Chapter 1 – Introduction

Groundwater provides a significant amount of drinking water to United States citizens. In 1997, 43,973 community ground water systems served 85 million people throughout the U.S. (U.S. Environmental Protection Agency (EPA), 2000a). The majority of rural areas depend almost entirely upon groundwater as their main source of drinking water (EPA, 1987).

When dealing with groundwater, the lack of visibility proves problematic. An old adage applies well; "out of sight, out of mind." Land use activities, such as gas stations and animal feed lots, surrounding groundwater wellheads and wellfields hold the potential to significantly impact water quality. Poorly dug wells, sinkholes, and poor soil aggravate the situation by acting as a conduit for contaminates to reach groundwater resources (Poff, J., 1997).

Contamination of groundwater sources proves not only complicated by its lack of visibility, but may carry serious health risks. Approximately half of the waterborne disease outbreaks have been attributed to contaminated groundwater drinking sources in the United States (Christman, 1998). The U.S. Congress adopted the Safe Drinking Water Act (SDWA) in order to protect human health and reduce exposure to government-regulated contaminants.

The astounding cost of groundwater contamination has also fueled federal, state, and local government interest in developing drinking water protection programs. Contaminated groundwater remediation will cost the U.S. government almost a trillion dollars over the next thirty years (EPA, 2000b). This price tag excludes the cost of future contamination and impacts upon public health (EPA, 2000b). Proactive drinking water programs enable communities to reduce the risk of contamination and increase the longevity of drinking water supplies.

1.1 Purpose of Paper

The 1986 Amendments to the Safe Drinking Water Act (SDWA) seek to protect public health by minimizing the risk of groundwater contamination (42 USC Sec. 300h-7). 42 United States Code (USC) Section 300h-7 created the "Wellhead Protection Program" (WHPP) (Witten, Horsley, Jeer, and Flanagan, 1995). 42 USC Sec. 300h-7(a) outlines the minimum mandatory steps that each state must include in their prospective program (Witten et al., 1995 and 42 USC Sec. 300h-7(a)). Each plan must designate a lead agency, assessment and implementation steps, public participation, and contingency planning (Witten et al. 1995).

The first section of this paper provides a basic overview of pollution sources, impacts on human and water system health, and contamination costs. This paper then discusses the 1986 and 1996 Amendments to the Safe Drinking Water Act. A description of the Environmental Protection Agency's framework outlines the guidance provided to states in the development of wellhead and source water protection programs. The third section of this paper compares and contrasts the frameworks of two state programs, Virginia and Massachusetts.

Finally, this paper evaluates how Virginia and Massachusetts implement the federal statutes to protect drinking water sources. These states take different management approaches to carry out the same goal. Massachusetts requires localities to adopt wellhead protection programs whereas Virginia encourages localities to participate in the program. Two sets of criteria were utilized to evaluate the programs: a comparison of community and non-community drinking water systems participation in wellhead protection activities and an analysis of state reported drinking water violations exceeding maximum contamination levels and monitoring/reporting from 1993 to 2001. These case studies provide valuable lessons for wellhead protection.

1.2 Impacts upon Health

Contaminated drinking water seriously impacts public health. In 1983, "contaminated groundwater accounted for about 60 percent of reported waterborne illnesses in the United States, including giardiasis, dysentery, conjunctivitis, and meningitis" (Virginia Water Resources Research Center (VWRRC), 1986). Other human health impacts from polluted groundwater sources include leukemia, cancer, blue-baby syndrome, and miscarriages (Poff, 1997 and Witten et al., 1995). Public health issues remain exceedingly complex due to the numerous pollution sources involved.

1.3 Contamination Costs

Groundwater contamination often proves too difficult, expensive, and impractical to clean up (Hrezon & Nickinson, 1986 and EPA, 3/15/2002). Installation of treatment plants and construction of new well or surface water intake systems in a community cost "$2.1 million to $3.1 million (in 1989 dollars), depending on the distance of the community from the new source of water" (Witten et al., 1995). The total cost to remediate groundwater utilized at "a typical nonfederal facility ranged from $6.3 million to $29.5 million" (Witten et al., 1995). Remediation of a contaminated drinking water source costs two to nine times as much as replacing one public drinking supply well. Drilling a new drinking water supply well offers communities the most economical choice (VGWPSC, 1992).

A drinking water program, such as wellhead protection, provides an inexpensive investment to protect the quality and longevity of drinking water sources (Witten et al., 1995). The most expensive activities in a wellhead protection program consist of delineation and land purchases. The cost of a wellhead delineation ranges "widely from a few hundred to several thousands dollars depending on the sophistication of the method employed, the number of wells

being delineated and the availability of basic data" (Report of the Ad Hoc Wellhead Protection Advisory Committee (Ad Hoc), 1991). Although the cost to prevent groundwater contamination through the wellhead protection program varies widely, for some communities "it may be possible to delineate a protection area for as little as $10,000" (Witten et. al, 1995). Adoption of long-range protection measures assist state and local governments to cost-effectively manage groundwater drinking sources (EPA, 3/15/2002).

The SDWA allows states to reduce or waiver some monitoring or treatment requirements for communities with adopted source water protection programs (42 USC 300g-7 and EPA, 3/15/2002). The SDWA requires states to follow EPA guidelines in this process (42 USC 300g-7). A drinking water system with a waiver could see a reduction in monitoring for a specified contaminant "from once every 3 months to once every 3 years" (EPA, 3/15/2002). Due to the expense of monitoring and treatment, cost reduction provides an incentive to local governments to adopt a program (EPA, 3/15/2002).

1.4 Pollution Sources

The vast majority of groundwater pollution comes from non-point sources (Elder, Killam, & Koberstein, 1999). Non-point source pollution occurs from the accumulation of various household, urban, and agricultural activities. The dispersed nature of the activities makes non-point pollution a complex problem for governmental agencies to control and contend with. Septic tank leaks, disposal or overuse of household pesticides and fertilizers, and oil and gas runoff from parking lots provide examples of common non-point sources of pollution (Randolph, 1999 and Poff, 1997).

Dispersed housing in rural areas make the provision of sewage treatment or public water systems prohibitively expensive. Therefore, most homes in rural areas utilize private on-site

septic systems and wells (Poff, 1997). State governments exert control through regulations and permitting systems for the placement of wells and septic tanks (Poff, 1997b). The responsibility for household activities such as fertilizer usage and septic tank pump outs lies with the homeowner (Poff, 1997b).

Karst terrain also poses a serious problem to protecting groundwater quality, particularly in rural areas with on-site septic systems (Poff, 1997). Karst terrain occurs in areas dominated by limestone geology (Zokaites, 1997). Erosion causes sinkholes and caving to occur in karst areas (Zokaites, 1997). Sinkholes function as recharge areas for groundwater aquifers (Weigmann & Kroehler, 1984 and Hirschman, Randolph, & Flynn, 1992). A sinkhole provides a direct conduit for water to drain into the groundwater aquifer (Weigmann & Kroehler, 1984 and Hirschman, Randolph, & Flynn, 1992). Thus, contaminants may easily enter groundwater aquifers through sinkholes. The complex and indiscernible patterns of groundwater flow in karst terrain pose other issues for localities (Randolph, 1999 and Poff, 1997).

In contrast to non-point source pollution, point source pollution originates from a known location (Davidson & Dolnick, 1999). Point sources of pollution trace back to landfills, agricultural practices, cemeteries, and industrial waste lagoons (Randolph, 1999). Government planners can utilize zoning regulations to mitigate the potential of point sources to contaminate groundwater. Determining where to site unpopular industries may turn into an arduous process if residents oppose the location. Thus, planners must balance between satisfying residents and finding environmentally suitable locations.

Chapter 2 - Federal Framework

2.1 Introduction

Congress designated EPA as the lead agency to implement the Safe Drinking Water Act. EPA developed a flexible framework to assist states in the development of wellhead protection programs (Witten et al., 1995). WHPP "protect groundwater that supply wells and wellfields that contribute drinking water to public water supply systems" (EPA, 1989). A wellhead protection program works as a pollution prevention strategy on the local and state government level in order to manage and prevent potentially harmful land use activities from contaminating public drinking water supplies (Witten et al., 1995).

The SDWA only applies to groundwater wells owned by the government or private companies that supply drinking water for public use (Ad Hoc, 1991). Public water supply systems provide water for public consumption such as residential, commercial, or recreational use. Public water supply systems refer to community and non-community systems. Either a municipality or a private company owns community and non-community wells (VGWPSC, 1993). A community drinking water system has at least fifteen service connections or providing service to a minimum of twenty-five people (Witten, 1995). A non-community drinking water system refers to a non-residential use such as an office, restaurant, campsite, and school (EPA, 2/20/2000). A particular non-residential user owns the well, which exclusively provides the owner with drinking water to support the non-residential use. Non-community systems must operate "at least 60 days out of the year" (VGWPSC, 1998c).

The EPA framework provides guidance for meeting the SDWA's requirements (Witten et al., 1995). EPA recognized the vital role local governments and communities play in the success of the WHPP (Witten et al., 1995). Therefore, the framework functions as an adaptive guidance

tool that allows states to "implement within their own unique hydrogeological, political, and social environment" (Witten et al., 1995).

This paper sets out the framework of the EPA WHPP guidance model into five sections: program, assessment, implementation, community participation, and contingency planning. Each section provides an overview of EPA guidance recommendations and rationale for activity in that particular area.

2.2 Safe Drinking Water Act

In 1974, Congress adopted the 42 United State Code Section 300h, known as the Safe Drinking Water Act (SWDA) (42 USC Sec 300h). The federal regulation aims to protect public health by setting minimum standards for public drinking water. The SDWA requires the Environmental Protection Agency to set the maximum contaminant levels (MCL) for all chemicals, nutrients, and microbes posing a risk to public health (42 USC Sec 300g-1). EPA updates the MCL list of contaminates and standards every five years (42 USC Sec 300g-1).

The SDWA also requires states to develop a permitting system for all underground injections (42 USC Sec 300h(a)). These programs prove particularly important in protecting ground water because no permit may be issued if it has the potential to contaminate any present or future source of drinking water (Lehan, Lowery, O'Donnell, & Kline, 1999). Permitting underground injection wells assist states in the enforcement of ground water protection regulations.

2.3 1986 Safe Drinking Water Act Amendments

The SDWA 1986 Amendments required all states to adopt a wellhead protection program (42 USC Sec 300h-7). The 1986 Amendments to the SDWA provides states with the tools to "develop a basic pollution prevention program aimed directly at reducing or eliminating the

threat of contamination to public drinking water supply wells" (Witten et al., 1995). Each state program was to submit their program to EPA by June 1989 for approval (42 USC Sec 300h-7(a)). The SDWA lists a minimum set of requirements that each state must include in its program. Each state program must:

1. Detail state, local, and public water supplier duties in the implementation process;
2. Delineate the wellhead protection area (WHPA);
3. Identify all sources of contaminants that pose public health risks within the WHPA;
4. Describe all of the technical, financial, implementation, and educational components of the program;
5. Develop contingency plans for alternative water sources;
6. Review contamination potential with WHPAs for all new water wells.
7. Provision for public participation

(EPA, 1989, Witten, et al., 1995, and 42 USC Sec 300h-7)

Congress failed to include an enforcement provision in the SDWA. The Act gives EPA no regulatory power to force state governments to adopt a wellhead protection program (42 USC Sec 300h-7(c)). However, the Act provided states with a financial incentive to adopt a program. States with an EPA-approved program become eligible to receive a federal grant (42 USC Sec 300h-7(k)). The federal grant compensated 50 to 90 percent of the cost to implement the state program (USC Sec 300h-7(k)). The financial incentive boosted state interest in wellhead protection programs because every state except Virginia submitted a wellhead protection program to the EPA (EPA, 2/20/2002).

Assessment Process

Local and state governments collect scientific data through the assessment process (Witten et al., 1995). The assessment process consists of delineating a wellhead protection area (WHPA), conducting a WHPA land use inventory, and ranking the potential threats to groundwater drinking sources within the WHPA.

A WHPA encompasses "the surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonable likely to move toward and reach such water well or wellfield" (42 USC Sec 300h-7 and Witten et al., 1995). The types of soil, bedrock, geological structures, and possible natural hazards affect the susceptibility of groundwater to contamination (EPA, 1989). The size of a wellhead protection area can range "from tens of acres to several square miles, and in some cases, to tens of square miles" (EPA, 1989).

Delineating the WHPA provides local governments with the information necessary to make management decisions. Localities learn where and what land use activities need management to prevent contamination of groundwater drinking supplies (EPA, 1989). Potential contamination threats include industrial processes, agriculture uses, underground injection wells, septic tanks, gas stations, parking lots, and roads (Randolph, 1999). All of these activities potentially discharge or leak pollutants, increase the amount of impervious surface causing a loss in groundwater recharge area, or provide a pathway for contaminates to flow into groundwater drinking sources (Hrezo and Nickinson, 1986 and Randolph, 1999).

Delineation of Wellhead Protection Areas

Delineations determine the recharge area directly contributing to the groundwater of a particular well (Witten et al., 1995 and EPA, 1989). A zone of influence and zone of contribution exist for each well. The zone of influence consists of the area in which withdrawal of groundwater impacts groundwater flow by "lowering water levels in an area around the well" (EPA, 1989). A wellhead protection area technically describes a well's zone of contribution (Witten et al., 1995). A zone of contribution encompasses the "full recharge area to the well" (EPA, 1989). Thus, surface water runoff within the wellhead's zone of contribution will

contribute to the recharge of the aquifer (Witten et al., 1995). The wellhead protection area "may constitute all or part of the zone of influence or zone of contribution" (EPA, 1989).

