Senator George J. Mitchell Center for Environmental and Watershed Research

Member of the University of Maine System

PROTECTING GROUNDWATER SUPPLIES: MAINE'S SOURCE WATER PROTECTION PROGRAM

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Bethel, Maine uses both surface and groundwater as sources of public water supply. Signs throughout the watershed notify the public that care should be taken within the source water protection area

More than 60% of Maine citizens rely on groundwater for their public and private drinking water supplies. Various land uses and activities threaten the quality of this valuable natural resource. Once groundwater is contaminated, it is difficult and expensive, and sometimes impossible, to clean up. Protecting groundwater from contamination is the most effective method to ensure abundant sources of clean drinking water. Land development has been identified as the dominant threat to public water supplies, and controlling land use through purchase, easement, or ordinance is the greatest challenge facing public water systems.

The goal of Maine's Source Water Protection Program is to protect the state's 2,100+ public water systems from the threat of contamination. As required by the Federal Safe Drinking Water Act Amendments of 1986, the Wellhead Protection Section of the program focuses on public water supply wells rather than private wells. The public wells serve more people and thus their management is more practical than that of thousands of private wells. This digest focuses on groundwater, but it does apply to surface water supplies since groundwater can be a significant input to surface water sources. Up to one-third of the water in rivers and lakes can be from groundwater input, therefore protecting surface water quality also requires protection of the groundwater component.

This digest is organized in two parts: 1) a summary of important groundwater principles that are fundamental to source water protection and 2) a discussion of the key elements of the Maine Wellhead and Source Water Protection Program.

GROUNDWATER BASICS

Groundwater is the source of water for wells and springs, and is found beneath all land in Maine. Groundwater occurs within the cracks or fractures in bedrock, and in spaces between soil particles. The zone in which all of these fractures and spaces are filled with water is called the **saturated zone**. The upper surface layer of the saturated zone is the **water table** (Figure 1).

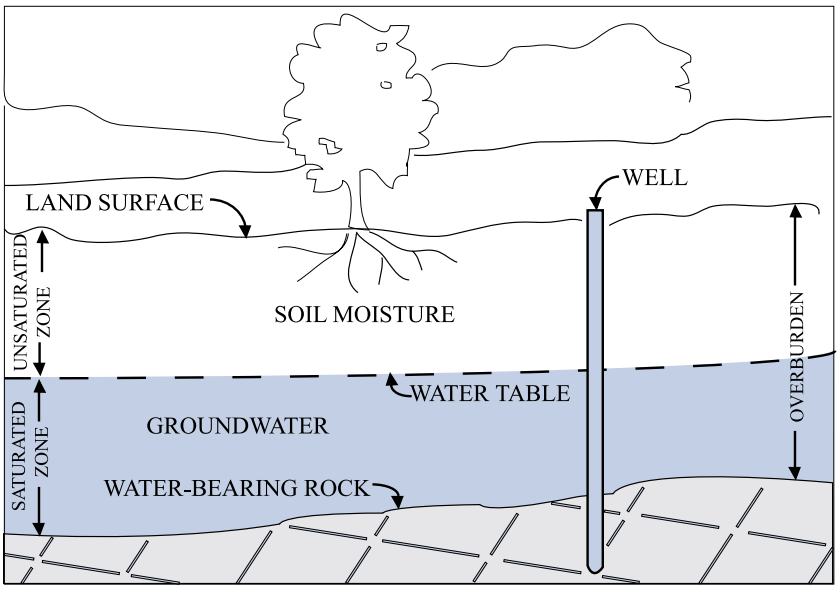


Figure 1. Divisions of Subsurface Water

Groundwater is part of the **hydrologic cycle** (Figure 2). Water falls as rain or snow to the land surface and infiltrates the soil or flows over land into streams, rivers, lakes, and oceans. Some of this water evaporates back into the air from wet surfaces or is released by growing plants. Water entering the soil fills open spaces in the unsaturated zone, and infiltrating water percolates downward to the water table and replenishes (recharges) the groundwater.

