RASER RIVER
CTION PLAN

GROUNDWATER QUALITY PROTECTION PRACTICES

Canada

Environment Canada Environnement Canada

GROUNDWATER QUALITY PROTECTION PRACTICES

Submitted to:

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Preparation of this report was carried out by Golder Associates Ltd. on behalf of Environment Canada. The primary goal of the study was to review the applicability of groundwater protection practices developed within other jurisdictions to the Fraser River Basin. The study recommends strategies for potential application in the Fraser River Basin to support or supplement proposed groundwater quality protection legislation. Project funding was provided by the Fraser River Action Plan (Greenplan).

EXECUTIVE SUMMARY

Groundwater is an essential and vital natural resource of British Columbia. It is the sole source of drinking water for over 20 percent of the province and plays a crucial role in the maintenance of many ecosystems within the province by providing a source of recharge to surface waters. In recent years, British Columbia's groundwater resources have come under increasing threat of contamination from a variety of sources, including agricultural activities, land application of wastes, septic systems, municipal landfills, leaking underground storage tanks and industrial activities. Once contaminated, groundwater is exceedingly difficult, and sometimes impossible, to restore and the costs of developing alternative supplies are high.

The key to ensuring a safe groundwater supply is to prevent contamination from occurring in the first place through the implementation of groundwater protection measures. To address this issue, a review of protection measures used in juristictions outside of British Columbia was carried out in order to identify those measures that could be applicable to the Fraser Basin. The review indicated that other juristictions, including Europe and the United States, have federal and state legislation requiring groundwater protection, while in Canada, there are relatively few controls and programs to protect this resource. The study also indicated that while federal and provincial or state initiatives offer a degree of groundwater protection, the most effective means of protection occurs at the municipal level through the implementation of site-specific groundwater protection plans.

Groundwater protection can be implemented through either regulatory or non-regulatory mechanisms. A traditional form of regulatory control is the use of zoning to regulate land use activities in sensitive areas such as lands in the immediate vicinity of water supply wells, or in groundwater recharge areas. An innovative approach to zoning that has been implemented in Dayton, Ohio and other regions is the control of types and quantities of hazardous materials rather than restrictions on land use. The review indicated that grandfathering, whereby non-complying uses are permitted to continue without restrictions or conditions, is not an acceptable approach.

Numerous groundwater protection measures can be implemented through non-regulatory means. Public participation and education are among the most important non-regulatory protection measures. They are essential to the success of a groundwater protection plan and provide a means of obtaining political and financial support. Another form of non-regulatory protection is the training of building inspectors to identify abandoned water wells that may serve as pathways for contamination to migrate to underlying aquifers. Another means of non-regulatory protection is the implementation of a spill response program, whereby addresses within a groundwater protection area are flagged in the 911

system so that the 911 operator will be alerted that the location of the call is within an area of public water supply concern.

One form of non-regulatory groundwater protection that offers a high degree of protection is the aquisition of lands within a sensitive zone, as was carried out in Amherst, Nova Scotia. Land aquisition is also a common approach to groundwater protection in Prince Edward Island, where some communities have purchased lands within sensitive zones and then leased the lands back to the owners.

Groundwater protection plans may be adopted for a wellfield, an aquifer, or a group of aquifers. They should be tailored to the needs of a municipality based on local hydrogeological conditions, land uses, and political and economic conditions. Municipalities are best suited to develop their own groundwater protection plans with input from provincial and federal governments and groundwater consultants. Ten steps that should be followed for the development of a groundwater protection plan are outlined below:

1. Define goals and objectives for the plan.

2. Identify a planning team.

3. Evaluate existing and future groundwater supply requirements versus alternative sources.

4. Assess available geological, hydrogeological and geotechnical information and delineate groundwater protection area.

5. Carry out a contaminant inventory and assess the results.

6. Select appropriate groundwater protection measures.

7. Design and implement a groundwater monitoring program.

8. Draw up spill response and contingency plans.

9. Secure funding.

10. Implement the groundwater protection plan.

The review concluded that the Fraser Basin is well suited to the implementation of groundwater protection plans managed at the municipal level. Provided the above steps are followed, the implementation of a protection plan will help a community to ensure a clean, economical source of groundwater for years to come.

1.0 INTRODUCTION

Groundwater is an important yet vulnerable resource of the province of British Columbia. It is the sole source of drinking water for 22 percent of British Columbia's total population and 40 percent of B.C.'s rural population, and accounts for 12 percent of the total water consumption in the province and 22 percent of all groundwater developed in Canada. In many areas of the province, groundwater represents the only viable and economic source of water supply and as a result its use is expected to increase over the coming years, particularly outside of the major metropolitan centres. In addition to providing a vital source of public water supply, groundwater plays an essential role in the maintenance of ecosystems by providing a source of recharge to wetlands, streams and lakes.

In recent years, British Columbia's groundwater resources have come under increasing threats from contamination. Some of the more accessible and economic groundwater resources in British Columbia are also derived from unconfined aquifers which are more vulnerable to pollutants arising from a variety of sources including agricultural activities, land application of wastes, septic systems, municipal landfills, leaking underground storage tanks and industrial activities. In most instances, groundwater contamination is discovered only after a water-supply well has been affected. Once contaminated, remediation of groundwater is a very costly and lengthy process, and often by the time the pollution is identified, the aquifer is damaged beyond repair. In cases where groundwater supplies have been lost through contamination, the costs of remediation and/or development of alternative water supplies have been estimated to be on the order of $10,000 to $50,000 per household (Reference #301). Furthermore, the effects of groundwater contamination do not end with the loss of well-water supplies. Surface waters in wetlands, streams and lakes that are receptors of groundwater discharge are subject to pollution by contaminated groundwater.

The most cost-effective means of ensuring a safe groundwater supply is to prevent groundwater contamination from occurring in the first place. This can be accomplished by implementing groundwater quality protection measures. Protection measures offer a means of managing a land area around an individual well field or above an entire aquifer to prevent groundwater contamination. Such measures provide a way of ensuring a safe groundwater supply and avoiding the costs of installing treatment facilities or locating an alternative source should the groundwater become contaminated. Although federal and provincial initiatives can provide a level of groundwater protection, the most effective means of groundwater protection occurs at municipal levels through the implementation of site-specific groundwater quality protection plans. Each municipality can best determine how to develop its own groundwater protection program based on the local hydrogeological conditions, land uses, and political and economic conditions. The objective of this report is to provide guidance to municipalities located within the Fraser Basin for the implementation of groundwater quality protection plans.

The report is presented in five chapters and five appendices. Background information on groundwater resources within the Fraser Basin is presented in Chapter 2. A discussion of common sources of groundwater contamination is presented in Chapter 3. Chapter 4 presents a review of groundwater quality protection measures that could be implemented at municipal levels through either regulatory or non-regulatory means. Chapter 5 outlines the steps involved in the development of a municipal groundwater quality protection plan. Groundwater protection measures recommended in this report were developed based on a review of groundwater quality protection practices used in jurisdictions outside of British Columbia, including the United States, Europe, Australia, Barbados and the nine other Canadian provinces. An outline of the methodology used for the compilation and review of this information is provided in Appendix I. Appendix II presents an overview of groundwater quality protection practices in western developed nations. Appendix III presents a detailed evaluation of nine selected groundwater protection plans that have been implemented at a municipal level. Summaries of groundwater protection practices compiled by others are provided in Appendix IV. All documents reviewed for the preparation of this report were organized into a project data base under a document reference number. The data base is presented in Appendix V.

2.0 GROUNDWATER RESOURCES WITHIN THE FRASER BASIN

The Fraser Basin consists of the land drained by the Fraser River and its tributaries. From its headwaters in the Rocky Mountains, the Fraser River flows 1375 km to its delta on the Strait of Georgia, draining more than a quarter of the province (Figure 1). The Fraser Basin is the heartland of British Columbia. It is home to 2 million people, or 60 percent of the province's population, and accounts for 80 percent of the gross provincial product. It is the source of almost half the productive forests and farmland, and two thirds of tourism revenue, metal mine production and sockeye and pink salmon catch. Most manufacturing, construction and service industries are located in the Basin. The Fraser and the Thompson Rivers serve as major transportation corridors between the West Coast and the rest of Canada (Reference #302).

The Fraser Basin is divided into four regions: Lower, Thompson, Middle and Upper. A description of the groundwater resources in each of these four regions is described below.

2.1 Lower Fraser Region

The Lower Fraser Region begins at its eastern limit at the city of Hope and includes the Fraser Valley to the west and Greater Vancouver at the Pacific coast. The Fraser Valley, including the communities of Chilliwack, Abbotsford, Langley and Richmond, is a predominantly rural area characterized by agricultural land use. However, in recent years, the area has undergone rapid urbanization due to its proximity to Greater Vancouver. Commercial fisheries are important throughout the Lower Fraser, and forestry is particularly significant in the vicinity of Hope, Kent, Harrison and Mission (Reference #302).

A recent pilot study carried out by the British Columbia Ministry of Environment, Lands and Parks (B.C. Environment) identified a total of 73 different aquifers located in the Fraser Lowland (Reference #272). These aquifers are situated within a complex sequence of glacial, fluvial and marine sediments. The most highly productive aquifers are shallow and unconfined, and many are used as a water supply source by private residences, farms, municipalities, industries and fish hatcheries.

From: *The Fraser River Action Plan Mid-Term Report 1991-1994*, Environment Canada.

There are an estimated 10,000 water wells in the Fraser Valley. Water supply systems range in size from those serving large urban communities to single domestic systems (Reference #089). Groundwater studies in the Lower Fraser Region have identified the presence of pesticides and elevated nitrates in groundwater as the result of agricultural activities and septic effluent fields (Liebscher et al., 1992). These studies have been widely publicized and there is a relatively high level of public awareness and concern over groundwater contamination issues in this area.

2.2 Thompson Region

The Thompson Region extends from Blue River in the north to the Nicola Valley in the south. It includes the communities of Kamloops, Clearwater, Merritt, Ashcroft, Salmon Arm, and Cache Creek, among others. Kamloops has a diverse economy based on forest industries, highway and rail services, mining, agriculture, regional trade, manufacturing, and tourism and recreation. Forestry, mining, and agriculture are the leading activities in Merritt, while mining, highway services and forest industries now employs more residents than farming in the Ashcroft area. In the North Thompson, forest industries dominate (Reference #302).

Principal aquifers within the area encompassing Kamloops, Ashcroft and Cache Creek are located in the main river valleys. Almost three quarters of the wells in the area are completed in water-bearing sand and gravel deposits, while the remainder, mainly in the vicinity of Kamloops, are completed in bedrock. Most of the higher yielding wells in unconsolidated aquifers are located in the Cache Creek area, where they are used for irrigation or municipal and other agricultural purposes.

A limited amount of groundwater development has occurred in the Merritt area, where roughly half of the wells are completed in bedrock and half are completed in unconsolidated deposits. Most of the higher yielding wells are being utilized for municipal water supply needs and industrial (mining) needs.

In the Clearwater and Salmon Arm areas, groundwater is obtained from relatively permeable deposits of glacial and post-glacial sediments located in the valleys. Many of the aquifers are hydraulically connected to nearby rivers, which serve as a source of groundwater recharge (Reference #301).

2.3 Middle Fraser Region

The Middle Fraser is the largest region in the Basin. It includes the communities of Quesnel, Williams Lake, Lillooet, 100 Mile House and Lytton. Land use is characterized by forestry, mining, agriculture and tourism (Reference #302).

Approximately 80 percent of the wells in the Middle Fraser Region are completed in unconsolidated deposits. Most of the productive aquifers are located within heterogeneous deposits of reworked glacial, glaciofluvial and lacustrine deposits which fill the large river valleys within the basin. The majority of wells are used for domestic and livestock purposes. Higher capacity wells used for industrial and community water supply are, for the most part, located within the major river valleys near major population centres (Reference #301).

2.4 Upper Fraser Region

The Upper Fraser Region extends from the Fraser River Headwaters in the Rocky Mountains to Bulkley House in the north and Quesnel in the south. Prince George is the major community in the Region. Land use is characterized by forestry and mining, with agricultural activities largely limited to the Nechako River Valley (Reference #302).

Similar to the Middle Fraser Region, approximately 80 percent of the wells are completed in unconsolidated deposites, and most of the productive aquifers in the Upper Fraser Region are associated with glaciofluvial, fluvial, alluvial and lacustrine deposits located within the valleys of the Nechako and Fraser Rivers. The majority of wells are for domestic and livestock use; high capacity wells have been completed for water supply and industrial use (Reference #301).