EPA approved of five different delineation methods for states to utilize (Witten, 1995). The "arbitrary fixed radius method" sets a WHPA based solely upon political decisions without consideration of hydrogeologic characteristics (Witten et al., 1995). States often utilize the method as a temporary solution (Witten et al., 1995). The size of a fixed radius may not provide enough protection to drinking water (Witten et al., 1995). A "calculated fixed radius" delineation method accounts for well construction, pumping rate, and aquifer characteristics in determining boundary size and shape (Witten et al., 1995). A "simplified variable shapes" approach utilizes "geometric forms designed to approximate the hydrogeologic characteristic assigned with pumping wells in a particular area" (Witten et al., 1995). Analytical and numerical models utilize mathematics to "predict the groundwater flow patterns surrounding a pumping well" (Witten et al., 1995). Both methods "simulate the movement of groundwater as a function of pumping rate, aquifer characteristics, and static water table/piezometric surface conditions" (Witten et al., 1995).

State and local governments consider time, cost, complexity, and ability to withstand legal challenges when determining which delineation method to utilize (Witten et al., 1995). Often more than one method is utilized in the delineation process. Several states, such as Massachusetts, employ a "three-tiered approach" (Witten et al., 1995). This approach divides a wellhead protection area into three zones. Each zone utilizes a different delineation approach based on a well's proximity to and potential impact from contamination sources (Witten et al., 1995 and EPA, 3/8/2002).

Identification of Potential Groundwater Threats

Inventory and analysis procedures describe the collection of data on all potential contamination sources (EPA, 1988). Each analysis includes "past, existing, and future potential land uses" in each delineated WHPA (Witten et al., 1995 and EPA, 1989). The extent of the analysis varies by locality on availability of resources and immediate concerns (EPA, 1989). Mapping out the inventory geographically locates the proximity of activities and facilities to public drinking wells (EPA, 1989).

The next step requires the categorization and ranking of items listed in the inventory based on the location or "degree of risk" posed to groundwater drinking supplies (EPA, 1989 and EPA, 1998). Each category describes information regarding specific source contamination release, transport, storage, or pollutant treatment (EPA, 1989). Existing permits and licenses provide useful information in the inventory data collection process (EPA, 1988).

Identifying contamination sources enables local government officials to evaluate the most appropriate or feasible strategies to protect public wellheads (EPA, 1989). Strategies range from the complete prohibition of threatening land uses, adoption and enforcement of regulations, and/or development of a cooperative effort to manage potentially harmful activities and facilities within delineated boundaries (EPA, 1989).

Public Participation and Education

Congress and EPA recognize the importance of community participation in carrying out wellhead protection programs (Witten et al., 1995). The SDWA mandates states include public participation "to the maximum extent possible" in the development of a WHPP (42 USC Sec 300h-7(b)). As major stakeholders in WHPP, local residents care about water quality from a health and homeowner perspective. Contaminated water supplies cause property values to

decrease (EPA, 3/15/2002). States need to provide residents and organizations with multiple opportunities to get involved in the development of the WHPP (EPA, 1989). The SDWA specifies creating local committees, notice and opportunity to attend public hearings (42 USC Sec 300h-7(b) and EPA, 1989). State and local governments should educate the public to gain support for wellhead protection programs (EPA, 1989).

EPA recommends public participation opportunities ranging from community meetings to actual citizen involvement in the assessment process activities (EPA, 1989). For example, community organizations can assist local governments in the inventory process (EPA, 1989). Community organizations provide a free source of localized knowledge and support for local government contamination prevention strategies (EPA, 1989). Localities may also draw on these organizations as a source of technical expertise (EPA, 1989).

Implementation of Wellhead Protection Programs

After developing a wellhead protection program, the next step consists of determining how to implement information from the assessment process. The WHPP needs to include and utilize "existing methods and programs that provide protection to wellheads and use prevention and clean-up approaches" (EPA, 1989). EPA recommends that state and local governments utilize a variety of regulatory and non-regulatory planning tools to protect groundwater resources (EPA, 1989). The implementation of WHPP expands existing planning programs to encompass groundwater protection. Most local governments regulate land use and development. Usually local governments prepare comprehensive plans, utilize zoning regulations, and participate in land purchase programs. The variety of planning tools available to a local government depends upon state enabling statutes. This section discusses how to use planning tools to mitigate risk to groundwater drinking supplies.

Comprehensive Plan

The master or comprehensive plan describes the characteristics of the county's physical environment and presents general information of present land uses and locations, residential, agricultural, and commercial developments, population density, and economic activity. The future-oriented plan provides guidance on how to reach the community's goals, objectives, and fulfill anticipated needs. The procedures and objectives promote the public's health, welfare, and safety.

Zoning Regulations

Zoning classifies and regulates different land uses, buildings, and economic activities allowed or prohibited within designated districts (Davidson and Dolnick, 1999 and EPA, 1989). Zones act as a separator of activities and attempt to promote an orderly development pattern (EPA, 1989). Zoning ordinances establish several land use classifications such as single-family residential types, agriculture, commercial, industrial, office, and overlay zones (EPA, 1989 and VGWPSC, 1998). Zoning ordinances set the standard code requirements for the construction of buildings such as set backs or heights. Traditional Euclidean[1] zoning separates residential, commercial, and industrial uses from each other. The zoning ordinance functions as an implementation tool of the town's comprehensive plan.

Local governments also utilize overlay zones to protect wellheads and wellfields. Overlay zones enforce tougher and location specific zoning regulations on an area (EPA, 1989 and Witten et al., 1999). Overlay zones "extend on top of more than one base zoning district and are intended to protect certain critical features and resources" (Davidson & Dolnick, 1999). The boundaries of a WHPA often frame an overlay zone (VGWPSC, 1998).

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[1] 1926 U.S. Supreme Court case Euclid (Ohio) v. Ambler Realty Co. The Supreme Court upheld the "validity of comprehensive zoning (Davidson & Dolnick, 1999).

Planners utilize cluster and incentive zoning methods to protect natural resources. Cluster zoning encourages development to occur on a smaller portion of the property in order to maintain a greater amount of open space and to protect natural resources (EPA, 1989). Overall density remains the same in cluster zoning. Incentive zoning allows the use of bonuses in the form of increased development and capacity in return for the developer providing features or amenities that benefit the locality (Davidson & Dolnick, 1999).

Subdivision Ordinances

A subdivision ordinance "controls the division of a tract of land by requiring development according to design standards and procedures adopted by a local ordinance" (Witten et al., 1999). A subdivision plan provides a drawing of the proposed development (Witten et al., 1999). Subdivision ordinances describe items such as storm water management procedures and distance from a wellhead or wellfield (Hrezo & Nickinson, 1986).

In contrast to a zoning ordinance which controls the intensity and type of uses on a given piece of land, a subdivision ordinance controls the "division of a tract of land by requiring development according to design standards and procedures" (Davidson and Dolnick, 1999). The subdivision of the land must comply with the zoning ordinance and comprehensive plan.

Non-regulatory Land Purchase Programs

Land purchases or easements provide a non-regulatory alternative to protect wellhead areas (Witten & Horsley, 1995). Government or non-profit organizations create land purchase programs in order to gain complete control over the subject property (Witten & Horsley, 1995). Purchasing property requires larger sums of money than regulations, especially, along a shoreline. The purchase of property easements from a landowner provides a less expensive alternative to complete property ownership (Witten & Horsley, 1995). An easement "does not involve the transfer of ownership of the land, instead, it means giving up certain development

rights of the property" (Witten & Horsley, 1995). Stipulations in the contract state permissible or prohibited activities on the property covered by the easement (Witten & Horsley, 1995).

Contingency Plan

The SDWA requires that states develop a contingency plan under the WHPP (EPA, 1989). A contingency plan indicates alternative drinking water sources and describes the short- and long-term emergency actions to "prevent or minimize contamination" of groundwater drinking supplies (Witten et al., 1995 and EPA, January 25, 2002). The plan "prescribes what to do, when to initiate action, who would do it, with what tools and materials, and how it would be done" (Witten et al., 1995).

The following list briefly describes the six required elements in a contingency plan:

- **Inventory of Threats:** Evaluate all possible contamination scenarios such as "accidents, spills, and leaks" (Witten et al., 1995)
- **Design of Response:** Understand contaminant characteristics and the amount potentially released that would reach source; steps to minimize or advert contact with well; plot out alternative drinking sources
- **Assignment of Responsibility:** List contact information and each person's responsibility and role
- **Identification of Logistical, Technical, and Financial Resources:** What resources are needed to carry out the plan and where are those materials located
- **Periodic Review and Update:** Important to keep track of personnel changes and new technologies that improve quality and time of response
- **Public Involvement:** Continuous involvement raises awareness and assists in the identification of existing and new potential contamination threats.

(Witten et al., 1995)

Contingency plans ready state and local governments to effectively assess and handle an emergency situation (42 USC 300h-7). A heightened awareness of the importance of contingency plans exists today due to concerns regarding potential terrorist attacks on drinking water sources.

2.4 1996 Safe Drinking Water Act Amendments

The 1996 SDWA Amendments extends the idea of wellhead protection assessment process to include all current and potential ground and surface drinking water sources (EPA, 1998a). Source water protection provides a comprehensive approach to protecting drinking water because it encompasses all water sources not just groundwater (EPA, 1998a). All states must submit a Source Water Assessment Program (SWAP) for EPA approval (42 USC 300j-13(a) 3). States must complete all source water assessments by May 2003 (EPA, 1998a).

A SWAP details the steps a state will take to accomplish surface and groundwater assessments (EPA, 1998a). The seven steps listed for states to include in a wellhead protection program also apply to a SWAP, but encompasses both surface and groundwater drinking water sources. States must encourage public participation in the SWAP process (42 USC 300g-4).

States choose to implement protective regulations or strategies at their discretion (EPA, 1998a). States are not required to develop and adopt a Source Water Protection Plan (SWPP) under the SDWA (EPA, 1998a). However, the EPA encourages states and localities to implement a SWPP (EPA, 1998a).

Another provision of the 1996 SDWA Amendments requires all public water suppliers to annually mail residents Consumer Confidence Reports (CCR) (42 USC 300g-4). The CCR provides consumers with information on the community drinking water system water quality and details whether any contaminants exceeded the maximum contaminant levels (MCL) standards (42 USC 300g-4).

2.5 Conclusions

Both wellhead protection and source water assessment programs provide states with a framework to proactively protect drinking water sources. These programs offer local and state

governments cost-effective methods to protect communities from harmful contaminates and reduce the risk of closing a public water supply well. Contingency planning prepares communities to quickly and effectively handle a natural or human-induced disaster.

Chapter 3 - Massachusetts Wellhead Protection Program

3.1 Introduction

Located in the northeastern part of the country, the Commonwealth of Massachusetts spans over an area of 7,840 square miles (US Census Bureau, 2000a). The 2000 Census counted 6,349,097 residents for a density of 809.8 persons per square mile (US Census Bureau, 2000a). Rich in colonial New England government traditions, Massachusetts's municipalities still hold town hall meetings (Galvin, 2/22/2002). The Commonwealth and town governments carry out the majority of legislative and judicial functions (Galvin, 2/22/2002). The fourteen counties in Massachusetts's embody a weak form of government (Galvin, 2/22/2002). Thirteen of the county governments do not have taxing authority (Galvin, 2/22/2002).

Massachusetts began contending with major groundwater issues in the 1970's. A major impetus in the adoption of state ground water protection initiatives resulted from several highly publicized groundwater supply contaminations (Witten, 1992). In the1970's an unusually high number of children residing in the Town of Woburn contracted leukemia (BYU, 2/23/2002). An investigation discovered that volatile organic compound (VOC) effluents from several industrial sources had contaminated Woburn's groundwater supplies (BYU, 2/23/2002). In 1977 a different incident occurred in the Town of Falmouth. A leak from an underground storage tank released "3,000 gallons of high-test gasoline into the ground less than 600 feet from the nearest well" in the municipality's wellfield (Witten, 1992). The remediation of the Falmouth's only drinking water source cost more than three million dollars (Witten, 1992). These two incidents captured the public's attention and raised community awareness as to the importance of protecting groundwater resources (Witten, 1992).

Community drinking systems provide water to approximately two million residents (EPA, 2001a). Small public groundwater systems serving a population of less than 10,000 people compose the largest group of drinking water providers in the state (MDEP, 2/16/2002). Out of 3446 surface and groundwater public water systems, 2950 systems draw drinking water from groundwater and spring sources (MDEP, 1999a).

Major Pollution Sources

In Massachusetts, population densities, automobile traffic, and a strong industrial sector cause the majority of contamination problems (GWPC, 1999 and MDEP, 2/16/2002). Massachusetts's adopted wellhead and source water protection programs to cost-effectively and efficiently prevent contamination of drinking water from these various pollution sources (MDEP, 2000a). In particular, Massachusetts attempts to mitigate the risk of chemical contamination to drinking water sources from volatile organic compounds (VOCs) (GWPC, 1999). Volatile organic compounds are used in industrial and dry cleaning solvent products (GWPC, 1999). In the past, over "70 communities have shut down at least one source due to contamination or rehabilitated 217 sources due to contamination, frequently from VOCs" (GWPC, 1999 and MDEP, 1999a).

Massachusetts has spent millions of dollars dealing with contaminated groundwater sources (GWPC, 1999, MDEP, 2001g, and Reimold & Leavell, 1990). Treatment techniques range from the remediation of polluted wells to the construction of replacement wells (GWPC, 1999 and MDEP, 2001g). Massachusetts maintains a Drinking Water database in order to keep track of contamination violations and treatment techniques (MDEP, 2/16/2002).

3.2 Drinking Water Programs

Massachusetts adopted a top-down, hands-on regulatory approach for the wellhead protection program. The state developed comprehensive drinking water programs for all municipal- or privately-owned systems that supply water to the public (MDEP, 2/16/2002). The Massachusetts Department of Environmental Protection (MDEP) administers the state drinking water program. MDEP oversees local governments and public water suppliers to ensure compliance with state water protection regulations (MDEP, 2/16/2002 and Lehan et al., 1999).