Only a fraction of total precipitation ends up as groundwater. The amount of precipitation that enters the soil as potential groundwater recharge depends on several factors including soil type (Table 1), slope of the land surface, and vegetative cover. For example, although Maine receives an average 42 inches of precipitation per year, only two to five percent of this precipitation recharges groundwater in areas underlain by fractured crystalline bedrock.

Areas that supply water directly to a groundwater source are called **recharge areas**. Recharge areas occur primarily in upland areas (Figure 3). Gravity causes groundwater to move downgradient (downhill) from recharge areas to lower regions where it discharges as surface water in springs, seeps, lakes, and rivers. In Maine, where only a thin layer of soil and broken rock overlies bedrock, groundwater follows the slope of the land surface, moving from hilltop to valley.

Geologic deposits are generally classified as either aquifers, which contain water, or confining layers. An **aquifer** is a subsurface layer of earth or permeable rock that yields useful quantities of groundwater to wells and springs. There are two types of aquifers in Maine: surficial and bedrock. **Surficial** or **unconfined aquifers** receive groundwater recharge directly from precipitation, and consist of a mixture of soil and broken rock deposited by glaciers. Sand and gravel aquifers, which can yield up to 50 gallons of water per minute, are a kind of surficial aquifer formed thousands of years ago by melting glacial ice. Glacial meltwater streams drained toward the ocean, depositing sand and gravel along valleys in southern and eastern Maine. In **bedrock aquifers**, water is stored in tiny cracks and fractures in the solid rock below surficial deposits.

Confining layers are low-permeability deposits (such as clay or unfractured bedrock) that restrict the movement of groundwater between aquifers. An aquifer that underlies a confining layer and is completely filled with groundwater (under pressure) is considered a **confined aquifer**. In Maine, confinement is usually the result of fracture patterns in the bedrock. Such an aquifer may receive its

Table 1. Recharge Potential for Typical Maine Geological Deposits

Surficial Deposit	Avg. Annual Recharge Rate (% of annual precipitation)	Equivalent Gallons per Acre
Sand and gravel	40% - 50%	478,000 to 597,900
Clay/silt	5% - 15%	59,700 to 179,200
Thick silty glacial till	5% - 15%	59,700 to 179,200
Thick course-grained till	15% - 35%	179,200 to 298,700
Thin sandy glacial till over bedrock	5% - 20%	59,700 to 238,900
Fractured bedrock	2% - 5%	23,900 to 59,700

water from locations some distance away. Whether an aquifer is surficial or confined has important implications for wellhead protection because the wellhead protection area for confined aquifers is more difficult to identify.

"Water table" wells tap surficial aquifers, and the water level in these wells is the same as the surrounding water table. In wells drilled into confined aquifers, sometimes called **"artesian wells"**, the water level rises above the top of the aquifer (but not necessarily to the land surface) to match the water pressure within the aquifer. It is common to refer to all wells drilled in bedrock as artesian, although many are not. True artesian wells are free-flowing: water trapped in deep-lying rock develops considerable pressure, which when tapped by a well is enough to cause the water level to rise above the land surface.