3.0 COMMON SOURCES OF GROUNDWATER CONTAMINATION

Groundwater contamination can result from a number of different sources related to residential, municipal, commercial, industrial and agricultural activities. Contaminants may reach groundwater from activities on the land surface, such as industrial spills; from sources below the land surface but above the water table, such as septic systems; or from structures beneath the water table, such as wells (Reference #111). Tables 1 and 2 provide a summary of common sources of groundwater contamination. Some of these sources are also discussed below.

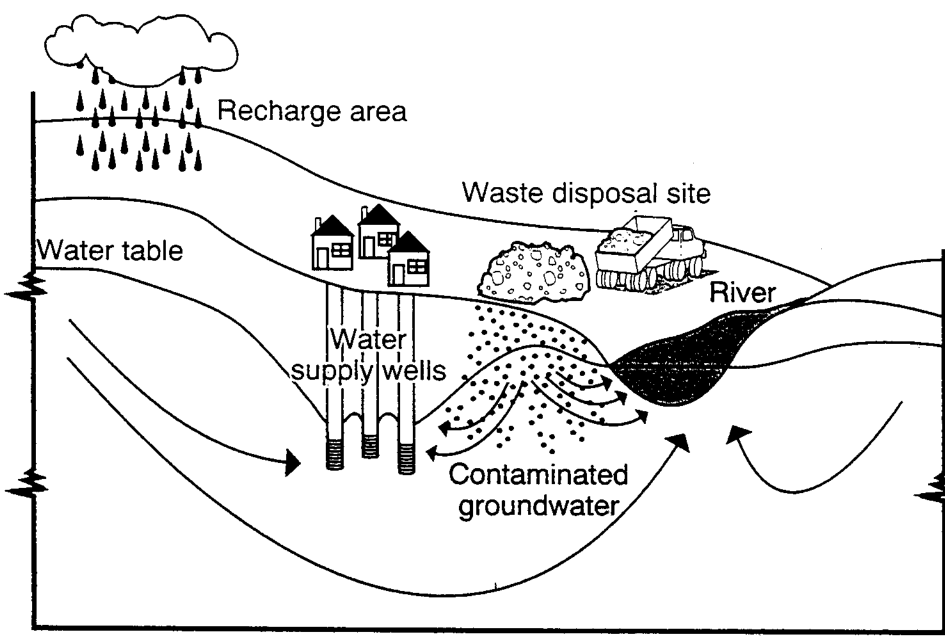
3.1 Category 1 - Sources Designed to Discharge Substances

Category 1 comprises sources that were specifically designed to discharge substances to the subsurface (septic systems, cesspools and dry wells) or to the surface (land application of wastewater and sludge). Septic systems and cesspools are the most frequently reported sources of groundwater contamination in the United States (Reference #111). Their large number and widespread use has resulted in groundwater contamination from bacteria, viruses, nitrates, detergents, oils and chemicals (Reference #111). Dry wells, which collect storm water runoff and spilled liquids, represent a severe threat to groundwater because they permit the direct transmission of contaminants to the subsurface. Land application of wastewater or sludge can contaminate groundwater with a number of contaminants including oils, nitrates and heavy metals.

3.2 Category 2 - Sources Designed to Store Substances

Category 2 consists of sources that were specifically designed to store, treat, or dispose of substances or that resulted from improper disposal. Private residences may contribute to groundwater contamination through the improper disposal of cooking and motor oils, lawn and garden chemicals, paints and paint thinners, disinfectants, medicines, photographic chemicals, and swimming pool chemicals. (Reference #111). Surface impoundments are potential sources because they usually comprise shallow lagoons used by industries and municipalities to store, treat and dispose of liquid wastes. In many cases these lagoons are not lined with impermeable barriers, thereby providing opportunity for seepage of wastes to the subsurface (Freeze and Cherry, 1979). Waste

Figure 2
Groundwater Contamination



From: Groundwater - Nature's Hidden Treasure, Freshwater Series A-5, Environment Canada

TABLE 1
Common Sources of Groundwater Contamination

CATEGORY 1: Sources designed to discharge substances:

Subsurface disposal (septic tanks, cesspools)
Land application of wastes (wastewater, sludge)

CATEGORY 2: Sources designed to store, treat, dispose of substances (unplanned release)

Residential sources
Surface impoundments (not mine tailings)
Waste piles
Materials stockpiles
Above & underground storage tanks
Containers
Open burning sites

CATEGORY 3: Transport or transmission sources

Pipelines (non-hazardous - sewer, water)
Materials transport & transfer operations (truck, railroad)

CATEGORY 4: Sources discharging substances as a result of planned activities

Irrigation practices
Pesticide application
Fertilizer application
Animal feeding operations
De-icing salts applications
Urban runoff

CATEGORY 5: Naturally occurring sources affected by human activity

Ground water/surface water interactions
Salt water intrusion

from: Table 1, Appendix "A", File No. KA601-3-0469, Environment Canada.

Table 2
Common Sources of Groundwater Contamination Listed Alphabetically

Agricultural

Animal burial areas
Animal feedlots
Chemical application
(e.g., pesticides, fungicides, and fertilizers)
Chemical storage areas
Irrigation
Manure spreading and pits

Commercial

Airports
Auto repair shops
Boat yards
Construction areas
Car washes
Cemeteries
Dry cleaning establishments
Educational institutions (e.g., labs, lawns, and chemical storage areas)
Gas stations
Golf courses (chemical application)
Jewelry and metal plating
Laundromats
Medical institutions
Paint shops
Photography establishments/printers
Railroad tracks and yards/maintenance
Research laboratories
Road deicing operations (e.g., road salt)
Road maintenance depots
Scrap and junkyards
Storage tanks and pipes (above-ground, below-ground, underground)

Industrial

Asphalt plants
Chemical manufacture, warehousing, and distribution activities
Electrical and electronic products and manufacturing
Electroplaters and metal fabricators
Foundaries
Machine and metalworking shops
Manufacturing and distribution sites for cleaning supplies
Mining (surface and underground) and mine drainage
Petroleum products production, storage, and distribution centers
Pipelines (e.g., oil, gas, coal slurry)
Septage lagoons and sludge
Storage tanks (above-ground, below-ground, underground)
Toxic and hazardous spills
Wells - operating and abandoned
(e.g., oil, gas, water supply, injection, monitoring (and exploration)
Wood preserving facilities

Residential

Fuel storage systems
Furniture and wood strippers and refinishers
Household hazardous products
Household lawns (chemical application)
Septic systems, cesspools, water softeners
Sewer lines
Swimming pools (e.g. chlorine)

Waste Management

Fire training facilities
Hazardous waste management units (e.g., landfill land treatment areas, surface impoundments, waste piles, incinerators, treatment tanks)
Municipal incinerators
Municipal landfills
Municipal wastewater and sewer lines
Open burning sites
Recycling and reduction facilities
Stormwater drains, retention basins, transfer stations

From: Wellhead Protection Programs: Tools for Local Governments, United States Environmental Protection Agency, 1989 piles and landfills also may contribute to groundwater contamination by generating leachate that can contain a variety of contaminants. Several open dumps and landfills that have no secondary controls (liners, interceptor trenches or ditches) are still in use. Materials stockpiles, such as treated lumber, that are stored on the ground and in uncovered areas also may leak or leach hazardous materials into the groundwater.

Underground storage tanks (USTs) are a well known source of groundwater contamination. It is estimated that approximately 10% to 15% of USTs that are over 25 years old in Canada are leaking. Above-ground storage tanks also pose a threat to groundwater when spills or leaks occur and adequate barriers are not in place (Reference #111). Leakage from USTs and above-ground storage tanks frequently results in groundwater contamination by fuels and chemicals.

3.3 Category 3 - Transport or Transmission Sources

Category 3 consists of sources related to the transport or transmission of substances. Accidents or spills that occur along highway or railway corridors above unconfined aquifers result in the contamination of groundwater by a number of substances. Sewer pipes carrying wastes leak fluids into the surrounding soil and groundwater if the pipes are not adequately tested and maintained. Abandoned or poorly maintained sewer and water pipelines also provide conduits for subsurface contaminant migration.

3.4 Category 4 - Sources Discharging Substances as a Consequence of Other Planned Activities

Category 4 comprises sources that discharge substances as the result of planned activities such as agriculture, road de-icing and urban activities. Freeze and Cherry (1979) estimate that, of all human activities that influence the quality of groundwater, agriculture is likely the most important. Agricultural activities resulting in groundwater degradation are related to farmers, homeowners, businesses (golf courses), and municipalities. Agricultural activities, including the use of chemical and manure fertilizers, feedlots and soil enhancement with livestock and fowl wastes result in the contamination of groundwater by nitrates. Liebscher et. al (1992) estimated that 60% of groundwater samples from the Abbotsford aquifer have nitrate-nitrogen concentrations in excess of the drinking water criterion of 10 mg/L.

Pesticides are another source of groundwater contamination resulting from agricultural activities. In addition to representing significant health and environmental concerns, certain pesticides tend to persist in soil and groundwater for long periods of time. Liebscher et. al (1992) have identified 13 pesticides in groundwater in the Abbotsford Aquifer resulting from agricultural activities.

Salt that is applied to roads to remove ice is also a source of contamination where it is washed into the soil and then into the groundwater by precipitation. High sodium levels in groundwater pose a health risk and may damage vegetation, vehicles and bridges (Reference #111). In addition to road salt, runoff from urban sources may contain oil or fuels leaked from vehicles and a number of other contaminants. Where runoff is allowed to pond, infiltration to the subsurface is likely to occur.

3.5 Category 5 - Naturally Occurring Sources Affected by Human Activity

Category 5 consists of naturally occurring sources that are affected or induced by human activity. For example, groundwater degradation may occur in areas where human activity has altered natural groundwater-surface water interactions such as the construction of golf courses and other developments. Salt water intrusion is another common form of groundwater contamination in coastal communities where overpumping occurs.

4.0 GROUNDWATER PROTECTION MEASURES

Groundwater quality protection measures can be implemented at municipal levels through either regulatory or non-regulatory means. A range of both types of groundwater protection measures were compiled from a "broad brush" review of protection strategies used in Canada, the United States, Europe, Australia and Barbados (Appendix II), in addition to a review of 36 groundwater protection plans from across Canada and the United States that were implemented at municipal levels. A detailed evaluation of nine of these groundwater protection plans is presented in Appendix III.

In the following discussion of groundwater protection measures, they have been grouped into the following three broad categories:

1. Non-regulatory groundwater protection measures,
2. Groundwater protection measures that may be implemented through either regulatory or non-regulatory means, and
3. Regulatory groundwater protection measures.

Most groundwater protection plans are implemented through a combination of regulatory (i.e., zoning) and non-regulatory (i.e., guidelines, public education) mechanisms. Every protection plan reviewed for this study contained some degree of regulatory control.

A summary of the groundwater protection measures that were implemented for each of the 36 groundwater protection plans is presented in Tables 3, 6 and 8. Tables 4, 7 and 9 provide an evaluation of the various protection measures based on the following criteria:

- extent to which the practice is proactive versus reactive
- degree of groundwater protection offered
- effort required for implementation
- relative cost to implement
- staffing requirements

- public acceptability
- flexibility (adaptability to site-specific hydrogeological, socio-economic and demographic parameters)

4.1 Non-Regulatory Groundwater Protection Measures

4.1.1 Public Involvement

Public involvement is the most commonly used non-regulatory groundwater protection measure. As shown in Table 3, almost every groundwater protection plan that was reviewed emphasized the need for public involvement. Public involvement has two related components: public participation and public education. Public participation is the involvement of the community in the development and implementation of the groundwater protection plan. Public education is the provision of information to the public to create an awareness of the importance of protecting groundwater resources, to reassure the public that their interests are protected, and to educate the public about the steps they can take to protect this resource.

Common forms of public participation and education include the following:

1. Public information meetings

   Public informational meetings were held by most agencies involved in the implementation of groundwater protection plans. The meetings involved consultation with municipal councils, community members, the general public, industry, government agencies, public interest groups, universities and professional organizations.

2. Groundwater issues survey

   A groundwater issues survey is a survey of a representative sample of the general public to determine attitudes and behaviours concerning groundwater and the need for groundwater protection. As an example, groundwater issues survey questionnaire was sent to over 900 households in Olmstead County, Minnesota at the outset of the development of their groundwater protection plan. The survey results were used to obtain support from elected officials and interest groups (Reference #151).

