular basis or through a special referendum, or collecting a fee in lieu of open space dedication for subdivisions will put the town in a position to acquire the most critical land before it is too late and will provide a substantial edge in applying for any state or federal matching grants for land acquisition.

Alternatives to outright ownership of important aquifer land include development restrictions such as conservation easements or purchase of development rights. These leave the land in private ownership but prevent its use for development, thus reducing the risk of groundwater contamination. Nonprofit conservation organizations can often help in protecting groundwater through open space acquisition. National groups like The Nature Conservancy, National Audubon Society, and the Trust for Public Lands may get involved in acquisitions that meet their own land protection agendas, and they are good sources of information and support. Your local or regional land trust, formed for the purpose of protecting open land in your community, can be a valuable partner in protecting groundwater through land acquisition. These organizations can help negotiate a purchase, accept donations of land or easements, and help to purchase and manage land.

Financing Groundwater Protection

Like governments everywhere today, it seems, Connecticut towns are experiencing financial constraints and an ever-increasing need for municipal services. With many other important tasks competing for limited funds, it can be difficult for a community to make the commitment to begin long-term planning for groundwater protection or to undertake major capital expenditures such as land acquisition. It may be equally hard to budget for the continuing operating expenses associated with regulation, monitoring and enforcement.

As some communities have learned the hard way, the cost of prevention, even when high, is far cheaper than curing groundwater contamination once it has occurred. Treating a contaminated supply, if it is feasible at all, typically costs several hundred thousand dollars; replacing the same supply can cost millions. In short, budgeting the funds necessary to protect a municipality's water supply is sound fiscal planning.

There are many ways to pay for a groundwater management program, and most towns will combine several sources. Though limited funding assistance may be available through government grants, the bulk of the money will come from the community's general revenues, dedicated taxes and fees, bond issues or loans. Specific program elements can be most appropriately funded from the following sources:

Planning and management activities may be most equitably financed through general revenues. Efforts such as planning studies, data collection and mapping, and public education provide broad-based benefits and their cost cannot be attributed to any specific segments of the community. Water utility rates may be an appropriate source of funding if a large part of the community is served by a public water supply.

Other approaches to funding could include special dedicated taxes, such as real estate transfer taxes or local sales taxes. State or federal grant assistance may be available for specific activities, such as public education, especially if they are innovative.

Administration and operating costs, which can in large part be attributed to specific land use activities, may be financed through fees on regulated facilities. Permit fees for zoning and/or aquifer protection permits can be set to cover the costs of processing and reviewing the application, and inspection and enforcement. The costs of groundwater monitoring, including installation of monitoring wells and periodic testing of water samples, may be provided by regulated facilities or water utilities. Some communities have required developers to pay impact fees as part of the zoning or subdivision permit process to recover costs imposed on public facilities and services.

Land acquisition and capital facilities construction costs require high initial expenditures and produce long-term, broad-based benefits. Bonding and bank loans enable the community to raise large amounts of money with repayment over a period of time. Government grant and loan programs can often help local communities meet these major expenses. Funds to assist in the construction of public water and sewer systems may be available from state and federal agencies. State matching grants for the acquisition of qualifying land for water supply protection may be available through the Connecticut Recreation and Natural Heritage Trust.

At the local level, there are several methods available to generate funds to purchase land or development rights. Connecticut law permits towns to establish a nonlapsing fund for open space acquisition. Money from general revenues (up to the equivalent of 2 mils on the property tax) can be appropriated to this fund annually, so that resources are available when opportunity arises. State law also permits towns to collect fees from developers in lieu of requiring dedication of a portion of subdivided land as open space. These fees must be earmarked for the protection of open space, enabling the town to focus on the open space most valuable to the community. Thus, when a subdivision is located outside a critical aquifer area, a town might waive the open space set-aside requirement, instead collecting an equivalent fee which will go toward the purchase of land on the aquifer.