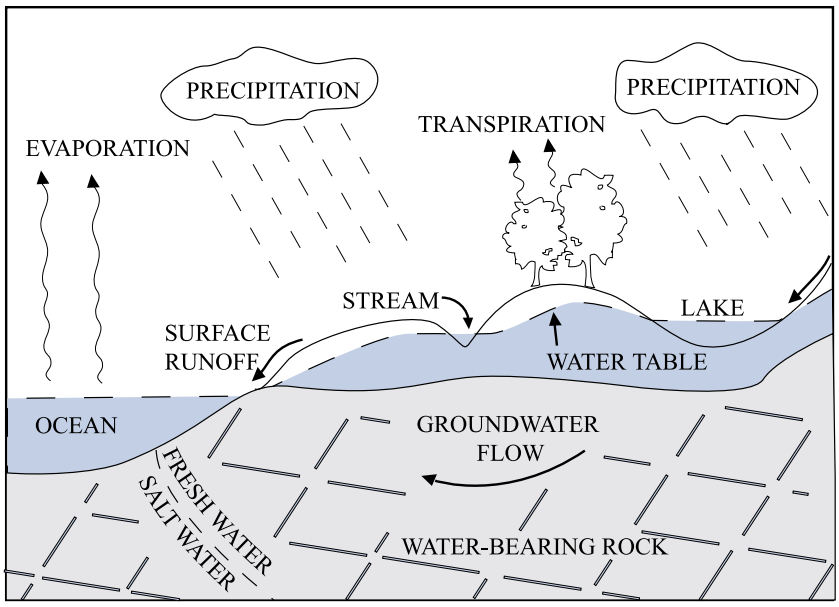


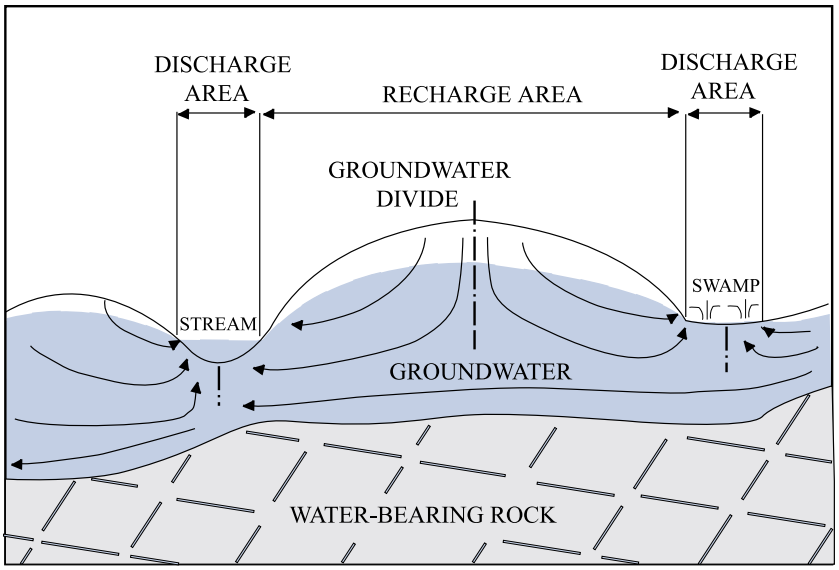
Figure 2. The Hydrologic Cycle

How much water a well can yield depends on the nature of the overlying material and the number and size of fractures in the bedrock. Thick sand and gravel deposits are excellent aquifers for public water supplies, and some yield from 10,000 to over one million gallons per day. Most of Maine's larger groundwater-based water systems tap sand and gravel aquifers.

Surface water bodies can influence water supply to a well. Wells near major lakes and rivers often induce recharge from these rivers and lakes; such wells are considered "groundwater under the influence of surface water". When recharge is below normal, such as during a drought, the contribution of surface water to a well can increase.

Most Maine households consume a few hundred gallons of water per day. For planning purposes, public water suppliers estimate that each person consumes approximately 60 gallons per day. A public water system supplying 2,000 persons would require approximately 120,000 gallons per day to satisfy residential demands. The water requirements of the commercial sector would depend on both the number and types of businesses. A manufacturing business or a restaurant may require substantially more water than a clothing retail store, for example.

Figure 3. Recharge and Discharge Areas in a Groundwater Flow System



WELLHEAD PROTECTION AND SOURCE WATER PROTECTION

All groundwater is vulnerable to contamination. The 1986 Amendments to the Safe Drinking Water Act required the states to develop Wellhead Protection programs to define and protect the source protection area around public groundwater wells. Each state was also required to identify and rank activities in the source protection area that may threaten water quality.