TABLE 3
Use of Non-Regulatory Groundwater Protection Measures

	Public Involvement	Wellhead Protection Area Delineation	Vulnerability Mapping	Aquifer Classification	Contaminant Inventory	Well Inventory	Groundwater Monitoring	Spill Response Planning	Contingency Planning	Hazardous Waste Collection	Technical Assistance	Land Aquisition	Purchase Development Rights	Conservation Easements	Cluster Development
1. Selected Protection Plans															
Dayton, Ohio	x	x	x	x	x		x	x		x				x	
Waterloo, Ontario	x	x			x		x	x	x						
Amherst, Nova Scotia	x	x			x		x	x				x			
South Fredericton, NB	x	x			x		x	x		x		x			
Regina, Saskatchewan			x				x	x							
Spokane, Washington	x	x			x		x	x		x					
Peel, Ontario	x	x			x	x			x						
Palm Beach, Florida	x	x					x								
Long Island, New York	x	x										x			x
2. Other Protection Plans															
Acton, Massachusetts				x			x					x			
Austin, Texas															
Biola Comm. Ser. Distr., California	x	x			x	x			x						
Brookings County, South Dakota															
Chelsea, Maine	x	x			x		x	x	x			x			
Cheyenne & Arapoho Tribes, Oklahoma	x		x					x							
Clark County, Washington	x	x			x	x	x	x		x					
Clinton Township, New Jersey															
Clover/Chambers Creek, Washington							x		x						
Crystal Lake, Illinois												x	x		
Dade County, Florida															
Danbury, Connecticut								x							
Descanso Comm. Ser. Distr., California	x	x			x				x	x					
Dorchester, Ontario		x			x										
Elkhart County, Indiana															
El Paso, Texas	x	x			x		x	x		x				x	
Falmouth, Massachusetts	x	x		x			x	x		x		x		x	x
Idaho's Panhandle Health District	x						x								
Issaquah, Washington	x	x			x		x	x	x						
Julian Comm. Ser. Distr., California	x	x			x				x						
Nantucket Island, Massachusetts	x														
Newcastle County, Delaware		x					x	x							
Olmstead County, Minnesota	x	x			x		x								
Pinelands, New Jersey												x			x
Renton, Washington	x	x					x								
Southington, Connecticut															
Thurston County, Washington	x	x		x	x		x	x			x				x

X = groundwater protection measure that has been implemented or is under consideration

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TABLE 4
Evaluation of Non-Regulatory Groundwater Protection Measures

Groundwater Protection Measure	Extent to Which Proactive	Degree of Protection	Implementation Effort	Relative Cost	Staffing Requirements	Public Acceptability	Flexibility
Public Involvement	L-H	M	L-H	L-H	L-H	H	H
Wellhead Protection Area Delineation	M	M	L	M-H	M	M	L
Vulnerability Mapping	M	H	L	H	M	M	H
Aquifer Classification	M	M	L	M	M	M	M
Contaminant Inventory	L	M	L	M	M	M	M
Well Inventory	M	M	L	M	M	M	M
Groundwater Monitoring	L	H	M	H	H	M	H
Spill Response Planning	H	H	M	L-H	L	M	M
Contingency Plans	H	M	M	L-H	L	M	H
Hazardous Waste Collection	M	L	L-M	M	L	H	M
Technical Assistance	M	M	H	H	H	H	H
Land Aquisition	H	H	H	H	L	M	L
Purchase of Development Rights	H	H	H	M-H	L	L	L
Conservation Easements	H	H	M	L	L	L	L
Cluster Development	H	L	H	L	M	L	L

L = Low
M = Medium
H = High

1/LOTUS/TAB-95/MAR/942-1832.xls

3. Use of the media (newspapers, television, magazine and radio features)

In a summary of its groundwater protection plan, the City of Dayton, Ohio (Reference #137) emphasized the importance of interaction with the media in order to obtain support for their groundwater protection program. According to officials, “The importance of the media in sustaining momentum and disseminating accurate information during the evolution of the WFPP (well field protection plan) cannot be overstated.”

4. Distribution of magazines, bulletins, pamphlets, and maps

Disseminating information through the production and distribution of magazines, bulletins, pamphlets and maps has been an important aspect of many public participation and information programs.[1]

As an example, Amherst, Nova Scotia published a public information paper (Figure 3) to launch the start of their groundwater protection plan (Reference #246). The paper described the events that led to the establishment of the protection zone and the measures being implemented to protect groundwater. Renton, Washington published a brochure providing information on the proper handing and disposal of hazardous wastes by home-owners (Figure 4).

Some forms of educational literature not directly associated with, but complimentary to protection plans are available through provincial governments. For example, Newfoundland, Quebec, Ontario and Alberta have published public information brochures on proper well construction and maintenance (Figure 5). Other jurisdictions have published similar brochures on proper septic design and maintenance.

5. Provision of signs at strategic locations

The use of signage around groundwater protection areas is considered to be a highly effective and relatively inexpensive means of raising public awareness. For example, the Town of Amherst, Nova Scotia has placed signs at 50 m intervals around its entire groundwater protection zone. The signs indicate that agriculture, forestry, open fires, motorized vehicles, pesticides, waste disposal and highway salting are not permitted in that area. The Cheyenne and Arapaho Tribes of Oklahoma installed signs along roads to their groundwater protection area that included a phone number of a contact person in case of an emergency or release of a contaminant (Reference #103).

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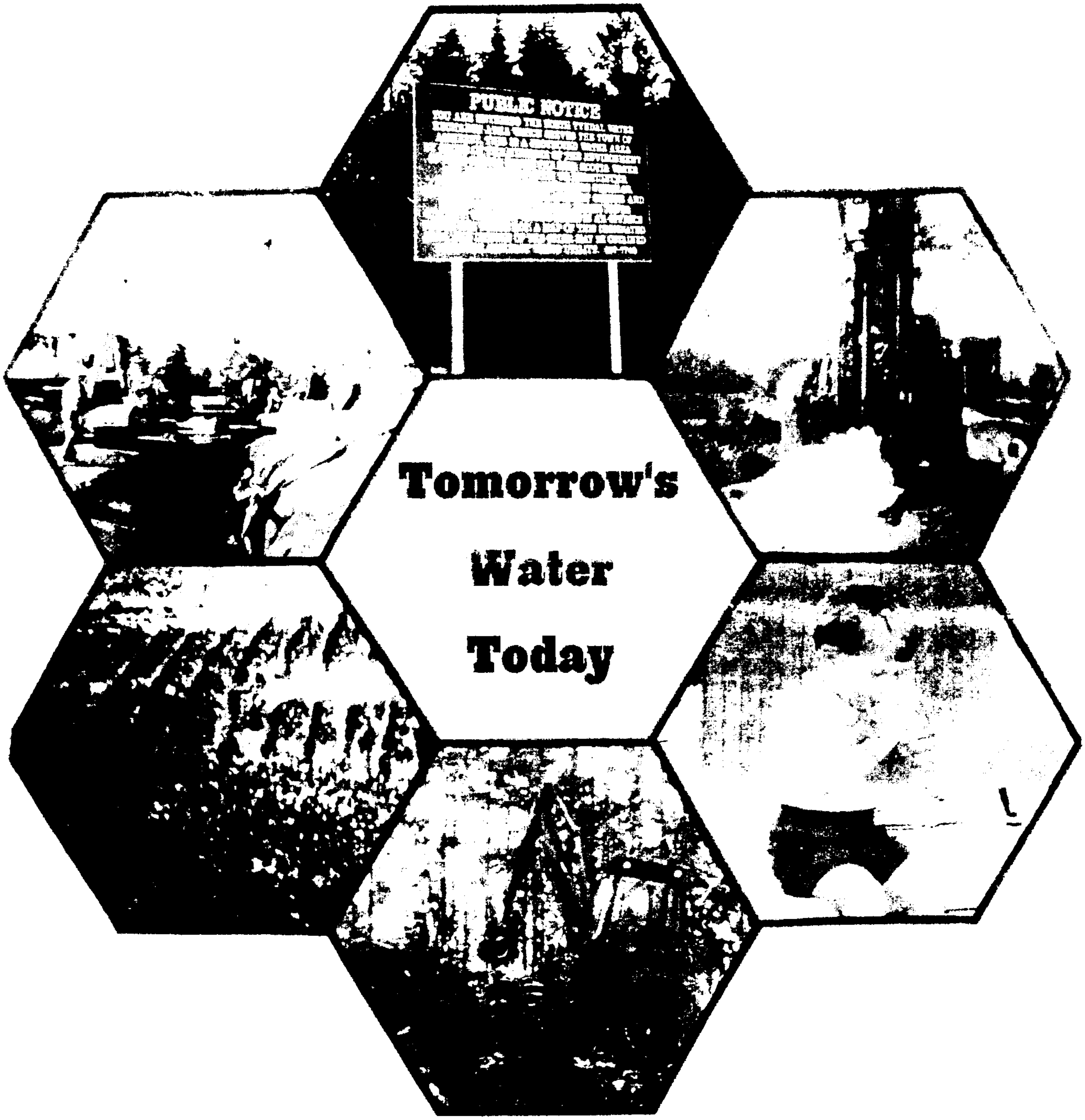
1 Examples of promotional literature have been provided to Environment Canada’s North Vancouver library, and may be obtained by contacting the library at 666-5914 or 666-1794.

Figure 3
Public Information Paper For Amherst, Nova Scotia

North Tyndal Wellfield



Index

Page 3 - History of Amherst Water Supply 1885 - 1983
Page 5 - Wellfield Exploration Program
Page 8 - Construction of News Wellfield
Page 9 - Groundwater Protection Strategy

This paper is published in conjunction with the Official Opening of the North Tyndal Wellfield - October 21, 1993

Figure 4
Public Information Brochure Published by the City of Renton, Washington

The City of Renton depends upon the Cedar River aquifer for up to 85% of its water supply. This aquifer lies in the Cedar River canyon near I-405 and the Maple Valley highway (shown on map as most sensitive area).

As much as 14 million gallons per day is pumped into the City's water system from five wells located near I-405. Water in the aquifer is replenished by precipitation above the aquifer, by underground flow from the Cedar River, and by overland and underground flow of precipitation from adjacent drainage areas (shown on the map as more sensitive and sensitive areas).

Contaminants can enter the aquifer by any of these replenishment routes. After contaminants have entered the soil, groundwater, or stream flows, they are extremely difficult to remove. They do not "just disappear"; most do not break down into harmless constituents, and small amounts of contaminants can render large amounts of water undrinkable.

The City currently enjoys high quality water from the Cedar River aquifer. No treatment is required, except chlorination to ensure total disinfection. Please do your part to protect Cedar River water quality.

Potential contaminants include the following:

- Poisons
- Pesticides, herbicides
- Paints, solvents
- Gasoline, fuel oils
- Lubricating oils, grease
- Antifreeze
- Household cleaners
- Detergents
- Acids, salts
- Sewage, manure
- Other hazardous wastes

Good ecological housekeeping dictates proper disposal of these and other contaminants regardless of where you live. However, if you are in the sensitive areas indicated on the map, it is particularly important to the City of Renton's water supply that you:

DO NOT

- Dump or spill these materials on the ground or into sumps.
- Dump or spill these materials into gutters, storm sewers, open drainage courses, or ponds.
- Dispose of these materials in your septic tank or garbage can.
- Allow fuel or heating oil tanks to leak onto or into the ground.

DO

- Dispose of these materials only at approved collection points.
- Call King County Health Dept. (228-2620 or 587-2722) for information about collection points.
- Call City of Renton (235-2631) to report spills of these materials or to request additional information.
- Check your home heating oil or fuel tanks and pipelines for leaks.
- Check your septic tank and drainfield for proper operation.

PROTECT YOUR WATER SUPPLY

City of Renton Water Department

Figure 5
Public Information Brochure Published
by the Department of Environment, Newfoundland

Where does groundwater come from?

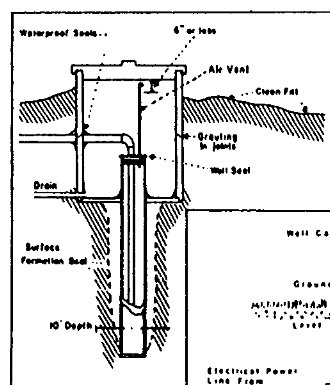
The groundwater that enters your well may have begun its journey many years ago. In most cases it is derived directly from precipitation; in others it first enters a pond or river. From either source groundwater must seep down vertically through the soil layers until it reaches the water table. Water beneath this level is always moving in a direction determined by the elevation of the water table at that point. Normally the movement is from high ground to low ground but this can be altered by the resistance to flow that is exerted by the soils and rock formations through which it seeps. Depending on the size of the openings in these materials, many years may elapse before the water that began as rain or snow reaches your well.