Buying development rights can be almost as expensive as buying land outright, but it does give the town control over land use while the private owner continues to be responsible for its management. Sometimes easements are donated by land owners who want to protect their land from development and take advantage of the tax benefits of charitable donation. Deed restrictions, which may be required, for example, as a condition of subdivision approval, can achieve similar results. Some towns also have zoning provisions that permit transfer of development rights (see discussion earlier).

For More Information

The American Planning Association's publication *Local Groundwater Protection* (Jaffe and DiNovo, 1987) includes a thorough discussion of local groundwater protection measures, especially regulatory approaches, with a variety of examples of actions taken by many communities across the country to solve specific groundwater protection problems. The Reference section of this manual lists several publications prepared for local officials in other states that may offer useful suggestions for your community (see Born et al., 1987; Raymond, 1986; and Schenectady County Planning Dept., 1987).

Education and Voluntary Action: The EPA workbook, *The Power to Protect*, provides another perspective on the basic mechanisms discussed in this section, focusing on wellhead protection areas. It offers some ideas for implementing programs and gives examples from New England communities. In conjunction with its companion video, this publication can be useful in educating the community about groundwater issues.

EPA's *Citizen's Guide to Groundwater Protection* is another useful educational tool that you may want to distribute widely in your community. It contains basic information on groundwater and sources of contamination and offers some guidelines for community and individual action.

School curriculum materials on groundwater protection can be obtained from the DEP Environmental Services Bureau. The South Central Connecticut Regional Water Authority and the Town of Cheshire are currently developing groundwater protection programs for public schools under an EPA grant.

Planning and Zoning: DEP's Water Management Bureau has example and model local aquifer protection overlay zone regulations. The Water Management Bureau may also be able to refer you to existing town regulations that may be appropriate models for your community.

The concept of cluster development is discussed from a design perspective in a well-illustrated book, *Dealing with Change in the Connecticut River Valley: A Design Manual for Conservation and Development* (Arendt, 1988), which also includes model zoning regulations. Although this publication does not deal in detail with clustering as a tool for groundwater protection, it provides a lucid and persuasive discussion of the use of cluster development to preserve the character and environment of a community.

Hazardous Materials: Model or example groundwater protection ordinances for the storage, handling and use of hazardous materials may be useful for a local hazardous materials ordinance. DEP has developed Best Management Practices for many industrial and commercial activities, which can be incorporated into local regulatory, inspection and educational programs. Recommended BMPs and examples of local hazardous materials ordinances can be obtained from DEP's Water Management Bureau.

Underground Storage Tanks: DEP has prepared a guide on USTs for Connecticut municipalities (Cimochowski, 1988). This publication explains the state's UST regulations and details recommendations for local controls on USTs not covered by state regulations, such as residential heating oil tanks.

Private Well Protection: The Lower Naugatuck Valley District Public Health Department has developed a publication which addresses this issue, *Ensuring the Quality of Drinking Water in Private Wells* (Buick et al., 1984), as has the Massachusetts Association of Health Boards (Benes, 1989). Educational literature on private well protection is available from the University of Connecticut Cooperative Extension System (1989) and in the Massachusetts Audubon Society's groundwater flyer series.

Septic Systems: DEP has two general publications on the design and installation of septic systems: *Septic Systems Manual* (1985) provides general information about on-site septic systems and provides guidance for developing a local review process. *Community Sewerage Systems: A Primer for Developers and Local Officials* (Lash and May, 1982) describes community septic systems and their potential to help protect the environment. The U.S. EPA has also developed information on septic systems and groundwater contamination.

Road Salt Storage and Use: Guidelines for the proper management of road salt are available from DEP and several sources listed in the Reference Section, including the Cornell Cooperative Extension Service (1988); Pioneer Valley Planning Commission (1986); and the Massachusetts Audubon Society.