A decade later, the 1996 Amendments to the Safe Drinking Water Act required public water systems to evaluate all public water systems as part of a Source Water Assessment Program. Similar to the Wellhead Protection Program, Maine's Source Water Assessment Program assessed the current and future threats to water quantity and quality of Maine's public water supplies. The EPA requires that each assessment include a delineation of the source water protection area (which for groundwater is the same as the wellhead protection area), an inventory of potential sources of contamination within the source water protection area, and an assessment of the susceptibility of the supply

to those threats. For groundwater systems, most of this information was already submitted as part of the previous Wellhead Protection Program, and the Source Water Assessment Program emphasizes predicting and preventing contaminant threats.

The Maine Wellhead Protection Program is a voluntary program. Participating water systems are eligible for waivers to some water tests and monitoring; because of this incentive, most of the larger systems are involved in the program. Systems involved in the Wellhead Protection Program were required to develop the following information: delineation of the protected area, an inventory of potential sources of contamination, a management plan to mitigate current threats and prevent future threats, and a contingency plan to deal with emergencies that affect service from a well.

What are the benefits of having a Wellhead Protection Plan? Without wellhead protection, public water suppliers must rely solely on enforcement of existing regulations for groundwater protection. The major benefit of developing a wellhead protection plan is the ability to control and prevent contamination specifically within the local source protection area and to effectively implement cleanup measures if an accidental spill occurs. By identifying the source protection area and performing an inventory of the potential contamination sources, the public water supplier can more effectively educate the public and enlist public participation for resource protection.

DELINEATION

A source protection area delineation maps the likelihood that well water is derived from a particular area of the land surface. Ideally, a source protection area includes all of the land area which contributes groundwater recharge to a well; this area is called the recharge area (also referred to as the zone of contribution or contributing area).

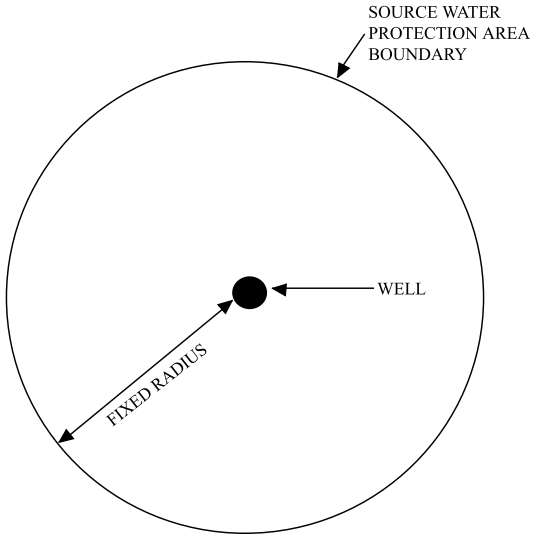


Figure 4. WHPA Delineation Using the Arbitary Fixed Radius Method

The source of water to a well is influenced by the regional flow of groundwater in the area. In an aquifer with no flow, a well would draw water equally from all directions.

In reality, the geometry of the aquifer and regional flow through the aquifer influence where the well obtains its water. In many sand and gravel aquifers, the gradient is relatively flat under non-pumping conditions. The gradient is usually parallel to the topographic slope, and this slope is used to approximate the regional groundwater flow gradient.

The recharge area is different from the cone-shaped depression, commonly called the cone of depression or the zone of influence, which develops in the water table around a pumping well. The cone of depression extends laterally from a well so that the rate of ground water recharge to the well equals the rate of pumping or withdrawal. Under idealized aquifer conditions with a flat water table, the recharge area is equivalent to the zone of influence; more often the two areas overlap but do not coincide. In order to be effective, programs to protect groundwater quality focus on the recharge process because recharge controls both the quantity and quality of water reaching a well. Delineating a recharge area can help water suppliers target land for special protection measures.

Groundwater systems in the Wellhead Protection Program were required to delineate a protection area around each well or group of wells. For transient systems, the source protection area was delineated as an arbitrary circle around the well with a fixed radius of 300 feet (Figure 4). For other small systems, a calculated fixed radius method was used, with areas ranging from 300 to 2,500 feet in radius, based on population served or pumping rate. In many cases, this was probably the only feasible approach given the cost of determining a more geologically reasonable protection area.