How does groundwater get contaminated?

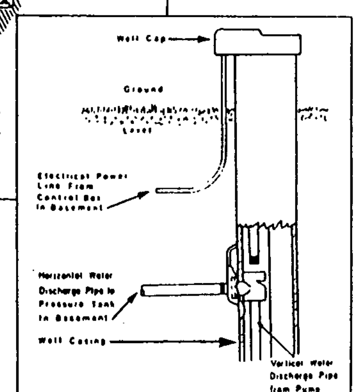
As groundwater seeps through the soil and rock formations in which your well is constructed, its quality is altered. This is usually to your advantage. Most surface waters are turbid and contain undesirable organisims. The filtering effect of soils gives us the crystal clear, clean water that is characteristic of groundwater. It can be well appreciated that if the soil itself is contaminated with substances such as oil, gasoline, animal wastes, or any soluable material, then the waters percolating through such soil will become contaiminated too. The other major cause of poor quality well water is the entrance of contaminated surface water directly into the well through defective casing seals or improper pump installations.

How do I protect my well from pollution?

Once a well has been drilled in a safe location, the most obvious way to protect it is to be sure that the ground around it slopes away from it. This will prevent surface water from ponding near the casing. The next step is to provide the proper hookup to the pressure system. Only the pitless adapter or the drained well pit are recommended for this purpose (these are depicted below). Burial of the well is not recommended. Remember! Your well should be accessible for inspection and investigation in case any problem should arise in the future. An undrained well pit is also to be avoided. Such a pit tends to fill up with water and promote leakage into the well casing.



Casing seal and well pit construction



Pitless adapter

The following common sense precautions need to be taken when finishing the well:

- Don't locate oil tanks near the well.
- Don't park old vehicles near the well.
- Don't store soluable materials near the well.
- And finally, check the well occasionally to make sure that all is in order.

What if I decide to abandon my well?

If you ever decide to abandon your well **remember,** groundwater belongs to everybody. In addition to providing you with access to the resource for your requirements, your well will be a ready conduit for surface waters when the casing corrodes away. Unwittingly, you may contaminate your neighbour's well. To prevent this from happening, it is a requirement of the Well Drilling Act that **an abandoned well must be back filled with cement grout or bentonite clay.**

What if I have any specific questions or problems?

If your questions have not been answered here, please contact us at the following address:

Department of Environment,
Water Resources Division,
Groundwater Branch,
P.O. Box 4750,
St. John's, Newfoundland.
A1C 5T7

or phone 576-2539 or 576-2563

6. Telephone Information Lines

Dade County, Florida set up a 24-hour information line ("pollution hotline") as part of their groundwater protection plan to respond to residents' questions and complaints (Reference #195). The City of Dayton, Ohio "flagged" all addresses within their designated groundwater protection area so that the 911 operator will be alerted that the location of the call is within an area of public water supply concern.

7. Posters, information booths and slide shows

The municipality of Peel, Ontario solicited public support for their groundwater protection plan by setting up displays at community fairs. Nantucket Island, Massachusetts produced a large colour poster depicting Nantucket's water resources. Posters have been placed in various public locations and sold at local bookstores (Reference #103). Olmstead County, Minnesota produced two slide/tape presentations during the early part of their program which highlighted the major groundwater resource issues in Olmstead County (Reference #151).

8. School educational programs

Several groundwater protection plans have involved education within schools about the need for groundwater protection. Other educational programs targeted at young people but not associated with a particular protection plan include Project "WET" (Water Education for Teachers) in Idaho (an interdisciplinary water education program for Idaho educators and young people) (Reference #241) and a recent Children's Groundwater Festival in Milton, Ontario.

9. Assistance Programs

Assistance programs have been established in the United States to enhance public awareness and education regarding groundwater quality issues. Home-A-Syst is a voluntary pollution risk assessment program established by the Cooperative Extension of Washington State University and targetted towards home owners and small farms (Reference #230). Workshops are held during which homeowners and farmers evaluate possible sources of toxics, microorganisms, and nitrates on their properties using worksheets. The property owners are provided with a series of fact sheets with information on actions to reduce groundwater contamination risks. A summary of work sheets and fact sheets available from Home-A-Syst is provided in Figure 6. Farm-A-Syst is a similar program to Home-A-Syst designed to provide assistance to larger farm operations. Farm-A-Syst Programs are underway across the United States (Reference #231).

Figure 6
Brochure for Home•A•Syst (Public Education) Program sponsored by the Cooperative Extension of Washington State University, 1995

HOME•A•SYST

The Homestead Assessment System For Clean Groundwater

■ Prevention is the Key...

Protecting your drinking water is vital to your health. Your homestead activities (water use, farm and home wastes, chemical and petroleum product storage, etc.) may be a major source of groundwater contamination. Keeping your groundwater free of contaminants helps to insure your drinking water stays clean as well. Without proper protection and management, your family, neighbors, and animals, could be at risk.

■ What Home•A•Syst can do...

The desire to protect your drinking water may provide motivation for action, but many people are not sure where to go for help. Now there is a voluntary program, the **Homestead Assessment System (Home•A•Syst)**, that is designed to give you the answers you need to protect your groundwater *and* your drinking water.

Home•A•Syst is a confidential assessment that you can use on your own or in consultation with local experts. **You** decide what to do with the results of your assessments and keep your action plan in your private records. It is like having a detailed environmental assessment of your homestead at little or no cost.

Home•A•Syst was developed for use on all homesteads with wells. Most homesteads contain on-site septic systems, animals, and petroleum storage tanks. These are all potential threats to your drinking water supply.

The Home•A•Syst Program...

- **Creates *awareness* of homestead activities and structures that may cause drinking water contaminations.**
- **Promotes *understanding* of groundwater protection and clean-up actions.**
- **Identifies *sources* of technical, educational, and financial assistance.**
- **Aids in developing a personal, voluntary *action plan*.**

Joyce Bergen ©1989

How Home•A•Syst works...

The program consists of two basic components-assessment **worksheets** and related **fact sheets.**

The **worksheets** are easy to use and take you step by step through a series of **risk categories(A)**. These risks are then **ranked(B1)**, allowing you to assess possible groundwater contamination activities or structures around your homestead. The assessment also helps you rate your homestead soil's geology and hydrologic features in order to give you an overall picture of potential and actual water quality problems at the site. The **rankings(B2)** can then be used to develop an overall **action plan** for protecting your drinking water. Each worksheet includes a helpful **glossary** of related terms used to complete the worksheets.

The companion **fact sheets** provide information on actions that reduce contamination risks, sources of additional information, as well as contacts for possible financial, educational, and technical assistance.

A | B2

Drinking Water Well Condition: Assessing Drinking Water Contamination Risk

B1

1. Use a pencil. You may want to make changes.
2. For each category listed on the left that is appropriate to your homestead, read across to the right and circle the statement that best describes conditions on your homestead. (Skip and leave blank any categories that don't apply to your homestead.
3. Then look above the description you circled to find your "rank number" (4, 3, 2, or 1) and enter that number in the blank under "your rank."
4. Complete the section "What do I do with these rankings?"
5. Allow about 15-30 minutes to complete the worksheet and summarize your risk rankings for well management practices.

	LOW RISK (rank 4)	LOW-MOD RISK (rank 3)	MOD-HIGH RISK (rank 2)	HIGH RISK (rank 1)	YOUR RANK
LOCATION (Addressed in fact sheet 1, section 1)					
Position of drinking water well in relation to pollution sources	Up gradient from all pollution sources. No surface water runoff reaches well. Surface water diverted from well.	Up gradient from or at grade with pollution sources. No surface water runoff reaches well.	Down gradient from most pollution sources. Some surface water runoff may reach well.	Settling or depression near casing. Surface water runoff from livestock lot, pesticide and fertilizer mixing area, fuel storage, or farm dump reaches well.	___
Separation distances between well and homestead contamination sources*	400 feet or more separation distance from all potential contamination sources.	200 to 400 feet separation distance from potential contamination sources.	Less than 200 feet from all potential contamination sources but meets required minimum separation distance of 100 feet .	***Less than 100 feet to any potential contamination sources.****	___

The origins of Home•A•Syst...

Home•A•Syst is a program developed by the Washington State University Cooperative Extension, with the aid of farmers and other rural dwellers, agricultural associations, industry, and state agencies. Support was provided by the Environmental Protection Agency and the Washington Department of Ecology.

Washington's **Home•A•Syst** program is a modification of **Farm*A*Syst**, a successful program developed through joint efforts between the University of Wisconsin and University of Minnesota Extension Services and an Environmental Protection Agency project. Farm*A*Syst is now a national program supported by U.S. E.P.A., USDA Extension Service, and SCS.

Worksheets and Fact sheets are available on the following topics:

1. Drinking Water Well Condition
2. Pesticide Storage and Handling
3. Fertilizer Storage and Handling
4. Petroleum Product Storage
5. Farm and Home Waste Management
6. Household Wastewater Treatment
7. Animal Manure Storage
8. Animal Lot Management
9. Silage Storage
10. Milking Center Wash Water Treatment

Two additional worksheets are also available:

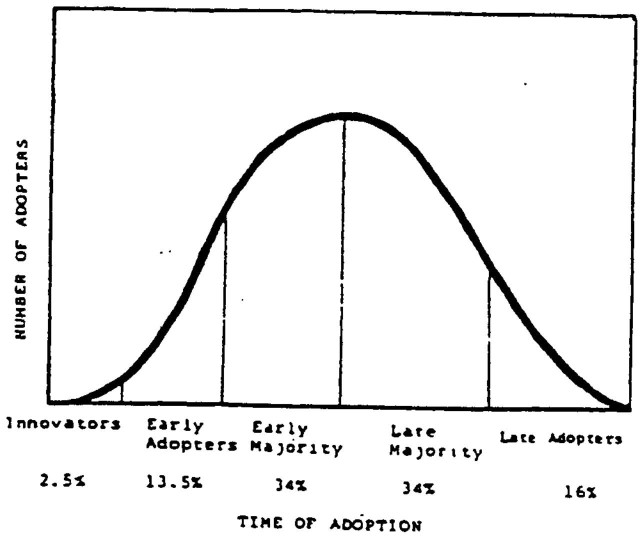
11. Site Evaluation
12. Overall Homestead Assessment and Action Plan

Public support is considered essential to the success of a groundwater protection plan and serves as a means of obtaining both political and financial support. Reference #247 provides a discussion of the process by which public awareness and support of new ideas, such as groundwater protection, occur. According to Rogers (Reference #298), the general public can be broadly categorized into five types of “adopters” (Figure 7). Innovators, which represent only 2.5% of the population, have the ability to grasp abstract ideas and are able to cope with the high degree of uncertainty associated with an innovation. Early Adopters represent about 13.5% of the population and have the greatest degree of opinion leadership in most social systems. The Early Majority, which represent about 34% of the population, adopt new ideas just before the average member of a social system. The Late Majority, represented by 34% of the population, adopts new ideas just after the average member of a social group. Late Adopters, representing 16% of the population, are the last in a social system to adopt an innovation. Roger's research has shown that the adoption of a new idea follows an S-shaped curve as illustrated in Figure 7. An idea is slow to be accepted at first and then accelerates until half of the people finally adopt it. The shaded area on Figure 7 marks the time that a new idea really “takes off”. Rogers’ research has shown that when 20% of the public has adopted a new idea it is virtually unstoppable (Reference #247). Roger's research also stresses the need for public awareness before adoption can be achieved. As shown in Figure 7, the rate of awareness is faster than the rate of adoption. Typically, a 10% level of adoption requires a 40% level of awareness.