Massachusetts consistently develops water quality protection programs on the state level (GWPC, 1999). Since 1980, MDEP has implemented a water supply protection program (MDEP, 2/4/2002a). Massachusetts adopted a Wellhead Protection Program in 1990 (GWPC, 1999). In 1995, the Commonwealth received EPA approval for their Comprehensive Water Protection Program (MDEP, 1999a). The CWPP aims to establish an EPA and state partnership that will "empower the states with greater flexibility and, by eliminating cross purposes, demonstrate the effectiveness of state programs and expedite funding for their support" (EPA, 1992). In August 1999, the EPA approved Massachusetts's Source Water Assessment Program (MDEP, 2001e).

Wellhead Protection Program

Massachusetts requires each local government to develop and implement a wellhead protection program that complies with state regulations (Massachusetts 310 CMR 22.21(2)). The Commonwealth provides a framework for localities to work within, but allows localities to adjust the framework to fit their specific situation (MDEP, 2001g). Public water supplies provided by private companies must also comply with state and local regulations (MA 310 CMR 22.21(2)).

Private water suppliers are encouraged to work closely with local governments in the development of a wellhead protection program (MDEP, 2001g).

Massachusetts WHPP includes a "best effort" requirement for both private water suppliers and municipalities (MA 310 CMR 22.21). Private water suppliers must exert a "best effort" attempt at persuading the local government to adopt wellhead protection controls prior to constructing, expanding, or replacing public water supply wells or wellfields (MA 310 CMR 22.21(1)d). Municipalities must engage in "best effort" to work with surrounding local governments if the Zone II (described below) crosses over political boundaries (MA 310 CMR 22.21 (1)e). Thus, the Commonwealth attempts to generate cooperation by requiring localities to work together in protecting drinking water supply sources. MDEP determines whether a town government exerted a "best effort" to work with surrounding localities that are apart of the aquifer (MA 310 CMR 22.21(1)d). However, a municipality receives an exemption from the "best effort" requirement if they "meet all of [Massachusetts] Wellhead Protection Regulations" (MDEP, 2001c).

Source Water Assessment Program

Massachusetts Source Water Assessment Program expands upon the WHPP and Comprehensive Water Protection Program (MDEP, 1999a). The SWAP contains four steps: delineation, inventory, susceptibility to potential contamination, and publication of outcomes (MDEP, 1990a). The SWAP utilizes, supplements, and improves upon already established programs in order to incorporate all public sources of drinking water (MDEP, 1999a). The program also expands upon or updates Geographic Information System (GIS) data layer information (MDEP, 2/4/2002a).

3.3 Wellhead Assessment Process

The following section discusses Massachusetts's assessment process. The process consists of wellhead protection area requirements for Zone I, II, III, and Intermediate Wellhead Protection Area (IWPA) and inventory and rankings of potential threats located within a WHPA. Figure 3.1 (below) provides an illustration of the boundaries of a Zone I, II, and III (MDEP, 2001g).

Table 3.1 (below) describes each of the delineation requirements for a wellhead protection area. The Zone I fixed radius automatically applies to every wellhead (Lehan et al., 1999 and MDEP, 2001g). The water supplier must eventually own or control the land through a conservation easement within a Zone I (Lehan et al., 1999). Table 3.1 shows that only activities related to the operation of a wellhead may occur in a Zone I (Lehan et al., 1999).

A Zone II encompasses the primary recharge area for a wellhead (Lehan et al., 1999 and MDEP, 2001g). As shown in Table 3.1, the Massachusetts Water Management Act (WMA) requires public water suppliers to delineate a Zone II within three years after receiving approval for a permit for the expansion or construction of a new well (Lehan et al., 1999 and MDEP, 2001g). Zoning and non-zoning controls must prohibit certain activities within the Zone II such as landfills, graveyards, junkyards, hazardous waste facilities, and wastewater treatment plants (MDEP, 2001g). As an immediate protective strategy, Massachusetts required the immediate adoption of IWPAs for every wellhead until the completion and approval of a Zone II delineation (Lehan et al., 1999 and MDEP, 2001g). Several municipalities still utilize IWPAs for public wellheads because they have not delineated a Zone II (MDEP, 1999a).

Table 3.1 describes how Zone III delineations must follow the drainage and topological patterns (Lehan et al., 1999 and MDEP, 2001g). Delineating a Zone III helps localities

recognize what types of land use activities occur in the secondary recharge area (Lehan et al., 1999). Both the public water supplier and locality are responsible for the delineation of Zone II and Zone III (Lehan et al., 1999). A Zone III does not have to adopt zoning and non-zoning controls unless the zone meets the standards set forth in the Massachusetts Wellhead Protection Regulations (MDEP, 2001g).

Table 3.1: Overview of Wellhead Primary and Secondary Recharge Area Regulations

Zone	Recharge	Protection Area	Responsibility	Time	Zoning Controls
Zone I	Primary Recharge Area	Fixed Radius 100-400 ft. Based on Gallons Pumped 400 ft if >100,000 gallons pumped daily (gpd)	State mandates supplier must own land or conservation easement within zone	Immediate	No Activity unless related to well; Zoning & No-zoning controls
IWPA	Primary Recharge Area	Temporary Protection until ZII delineated; 400 to ½ mile radius based on gpd	State Mandate 1987	Immediate	
Zone II	Primary Recharge Area	Boundary area of aquifer contributes under water to well under severe conditions	Supplier & locality WMA required to delineate if >100,000 gpd pumped	WMA permit implement within 3 years of approval	Zoning & non zoning controls; Prohibit activities such as landfills, junkyards, hazardous waste facilities, wastewater treatment plants
Zone III	Secondary Recharge Area	Follows surface and groundwater drainage and topography that flow into Zone II	Supplier & Locality		Must adopt zoning & non-zoning controls only if the ZIII meets Massachusetts Wellhead Protection Regulations

(Lehan et al., 1999 and MDEP, 2001g)

In terms of wellhead protection, the SWAP describes several delineation projects for MDEP to undertake (MDEP, 1999a). One MDEP project seeks to conduct Zone II delineations for all communities with non-complying public wellheads and/or to improve the delineation of IWPAs (MDEP, 1999a). MDEP set the goal to assist "all community water supply wells with

approved yields of 100,000 gpd and greater" to obtain an approved Zone II (MDEP, 1999a). MDEP staff will conduct the majority of the delineations, however a contractual agreement commits the United States Geological Service (USGS) to conduct several aquifer studies (MDEP, 1999a).

Local governments receive technical support from the Commonwealth staff or contractors (MDEP, 1999a and MDEP, 2001e). MDEP also provides training to local government staff (MDEP, 1999a). MDEP and contracted assistance appears ready to complete the majority of the assessments within the two-year time frame set out by EPA (MDEP, 2001e).

Figure 3.1 shows how Massachusetts's Zone I, II, and III correspond to each other (MDEP, 2001g). Zone I immediately surrounds the wellhead with a circular radius. Zone II follows the primary recharge area around for the wellhead. Although not fully pictured, the Zone III (represented by dash marks) delineates the secondary recharge area for the wellhead.

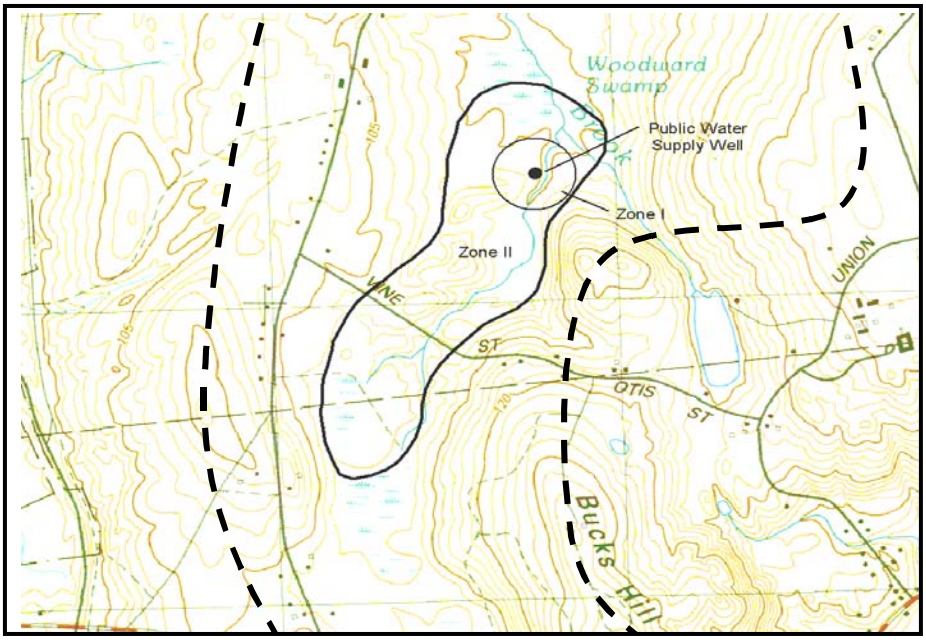

Figure 3.1: Map shows Zone I, II, and III (- -) boundaries surrounding a public groundwater supply
Courtesy of MDEP

Inventory and Rankings

The SWAP updated the WHPP approach in the determination of an aquifer's susceptibility to contamination and inventorying land uses (MDEP, 1999a). The SWAPs "Land Use Pollution Potential Matrix" accounts for "land uses, inherent characteristics of contaminants, and hydrologic and hydrogeologic factors" (MDEP, 1999a). The program stresses listed land use activities only present potential threats (MDEP, 1999a). With careful management, the land use activities may never cause contamination (MDEP, 1999a). Massachusetts "desires to de-emphasize the actual susceptibility ranking and focus attention on the recommendations for improving protection" (MDEP, 2001f). The Matrix excludes the name of potential polluters in order to maintain a cooperative relationship with all parties rather than assigning blame and risking opposition (MDEP, 1999a). The public can access the Matrix information in map format and a land use characterization table describing the Zone II area (MDEP, 1999a).

3.4 Implementation

The Massachusetts Department of Environmental Protection (MDEP) administers the Drinking Water Program. The MDEP provides local governments with technical assistance and guidance on how to develop programs and regulations. MDEP reviews and approves wellhead protection area delineations, groundwater zoning regulations, and best effort requirements.

Local governments are responsible for developing a wellhead protection program. While the WHPP reflects the local situation, it must meet the minimum standards set out by MDEP in order to receive approval (MDEP, 2001g). When a program fails to meet the statutory requirements, the MDEP works with the locality to bring the program into compliance (MDEP, 2001g). Local governments must receive MDEP approval of wellhead protection measures in

order to receive a Water Management Act permit to connect a new well to an existing water line (Lehan et al., 1999).

Localities have three years to adopt "zoning and non-zoning" measures once MDEP approves a Zone II delineation (Lehan et al., 1999). MDEP developed the "Model Conservation Restriction For Water Supply Protection" for Zone I, II, III and "Model Groundwater Protection District Bylaw/Ordinance" to guide local governments in the development of ordinances (MDEP, 1997a and MDEP, 2/4/2002 (b) and (c)). To receive MDEP approval, a local zoning ordinance must, at a minimum, contain standards at least as stringent as described in the model ordinance (MDEP, 1997b). Massachusetts encourages, rather than mandates, the enactment of local groundwater protection laws (MDEP, 2001g).

MDEP developed a "Sample Water Supply Protection Checklist" to assist in the review process for proposed land uses within a WHPA for local governments with adopted groundwater protection regulations (MDEP, 2001g). Utilizing the Checklist improves coordination of "information and efforts among the multiple entities that play a role in water supply protection" (MDEP, 2001g).

Agency and Partnership Framework

Various departments participate in drinking water management activities. The Massachusetts Department of Water Supply (MDWS) issues groundwater withdrawal permits in compliance with Water Management Act (MA 310 C.M.R. 36.00). The Massachusetts Department of Environmental Management administers the well driller permit program (MDEM, 3/28/2002). The Massachusetts Department of Food and Agriculture (MDFA) approves "pesticide management plans" for applications of "any product on the groundwater protection list" within a Zone IIs or IWPAs of a well pumping greater than 100,000 gallons per day

(MDFA, 2000). The New England Interstate Pollution Control Commission works with the Commonwealth to assist and "coordinate the management of the region's vital groundwater resources, protecting them from pollution and depletion" (NEIWPCC, 3/4/2002).

Financial Assistance and Incentives

The cost to conduct groundwater drinking water protection activities, excluding land acquisition purchases, range in Massachusetts from "$10,000 to $100,000 for large ground water systems and up to $200 for small ground water systems" (GWPC, 1999). To offset the costs, localities apply for financial assistance from several different sources such as the Water Pollution Abatement Trust, Aquifer Land Acquisition Program, Wellhead Protection Grant Program, and Source Water Protection Grant Program.

The Water Pollution Abatement Trust accepts applications from local governments interested in obtaining low-interest loans (Massachusetts Department of State Treasurer (MDST), 3/3/2002). The Trust functions under the State Revolving Loan Fund for wastewater treatment (MDST, 3/3/2002). The SRLF received a total of $375 million from federal grants and Massachusetts matched with $75 million (MDST, 3/3/2002). Under the SWAP, Massachusetts awarded $1.25 million in grants to 40 out of 51 public water supply applicants in December 1999 (MDEP, 1999e).

Massachusetts's Aquifer Land Acquisition Program provides funds for the purchase of critical aquifer recharge land (EPA, 1989 and Lehan et al., 1999). Localities with approved Zone IIs receive an advantage over localities without an approved Zone II in the grant application process (Lehan et al., 1999).

The Massachusetts Wellhead Protection Grant Program has a proposed budget of $380,000 for 2002 (MDEP, 2002b). Municipal and privately owned public water suppliers may

receive a maximum of $45,000 for wellhead protection activities (MDEP, 2002b).

The Massachusetts Source Water Protection Grant Program has a proposed budget of $245,000 for 2002 (MDEP, 2002a). This grant program offers eligibility to a wider range of applicants such as regional planning agencies, citizen and business organizations, and land trusts (MDEP, 2002a).