The Drinking Water Program, in cooperation with several other agencies including the Maine Geological Survey, has refined wellhead protection area delineations for the 139 sand and gravel well sources serving more than 250 people. The 200-day and 2,500-day time-of-travel zones for sand and gravel wells were analyzed using geologic maps, pump test data, groundwater level monitoring data, and computer modeling (Figure 5). Computer model simulations were then used to estimate groundwater flow paths and capture zones for the individual public water systems. The models simulate groundwater flow through the geological materials around the well, calculate recharge areas, and estimate time-of-travel to the well.

The Drinking Water Program, with Maine Geological Survey, has also evaluated and refined delineations of the contributing areas to public water supplies utilizing bedrock aquifers. Most public water systems lack adequate hydrogeologic data and resources to invest in extensive hydraulic testing and investigations of their water supply wells. Yet for bedrock wells, a fixed radius circle is a poor representation of the zone of contribution. A combination of hydrogeologic mapping and groundwater flow modeling was used to determine recharge zones of bedrock wells. The resulting recharge areas do not take the form of a fixed-radius circle (Figure 6).

POTENTIAL CONTAMINATION SOURCES WITHIN THE SOURCE WATER PROTECTION AREA

Once the source protection area was delineated, potential groundwater contamination sources within the area were identified and mapped. Participating systems submitted an inventory to the Drinking Water Program, based on a list of 76 potential contaminants and contaminant sources (Table 2). Inventories were revised as part of the Source Water Assessment Program; it is the public water supply manager's role to periodically review and update the inventory of potential contaminant sources.

Hundreds of chemical and biological substances that are used or generated by agriculture, industry, or households are potential contaminants. Accidental releases of contaminants to soil and groundwater are widespread and common. Contaminants often found in Maine groundwater include petroleum compounds, cleaning solvents, pesticides, heavy metals, nitrate, chloride, sodium, and bacteria. Potential contaminant sources are also ranked based on the relative risk they pose to the water supply.

MANAGING WELLHEAD PROTECTION AND SOURCE WATER PROTECTION AREAS

All public water systems have received a copy of their Source Water Assessment Program report from the Drinking Water Program, which will aid in development of a management plan. The reports are also available on the Drinking Water Program website. The Source Water Assessment ranks the risks identified in the inventory based on well type and site geology, and existing and future risk of contamination. A good management plan includes steps a system can take to eliminate or reduce existing threats and a long-term plan for protection of the groundwater well.

Very few public water sources have high levels of protection in place. Public water systems are not in control of land use activities in the surrounding communities. Most do not own the entire recharge area for their source, and