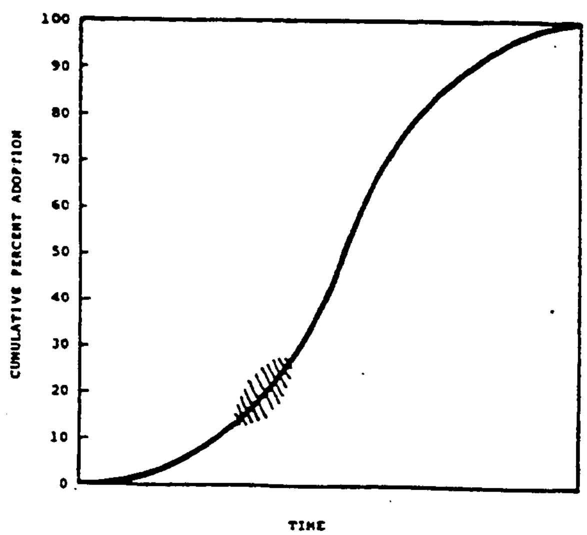
One important aspect of public education is that the process must continue long after the program is first implemented. Not only does this ensure that groundwater protection measures will be followed, it helps to encourage a continual source of funding for the duration of the project. It also serves to educate people who have recently moved to the area. Another aspect of public education is that, as encountered by the Regional Municipality of Peel, public interest may be low if there is a perceived lack of problems with the groundwater quality in an area. In these cases it may be necessary for the agency to be more proactive to seek public support to and explain the consequences of not implementing groundwater protection measures.

The cost of public education programs can be highly variable, depending on the forms of education used. For example, the use of signage around groundwater protection areas is

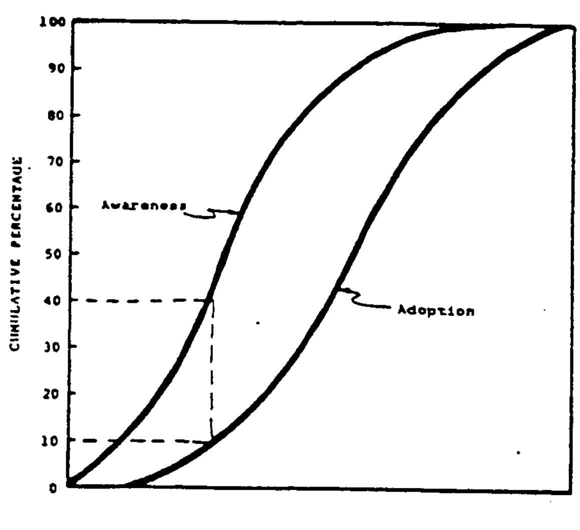
Figure 7
Public Support for Groundwater Protection



A. "Adopter" Categories



B. Rate of Awareness and Rate of Adoption



C. Rate of Adoption

From: *Management Options for Groundwater Protection in Thurston County, Washington, Thurston County Planning Department, May, 1989* highly effective and relatively inexpensive. Our review of groundwater protection plans indicates that most agencies have dedicated considerable resources to public education. For example, officials involved in the implementation of the protection plan for Palm Beach, Florida spend approximately 30% of their time on public education programs. Although essential to the success of a protection program, the effectiveness of public education may be difficult to measure.

4.1.2 Wellhead Protection Area Delineation

Wellhead protection consists of the protection of groundwater in an area immediately around an individual well or wellfield. Until recently, this has been the classical approach to groundwater protection in the United States and Europe. Wellhead protection areas are established based on one or more of the following characteristics: distance, drawdown, travel time, flow boundaries and assimilative capacity (ability of a subsurface formation to attenuate the concentrations of contaminants). The United States' Environmental Protection Agency (U.S. EPA) has identified six methods that can be used to delineate a wellhead protection area. The methods, listed below, are in order of increasing technical sophistication:

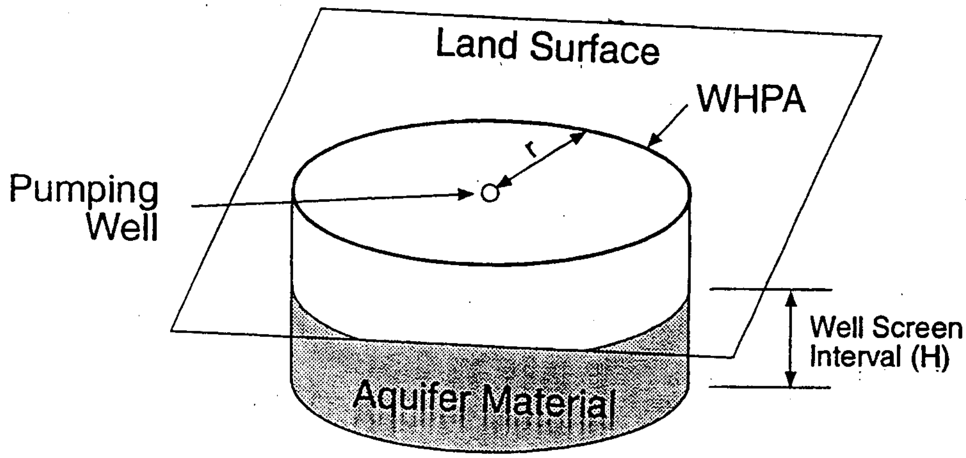
- arbitrary fixed radii
- calculated fixed radii
- simplified variable shapes
- analytical models
- hydrogeological mapping
- numerical flow and transport models

Arbitrary fixed radius refers to drawing a complete circle of specified radius around each well or wellfield to delineate the wellhead protection area. The radius may be selected on the basis of very generalized hydrogeologic considerations and/or professional judgment (Figure 8).

Calculated fixed radius consists of drawing a circle around the well or wellfield based on a calculated time of travel. The radius is calculated using an analytical equation that is based on the volume of water that will be drawn to a well in the specified time (Figure 8).

Figure 8

Wellhead Protection Area Delineation
Using the "Arbitrary Fixed Radius" Method

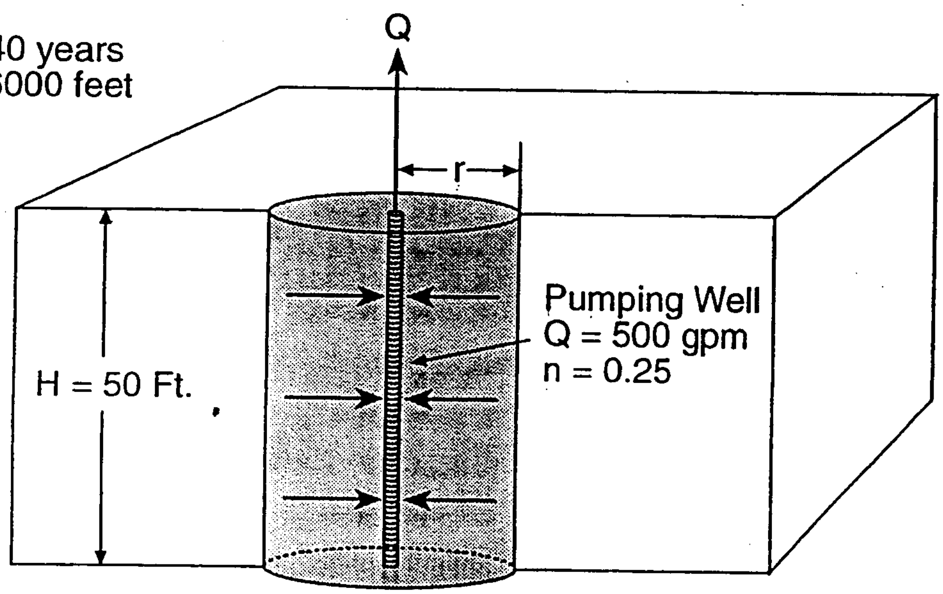


From: Converse Consultants NW and Guidelines for Delineation of Wellhead Protection Areas, United States Environmental Protection Agency, June, 1987

Wellhead Protection Area Delineation
Using the "Calculated Fixed Radius" Method

$$Qt = \pi n H r^2 \longrightarrow r = \sqrt{\frac{Qt}{\pi n H}}$$

When $t = 40$ years
$r = 6000$ feet



From: Wellhead Protection Strategies for Confined Aquifer Settings, United States Environmental Protection Agency, 1991

Simplified variable shapes involves the use of analytical models to produce various "standard form" capture zones using different sets of representative or probable hydrogeological settings. A best-fit standard form is then selected by determining which representative conditions most closely match the pumping rates and hydrogeology of the well. The appropriate standard form is then oriented around the well according to groundwater flow patterns and is taken as the area needing protection (Figure 9).

Analytical modelling typically involves the use of mathematical equations that represent two-dimensional problems to solve well hydraulic and flow equations to delineate capture zones of wells (Figure 10).

Hydrogeological mapping uses geological, geomorphic, geophysical and tracer dye methods in the field to map aquifers, flow boundaries, flow patterns and directions (Figure 11).

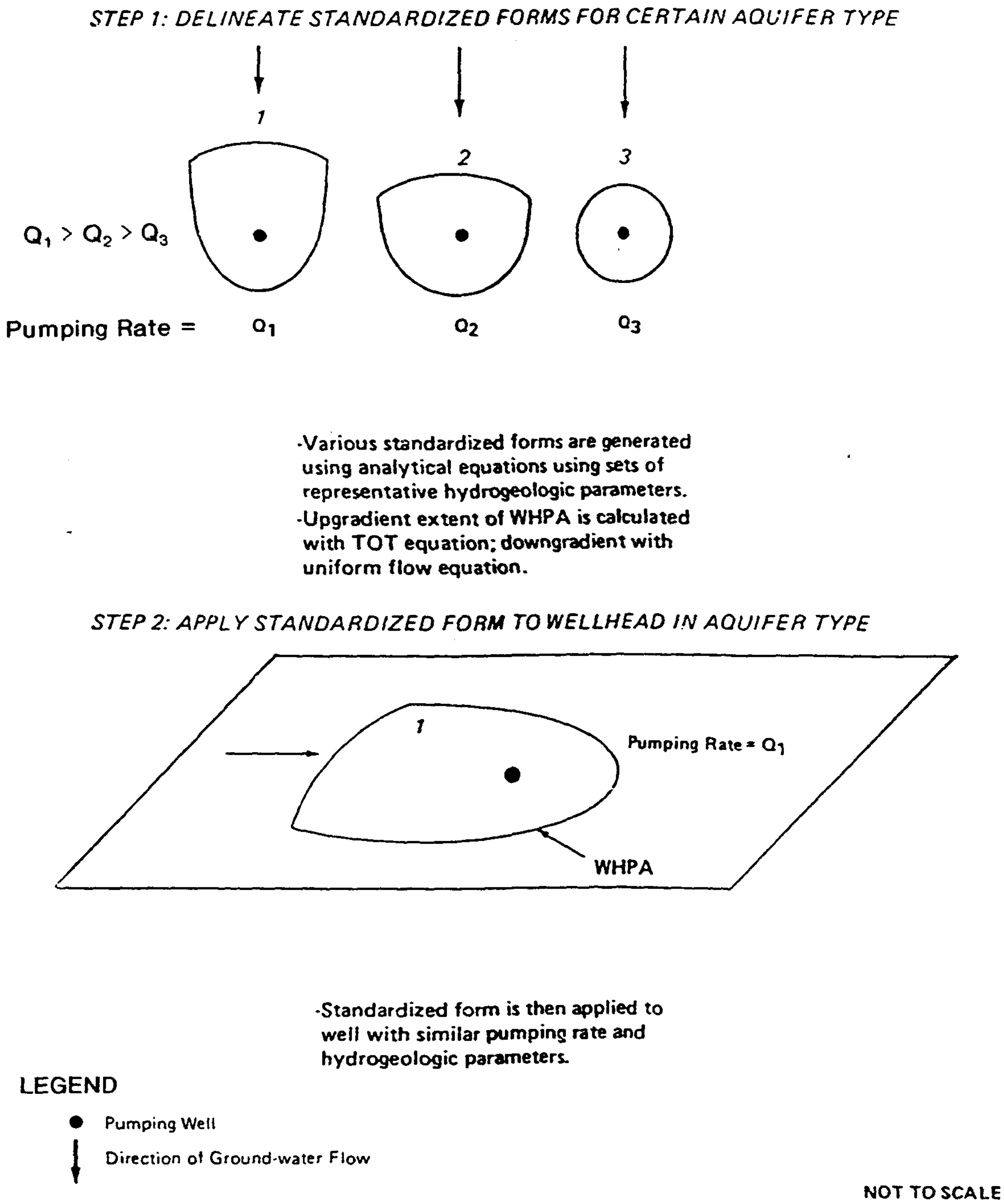
Numerical modelling uses computer codes to simulate a two- or three-dimensional representations of an aquifer by solving numerical equations (Figure 12) (References #99 and #110).