Household Hazardous Waste: Guidance on organizing a local household hazardous waste collection day can be obtained from the DEP Waste Management Bureau or your regional planning agency. For information on developing a permanent collection center, you can contact HazWaste Central at the South Central Connecticut Regional Water Authority in New Haven. Educational materials on the proper use and disposal of hazardous household products are available from DEP's Environmental Services Bureau.

Part V

How To Develop A Local Groundwater Protection Plan

Chances are that at least a portion of your community's drinking water comes from groundwater sources. Cities and suburbs with public water service often rely on public wells, while most people in rural communities depend on private wells. Though we usually take for granted that we will have clean, safe drinking water at the turn of a tap, we must always be aware that what happens on the land can affect the groundwater underneath. Even if we are not directly drinking groundwater from a well, groundwater is an important source of water for base flow to surface water, such as lakes, streams, and reservoirs.

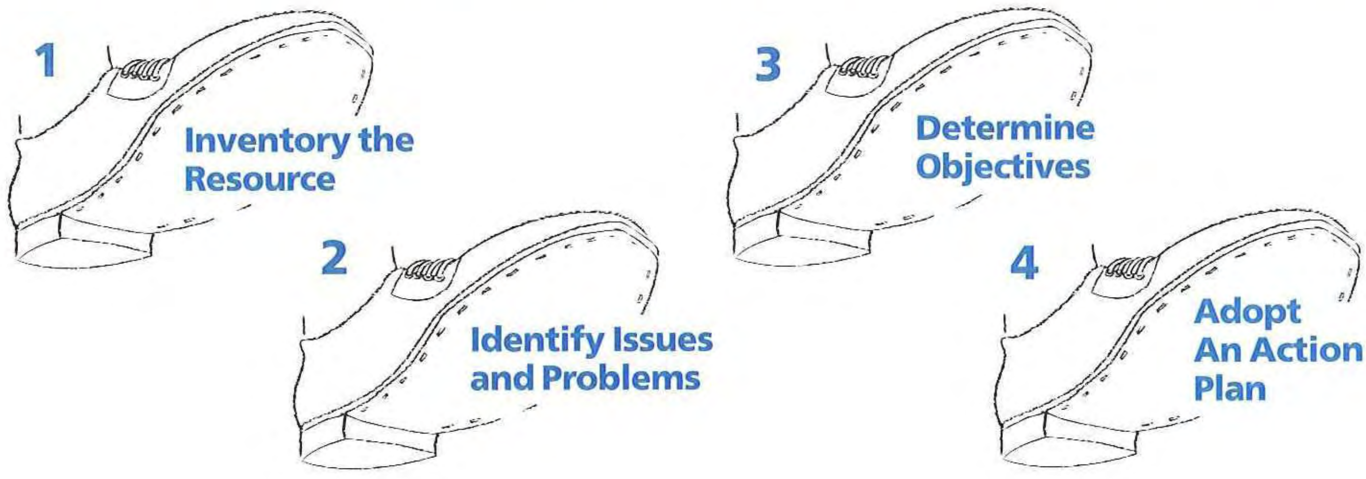
It's important for every town to take stock of its water resources and develop a management program that assures protection of these resources now and for the future. A local groundwater protection program cannot be pulled off a library shelf, borrowed from another community, or photocopied from a statewide model. Instead, it must be tailored to protect the specific resources in *each* town and to meet the community's needs and goals. It involves community learning, resolving conflicting priorities, and building a consensus to take necessary actions. Information about the town should be collected, studied, and then used to create a specific action plan.

...Developing a local plan is, in essence, a matter of finding the answers to key questions about your community...

Developing a local plan is, in essence, a matter of finding the answers to key questions about your community:

- What, and where, are our existing groundwater resources (or those we share with neighboring communities)?
- What problems or threats exist?

The Four Steps to Preparing a Local Groundwater Protection Plan



- What are our goals for protection and management of groundwater?
- What is being done to protect and manage our groundwater, and what additional action should we take?