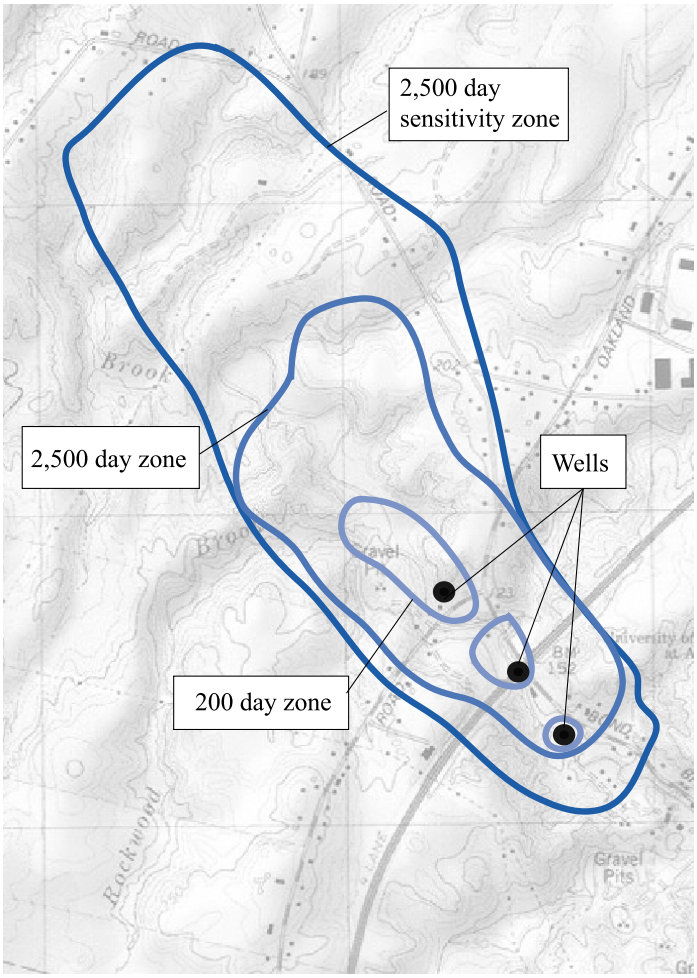


Figure 5. Example of Multiple Wellhead Protection Zones Based on Time-of-Travel Concept

local governments have been reluctant to adopt protective zoning or other ordinances to reduce the risk of development in these areas. ***The Source Water Assessments have identified future growth in source protection areas as the dominant risk factor threatening public water supplies.*** **Controlling growth through land purchase, easement, or ordinance is the greatest challenge facing water systems, towns, and the Drinking Water Program.**

Limiting the potential contaminant sources listed in Table 2 is the most effective source water protection strategy. A management plan that includes land acquisition, easements, local ordinances and zoning, and enforcement of existing land use regulations will reduce the threat of contamination and water quality degradation. Best management practices (BMPs) may also be included in a management plan, especially in areas with agricultural land uses.

The Drinking Water Program advocates that public water suppliers utilize the following management techniques:

1) Information and education;

2) Land use regulations; and

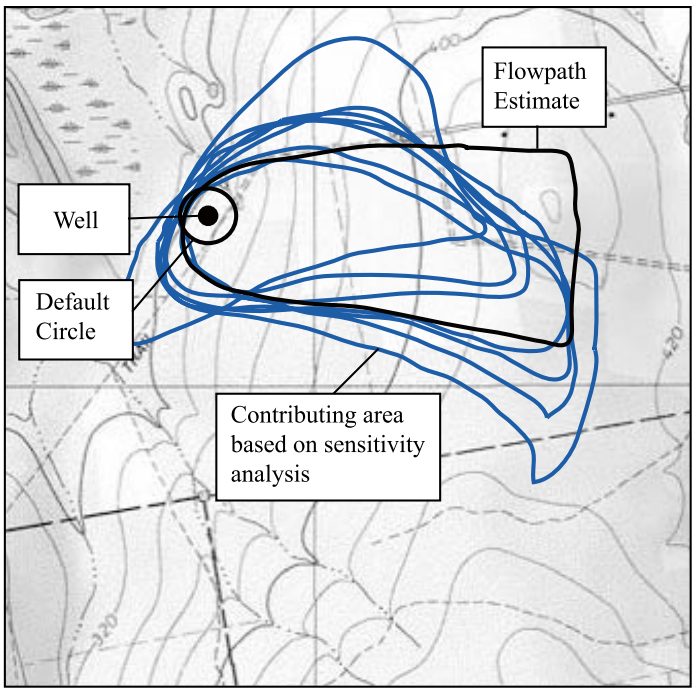


Figure 6. Example of recharge area delineations for a bedrock well

3) Capital improvements, especially land purchase and easement.

1. Information and Education Tools

- Post signs identifying the source protection area boundary along roadways and at stream crossings.
- Notify local, state, federal officials of the source protection area location. Post a map in town office buildings.
- Educate the public through the local media (press releases, public service announcements, newspaper articles). Provide information on BMPs for land-use activities, water conservation, and actions citizens can take to reduce threats to water quality. Household hazardous waste collection programs will reduce threats to water quality and educate citizens.
- If the municipality has a Comprehensive Plan, work with citizens and government officials to include source water protection measures.