The appropriateness of the various methods for wellhead area delineation is dependent on the objectives of the program, the local hydrogeological conditions and available resources (Reference #99). A summary of the advantages and disadvantages of each delineation method prepared by B.C. Environment (Reference #99) is provided in Table 5. Further information on the various delineation methods can be obtained in the guidance document issued by the EPA entitled *Guidelines for Delineation of Wellhead Protection Areas* (Reference #110). A map showing proposed groundwater protection areas for the South Federicton Aquifer in New Brunswick is present in Figure 13.

4.1.3 Vulnerability Mapping

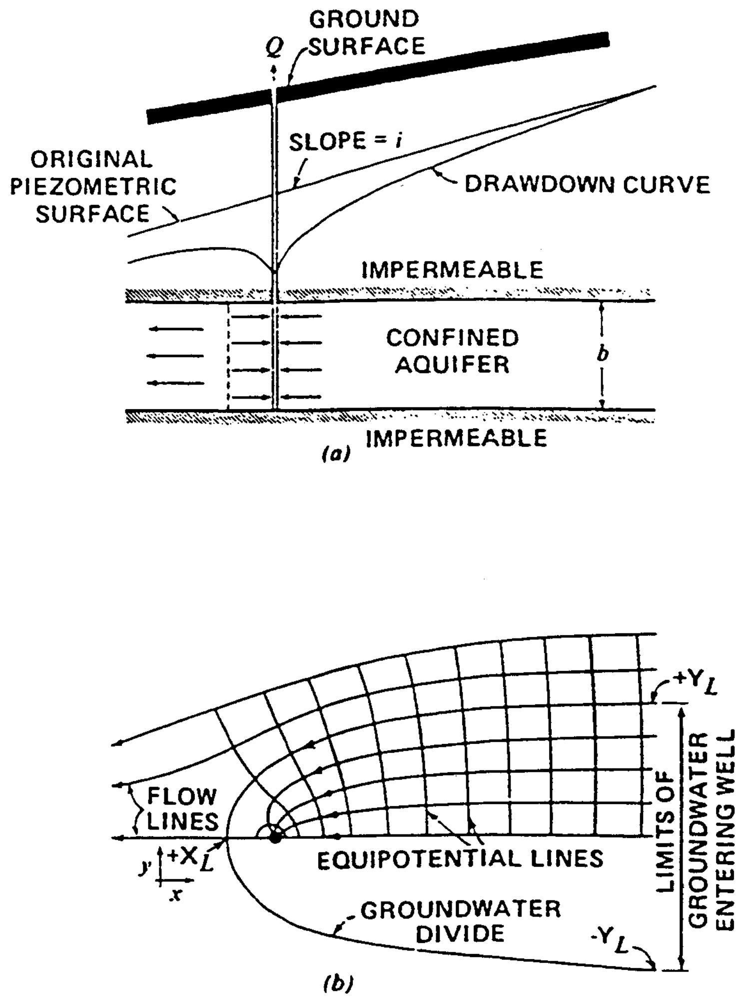
Vulnerability mapping consists of determining the sensitivity of a groundwater resource to contamination through consideration of a number of hydrogeological variables. It provides a means of identifying groundwater protection areas on a regional scale rather than through classical wellhead protection area delineation. A number of different

Figure 9
Wellhead Protection Area Delineation Using "Simplified Variable Shapes" Method



From: Guidelines for Delineation of Wellhead Protection Areas, United States Environmental Protection Agency, June, 1987

Figure 10
Wellhead Protection Area Delineation
Using Analytical Models



$$-\frac{Y}{X} = \tan\left(\frac{2\pi Kbi}{Q}\,Y\right)$$
UNIFORM-FLOW EQUATION

$$X_L = -\frac{Q}{2\pi Kbi}$$
DISTANCE TO DOWN-GRADIENT NULL POINT

$$Y_L = \pm\frac{Q}{2Kbi}$$
BOUNDARY LIMIT

LEGEND:

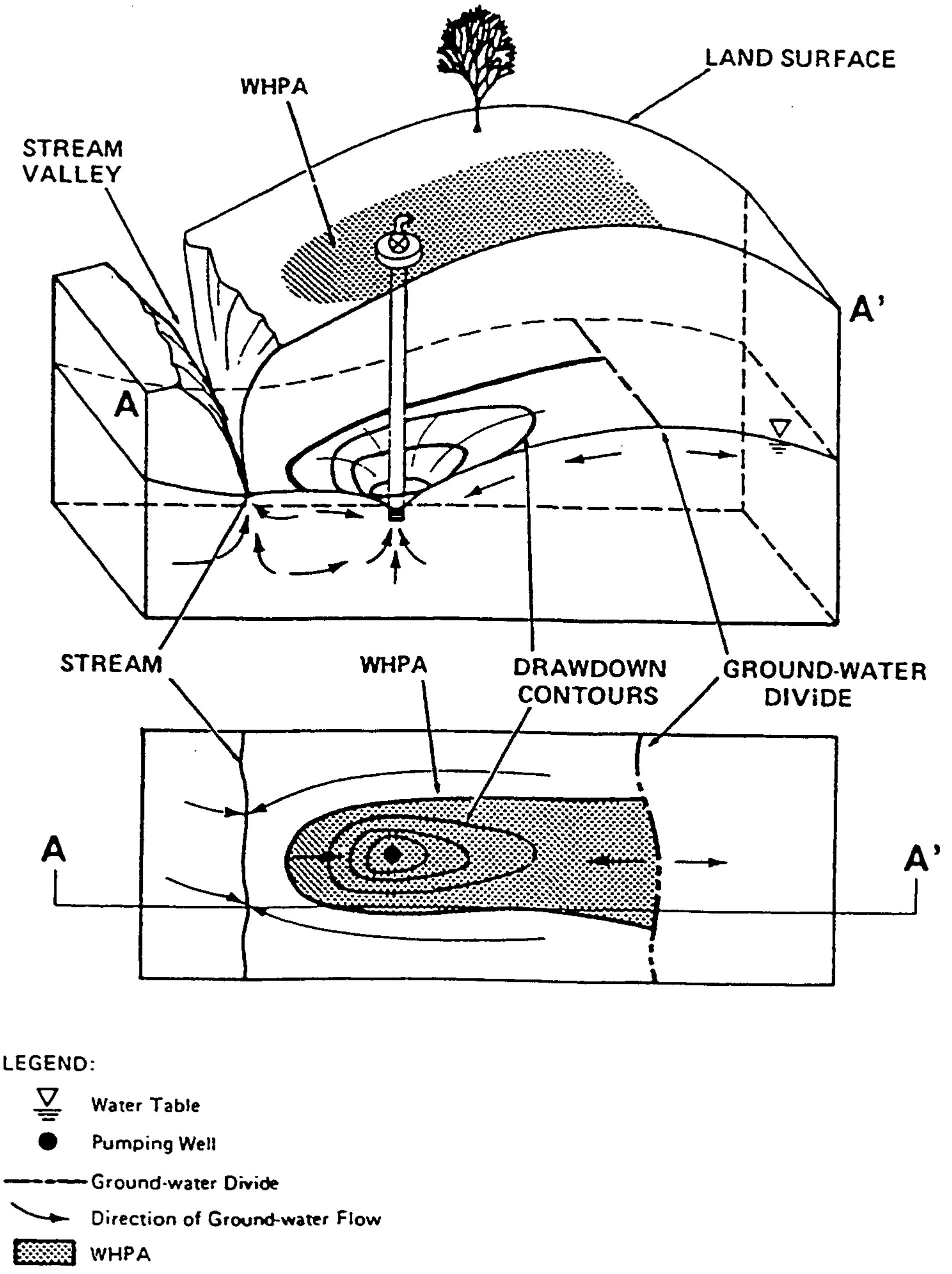
- ● Pumping Well

Where:
Q = Well Pumping Rate
K = Hydraulic Conductivity
b = Saturated Thickness
i = Hydraulic Gradient
π = 3.1416

NOT TO SCALE

From: Guidelines for Delineation of Wellhead Protection Areas, United States Environmental Protection Agency, June 1987 and Todd, 1980

Figure 11
Wellhead Protection Area Delineation Using Hydrogeological Mapping



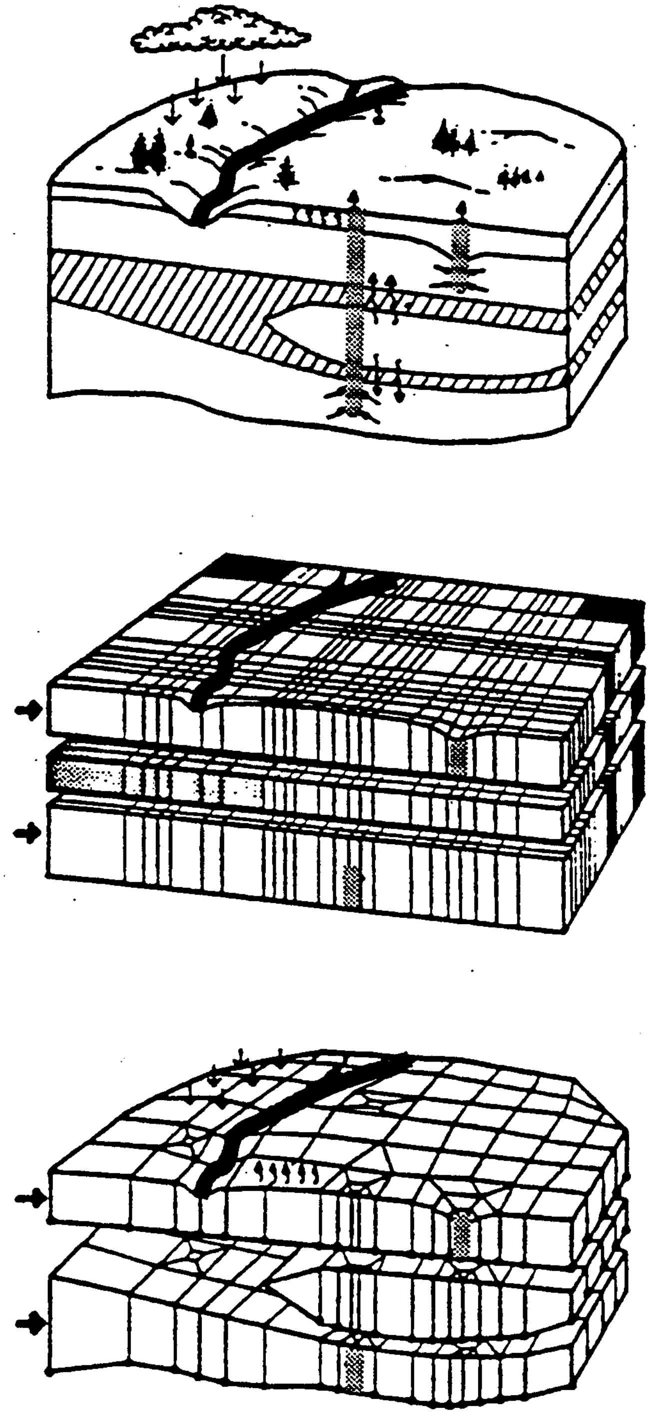
From: *Guidelines for Delineation of Wellhead Protection Areas, United States Environmental Protection Agency, June, 1987*