Getting Started: Who Should Be Involved?

However varied their interests may be, everyone in your community shares the goal of having clean water: if groundwater is contaminated, public health, the environment, and the economic well-being of the community may be threatened. Equally, everyone shares the responsibility for *protecting* groundwater. Almost any activity involving chemicals, for instance, has the potential to contaminate groundwater if handled improperly. Everyone in the community, therefore, should know where their water comes from, be alert when handling potential contaminants, and have a voice in deciding what will be done to protect their groundwater.

Special Responsibilities For Communities With Aquifer Protection Areas

If your community includes major public water supply wells designated by the state as Aquifer Protection Areas, it will have some special responsibilities in protecting these particular areas. Public water utilities, for instance, will ultimately be required to develop detailed technical information about these aquifers, and your town will have to protect these areas in accordance with state regulations. However, as discussed previously, many groundwater resources will not be addressed under this state program. Your community, therefore, should examine all of its groundwater resources.

Suggested Participants in Groundwater Protection Planning

Here are some of the individuals and groups you may want to consider inviting to your initial meeting:

Town Officials and Staff

Chief Elected Official
Planning/Zoning Commission
Conservation Commission
Inland Wetlands Commission
Economic Development Commission
Board of Finance
Selectmen
Town Planner
Health Officer
Public Works Director
Water Supplier

Community Organizations

League of Women Voters
Land trust
Local environmental groups
Chamber of Commerce
Neighborhood associations

Special Interests

Farmers
Developers
Business owners
Manufacturers

Consider inviting a representative of DEP's Water Management Bureau to your initial public meeting to provide some basic information about your community's water resources and to help identify potential groundwater issues in your town. A half-hour video, *Troubled Waters*, available from DEP, also provides a good introduction to groundwater protection, and will help to spur discussion at your public meeting.

And it is important to plan pro-actively — don't wait until a crisis occurs. A good first step is to hold a public meeting to discuss the need to protect the community's drinking water. A central task of this initial meeting will be to identify the people who will take the lead in organizing the planning process and keeping it moving. This group should be drawn from a cross-section of the town's boards and commissions, members of community organizations, representatives of special interests (such as farming, industry and business), and energetic, interested citizens. The main qualification is a commitment to seeing the job through, along with a willingness to learn and to teach. This group will be responsible for promoting awareness and understanding of the issues, encouraging broad involvement in setting protection goals, and building a consensus for action.

Towns with a professional planning staff or assistance of a Regional Planning Agency will be aided by their ability to gather information, display it on maps, and provide administrative and technical coordination. Groundwater management can and should be coordinated with other planning efforts, such as the town's Plan of Development and Zoning. An update of the Plan of Development or Zoning Regulations provides a perfect opportunity to look at groundwater protection needs.

Even an all-volunteer group without technical training, however, can successfully complete a groundwater protection plan if participants are willing to devote the necessary time and energy to the task. DEP can provide technical assistance and training to such groups. Alternatively, your town may want to consider hiring a consultant to help gather and evaluate information. However you decide to handle the technical aspects of the planning process, your planning group will need good information so it can guide the community to informed decisions.

Step One — Taking Stock: Inventory

The first step in groundwater protection planning is collecting information about your town — its water resources, water uses, and land uses. The basic task of this step is to convert the mass of information available about your town into *knowledge*, into an understanding of where your water comes from and what needs to be done to protect it. Part I of this manual will give you a basic understanding of groundwater and its behavior, and provide a context for this information-gathering phase.

Most of the information you will need is in the form of maps, and will be readily available at your town hall or regional planning agency, from DEP, or from the water utility that serves your town. These various maps may be drawn at different scales, however, so that relationships between different sets of information may be difficult to see. You will need to get this information mapped at the same scale, preferably on overlays, before you can make comparisons. The Supplement at the end of this manual provides a detailed description of the inventory information you may need, where to find it, and what it means; it includes an example of the inventory for a typical Connecticut town.