2. Working with existing regulations

- Work with local officials to develop a municipal source water protection ordinance to define the land use activities that can occur within the source protection area and the associated performance and design standards.
- The Drinking Water Program has authority to require additional water quality monitoring where threatening activities are located within the source protection area (e.g., landfills and industrial facilities).
- Special provisions can be attached to local, state, and federal building and siting permits issued for activities within the source protection area.
- Target the source protection area for local and state environmental inspection and enforcement.
- Notify local officials of Public Law 761, which requires that a public water supplier be notified of public hearings on proposed commercial and residential development in the source protection area.
- Enforce existing ordinances that have provisions for groundwater protection.

3. Capital Improvements

- Negotiate land-use control easements or land acquisition within the source water protection area.
- Install or extend public sewer.
- Secure or remove potential contaminant sources (e.g., manure piles, junk yards, underground storage tanks).
- Secure back-up supplies.

ROLES OF PUBLIC WATER SUPPLIERS, GOVERNMENTS, AND ORGANIZATIONS

The public water supplier has the primary responsibility for protecting drinking water sources from contamination. This responsibility applies whether the public water supplier is a corporation, municipality, or water district. But protection areas and assessments are merely a tool for further management efforts, and must be locally driven to be successful. Federal and state agencies, municipalities, and the public have supporting

Table 2. Land uses that are potential sources of groundwater contaminants

Above/Underground chemical or fuel storage tanks	Laundry & dry-cleaning facilities	Laboratories
Transportation corridors (highways and railroads)	Manufacturing facilities	Metal-plating facilities
Automobile service stations and autobody shops	Open dumps and landfills	Pesticide application and storage
Chemical drum storage areas	Petroleum pipelines	Printing and publishing facilities
Floor drains in repair garages & industrial facilities	Septic systems and sewer systems	Airports
De-icing salt storage piles and loading areas	Construction projects	Fueling operations
Stormwater runoff, catchbasins and drains	Fertilizer application	Graveyards
Land application/storage of sludge & manure	Junkyards	Military Facilities

roles in land acquisition and development of land use ordinances.

Public Water Supplier

- Monitor and update the inventory of potential contaminant sources.
- Review the Source Water Assessment Program report and develop a management plan.
- Communicate with the Drinking Water Program, local officials, and customers.
- Actively seek opportunities to improve land use management and control in the source protection area.

Drinking Water Program

- Work with the water suppliers to select and develop appropriate management options.
- When water supply testing results exceed drinking water standards, work with the water supplier to develop and implement corrective actions.
- Review and approve the wellhead protection management and contingency plans that water suppliers submit.
- Coordinate the efforts of the Source Water Protection Program with other state agencies, Indian tribes, and Canadian provinces.

Department of Environmental Protection

- Permit and license certain development and land use activities; proposed activities within the source protection area must comply with rigorous groundwater protection provisions and performance standards.
- Regulate use, storage, and disposal of petroleum and hazardous chemicals, provide emergency response for chemical and petroleum spills, and coordinate spill cleanup and groundwater remediation; enforcement and response activities within the source protection area are given priority.
- Coordinate wellhead and source protection with other watershed protection, habitat restoration, and water quality efforts.

State Planning Office

- Train and certify municipal code enforcement officers.
- Assist towns with comprehensive planning.
- Provide expertise on development and implementation of management options.
- Coordinate wellhead and source protection with other land conservation programs.

Department of Agriculture, Food, and Rural Resources

- Coordinate agricultural land conservation programs, such as the federal Conservation Reserve Program and Wetlands Reserve Program.
- Regulate pesticides application through the Board of Pesticides Control.
- Develop BMPs for activities that have potential to degrade water quality (e.g., pesticide and fertilizer application, manure spreading and storage) and work with farmers to develop solutions and implement BMPs.
- Work with the county Soil and Water Conservation Districts to implement nutrient and pesticides management plans in priority watersheds.

Department of Transportation

- Cover or move state-owned sand-salt storage piles that are located within the source protection area.
- Provide funds to municipalities to help construct sand-salt storage buildings.
- Reduce or prohibit pesticide and herbicide application.
- Retrofit DOT maintenance facilities to comply with groundwater protection standards and practices.