Figure 12
Wellhead Protection Area Delineation
Using Numerical Flow Models

Conceptual
Model

Finite
Difference
Grid

Finite
Element
Mesh



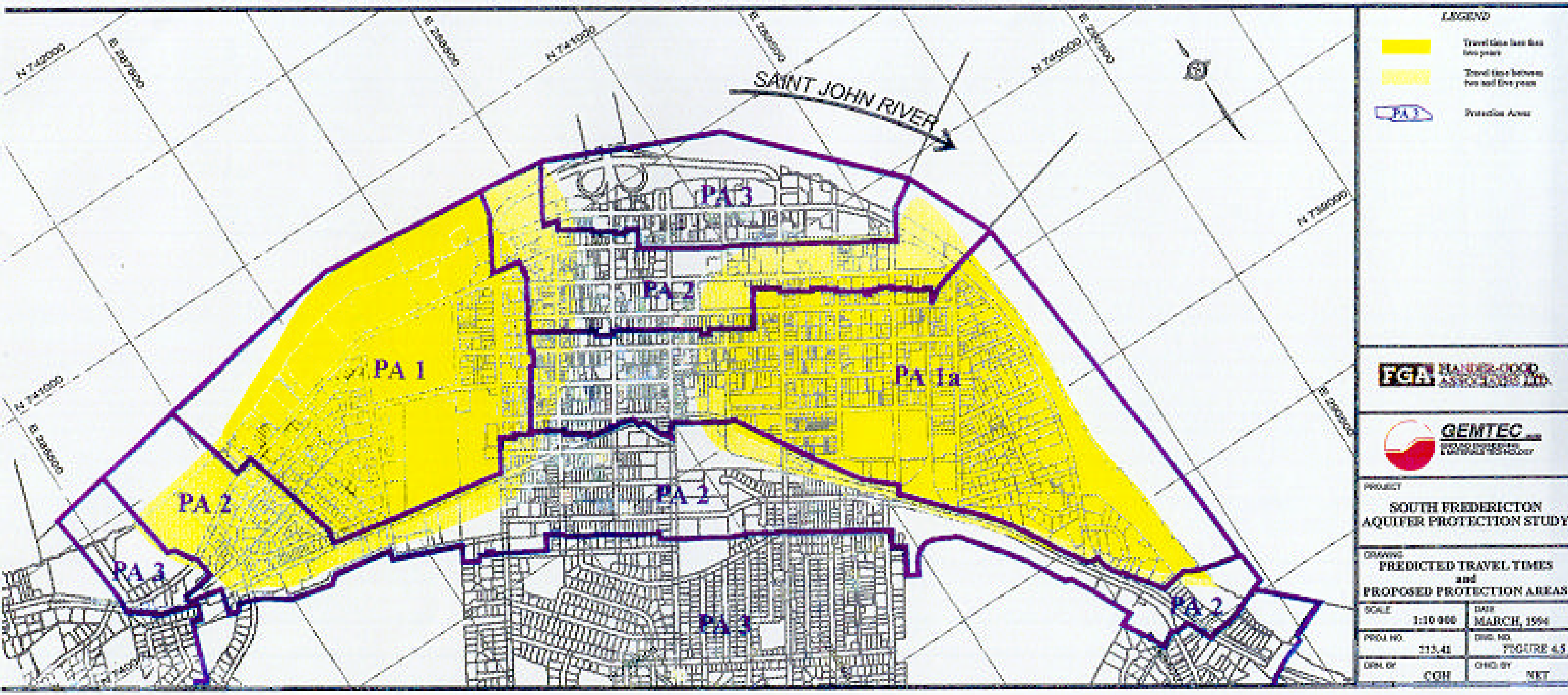
From: Golder Associates Ltd., 1983.

Table 5
Advantages and Disadvantages of
Methods For Wellhead Protection Areas

METHOD	ADVANTAGES	DISADVANTAGES
ARBITRARY FIXED RADIUS	Quick implementation Inexpensive Requires little technical input	Does not use local hydrogeology May be highly inaccurate Scientifically indefensible
CALCULATED FIXED RADIUS	Uses hydrogeological data Ease of application Low cost Little technical skill needed	Does not consider all hydrogeological factors May be erroneous for sloped watertable
VARIABLE SHAPES	Uses hydrogeological data to generate type curves Is site specific (if data available) Quick and easy to use	Not accurate in complex settings Large data requirement can be costly Greater time and expertise Small data errors can skew results
ANALYTICAL MODELS	Quick and inexpensive if data available Site specific applicable Powerful and accurate tool	Detailed data needed Higher technical skill needed More time consuming More costly
HYDROGEOLOGIC MAPPING	Highly detailed Useful in complex settings	Labour intensive Large time commitment High level of expertise needed
NUMERICAL MODELLING	Models complex problems Use as predictive tool High degree of accuracy and confidence in results Handles many parameters	Most costly Requires highly skilled users Require large database as input Requires reality checks May be over-utilisation

From: Delineating Protection Areas, B.C. Environment, Wellhead Protection Seminar, Clearbrook, British Columbia, January 12, 1994

Figure 13
Predicted Travel Times and Proposed Protection Areas For The South Fredericton Aquifer, New Brunswick



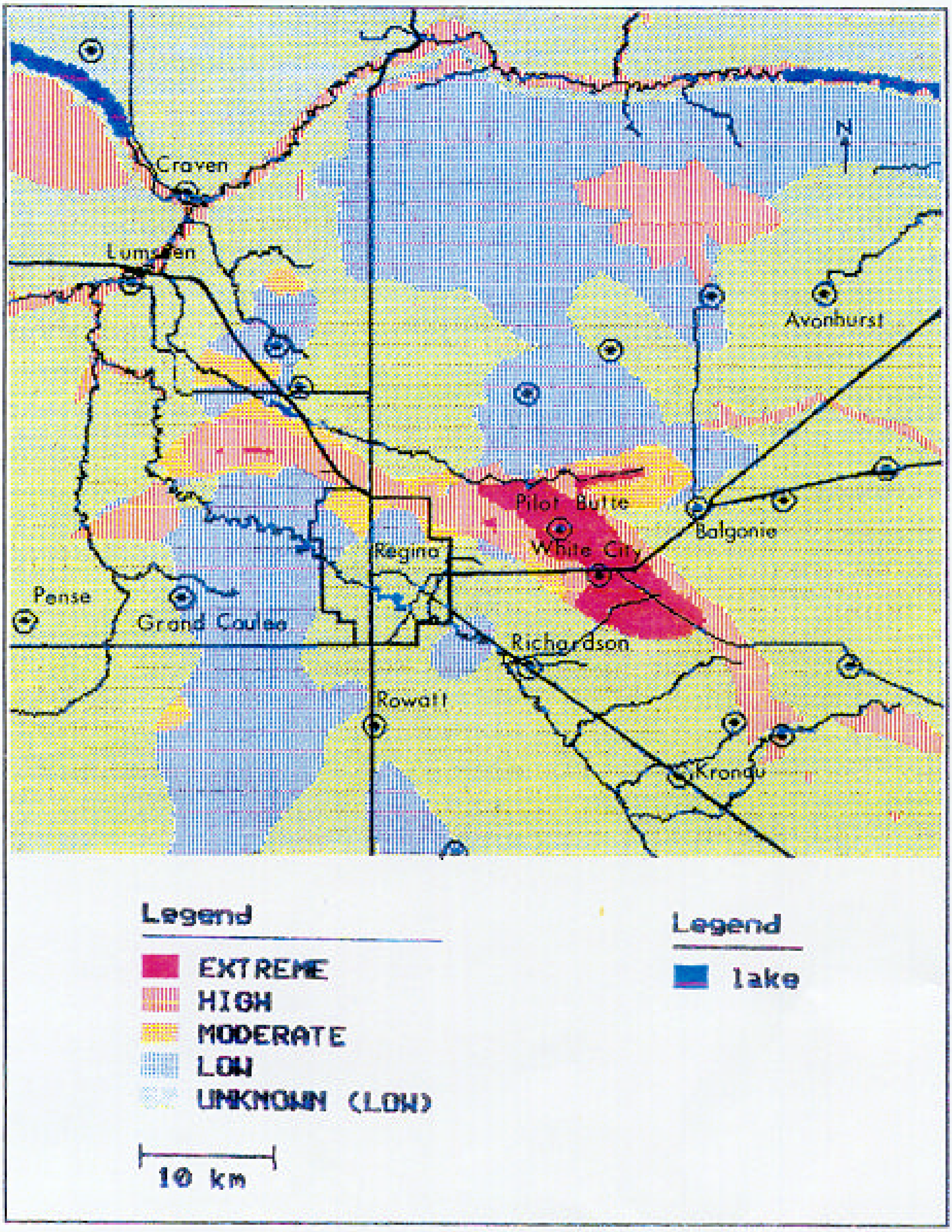
From: Figure 4.5, Draft South Fredericton Aquifer Protection Study, A summary Report, Gemtec Ltd., March 1994 schemes for mapping aquifer vulnerability are available. Among these, the DRASTIC scheme is the best known. The acronym for this mapping approach, DRASTIC, represents the following seven hydrogeological variables that are combined to create a vulnerability map:

D = Depth to water
R = Recharge
A = Aquifer media
S = Soil media
T = Topography
I = Impact of vadose zone
C = Hydraulic Conductivity of the Aquifer

DRASTIC provides a good guide to vulnerability at a regional scale, but has limited potential for classifying true vulnerability at specific sites and should not be used to the exclusion of additional site assessment tools. According to the Australian Water Resources Council, the Le Grand classification system, a standardized system for evaluating waste-disposal sites developed by the National Water Well Association, is more suited to site-specific evaluation (Reference #174). Limitations of existing vulnerability schemes are that they do not account for existing groundwater contamination and they assume that any potential future contaminant releases would occur from surface sources. In other words, the schemes do not address potential contaminant releases from deep, subsurface sources such as abandoned wells, or contaminants such as dense non-aqueous phase liquids (DNAPLs) that would tend to penetrate to greater depths within an aquifer (Reference #131).

As discussed in Appendix II, vulnerability mapping is becoming increasingly popular in Europe, the United States, and Canada. As an example, a vulnerability map was prepared for Clark County, Washington using DRASTIC (Reference #139). Aquifers supplying Regina, Saskatchewan were classified into four sensitivity categories (extreme, high, moderate, low) and one category of unknown sensitivity, based on the thickness and permeability of surficial materials overlying the aquifer (Figure 14). Sensitivity maps were generated using spatial analysis software (SPANS) to analyze and amalgamate existing “depth to aquifer” and geological source maps.

Figure 14
Groundwater Sensitivity Map,
Regina Regional Aquifers, Saskatchewan



From: Figure 4, Regina Aquifer Sensitivity Mapping and Land Use, Saskatchewan Environment and Public Safety, July 1990.

Vulnerability mapping is an effective means of identifying groundwater protection zones because it recognizes the significance of protecting groundwater recharge areas in addition to wellhead areas. Vulnerability mapping is more appropriate than the classical wellhead delineation approach in areas where the geology is complex and numerous water wells are present. Depending on the level of mapping required, the vulnerability mapping may involve significant costs.