Massachusetts offers other incentives to drinking water suppliers and localities. MDEP offers monitoring waivers to encourage small and large water systems to voluntarily meet protection standards (MDEP, 2001b). A waiver reduces water suppliers monitoring requirements and associated costs (MDEP, 2001b). The Massachusetts Drinking Water Awards Program recognizes private and municipal water suppliers for their accomplishments in protecting drinking water sources (GWPC, 1999).

Local Government Participation

Massachusetts's regulatory approach and active involvement in wellhead protection assists many communities in the protection of groundwater drinking sources. All public drinking water supply wells automatically receive Zone I protection. The MDEP "digitized WHPAs for all 2,950 wells" in MassGIS (MDEP, 1999a). However, many wellheads do not have a delineated Zone II. As of 1999, MDEP "approved 337 Zone II analyses for a total of 766 public supply wells" (MDEP, 1999a). The 2,184 public groundwater wells without an approved Zone II utilize an IWPA until the completion and approval of a Zone II (MDEP, 1999a).

A small number of local governments and private water suppliers surpass Massachusetts's regulatory requirements in public drinking water protection. As of 1999, "63 public water systems (308 sources) meet MDEP's most stringent requirements for groundwater protection" (MDEP, 1999a). In addition, "179 communities have voluntarily adopted

groundwater protection bylaws and 81 have voluntarily adopted watershed protection regulations" (MDEP, 1999a).

Citizen involvement in the wellhead protection process has generated efforts to move beyond local boundaries to form regional groups "for the purpose of protecting their shared groundwater resource" (Lehan et al., 1999). Public awareness and involvement motivates local governments to undertake more rigorous groundwater pollution prevention strategies.

3.5 Public Participation and Education

Massachusetts encourages local governments to utilize a variety of public outreach tools in order to raise awareness of surface and ground water protection issues (MDEP, 2001g). Suggested tools include posting signs in recharge areas, submitting newspaper articles, and offering educational activities (MDEP, 2001g). Massachusetts integrated public participation in the development and implementation of SWAP through traditional formal meetings and "requested input at public forums and inter-agency meetings" (MDEP, 1999a). Two SWAP advisory committees include citizens and community organizations as members (MDEP, 2/4/2002a). The Massachusetts Drinking Water website provides the public with information on SWAP and provides an e-mail or form for comments on the program (MDEP, 1999a).

Figure 3.2: Wellhead Protection Area Sign
Courtesy of MDEP

Massachusetts Drinking Water Education Partnership provides a wealth of information geared toward residents, teachers, and children (MDWEP, 3/4/ 2002). The Partnership focuses on the protection of drinking water resources and public health through collaborative processes (MDWEP, 3/4/ 2002). The Partnership offers educational programs and participates in Drinking

Water Week activities, such as sponsoring an interactive water resource protection play for children (MDWEP, 3/4/2002).

MDEP requests that local Boards of Health provide assistance in gathering or providing data for source water assessments (MDEP, 2000). The Boards should advise local officials on public health aspects of protecting drinking water supplies and assist in public education (MDEP, 2000).

3.6 Contingency Planning

Massachusetts requires water supplier's to work with local officials to develop contingency and emergency plans (MDEP, 2001g). Massachusetts requires a contingency plan to identify "short-term storage, temporary and permanent alternative sources, interconnections and measures for treating a water supply should contamination occur" (MDEP, 2001g). Emergency plans outline the government's response to natural or human-induced disasters (MDEP, 2001g). Massachusetts's "Wellhead Protection Implementation Biennial Report" to the EPA counted the completion of approximately 1500 contingency plans for public water systems from 1993 to 1997 (EPA, 2/20/2002).

3.7 Conclusion

Massachusetts's Wellhead Protection Program and Source Water Assessment Program provide substantial guidance to municipalities. The WHPP stresses cooperation and coordination among all stakeholders. As an oversight agency, MDEP handles technical and financial resources as well as enforcement capabilities. Massachusetts provides financial and monitoring waiver incentives to communities and water suppliers to adopt control and non-control groundwater management programs and regulations.

Chapter 4 - Virginia Wellhead Protection Program

4.1 Introduction

Located in the mid-Atlantic region, the Commonwealth of Virginia covers over 39,594 square miles (US Census Bureau, 2000b). The 2000 Census counted 7,078,515 residents in Virginia at an average population density of 178.8 people per sq mile (US Census Bureau, 2000b). Virginia legislation grants local governments the legal authority to regulate land use within the locality's boundaries. Land use decisions fall under the domain of county and city governments. As a Dillon's Rule state, "local governments have only those powers expressly given to them by the state legislature" (Hrezon and Nickinson, 1986). Thus, the state legislature determines the tools, if any, available to local governments to protect public drinking water wellheads (Hrezo & Nickinson, 1986).

The majority of Virginia's public water systems withdraw groundwater as a source of drinking water. Privately owned drinking water suppliers operate two-thirds of Virginia's community wells (Ad Hoc, 1991). 40% of Virginia's 95 counties depend on groundwater to supply all public drinking water systems (GWPC, 1999). There are 3805 public drinking water supply systems in Virginia and 90% of the systems utilize groundwater (EPA, 2/20/2002 and EPA, 2001c). Pubic water supply systems dependent upon groundwater support 1,616,680 citizens (EPA, 2001c).

Virginia's diverse geology plays an important role in groundwater protection. Five different geologic provinces exist in Virginia (Weigmann & Kroehler, 1984). Each province is grouped by common geological composition characteristics (Weigmann & Kroehler, 1984). As shown in Table 4.1, the Valley and Ridge province rated very high on a pollution potential scale due to the high levels of karst terrain (Weigmann & Kroehler, 1984). As discussed previously,

karst terrain occurs in areas dominated by limestone geology (Zokaites, 1997). Common features in karst terrain include "sinkholes, disappearing streams (streams that suddenly disappear underground), and numerous caves and springs" (VGWPPSC, 1993). Sinkholes serve as surface recharge areas in karst terrain and provide contaminates with a direct path to reach the groundwater table (Weigmann & Kroehler, 1984 and Hirschman, Randolph, & Flynn, 1992). As shown in Table 4.1, the Coastal Plain pollution potential is high due to the permeability of sand and gravel soils and high density of population (Weigmann & Kroehler, 1984). The Coastal Plain province also faces potential contamination of groundwater sources from saltwater intrusion (Weigmann & Kroehler, 1984).

Table 4.1: Characteristics of Virginia's Five Geological Provinces

Province	Geological Composition	Pollution Potential	Groundwater Yield
Cumberland Plateau	Sandstone, shale, and coal	Moderate	15 - 50 gpm
Valley and Ridge	Limestone, dolomite, shale, and sandstone	Very high	Up to 3,000 gpm
Blue Ridge	Granite, gneiss, and marble	Low	20 gpm
Piedmont	Crystalline	Moderate to low	3 – 20 gpm
Coastal Plan	Sand, gravel, clay, shell rock	High	10- 50 gpm; Industrial production wells 2,000 to 3,000 gpm

Gpm= gallons per minute (Weigmann & Kroehler, 1984)

In addition to geological differences, rural and suburban areas face different contamination threats. Several counties within the greater Washington, D.C. metropolitan area constitute the area commonly referred to as Northern Virginia. Massive population growth and development pressures force Northern Virginia to contend with potential drinking water contamination resulting from increased urban runoff (Northern Virginia Planning District Commission & Engineers and Surveyors Institute, 1992). In more rural parts of the state, communities face potential drinking water contamination from leaking septic tanks and agriculture runoff (Weigmann & Kroehler, 1984). Both rural and urban areas contend with leaking petroleum underground storage tanks (GWPSC, 1999). Throughout the 1990's the

Department of Environmental Quality "reimbursed [underground storage] tank owners $67 million for remediation of ground water contamination" (GWPSC, 1999). However, no comprehensive assessment of the Virginia's groundwater contamination costs exists (GWPSC, 1999).

4.2 Drinking Water Program

The Commonwealth of Virginia advocates the voluntary participation of local governments in wellhead protection programs (VGWPSC, 1992). Virginia remains the only state to not submit a wellhead protection program to the EPA in accordance with the 1986 SDWA Amendments (EPA, 2/20/2002). The Commonwealth submitted a source water assessment program to EPA in accordance with the 1996 SDWA amendments (VDH, 2001). Virginia's SWAP incorporates wellhead protection assessment activities (VDH, 1999). Local governments participate voluntarily in the Source Water Assessment Program (VDH, 1999). This section focuses mainly on the SWAP because Virginia describes recommended steps and methods for localities to utilize in both wellhead and surface water assessments.

Wellhead Protection Program

The Ad Hoc Wellhead Protection Advisory's 1991 Committee Report recommended a voluntary wellhead protection program due to the lack of "public awareness and support, the availability of important data, development of needed technical capability and the funding necessary for undertaking a mandatory statewide program" (Ad Hoc, 1991). Thus, Virginia local governments voluntarily undertake the WHPP process. The Commonwealth relies on the Department of Health (VDH), Department of Environmental Quality (DEQ), Virginia Groundwater Protection Steering Committee (VGPSC), Virginia Water Resources Research Center, and Virginia Rural Water Association (VRWA) to provide technical assistance and

support to localities (VDH, 1999). The agencies and organizations also educate communities on the importance of both public and private wellhead protection (VDH, 1999).

Source Water Assessment Program

VDH intends to complete all source water assessments by 2003 (VDH, 1999). The following committees worked together to develop the SWAP: Source Water Assessment Technical and Citizens Advisory Committee (TAG), Source Water Assessment Team (Team), and a Waterworks Advisory Committee (WAC) (VDH, 1999). Committee membership included technicians, government agencies, and citizens (VDH, 1999).

Virginia's major SWAP goal states: "Assessments will be conducted for the protection and benefit of waterworks thereby protecting the public's health and for the support of monitoring flexibility" (VDH, 1999). During the public comment period, citizen groups pointed out the exclusion of public health from the SWAP goal (VDH, 1999). The final SWAP revision included public health along with considerations to not overly burden waterworks (VDH, 1999).

SWAP employs preexisting regulations and monitoring programs. Virginia Code Section 1453(a)(6) requires SWAP to utilize established programs in order "to avoid duplication and to encourage efficiency, the program under this section may make use of any of the following vulnerability assessments, sanitary surveys, and monitoring programs" (VDH, 1999). VDH must use all available information collected under preexisting regulations to the maximum potential in order to support the assessment process (VDH, 1999). Building upon established programs reduces financial expenditures, condenses existing information, and decreases strain on available resources (VDH, 1999). Another major consideration in the development of the plan includes time constraints of available technical and employee resources (VDH, 1999).

4.3 Wellhead Assessment Process

The assessment process consists of two main parts: Source Water Assessment Area Delineation and Susceptibility Determination (VDH, 1999). Assessments utilize fixed delineations for ground and surface water drinking sources (VDH, 1999). The SWAP adopted a fixed delineation method for wellhead protection areas (VDH, 1999). Two different zones divide each WHPA. Zone I fixes the WHPA boundary at a 1000-foot radius (VDH, 1999). Zone II fixes the WHPA boundary at a one-mile radius (VDH, 1999). The decision to set fixed radiuses was based upon cost-effectiveness, current monitoring and permitting programs, regulations, and existing information (VDH, 1999).

VDH completed "Groundwater Under Direct Influence of Surface Water (GUDIS) assessments" (VHD, 1999). The GUDIS study identified "sources experiencing microbiological contamination resulting from surface water influence" (VDH, 1999). Utilizing the existing information from the GUDIS assists VDH in concentrating on areas with known susceptibility problems (VHD, 1999).

VDH contracted the USGS and Department of Conservation and Recreation (DCR) to conduct sampling studies (VDH, 2001). Instead of assessing every public drinking water source throughout the state, VDH intends to conduct in-depth assessments in areas with higher levels of susceptibility (VDH, 1999). This assessment approach allows the VDH to concentrate financial and technical resources in areas with the greatest need (VDH, 1999).

VDH contracted with the USGS to develop and conduct a four year "Virginia Aquifer Susceptibility (VAS) Study" (GWPSC, 2000). The study plans to sample 160 wells and springs in the four physiographic provinces in Virginia. The VAS Study "use[s] age determinations as a guide for the classification of areas in terms of the susceptibility of ground water to near-surface

contamination" (GWPSC, 2000). To determine the age of groundwater "environmental isotopes and tracers", such as carbon-14, chlorofluorocarbons, and tritium, are utilized (USGS, 4/1/2002). The age of the groundwater relates information on how quickly groundwater moves through the aquifer (GWPSC, 2000). The groundwater's age also provides information regarding the aquifer's susceptibility to contamination (GWPSC, 2000). Groundwater less than fifty years old faces a greater susceptibility to contamination (GWPSC, 2000). The study outcomes will "aid in screening groundwater supplies to identify those [aquifers] that may require a higher level assessment during the source water protection phase" (GWPSC, 1998).

VDH contracted with VDCR for a five-year karst terrain study to assist in the delineation of drinking water supplies (VDH, 2001 and GWPSC, 1998). Each year VDCR conducts "four to six geological studies" in VDH targeted areas (GWPSC, 1998). Fast moving waters through underground conduits in karst terrain poses a problem because of the difficulty in knowing "whether protecting the area in the immediate vicinity of the well will be adequate" because groundwater "could come from many miles away" (Ad Hoc, 1991). Outcomes from the study will be utilized in the source susceptibility determinations phase (GWPSC, 1998).

The second step in Virginia's source water assessment requires a "Susceptibility Determination Process" (VDH, 1999). The three-step process determines susceptibility, conducts an inventory of "Land Use Activities (LUA) of concern and potential conduits to groundwater", and rates the groundwater sources susceptibility (VHD, 1999). The outcome of the three-step process categorizes the susceptibility determination for each groundwater source as "very low, low, moderate, [or] high" (VDH, 1999).