CONTINGENCY PLANNING AND SECURITY

What happens if a chemical spill occurs in the source protection area or the water supply is declared unsafe to drink? The final step for completing a wellhead protection program will be a contingency plan for emergencies. While detailed contingency plans will only be required of threatened Category III and all Category IV systems, all public water supplies should be prepared to deal with accidental and intentional disruptions of water quantity or quality. In addition, the EPA requires every public water system that serves a population greater than 3,300 to complete a vulnerability assessment and develop an emergency response plan based on the assessment.

A contingency plan should encourage the quickest emergency response possible and minimize the amount of contaminant released. Planning involves knowing whom to call in an emergency, but also making sure local law enforcement and County Emergency Planning Commissions know to notify the water supplier if and when the water supply is threatened. Other components of a contingency plan include an efficient and effective process for alerting the water system customers and identification of back-up water supplies. An alternative water supply should be outside of the source protection area and brought on-line within 24 hours of system contamination or failure.

Public water systems experiencing an active threat to the water supply should follow the Security Response Protocols developed by the Drinking Water Program.

- Require strict application of groundwater protection BMPs for highway construction projects and maintenance activities.
- Provide notification signs for state roads that cross source water protection area boundaries.

Maine Geological Survey

- Distribute maps and information on surficial and bedrock geology and sand & gravel aquifers.
- Provide hydrogeological expertise to state agencies and public water suppliers.

Municipal Governments

- Code enforcement officers pay special attention to construction activities in the source protection area.
- Planning boards give special consideration to groundwater protection issues during their deliberations on development applications and zoning.
- Planning boards notify public water suppliers of development proposals for land in the source protection area.

U.S. Environmental Protection Agency

- Administer the Safe Drinking Water Act and other laws that affect groundwater and wellhead protection.
- Fund state programs that support the Drinking Water Program, and regulations that control potential groundwater contaminants.

The Public

Development and implementation of a successful source water protection plan is part technical, part educational, and part political. However, success may ultimately depend on the effectiveness of the educational component and how well the water customers, the affected municipality, and landowners understand basic groundwater concepts and the importance of restricting potential contaminant sources. Understanding and addressing the public's concerns early will help gain acceptance of a program and participation in groundwater protection.

Wellhead Protection Grant Program

Community and non-profit non-community public water systems are eligible for funding to plan or implement groundwater protection projects. Possible projects include developing or implementing a wellhead protection plan, developing public educational materials, or developing useful base maps.

For more information contact:

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For guidance on developing a source water protection plan, see the publication Source Water Protection, available from the Senator George J. Mitchell Center and at http://www.umaine.edu/waterresearch/research/pdfs/SourceWaterProtection.pdf.

PUBLIC WATER SYSTEMS

The Wellhead Protection and Source Water Protection Programs apply to public water systems: systems that provide water to at least 15 service connections or 25 people daily for at least 60 days a year. There are two main types of public water systems, each regulated based on the type of population it serves.

1. Community water systems provide water to 25 or more people or 15 or more service connections with a residential population on a year-round basis.
2. Non-community water systems provide water to a non-residential population of workers, students, or customers. There are two types of non-community systems:
   a) Non-transient non-community systems, like schools and factories, regularly serve the same population at least four hours a day, four or more days a week, six or more months a year;
   b) Transient non-community systems serve water to different individuals, and serve at least 25 persons daily for more than 30 days a year (e.g., a restaurant).

Each type of public water system has different protection needs related to the volume of water pumped and the number of people at risk if the source becomes contaminated. Each system falls into one of four Wellhead Protection categories with different degrees of protection and program development effort depending on the size of the water system.

- Category I is the least protective and applies to non-community transient systems.
- Category II applies to non-community non-transient systems serving water to employees or students during working hours and small community systems serving less than 250 people and or pumping less than 14,500 gallons per day.
- Category III applies to community and non-transient non-community systems serving between 250 and 1,200 people or pumping between 14,500 and 72,000 gallons per day.
- Category IV applies to large community systems serving more than 1,200 people and pumping more than 72,000 gallons per day.