Step Two — Identifying Issues and Problems: Evaluation

The next planning step is to evaluate the data you have collected in order to identify the existing and potential risks to your community's water quality. This evaluation phase will also help you identify any additional information you may need to understand and resolve the groundwater protection issues facing the town.

Some of the basic questions you will need to answer in the evaluation phase are...

- What groundwater resources are present in the community? Are major aquifers present?
- Who is using them? Are they clean?
- Are there sensitive areas that require special protection?
- Where are the likely sources of groundwater contamination?
- What are the community's likely future water supply needs?
- Is planned land use appropriate?

Part II of this manual helps you understand where contaminants come from and how they get into groundwater. The Supplement provides checklists and other guides that show you how to analyze the information you gather to identify sensitive areas, evaluate risks, and identify potential problems and solutions in your town.

Step Three — Choosing the Future: Determine Protection Goals

When you have reached this phase in the planning process, you will have learned a great deal about your town and where it is headed. This is a good time to hold a workshop to communicate your findings to the town's boards and commissions and to the general public. A broadly shared understanding of this information will provide a sound basis for planning future land use and water use in sync with your community's needs and priorities.

As a community, you will have to determine whether current conditions, and those likely to exist in the future, threaten essential water supplies. If groundwater is already contaminated, you must decide whether to clean it up or abandon the polluted supplies and develop alternate sources of drinking water. If the water you need is not safe, you will have to determine whether it can be protected by minor corrective action or whether fundamental changes in land and water use and waste disposal practices will be necessary. If you decide to prohibit high-risk land uses in sensitive areas, such as high yielding aquifers supplying public wells, you may want to consider whether there are other areas in town where such uses might be suitable. And if the community is widely dependent on private wells for residential use, you may want to restrict certain land uses.

For the most part, once residents understand their groundwater supplies, future needs, and land use risks, there will be a substantial consensus about long-range protection goals. Meeting these goals, however, may require tradeoffs that are difficult for the community to accept. In these cases, the value of its water resources must be carefully weighed against other values.

Step Four — Selecting Solutions: An Action Plan

After identifying its protection goals, a town is ready to select specific measures to achieve those goals. The first step is to assess current measures to protect groundwater within the community. You must then determine how adequately this network of safeguards meets your protection goals, and then select specific measures tailored to your community's needs. To assist you in this task, Part III of this manual describes federal and state programs in place to protect groundwater, and Part IV discusses regulatory and nonregulatory measures you might take in your community. The Supplement provides more implementation information and models.

The task of developing a groundwater protection plan does not end, of course, with preparing a plan and putting it down on paper. You should set priorities, create a timetable for implementation, and specify the agencies and individuals responsible for each major initiative. Periodically you should review your program to ensure that it continues to meet the community's needs. And community education, communication, and building a consensus will ensure the success of your plan.

Developing a protection program requires time, resources, and commitment. But the rewards are substantial. Your town will be more self-aware, and more successful as a result of this process, and your citizens will become more responsible in doing their part to use land and water resources wisely. And you will have the assurance of clean, safe drinking water for your community, now and in the future, because you acted to prevent costly pollution problems.

For More Information

Section A of the Supplement to this manual is one of many possible approaches to groundwater protection. Other planning guides that you may find useful include:

- *The Power to Protect*, companion workbook to the EPA video, is a practical guide that focuses on wellhead protection areas for public wells, equivalent to Connecticut's Aquifer Protection Areas; it provides detailed guidance on conducting a land use inventory.

- Massachusetts has developed *Guidelines* for preparing local water resource management plans; these provide a comprehensive questionnaire and checklist, covering both groundwater and surface water resource management, to guide the work group through each phase of planning.

- *The Groundwater Action Project Workbook, A Guide to Protecting Community Groundwater Resources*, prepared by the Housatonic Valley Association, Inc. provides step-by-step guidance to towns for groundwater protection.