The susceptibility determination classifies a source as either sensitive or not sensitive (VDH, 1999). VDH automatically considers a "GUDIS source as sensitive" to contamination or

if the source is located in an "area that tends to promote contamination migration" (VDH, 1999). The SWAP lists five requirements for a groundwater source to meet before classifying a source as not sensitive (VHD, 1999). These requirements include well casing requirements, no contamination detection over a five-year period, and a recent confirmation that the well meets "construction standards of the *Virginia Waterworks Regulations*" (VDH, 1999).

The committees composed a Land Use Activity Inventory (VDH, 1999). The list consists of land use activities that pose potential threats to drinking water sources (VDH, 1999). Local governments should only inventory the land uses listed in the Virginia SWAP (VDH, 1999). Each land use activity becomes characterized by perceived risk potential and types of contaminants potentially released (VDH, 1999). Listed besides each item: contaminants released, surface and ground water risk, and North American Industry Classification System (NAICS) (VDH, 1999). VDH must ensure all land use activities listed in the SWAP are inventoried within a Zone I (VDH, 1999). The SWAP does not require local governments to prohibit potentially harmful land use activities from either Zone I or Zone II WHPAs (VDH, 1999).

The last step in the Susceptibility Determination Process rates groundwater sources on a very low to high scale based on source sensitivity and LUAs (VDH, 1999). Susceptibility assignments depend upon the source water's hydrogeologic sensitivity to land use activities in the WHPA (VDH, 1999). LUAs are ranked "as to relative health risk" posed by "perceived risk of release of the contaminant from a LUA, chance of transport of the contaminant from the source water," and the "relative public health risk of the contaminant itself" (VDH, 1999). Any information regarding the best management practices or "inappropriate operation or housekeeping" by a LUA will not change the ranking but will be included in the final report

(VDH, 1999). VDH suggests utilizing the information for "setting priorities for source water protection activities" (VDH, 1999).

4.4 Implementation

VDH Division of Drinking Water administers drinking water protection activities. Due to the voluntary nature of the program, VDH does not oversee or administer an approval process for local programs. Virginia Waterworks Regulations appointed the Virginia Department of Health (VDH) as the agency responsible for "protection of public health in the construction of public water supply wells" (VGWPSC et al., 1992). The VDH Division of Water Supply Engineering runs the permitting section for the construction of septic tanks, the construction and abandonment of private and public wells, and regulates public water suppliers (VDEQ, 1998 and Hrezon & Nickinson, 1986).

The Commonwealth has several regulations and programs that regulate activities which may potentially impact groundwater quality (VDEQ, 1998). Different state agencies administer these regulations and programs. VDEQ administers the Ground Water Management Act of 1992, Underground Storage Tank Program, and enforces "groundwater quality standards" (VDEQ, 1998). VDCR administers the Nonpoint Source Pollution Management Program (VDEQ, 1998). Virginia Department of Agriculture and Consumer Services (VDACS) runs the Pesticide State Management Plan (VDEQ, 1998).

Partnerships and Activities

VDH's Office of Water Protection has a joint contract with the Virginia Rural Water Association (VRWA) to assist communities with small water systems engage in source water and wellhead protection activities (VDH, 2001 and GWPSC, 2000). Four VRWA technicians actively contact communities and provide assistance and training in the development and

implementation of either a SWPP or WHP (VDH, 2001). Technicians have aided several localities. VRWA technicians made almost four hundred on-site visits between 1998 and 2000 (GWPSC, 2000). The technicians provided SWAP development and implementation assistance to the counties of Page, Shenandoah, Lunenburg, King George, and Charlotte (GWPSC, 2000).

Localities have authority to utilize land use regulations to protect groundwater sources (Ad Hoc, 1991). Local governments bear the burden of implementing wellhead protection activities due to minimal state and contract resource and technical assistance. However, insufficient knowledge and data regarding the interface of groundwater flow paths and potential contamination threats impede the adequacy of land use planning tools to protect groundwater (Technical Advisory Group (TAG), 2002).

The House Joint Resolution No.161 (HJR 161) was appointed by the State Water Commission to lead an evaluation of groundwater issues in karst terrain from 2000-2002 (TAG, 2002). HJR 161 required the formation of a Technical Advisory Group (TAG, 2002). TAG provided technical assistance in evaluating the feasibility of conducting a "karst groundwater monitoring study" in Virginia's Shenandoah Valley.

TAG discovered a major disparity in the implementation of the Groundwater Management Act between the Coastal Plain and the central and western regions of Virginia (TAG, 2002). The Act allows the "creation of ground water management areas" and requires a permit for wells pumping "more than 300,000 gallons per month" (VDEQ, 1998). In comparison to the Coastal Plain, the central and western regions lack adequate monitoring, data collection, and protection activities to adequately manage groundwater sources (TAG, 2002). The central and western regions of the state have deficient information regarding "groundwater level and stream flow data on the local- to regional scale" (TAG, 2002). The regional disparity

emphasizes the need for a statewide comprehensive program to provide coordination between "local groundwater protection efforts" and the development of a "data management system for groundwater resources" (TAG, 2002).

Financial Provisions and Incentives

In 1999, the Virginia General Assembly adopted the Water Supply Assistance Grant Fund (Code of Virginia Section 32.1-171.2). Localities and waterworks owners may apply for financial assistance if it falls under the following categories: surface water development or improvement, small project construction, or planning activities (VDH, 2002). The available funding for 2002 is $360,000 (VDH, 2002). Over half of the funding is for surface water development or facility improvements (VDH, 2002).

The federal government provides a significant amount of money to support local and state water protection activities. EPA provides an annual grant of one million dollars to the VDH for "assistance and enforcement activities" of drinking water standards under of the SDWA (Crumbley, 1992). The 1996 SDWA Amendments created the Drinking Water State Revolving Fund (VDH, 2001). State governments match 20% of the federal grant (VDH, 20001). Localities receive money in the form of a low-interest loan (VDH, 2001). The loans may be used to fund set-aside activities and projects. A set-aside fund takes care of non-project activities such as administration costs (VDH, 2001). For example, set-aside funds pay for the VRWA contract (VDH, 2001). Project funds support larger scale project such as construction of treatment facilities (VDH, 2001). In fiscal year 2002, the federal government will provide Virginia with an estimated $10,760,000 and Virginia will match $4,500,000 (VDH, 2000).

High levels of competition exist between Virginia localities for an average of only sixteen million dollars per year available to finance drinking water facility construction,

treatment, monitoring and source protection activities (TAG, 2002 and VDH, 2001). Source protection activities receive only a small portion of the financial assistance (VDH, 2002). Without adequate financial assistance, incentives to participate in groundwater protection activities remain low.

Local Government Participation

Virginia's wellhead protection has achieved minimal success in adequately protecting public groundwater resources. Since the 1986 SDWA amendments, only 37 entities have participated in the wellhead protection activities (VGWPSC, 1998c). These entities consist of towns, counties, water suppliers, Planning District Commissions (PDC), and Public Service Authority (PSA) (VGWPSC, 1998c). County and PDC participation provides coordination of wellhead protection activities among towns and counties (VGWPSC, 1998c). However, the number falls short of sufficient participation in groundwater drinking source protection.

Virginia's Biennial Wellhead Protection Report for 1997 to 1999 provided community water system participation information on five steps in wellhead protection process: getting started, delineation, potential sources of contamination identification, source management, and contingency planning (VDEQ, 1999). Small community drinking water systems represent the majority of suppliers involved in various stages of wellhead protection activities (VDEQ, 1999). Small community systems supply 25 to 1000 residents with drinking water (VDEQ, 1999). Virginia reported three small systems had started the process, 21 small systems had conducted delineations, five small systems had identified potential sources of pollution, and four small systems had participated in management activities within the protection area (VDEQ, 1999). The systems may not have completed each step but made significant progress towards completion (VDEQ, 1999). From 1997 to 1999, a total of 33 systems serving a population of

36,865 participated in a wellhead protection activity (VDEQ, 1999). Only nine of the local governments moved beyond assessment stages and identified and managed sources (VDEQ, 1999).

TAG opined that Virginia has neither a "comprehensive policy [nor] program for coordinating local groundwater protection efforts, nor a centralized monitoring and data management system for groundwater resources" (TAG, 2002). Virginia's SWAP did not alter state agency oversight roles, support, or involvement in water supply protection activities. Local governments with "groundwater supply and quality concerns can expect little relief from agencies constrained by current policies" (TAG, 2002).

4.5 Public Participation and Education

In 1984, Virginia received a grant from the EPA's Groundwater Protection Strategy (VGWPSC, 1987). The EPA Strategy intends to help strengthen state programs (VGWPSC, 1987). As a result, the Virginia Groundwater Protection Steering Committee formed in 1985 (VGWPSC, 1987). Eight different state government departments, along with the Virginia Water Control Board, and the Council on the Environment made up the VGPSC membership (VGWPSC, 1987 and VGWPSC et al., 1992). Each member permits or administers programs regulating surface and underground activities with potential groundwater contamination impacts (VGWPSC et al., 1992). The VGPSC developed several manuals to aid localities in the development of a WHPP (VGWPSC et al., 1992). The Steering Committee also publishes an annual report on statewide groundwater protection activities. In 1998, GWPSC hosted "three one-day workshops, and the voluntary completion of two Biennial Wellhead Protection Reports" (VDEQ, 1998).

In 1998 the Virginia Ground Water Guardians Affiliate Team (Team) "improved networking and outreach and education efforts" (GWPSC, 1998). The Team promotes the development of partnerships between "communities and businesses on ground water protection goals" (GWPSC, 1998). Membership on the Virginia Team consists of "federal, state, and local organizations, non-profit groups, and environmental interest groups" (GWPSC, 1998). VDCR staff coordinates the Team activities (GWPSC, 1998).

Local governments are encouraged to educate residents on the importance and methods to utilize in order to protect ground water resources (GWPSC, 1998). Virginia suggests educational activities include: "informational brochures, public forums, curricula, and other creative avenues" (GWPSC, 1998).

4.6 Contingency Planning

As of September 1999, no local governments had started or completed a contingency plan (EPA, 2/20/2002). With the low completion rates of WHPA and SWAP, the focus remains on finishing the assessment, potential sources of contamination identification, and source management steps (EPA, 2/20/2002). However, a greater emphasis on contingency planning may result from the September 11, 2001 terrorist acts.

4.7 Conclusion

Virginia's early approach to wellhead protection failed to adequately stimulate local government participation. The Commonwealth's Source Water Assessment Program provides a more comprehensive approach to assessing drinking water protection. Participation for local governments in the assessment process remains voluntary. The voluntary approach provides an opportunity for local and state agencies, non-profit organizations, and community groups to collaborate together in undertaking wellhead protection activities. However, local governments'

ability to participate in and adopt wellhead protection initiatives remains hindered by the lack of financial provisions, incentives, availability of technical assistance, and accessible data.

VDH is utilizing a cost-effective method to conducting in-depth delineations by prioritizing areas based on susceptibility to contamination. This tactic works well in Virginia because financial resources are utilized to target the regions in need of greater protection. This method should provide quality data for susceptible aquifers instead of over expending financial and technical resources by attempting to conduct in-depth delineations for every wellhead.

Chapter 5 - Evaluating Success

A comparison of both programs provides insight into the success achieved by Massachusetts and Virginia. This paper uses the percentage of protected public groundwater systems and the percentage of state reported water quality violations as possible measures to evaluate success. The number of community and non-community systems participating in wellhead protection activities provides insight into the level of local government participation under each approach. A comparison between the percentage of state reported violations and systems reported for maximum contaminant levels (MCL) and monitoring/reporting (MR) violations in the SDWI-FED data tables reveal trends in water quality violations from 1993 to 2001 (EPA, 2001a).

This study intended to compare two local governments with an adopted wellhead protection program. A comparison proved impractical due to the lack of two similarly situated local governments in both states. These differences also lead to difficulty in assessing the programs at the state level. Each state contends with different issues regarding density and contamination sources. Water quality monitoring data prior to the implementation of wellhead protection program proved non-existent or difficult to access.

The addition of new contaminants to the MCL list over the years impedes an analysis of each wellhead protection program's impact on reducing the number of drinking water violations. The number of violations may not decrease because water suppliers are required to monitor for additional contaminants. EPA also notes a problem with state underreporting of violations (EPA, 2001a). Therefore, the number of violations reported may not reflect the true number of public water system violations (EPA, 2001a).

5.1 Comparison of Participating Public Water Systems

The success of each program depends upon the number of community and non-community water systems under wellhead protection. Public water supply systems without wellhead protection risk a potential contamination and shutdown of wells and well fields. Community water systems serve 25 or more residents (EPA, 2/20/2000). Non-community systems refer to non-residential uses such as businesses, restaurants, and schools (EPA, 2/20/2000). EPA's "Wellhead Protection Implementation: Summary of Biennial Data" publication provides state reported data for two-year periods from 1991 to 1997 (EPA, 2/20/2000). Section 4.4 of this paper discusses Virginia Biennial Wellhead Protection Report from 1997 to 1999. Both reports count the number of systems that completed the following five steps: getting started, delineation, identify sources of potential pollution, manage sources in wellhead protection areas, and contingency planning (EPA, 2/20/2002). This section only utilizes EPA's report to discuss community and non-community participation in Massachusetts and Virginia.

Virginia voluntarily reported 1993-1995 and 1995-1997 data to EPA (EPA, 2/20/2002). Out of 3712 total groundwater-dependent public water systems, only 30% (or 1132) are community water systems (EPA, 2/20/2002). No data is available for the 2580 non-community water systems (EPA, 2/20/2002). Community water systems were the only type of public water systems reported as participating in wellhead protection activities (EPA, 2/20/2002). Out of 1132 community water systems, 35 started WHP activities, 28 conducted delineations, 12 identified potential sources of pollution, and 1 managed wellhead protection areas (EPA, 2/20/2002). No community drinking water system started or completed a contingency plan.

Massachusetts reported for each two-year period between 1991 and 1997. Out of 1501 total public water systems, 28% (or 424) are community water systems and 70% (or 1077) are non-community water systems (EPA, 2/20/2002). EPA included mixed ground and surface water drinking water sources because "Massachusetts protects source water; therefore, it is at times difficult to differentiate systems that are solely groundwater dependent from those that are both ground and surface water sources" (EPA, 2/20/2002).

Both community and non-community water systems participated in wellhead protection activities (EPA, 2/20/2002). All non-community water systems started and delineated wellheads (EPA, 2/20/2002). Out of 424 community water systems in Massachusetts, 383 started, 383 conducted delineations, 368 identified sources of pollution, 347 managed sources in WHPAs, and 242 completed contingency plans (EPA, 2/20/2002).

Table 5.1 (below) provides the percentages for community and non-community public water systems participation in each state. Only 3% of Virginia's community systems started wellhead protection planning process and conducted wellhead delineations (EPA, 2/20/2002). In comparison, 90% of Massachusetts community systems participated in each of those steps (EPA, 2/20/2002). As Table 5.1 shows, 57% of Massachusetts community systems managed sources in wellhead protection areas while Virginia reported only 1 community system engaged in management activities (EPA, 2/20/2002). Virginia provided no information regarding non-community system participation in wellhead protection activities. In contrast, 100% of Massachusetts non-community systems started and delineated wellhead protection areas. However, none of the non-community systems in Massachusetts identified potential pollution sources and only 14% engaged in the management of contamination sources in WHPAs. Table 5.1 shows only 58% of Massachusetts community systems and none of the non-community

systems reported participation in contingency planning. None of the community drinking water systems in Virginia participated in contingency planning.

Table 5.1: Comparison of Virginia and Massachusetts Public Water Systems Participation in Wellhead Protection Activities in Percentages

	Virginia's 3712 Public Water Systems		Massachusetts 1501 Public Water Systems	
Steps Started or Completed	1132 Community	2580 Non-Community	424 Community	1077 Non-Community
Started	3%	Not available	90%	100%
Delineated	3%	-	90%	100%
Identified Sources	1%	-	86%	0%
Managed Sources	0%	-	82%	14%
Contingency Plans	0%	-	57%	Not available

(EPA, 2/20/2002)

Based on the rates of implementation, Massachusetts enjoyed a far greater success in garnering participation than Virginia. Massachusetts's program succeeds in implementing the wellhead protection program for both community and non-community water systems. Virginia's approach results in extremely low participation levels. The adoption of Virginia's SWAP in the late 1990's may spur an increase of public water supplier participation. The outcomes from the USGS and DCR studies in Virginia should help the VDH to prioritize the areas in greatest need of wellhead protection activities.

5.2 Local Government Participation

A part of a state's wellhead protection programs success depends on how local governments develop and implement a wellhead protection program under the state framework. This study intended to compare two locality's wellhead protection programs. The comparison required two localities with similar situations such as: population, total area, no serious contamination problems prior to adoption, dependency on groundwater as a source of drinking water, and an adopted wellhead protection program. The requirement of no past pollution problems resulted from concern that localities react differently to drinking water contamination.

A program adopted in reaction to a contamination problem does not accurately portray how a locality would normally develop and implement a program under the state framework.

A comparison of local wellhead protection programs was not possible because no Virginia locality met all of these standards. The few localities implementing a wellhead protection program had previously dealt with contamination problems. Other localities completed the assessment process, but needed to work through the political process for adopting a wellhead protection program. Virginia localities should incorporate assessment findings into a wellhead protection program. Without a program, groundwater drinking sources face an increased risk from pollution sources. A proactive approach helps to protect communities from experiencing contamination problems by taking steps to prevent or reduce the risk of such an incident. In contrast, a reactive approach responds to a contamination problem in order to prevent future reoccurrences.

5.3 Comparison of Reported Violations

EPA's SDWI-FED data tables provide state reported information on violations from 1993 to 2001 (EPA, 2001a). This section concentrates on total maximum contaminant level (MCL) and monitoring/reporting (M/R) violations. These two measures are focused upon because exceeding MCL limits places human health at risk. A monitoring/reporting violation occurs when "no samples were taken or no results are reported during the entire compliance period" (MDEP, 2/16/2002). Failure to comply with monitoring or reporting violations proves problematic because "those consuming the water are denied information that could be important to their continued good health" (MDEP, 2/16/2002).

This comparison is limited by the sufficiency of the data. The state reported data presents accuracy issues. EPA notes the possibility of state underreporting of violations (EPA, 2001a).

EPA also notes "FY2001 does not (yet) include [Chemical] M/R violations" (EPA, 2001a). Therefore, the total number of monitoring and reporting violations is incomplete.

In addition, a comparison of the data from these tables over the eight-year time period proves problematic. SDWA requires EPA to update the maximum contaminant level listing every five years (42 USC 300h). The addition of contaminants to the MCL list may cause the number of violations to rise over time due to an increase in monitoring requirements. The increase in monitoring requirements and consequent violations may not accurately reflect the true impact of wellhead protection activities.

Another issue in analyzing and comparing the number of violations stems from the lack of available baseline data prior to the implementation of wellhead protection activities. For the purposes of analyzing the success of a wellhead protection program in reducing contamination violations, data must be collected before and after the implementation of wellhead activities. The lack of available baseline data generates insufficient comparisons in evaluating the success of a WHPP.

According to the SDWI-FED "FY2001 Inventory data" the number of public groundwater systems differ from the numbers submitted in the "Wellhead Protection Implementation: Summary of Biennial Data" report (EPA, 2001a and EPA, 2/20/2002). The 2001 inventory for all public drinking water systems reports 1485 systems in Massachusetts and 3331 in Virginia (EPA, 2001a and EPA, 2/20/2002). Possible reasons for a decrease of 381 systems in Virginia between 1997 and 2001 may result from either closed systems from contamination, drought conditions or a miscount in the number of systems. The 2001 inventory reports Massachusetts has five less drinking water systems since 1997 (EPA, 2001a and EPA, 2/20/2002).

Table 5.2 provides a comparison of the percentage of violations in MCL and M/R reported by Massachusetts and Virginia from 1993 to 2001. The percentages compare the number of violations for MCL and M/R in relation to the total number of violations per year reported for each state. The information is derived from the Massachusetts and Virginia SDWIS-FED tables. For detailed data refer the tables to located in Appendix 1. These tables contain the number of violations, number of public groundwater systems in violation, and the population affected.

The percentage of MCL violations in Massachusetts remains extremely low in comparison with Virginia (EPA, 2001a). As Table 5.2 shows, 2.35% of Massachusetts total violations were from MCL violations in comparison with Virginia's 25.83% in 2001 (EPA, 2001a). In 2001, Virginia has ten times as many MCL violations as Massachusetts. From 1993 to 2001, Virginia consistently reports a significantly higher percentage of MCL violations than Massachusetts (EPA, 2001a).

Table 5.2: Comparison of MCL and M/R Violations in Massachusetts and Virginia

Fiscal Year	Massachusetts		Virginia	
	MCL	M/R	MCL	M/R
2001	2.35%	94.39%	25.83%	56.21%
2000	1.43%	96.88%	19.20%	65.15%
1999	0.34%	99.57%	19.77%	70.78%
1998	0.95%	98.96%	23.29%	73.29%
1997	5.31%	94.47%	23.35%	74.21%
1996	1.31%	98.58%	22.60%	76.70%
1995	0.90%	98.96%	29.49%	68.09%
1994	0.66%	99.16%	20.96%	75.16%
1993	2.40%	97.33%	23.61%	73.71%

Both Massachusetts' and Virginia's largest percentage of violations occur from M/R (EPA, 2001a). Massachusetts's consistently has a much higher percentage of M/R violations than Virginia (EPA, 2001a). Massachusetts describes M/R violations as "poor management of these system's sampling programs" rather than a water quality issue (MDEP, 2/16/2002). Strict

drinking water regulations and enforcement may explain why Massachusetts reports a higher percentage of M/R violations. Due to the stricter drinking water regulations, Massachusetts reports fewer MCL violations.

5.4 Conclusions

The Massachusetts source water protection program enjoys success measured in the number of public water systems participating in wellhead protection activities. Massachusetts should concentrate on increasing the number of contingency plans for community and non-community public water systems. Non-community systems in Massachusetts need to identify and manage sources of potential contamination within wellhead protection areas and adopt contingency plans.

The low number of public water systems participating in Virginia demonstrates the need for stronger resource and financial support at the state level. Local governments with completed assessments need encouragement to adopt and implement wellhead protection programs. The USGS and DCR studies provide Virginia's Department of Health with a cost effective method in targeting areas with the greatest need of wellhead protection.

Comparing the percentage of MCL and M/R violations illustrate the importance wellhead protection activities play in reducing contamination violations in Virginia and Massachusetts. Virginia should take measures to reduce MCL violations because exceeding maximum contaminant levels may lead to harmful health impacts. Massachusetts and Virginia need to address problems encountered by public drinking water systems in meeting monitoring/reporting requirements. Due to tough drinking water regulations and enforcement, the majority of violations in Massachusetts occur from M/R violations. As a result of the regulations and enforcement, Massachusetts reports fewer MCL violations.

Baseline data should be collected and accessible in order to improve the comparative analysis of how much impact wellhead protection has upon the prevention or reduction of contamination violations. The reported violations provide insight as to the extent and type of problems existing in Virginia and Massachusetts.

Chapter 6 - Conclusions & Recommendations

6.1 Massachusetts and Virginia Summary

The Environmental Protection Agency's Wellhead Protection Program provides a flexible framework for states to work within and configure to their own needs. Table 6.1 (below) provides a simplified framework comparison between Virginia and Massachusetts. Virginia and Massachusetts provide two strikingly different ways states have approached WHPP. As shown in the table, Virginia's WHPP and SWAP rely on the voluntary participation of local governments and water suppliers. Massachusetts's top-down approach to WHPP and SWAP mandates the participation of local governments and water suppliers.

Table 6.1 shows both the Department of Health and Department of Environmental Protection oversee the drinking water programs and provide assistance to localities. However, the localities in Massachusetts must undergo the MDEP review and approval process for activities such as wellhead delineations and groundwater zoning ordinances. Localities in Massachusetts are also required to adopt zoning and non-zoning ordinances in Zone I and II. In contrast, VDH encourages localities to utilize zoning tools to provide protection to wellhead protection areas.

Massachusetts's approach seeks to provide a proactive strategy on the local, state, and regional levels. Massachusetts mandates all public groundwater systems are to receive Zone I protection. If the wellhead pumps at least 100,000 gallons per day, Massachusetts requires Zone II protection. As shown in Table 6.1, several financial options are available to localities, water suppliers, and regional groups to fund wellhead protection activities.

In contrast to Massachusetts, Virginia's approach depends upon the voluntary motivation of local governments to undertake wellhead protection activities. In Virginia only a small

percentage of the public groundwater systems implement wellhead protection measures. Localities now implementing wellhead protection programs in Virginia adopted a program in response to groundwater contamination problems.

Table 6.1: Comparison of Virginia and Massachusetts Wellhead Protection

State	Participation	Agency Administering	Agency Role	Wellhead Protection Areas	Protection Strategies	Local Government Participation
VA	Voluntary	Dept of Health	Oversee Program Provide technical and financial assistance to localities	Zone I and II	Encourage zoning regulations, subdivision, and land acquisition	Water Supply Assistance Fund Drinking Water State Revolving Fund
MA	Mandated	Dept of Environmental Protection	Oversee program Provide technical and financial assistance to localities Reviews and approves delineations, best effort, & groundwater zoning ordinances	Zone I, II, III, and IWPA	Require zoning and non-zoning controls	Water Pollution Abatement Trust Wellhead Protection Grant Program Source Water Assessment Program Aquifer Land Acquisition Program

6.2 Conclusions

Massachusetts regulatory approach work wells to ensure local government participation because the MDEP provides oversight and enforces compliance with state regulations. Every wellhead receives the minimum amount of protection. However, a regulatory program places a large technical and financial burden on both localities and state agencies. Localities may not have the financial and technical resources to engage in wellhead protection, but state regulations do not leave localities with an option. Local governments must also adopt zoning and non-zoning controls in order to comply with Massachusetts's regulations. This mandate may reduce the willingness to engage in a thorough local wellhead protection program. The cost of administering regulatory programs places a large financial burden on the state government. The

state must fund the MDEP's activities in order to provide oversight and technical and financial resources to localities.

Several Massachusetts municipalities continue to utilize IWPAs instead of delineating Zone IIs. Municipalities receive a reduced incentive to delineate Zone IIs without MDEP assistance. MDEP and associated contractors are in the process of completing the remainder of Zone II delineations by 2003. After MDEP approves a Zone II, localities have three years to adopt zoning and non-zoning controls within the wellhead protection area.

After Zone II delineations have been completed for all wellheads, MDEP should encourage these localities to begin Zone III delineations. A delineated Zone III improves the comprehensiveness of groundwater protection, however MDEP will have to encourage cooperation and coordination among stakeholders. MDEP should encourage localities to adopt more stringent groundwater protection regulations.

Virginia's voluntary approach encourages local governments to participate in wellhead protection activities and adopt a wellhead protection program. The majority of Virginia localities currently participating in wellhead protection activities are working through the initial assessment steps. Virginia counties and Planning District Commissions participate in wellhead protection activities. The regional approach improves the comprehensiveness of wellhead protection because counties seek to coordinate activities among the different towns within the county boundaries. PDCs offer a regionalized approach by coordinating a few counties in wellhead protection activities. However, all the localities with an adopted wellhead protection program have had previous groundwater contamination problems. Virginia localities tend to react to groundwater contamination rather than proactively take measures to prevent contamination.

Virginia's voluntary program is less expensive to administer than a regulatory program because the administrating agency does not have to review local activities or enforce compliance with state regulations. The Virginia Department of Health intends to target susceptible areas as a cost-effective approach to providing more in-depth protection to drinking water sources. Aquifers are prioritized based on susceptibility to contamination. This tactic works well in Virginia because financial resources are utilized to target the regions in need of greater protection. This method should provide quality data for susceptible aquifers instead of over expending VDH's resources by conducting in-depth delineations for every wellhead. VDH's approach will prioritize areas on susceptibility, but localities are not required to adopt protective measures or strategies.

Inadequate funding of the program most likely provides the biggest deterrent to local government participation. Potential for collaboration among government, community groups, and industries could be realized if adequate funding was provided. In the past, Virginia localities have only adopted WHPP after the contamination of drinking water sources has occurred. Continued low participation levels in wellhead protection activities may prove costly to Virginia in the future (EPA, 3/15/2002). Contamination problems would require Virginia to provide localities with the financial and technical assistance necessary to remediate or construct an alternative drinking water source (EPA, 3/15/2002). Adequately funding wellhead protection activities would encourage local government participation and save Virginia a significant amount of financial and technical resources (EPA, 3/15/2002).

The Commonwealth of Virginia should expand the Department of Health's oversight role in order to promote cooperation, coordination, and accessibility to technical, financial, and educational assistance. Fragmentation of the groundwater management program and inadequate

funding fail to provide localities with sufficient support and incentive to undertake WHPP and SWAP activities. The Commonwealth of Virginia should consider consolidating water pollution prevention programs into VDH or require greater coordination among all the agencies. VDH should increase efforts to coordinate activities with federal, state, regional, county, city, town, community organizations, public water suppliers, and industries. VDH should expand public educational efforts on providing information on the health implications from poor groundwater quality and costs saved from lengthening the lifecycle of a well.

Virginia also faces an issue with the number of public groundwater systems. Out of 3300 total public water suppliers, 811 very-small community systems serve 25-100 residents (EPA, 2001a and VDEQ, 1999). Sparsely populated, rural counties face tight budgets, employ small staffs, and lack technical expertise. Such localities require assistance to proceed through the wellhead protection program. Three VDRWA staff members provide technical assistance to these rural localities. Although progress is slow, more local governments are working towards participating in and completing the wellhead protection process.

Virginia can pursue a variety of options to increase participation. First and foremost, funding must be increased. Funding should be specifically set aside to support wellhead protection activities. The funding could be split into categories of: delineation, identification, management, and contingency planning. The purpose of earmarking wellhead funding into specific categories is to show localities the availability of funding for the entire process. By providing funding for specific steps, localities receive a financial incentive to move beyond initial delineation steps.

Education provides another component for increasing participation in Virginia. VDH should utilize the agency website as an educational tool. A website offers a low cost method to

communicate information to a large audience. The current VDH website provides very little information or guidance on wellhead protection. The VDH website should be updated to provide information to interested communities and citizens. An updated website should offer information on a variety of educational and interest levels. The website should also provide a discussion of the contamination problems faced by water suppliers, the benefits of wellhead protection, financial strategies available to localities, and direction to other sources of information and agencies involved with groundwater protection activities.

A symposium provides another opportunity for Virginia to educate local governments and community groups. VDH and other state agencies involved in groundwater protection activities should host a wellhead protection symposium. The symposium could provide information and workshops on how to develop and implement a wellhead protection program, assess potential sources of contamination, and funding opportunities.

The percentage of MCL violations indicates Virginia needs to address drinking water quality issues. Increasing the number of local governments involved in wellhead protection activities may help reduce MCL violations. Identifying potential pollution sources and managing wellhead protection areas will help local governments to determine which planning tools best fits their situation. In comparison to the cost of constructing new treatment facilities, wellhead protection provides a relatively inexpensive method to reduce potential health risks and increase the longevity of a groundwater drinking source.

Despite administering an expensive regulatory drinking water program, Massachusetts's water suppliers still have numerous monitoring/reporting violations. MDEP should study why Massachusetts M/R requirements present a compliance issue to numerous water suppliers. However, it is important to recognize Massachusetts's strict monitoring and reporting regulations

has resulted in fewer MCL violations. The purpose of drinking water protection activities is to protect human health from being exposed to harmful contaminants. Massachusetts regulatory program has enjoyed success due to the low occurrence of MCL violations.

6.3 Recommendations for Future Areas of Study

Coordination and Collaboration

Wellhead protection programs must be coordinated between state, regional, county, and community organizations (Witten, 1992 and EPA, 1988). Coordination enables information to move among participants efficiently. Thus, preventing or reducing the amount of overlap and gaps in data and/or administration. Data collected by various departments and organizations needs to be consolidated into one centralized location (TAC, 2002). Data should be easily accessible by communities. Fragmentation of data increases time, cost, and complications to localities participating in the wellhead protection process (TAC, 2002 and EPA, 2000b). Fragmentation of agency activities also creates "conflicting priorities and goals" (EPA, 2000b). Coordinated and centralized location of data offers public water operators and communities with one-stop groundwater protection shopping. Although the initial cost to overhaul the present system may be expensive, the long-term benefits will reduce the amount of resources wasted by both communities and agencies.

Increased collaboration throughout the wellhead protection process must occur between all stakeholders. To accomplish this, both states should encourage the involvement of industries and businesses in wellhead protection programs. Industries and businesses should be provided with information regarding the risk industrial activities pose to groundwater and remediation costs. State and local governments should consider working with insurance companies to encourage reduced premiums to entities participating in both wellhead protection and pollution

control activities (Bahorskv, 2002). State and local governments should offer cooperative businesses that reduce potentially threatening activities, install waste treatment equipment, or relocate with a financial incentive such as a tax break, public relations campaign, or reduced liability from remediation costs.

State and local governments should work towards creating a "pollution prevention culture" through education of the community, government officials and staff, and businesses (Bahorskv, 2002). EPA recognizes the importance of community involvement in the local wellhead protection (EPA, 1989). As part of the solution, citizens need to learn how household activities impact groundwater quality. Influencing citizen attitudes and behaviors in the usage of household chemicals functions as a cost-effective non-point pollution strategy (Bahorskv, 2002).

Both Virginia and Massachusetts administer various programs that directly or indirectly assist in protecting groundwater from pollutants. To improve efficiency and coordination, both states should consider integrating various "programs, information collection, and data storage" (Bahorskv, 2002). The number of agencies involved with the administration of state programs increases the complexity of drinking water protection. Integration of programs and coordination among agencies help simplify the process for localities.

Water quality monitoring waivers reduce compliance demands on both the water supply operator and the administrating agency. The agency does not have to expend staff and financial resources on ensuring compliance at every source (Bahorskv, 2002). Monitoring waivers provide water suppliers with the incentive to work with local governments in the development of wellhead protection programs.

Financial Considerations

To reduce government dependence upon federal or state grants or low-interest loans, localities should consider multiple financial strategies for funding wellhead protection programs. User fees provide one option for local governments to finance WHPP (Crumbley, 1992). User fees pass the cost onto the direct beneficiary, the consumer, who benefits from higher quality water (Crumbley, 1992). Corporation's pay a higher proportion of the user fee compared to residents due to the greater amount used in industrial process (Crumbley, 1992). User fees provide local governments with an "equitable, efficient, and low-risk" strategy for supporting wellhead protection (Witten et al., 1995). Monthly user fees do not result in major price hikes to consumer (Crumbley, 1992). However, the user fee does not work for non-community drinking water systems because a system only serves the owner of the non-residential use.

Local governments without wellhead protection programs need to consider the affordability of contamination (Ad Hoc, 1991). Instead of estimating the immediate cost of wellhead protection activities, local governments need to also calculate "avoided costs and external costs" (Bahorskv, 2002). Avoided costs of drinking water contamination calculate savings from not paying potential well remediation costs, locating and drilling new alternative well sites, potential fines, staff overtime, and protracted lawsuits (Bahorskv, 2002). External costs from contaminated water supplies include a decrease in market property values, loss of community confidence, and increase public health threats (Bahorskv, 2002).

Appendix 1

The following two tables are from EPA's SDWI-FED database.

SDWI-FED Massachusetts Reported Violations by Violation Type

		Violation Type				
FY	Data	MCL	TT	MR	Other	Total
2001	# viols	44	54	1,768	7	1,873
	# in_viol	33	49	269	7	337
	pop	224,639	235,690	257,947	1,675	598,313
2000	# viols	60	53	4,074	18	4,205
	# in_viol	52	47	339	18	418
	pop	229,071	247,956	216,392	93,042	623,224
1999	# viols	8	2	2,311		2,321
	# in_viol	8	2	185		193
	pop	37,462	11,300	191,994		238,906
1998	# viols	42	3	4,378	1	4,424
	# in_viol	36	3	265	1	293
	pop	284,763	16,134	167,693	150	436,698
1997	# viols	94	1	1,673	3	1,771
	# in_viol	70	1	217	3	278
	pop	402,014	1,400	80,763	2,083	466,168
1996	# viols	81	7	6,110		6,198
	# in_viol	62	7	507		555
	pop	290,847	3,697	523,150		763,505
1995	# viols	73	10	7,999	1	8,083
	# in_viol	56	10	514	1	565
	pop	335,683	17,571	445,828	100	740,876
1994	# viols	22	6	3,290		3,318
	# in_viol	19	6	408		428
	pop	148,667	36,120	223,352		401,547
1993	# viols	43	5	1,747		1,795
	# in_viol	33	5	188		219
	pop	159,630	22,696	296,581		463,709

(EPA, 2001a)

SDWI-FED Virginia Reported Violations by Violation Type

		Violation Type				
FY	Data	MCL	TT	MR	Other	Total
2001	# viols	256	108	557	70	991
	# in_viol	198	93	361	58	591
	pop	172,311	24,318	91,017	9,582	273,692
2000	# viols	270	112	916	108	1,406
	# in_viol	183	98	443	102	678
	pop	60,851	24,347	603,507	14,029	674,453
1999	# viols	205	98	734		1,037
	# in_viol	166	90	349		536
	pop	62,549	29,322	69,419		148,601
1998	# viols	150	12	472	10	644
	# in_viol	116	1	245	4	327
	pop	59,556	60	68,573	504	116,935
1997	# viols	163	12	518	5	698
	# in_viol	121	1	338	5	426
	pop	46,560	60	73,018	1,297	116,126
1996	# viols	193	3	655	3	854
	# in_viol	143	1	403	3	499
	pop	46,206	60	89,901	260	126,410
1995	# viols	207	7	478	10	702
	# in_viol	160	7	320	8	448
	pop	58,675	1,571	70,695	1,607	122,509
1994	# viols	292	36	1,047	18	1,393
	# in_viol	219	35	550	14	721
	pop	77,728	9,919	123,368	6,226	193,708
1993	# viols	361	25	1,127	16	1,529
	# in_viol	283	25	632	14	831
	pop	102,939	8,268	198,380	4,077	269,887

(EPA, 2001a)

References

Ainsworth, S., Brown, H., and Jehn, P. (1996) Source Water Protection: What's in it for you? Public Management pp 15-19

Bahorskv, Mike. (2002). Virginia Lean and Clean Project Contributions. [Class Presentation] Richmond, VA: Department of Environmental Quality.

Christman, K. (1998) What Lies Ahead for Chlorine Disinfection: The risk posed by microbial pathogens is greater than that associated with disinfection byproducts. WaterWorld. Retrieved 4/6/2002 from http://c3.org/news_center/third_party/whatlies.html

Crumbley, E. (1991). Point/Counterpoint: Ensuring Safe Drinking Water – A Financial Dilemma for Virginia? Blacksburg, VA: Virginia Water Resource Center and Virginia Polytechnic Institute and State University.

Davidson, M. & Dolnick, F. (Eds.). (1999). Glossary of Zoning, Development, and Planning Terms. Planning Advisory Service Report Number 491/492. Chicago, IL: American Planning Association Press.

Elder, D. Killam, G. & Koberstein, P. (1999) The Clean Water Act: An Owner's Manual. Portland, OR: River Network

Groundwater Protection Council & Association of State Drinking Water Administrators & Association of State and Interstate Water Pollution Control Administrators. (1999). Ground water report to Congress: Summaries of state ground water conditions. Retrieved 2/12/2002 from http://www.gwpc.org/gwreport

Hrezo, M. and Nickinson, P. (1986). Protecting Virginia's Groundwater: A Handbook for Local Government Officials. Blacksburg, VA: Virginia Water Resource Center & Virginia Polytechnic Institute and State University.

Hirschman, D., Randolph, J., & Flynn, J. (1992). The can-do book of local water resources management in Virginia. Blacksburg, VA: College of Architecture and Urban Studies Virginia Polytechnic Institute and State University.

Jones, N. Woburn hydrogeology data: Brief history. (Last Updated April 2001). Retrieved 2/23/2002 from Brigham Young University http://research.et.byu.edu/woburn/brief.htm

Lehan, R., Lowery, A., O'Donnell, A., Kline, E. (Lehan, et al.). (1999). Massachusetts Environmental Law: Chapter 17 Drinking Supply. Massachusetts Continuing Legal Education, Inc.

Massachusetts General Laws. 310 CMR 22.00 Massachusetts Drinking Water Regulations. (Revised November 2001) Retrieved 2/02/2002 from http://www.state.ma.us/dep/brp/dws/regs.htm

Massachusetts General Laws. 310 CMR 36.00 Water Management Act Regulations. (1994) Retrieved 2/02/2002 from http://www.state.ma.us/dep/brp/dws/regs.htm

Massachusetts Department of Environmental Management (MDEM). Welcome to the Office of Water Resources Well Driller Program Web Site. Retrieved 3/28/2002 from http://www.state.ma.us/dem/programs/welldril/index.htm

Massachusetts Department of Environmental Protection (MDEP). 1996 Mass. Annual Public Water Supply Compliance Report. Retrieved 2/16/2002 from http://www.state.ma.us/dep/brp/dws/progress.htm

Massachusetts Department of Environmental Protection. (1997a). Model Groundwater Protection District Bylaw/Ordinance. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/modgwpd.doc

Massachusetts Department of Environmental Protection. (1997b). Making Wellhead Protection Work in Massachusetts. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/whpguide.pdf

Massachusetts Department of Environmental Protection, Massachusetts Water Resource Authority, Metropolitan Area Planning Council, Water Supply Citizens Advisory Committee, & Camp Dresser and McKee Inc. (Amended March 1997c). Model groundwater protection district bylaw/ordinance. Retrieved 2/15/2002 from http://www.state.ma.us/dep/brp/dws/files/modgwpd.doc

Massachusetts Department of Environmental Protection. (Revised August 1999a) Massachusetts Source Water Assessment Program Strategy. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/swapstra.doc

Massachusetts Department of Environmental Protection. (Revised August 1999b) Massachusetts Source Water Assessment Program Strategy Appendices: Appendix A. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/app60a.doc

Massachusetts Department of Environmental Protection. (Revised August 1999c) Massachusetts Source Water Assessment Program Strategy Appendices: Appendix B. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/app60b.doc

Massachusetts Department of Environmental Protection. (Revised August 1999d) Massachusetts Source Water Assessment Program Strategy Appendices: Appendix C. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/app60c.doc

Massachusetts Department of Environmental Protection. (1999e) DEP News: State awards $1.5 million in grants to boost local, regional water supply protection efforts. Retrieved 2/22/2002 from http://www.state.ma.us/dep/pao/files/swap1199.htm

Massachusetts Department of Environmental Protection. (1999f). Source Water Protection Technical Assistance/Land Management Grant Program. Retrieved 2/24/2002 from http://www.state.ma.us/dep/brp/dws/files/swgrant.doc

Massachusetts Department of Environmental Protection. (2000). How does SWAP affect Boards of Health? Retrieved 2/20/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/swapboh.doc

Massachusetts Department of Environmental Protection. Annotated Wellhead Protection Regulations (2001a). Retrieved 2/2/2002 from http://www.state.ma.us/dep/brp/dws/files/annotreg.doc

Massachusetts Department of Environmental Protection. Drinking Water State Revolving Fund Draft Intended Use Plan (2001b). Retrieved 2/20/2002 from http://www.state.ma.us/dep/brp/dws/files/srfiup01.doc

Massachusetts Department of Environmental Protection. (2001c). Monitoring Waiver Program - Source Protection Policy Changes. Retrieved 2/16/2002 from http://www.state.ma.us/dep/brp/dws/files/waivguid.doc

Massachusetts Department of Environmental Protection. (2001d). Water Supply Protection Areas and Wellhead Compliance. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/wspamain.htm

Massachusetts Department of Environmental Protection. (2001e) SWAP Update. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/swapupda.htm

Massachusetts Department of Environmental Protection. (2001f) SWAP Strategy Addendum. Retrieved 2/24/2002 from http://www.state.ma.us/dep/brp/dws/files/swap/swapadd.doc

Massachusetts Department of Environmental Protection. (2001g). Developing a Local Wellhead Protection Plan. Retrieved 2/04/2002 from http://www.state.ma.us/dep/brp/dws/files/whplan.pdf

Massachusetts Department of Environmental Protection. (2002b). Source Water Protection Grant Program. Retrieved 3/01/2002 from http://www.state.ma.us/dep/brp/dws/grants.htm

Massachusetts Department of Environmental Protection. (2002c). Wellhead Protection Grant Program. Retrieved 2/24/2002(a) from http://www.state.ma.us/dep/brp/dws/files/wellhead.doc

Massachusetts Department of Environmental Protection. Massachusetts Source Water Assessment Program Overview. Retrieved 2/04/2002(a) from http://www.state.ma.us/dep/brp/dws/files/swapover.htm

Massachusetts Department of Environmental Protection. Zone I Model Conservation Restriction. Retrieved 2/04/2002(b) from http://www.state.ma.us/dep/brp/dws/files/ZIMCR.doc

Massachusetts Department of Environmental Protection. Zone II Model Conservation Restriction. Retrieved 2/04/2002(c) from http://www.state.ma.us/dep/brp/dws/files/ZIIMCR.doc

Massachusetts Department of Food and Agriculture (MDFA). (2000). Retrieved 3/28/2002 from http://www.state.ma.us/dfa/

Massachusetts Department of the State Treasurer. Water Pollution Abatement Trust. Retrieved 3/03/2002 from http://www.state.ma.us/treasury/wpat.htm

Massachusetts Drinking Water Education Partnership. (2001) Drinking Water Week Activities. Retrieved 3/04/2002 from http://www.newwa.org/madwep/

Massachusetts Secretary of the Commonwealth Galvin, W. Massachusetts Facts Part One: Concise Facts. Retrieved 2/22/2002 from http://www.state.ma.us/sec/cis/cismaf/mf1b.htm

National Environmental Policy Institute (NEPI). (2002). Lean and Clean Financial/Economic Incentives Working Group [Powerpoint Presentation]. NEPI Lean and Clean Manufacturing: Improving Environmental and Financial Performance Conference of the Parties March 14 -15 2002. Washington, DC.

New England Interstate Water Pollution Control Commission (NEIWPCC). New England Interstate Water Pollution Control Commission History. Retrieved 3/4/2002 from http://www.neiwpcc.org/history.html

Northern Virginia Planning District Commission & Engineers and Surveyors Institute. (1992). Northern Virginia BMP handbook: A guide to planning and designing best management practices in Northern Virginia. Annandale, VA: Northern Virginia Planning District Commission. Retrieved 2/20/2002 from www.novaregion.org/pdf/NVBMP-Handbook.pdf

Poff, J. (Revised.) (1997). A Guide to Protecting Virginia's Valuable Resource: Ground Water. Blacksburg, VA: Virginia Water Resource Center & Virginia Polytechnic Institute and State University.

Randolph, J. (1999). Class packet for UAP 4374 - Land Use & Environment. Blacksburg, VA: Department of Urban Affairs and Planning.

Reimold, R. & Leavell, D. (1990) "Preventive medicine for water supplies". American City & County. V105 n12 p28(6)

Report of the Ad Hoc Wellhead Protection Advisory Committee (Ad Hoc). (1991). Richmond, VA: Department of Environmental Quality.

Technical Advisory Group (TAG). (2002). Draft II Report to the Joint Subcommittee on Karst Groundwater Monitoring in the Shenandoah Valley. House Joint Resolution No. 161. Not published as of 4/1/2002.

U.S. Bureau of the Census. (2001a) Census 2000 Quick Facts for Massachusetts Retrieved 2/25/2002 from http://quickfacts.census.gov/qfd/states/25000.html

U.S. Bureau of the Census. (2001b). Census 2000 Quick Facts for Virginia. Retrieved 2/25/2002 from http://quickfacts.census.gov/qfd/states/51000.html

U.S. Congress. 42 USC Section 300 Safe Drinking Water Act. Retrieved 2/6/2002 from http://web.lexis-nexis.com/universe/document

U.S. Environmental Protection Agency (EPA). (1988) Developing a State Wellhead Protection Program: A User's Guide to Assist State Agencies under the Safe Drinking Water Act. EPA 4440-6-88-003. Office of Ground Water Protection. Retrieved 2/8/2002 from www.epa.gov/safewater/Pubs/04ground.html

U.S. Environmental Protection Agency. (1989). Wellhead Protection Programs: Tools for local governments. Washington DC: GPO.

U.S. Environmental Protection Agency. (1992). Final Comprehensive State Ground Water Protection Program Guidance. EPA 100-R-93-001. Office of the Administrator, Paper. Retrieved 2/8/2002 from http://www.epa.gov/safewater/swp/csgwpp/06ground.html

U.S. Environmental Protection Agency. (Revised January 1998a) State source water assessment and protection programs guidance. Retrieved 2/28/2002 from http://www.epa.gov/safewater/source/chap1.html

U.S. Environmental Protection Agency. (1998b) 1996 National Public Water System Annual Compliance Report and Update on Implementation of the 1996 Safe Drinking Water Act Amendments**.** Retrieved 2/8/2002 from http://www.epa.gov/safewater/annual/

U S. Environmental Protection Agency. (1999) 1997 National Public Water System Annual Compliance Report and Update on Implementation of the 1996 Safe Drinking Water Act Amendments. Retrieved 2/8/2002 from http://www.epa.gov/safewater/annual/

U.S. Environmental Protection Agency. (2000a) 1998 National Public Water Systems Compliance Report [305-R-00-002]. Retrieved 2/8/2002 from http://www.epa.gov/safewater/annual/

U.S. Environmental Protection Agency. (2000b) 1998 Ground Water and Drinking Water Section: Report to Congress 1996/1998 The National Water Quality Inventory Report to Congress (305(b) report). Retrieved 2/8/2002 from http://www.epa.gov/safewater/protect/natgwrep.html

U.S. Environmental Protection Agency. (Website Revised August 2000c). Draft Drinking Water Contaminant Source Index Introduction. Retrieved 2/05/2002 from http://www.epa.gov/ogwdw/swp/intro4.html

U.S. Environmental Protection Agency. (2000d). Protecting Drinking Water with the Clean Water State Revolving Fund. Fact sheet about Source Protection funding for protecting drinking water through the Clean Water State Revolving Fund. Retrieved 2/12/2002 from http://www.epa.gov/owm/pdfs/cwsrf8.pdf

U.S. EPA. (Updated 2001a). Accessing SDWIS/Fed drinking water data in Excel PivotTables®. Retrieved 3/18/2002 from http://www.epa.gov/safewater/data/pivotinstrux.pdf

U.S. Environmental Protection Agency. (2001b) Public Drinking Water Systems: Facts and Figures. Retrieved 2/7/2002 from http://www.epa.gov/safewater/pws/factoids.html

U.S. Environmental Protection Agency. (2001c). Factoids: Drinking water and ground water statistics for 2000. EPA 816-K-01-004. Retrieved 3/15/2002 from http://www.epa.gov/safewater

U.S. Environmental Protection Agency. Wellhead protection implementation: Summary of biennial data. Retrieved 2/20/2002 from http://www.epa.gov/safewater/protect/gwr/report.htm#Appendix%20B

U.S. Environmental Protection Agency. Website last updated 07/23/2001. Why? Incentives and Benefits for your Efforts. Retrieved 3/15/2002 from http://www.epa.gov/safewater/protect/incentives.html

U.S. Geological Survey (USGS). Virginia Aquifer Susceptibility Study. Retrieved 4/2/2002 from http://fs01svarmd.er.usgs.gov/vas_handout.htm

Virginia Department of Environmental Quality (VDEQ). (1998). 1998 Virginia Water Quality Assessment Report. Retrieved 3/2/2002 from www.deq.va.state.us/pdf/305b/chapter4.pdf

Virginia Department of Environmental Quality. (1999). Commonwealth of Virginia's Biennial Wellhead Protection Report October 1, 1997 to September 30, 1997. Richmond, VA: Virginia Department of Environmental Quality.

Virginia Department of Health (VDEH). (1999) Virginia Source Water Assessment Program. Retrieved 1/30/2002 from http://www.vdh.state.va.us/dwse/swap.htm

Virginia Department of Health. (2001). Virginia's Drinking Water State Revolving Fund Program: Intended use plan for FY 2002 draft. Retrieved 2/18/2002 from http://www.vdh.state.va.us/dwse/index.htm

Virginia Department of Health. (2002). Attachment Drinking Water Funding. Retrieved 2/24/2002 from http://www.vdh.state.va.us/dwse/WSAssistanceGrant.htm

Virginia Department of Health. Virginia Source Water Assessment Program and Protection Activities. Retrieved 1/30/2002 from http://www.vdh.state.va.us/dwse/swap.htm

Virginia Ground Water Protection Steering Committee (VGWPSC). (1987). A Groundwater Protection Strategy for Virginia . Richmond, VA: Virginia Ground Water Protection Steering Committee

Virginia Ground Water Protection Steering Committee& University of Virginia's Institute for Environmental Negotiation& Department of Urban and Environmental Planning. (1992). Wellhead Protection: A handbook for local governments in Virginia. Richmond, VA: Virginia Water Control Board.

Virginia Ground Water Protection Steering Committee. (1993). Wellhead Protection: Case Studies of Six Local Governments in Virginia. Richmond, VA: [No longer in print] Contact Mary Ann Massie, Department of Environmental Quality for copies.

Virginia Ground Water Protection Steering Committee. (1996). 1996 Annual Report. Retrieved 1/25/2002 and 2/7/2002 from http://www.deq.state.va.us/gwpsc/annrept.html

Virginia Ground Water Protection Steering Committee. (1997). 1997 Annual Report. Retrieved 2/7/2002 from http://www.deq.state.va.us/gwpsc/annrept.html

Virginia Ground Water Protection Steering Committee. (1998a). 1998 Annual Report. Retrieved 2/8/2002 from http://www.deq.state.va.us/gwpsc/annrept.html

Virginia Ground Water Protection Steering Committee (1998b). Virginia Groundwater Management Handbook: State Agency Programs for Groundwater Protection. Richmond, VA.

Virginia Ground Water Protection Steering Committee. (1998c). Implementing Wellhead Protection: Model Components for Local Governments in Virginia. Richmond, VA.

Virginia Ground Water Protection Steering Committee. (2000). 2000 Annual Report. Retrieved 2/8/2002 from http://www.deq.state.va.us/gwpsc/annrept.html

Virginia Ground Water Protection Steering Committee. Frequently Asked Questions. Retrieved 12/2/2001 from http://www.deq.state.va.us/gwpsc/faq.html

Weigmann, D. and Kroehler, C. (1988). Threats to Virginia's Groundwater. Blacksburg, VA: Virginia Water Resource Center & Virginia Polytechnic Institute and State University.

Witten, J., Horsley, S., Jeer S., & Flanagan, E. (Witten et al.) (1995). A Guide to Wellhead Protection. Planning Advisory Service Report Number 457/458. Chicago, IL.: American Planning Association Press.

Witten, J. (1992) . The basics of groundwater regulation. Planning, 58 (6) 22-27.

Zokaites, C. (1997). Living on Karst. Richmond, VA: Cave Conservancy of the Virginias.