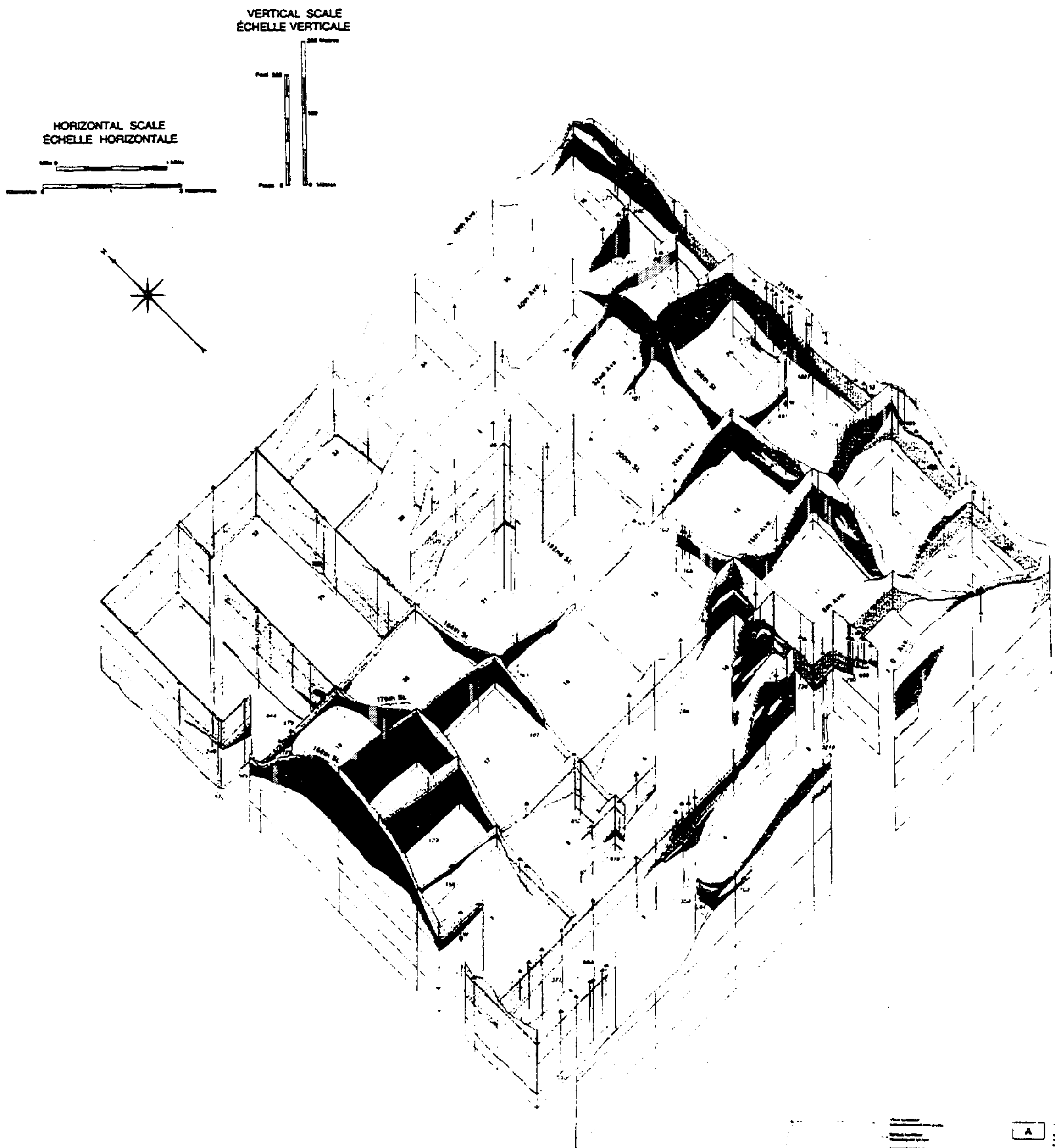
4.1.4 Aquifer Classification

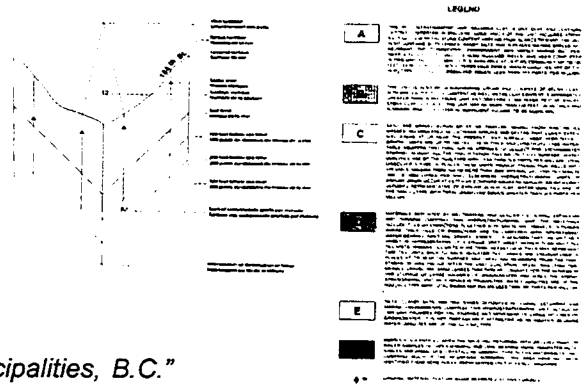
Aquifer classification is similar to vulnerability mapping except that, in addition to susceptibility to contamination, aquifers are classified according to their present use as a water supply source (i.e., human consumption & food production; agricultural, industry & mining; ecosystem support, or no definable use), their potential use for future water supply, and their existing water quality. Aquifer classification is used as a means of establishing the degree of protection that an aquifer may require. It is a major component of the United States EPA groundwater strategy, with numerous states having developed some type of aquifer classification system. Some of the state classification systems have been adopted or revised to suit particular groundwater management plans. For example, Southington, Connecticut has adopted an aquifer classification similar to the state of Connecticut, but more complex (Reference #247). The Town's program has eight aquifer classes instead of four and has eliminated the state zone that allows for waste disposal. B.C. Environment recently developed a map-based aquifer classification system and is currently applying the system to selected areas in the Fraser River Basin. So far, over 200 aquifers have been delineated and classified. Fence diagrams of hydrostratigraphic units within the Fraser Lowland have also been produced by Environment Canada (Figure 15) (Reference #299).

4.1.5 Contaminant Inventory

Contaminant inventories are most often carried out prior to the implementation of a groundwater protection plan. The purpose of the inventory is to identify past, present and potential point and non-point sources of groundwater contamination within a protection area. The groundwater protection plan can then be tailored to address the risks identified by the contaminant inventory. For example, in Spokane, Washington, an

Figure 15
Hydrogeological Fence Diagram, Township 7, Surrey and Langley District Municipalities, British Columbia





From: Figure 9, "Township 7, Surrey and Langley District Municipalities, B.C." Compiled by E.C. Halstead to Accompany Report by E.C. Halstead, National Hydrology Reseach Institute, Inland Waters Directorate, 1979.

assessment of the relative contributions from various contaminant sources indicated that 60% of groundwater contamination resulted from sanitary waste discharge, 30% from storm water discharge and 10% from other sources. Based on this information, the protection plan was tailored to address sanitary and storm water discharges. A contaminant inventory should be updated on a regular basis following implementation of the protection plan. Several communities (for example Dayton, Ohio) use data management systems to organize and update their inventories.

Various sources of information for a contaminant inventory are listed below:

- land use maps
- local, provincial and federal data bases (i.e., waste permits)
- assessors files
- business licenses
- air photographs
- telephone directories for historical information
- zoning regulations
- environmental health files
- emergency services databases/ historical fire insurance maps
- construction permits
- real estate title searches
- surveys (mail, phone, windshield, door to door, personal interviews)
- field searches

Contaminant inventories are relatively simple to implement and well accepted by the public. However, the costs of conducting a contaminant inventory and maintaining that inventory can be significant, depending on the area of concern and the density of development. In order to reduce costs, some communities have used volunteers to assist with the contaminant inventory. For example, in Dayton, Ohio, the Sierra Club carried out an independent contaminant inventory; whereas, in El Paso, Texas, private senior citizens were involved in conducting the inventory. Senior citizens were targeted for the El Paso project because they had historical knowledge of where old wells, old gas stations and other potential sources of contamination might be located (Reference #100). Examples of contaminant inventory survey forms prepared by the Idaho Water Resources Research Institute and the State of Washington are provided in Reference #241 and Figure 16, respectively.

Figure 16
Sample Contaminant Inventory Form Published by Washington State Department of Health

Appendix F
Sample Inventory Form

Source Number ____________
Public Water Supply Well # ____________
Inventory Person ____________
See Attached Map # ____________

A. Landowner's Name: ____________________

B. Address: ____________________

C. Phone Number: ____________

D. City: ____________ Zip Code: ____________

E. County: ____________

Description of Location: ____________________

____

Nature of Property

Residential	____	Commercial	____	Agricultural	____	Industrial	____
City Gov't Site	____	State Gov't Site	____	Rental	____	Other	____

Potential Sources of Contamination

Circle the potential contaminant sources listed below that you have identified at this site. In the space provided, indicate the # of each potential source present at the site (e.g., 2 underground storage tanks).

Potential Source	Quantity	Potential Source	Quantity
Abandoned Water Well	___	Holding Pond	___
Above Ground Storage Tank	___	Injection Well	___
Airport	___	Landfill	___
Animal Feedlot	___	Mine	___
Artificial Recharge	___	Municipal Sewage Line	___
Auto Salvage Yard	___	Quarry	___
Cemetery	___	Railroad	___
Cesspool	___	Septic Tank	___
Chemical Storage Facility	___	Service Station Disposal Well	___
Drainage Well/Canal	___	Sewage Plant Sludge Disposal	___
Dump	___	Stream (lake, river, creek)	___
Fertilizer/Pesticide Application	___	Underground Storage Tank	___
Golf Course	___	Contents	___
Grain Storage Bin	___	Water Well	___
Highway	___	Other	___

Notes: ____________________

____

4.1.6 Well Inventory

A well inventory program consists of identifying all water wells in a groundwater protection area. A well inventory, combined with a contaminant inventory and hydrogeological information, can be used to define a groundwater protection area. It also provides useful information regarding surficial geology and aquifer classification. From the groundwater protection plans reviewed, three communities were identified where well inventory programs were being considered but had not yet been implemented; the Regional Municipality of Peel, Ontario; Clark County, Washington (Reference #139) and the Biola Community Service District, California (Reference #150).

In British Columbia, well records that are submitted on a voluntary basis by drillers are maintained by B.C. Environment. A well inventory program would likely involve obtaining available well records from B.C. Environment and supplementing the information with field surveys. The Geological Survey of Canada has recently developed a database containing information from about 4,300 water wells in the Fraser Lowlands (Reference #297). Locations of wells in the Fraser Lowlands have also been summarized on maps produced by Environment Canada (Reference #299).

4.1.7 Groundwater Monitoring

Groundwater monitoring is one of the most common non-regulatory forms of groundwater protection. It may involve monitoring of both groundwater chemistry and the physical groundwater flow regime (water-level monitoring). For some communities, such as the Regional Municipality of Waterloo, groundwater monitoring is only carried out at water supply wells. Other communities, such as Dayton, Ohio, have installed groundwater monitoring wells downgradient of known or potential sources of contamination to provide early warning of impending water quality problems.

Specific facilities that may warrant groundwater monitoring include landfills, industrial sites, underground storage tanks and agricultural lands. Groundwater monitoring may also be carried out for new land developments. For example, in Newcastle County, Delaware, where a new 35 acre residential development was under construction adjacent to a public supply well field, permanent monitoring wells were installed and are monitored on a quarterly basis for pH, specific conductivity, total dissolved solids and total organic carbon (Reference #196). In addition to groundwater monitoring, several groundwater protection plans include surface water monitoring in areas of storm water discharge.

In addition to ongoing groundwater monitoring following implementation of a protection plan, monitoring should be carried out prior to implementation to characterize baseline groundwater conditions. This baseline information is used to select appropriate groundwater protection measures and also provides a means of assessing the success of the protection program. Several communities have developed data management systems to process their groundwater monitoring data.

4.1.8 Spill Response Planning

Spill response planning consists of coordinating with emergency response personnel to identify special procedures that should be implemented to protect groundwater quality in the event of a spill or accident. These measures may be as simple as ensuring that sufficient quantities of absorbents are on hand to respond to a spill (Reference #098).

Several groundwater protection plans include spill response measures. Of these, the spill response plan for Dayton, Ohio is perhaps the most comprehensive. Dayton has set aside a contingency fund for emergency response totaling 5 million dollars. Dayton has a standing contract with a contractor to provide necessary services in the event of an emergency. The contract includes the provision of drilling equipment, an on-site laboratory for volatile chemical analyses, and systems for extraction and treatment of contaminated groundwater. In addition to the emergency response contract, signs have been posted in key areas of the designated protection area to enhance the spill reporting process. All addresses within the designated area are also “flagged” in the 911 system so that the 911 operator will be alerted that the location of the call is within an area of public water supply concern.

Similar to Dayton's signs, the Cheyenne and Arapaho tribes of Oklahoma are planning to install signs along roadways into their groundwater protection area with telephone numbers of individuals to contact in the case of an emergency or the release of a contaminant (Reference #103).

Other communities that have established contingency funds or are planning to do so include Newcastle County, Delaware, which posted an escrow bond for emergency remediation (Reference #196), and Clark County, Washington, which is considering the establishment of an emergency fund and the purchase of water-specific emergency equipment (Reference #139). Both Fredericton, New Brunswick and Thurston County, Washington (Reference #247) are considering training and educational programs for emergency response personnel. Amherst, Nova Scotia and Waterloo, Ontario have prepared spill response plans that include information regarding team leader responsibilities, reporting procedures, available resources and operational methods. The State of Washington is developing a set of standard operating procedures to be used by emergency response personnel in groundwater protection zones (Reference #098).

Although not specifically related to a groundwater protection plan, Danbury, Connecticut has implemented a comprehensive spill response program through regulatory means. The City passed an ordinance requiring facilities handling hazardous materials to prepare an emergency response plan. The plan must contain a map of the facility, a hazard identification statement, a notification procedure, a fire response plan, an evacuation plan and a spill prevention, control and countermeasure plan (Reference #213).

4.1.9 Contingency Plans

Contingency planning consists of developing a plan for the location and provision of alternative drinking water supplies in the event that the existing well field cannot be used. Disruptions to the existing well field may be related to either contamination or non-contamination effects. The contingency plan should identify short-term alternatives in the event of a minor disruption, and long-term alternatives in the event of a complete loss of water supply.

Several groundwater protection plans have either developed or are considering provisions for an emergency water supply. For example, Julian Community Services District, San Diego County, California has arrangements with a private well owner to fill a tanker truck with clean water in the event of an interruption in their water supply (Reference #150).

The development of a contingency plan is considered an essential part of groundwater protection.

4.1.10 Hazardous Waste Collection

Hazardous wastes are defined as materials that are designated under local environmental regulations. Hazardous waste collection most commonly involves the collection of household hazardous wastes within a groundwater protection area. The purpose of a collection program is to limit groundwater contamination by the inappropriate disposal of household wastes or by accidental spills from accumulated hazardous materials.

Hazardous waste collection may take several forms. It may involve organizing a hazardous waste collection day once or several times a year, operation of drop-off stations for generators of small quantities of hazardous waste, or a “mobile unit” program whereby vehicles travel to a number of locations to collect hazardous waste.

Hazardous waste collection programs are currently underway in Dayton, Ohio; El Paso, Texas and Spokane, Washington. Here in British Columbia, there is no central depot that accepts household hazardous waste. Recently, a program was launched requiring paint wholesalers and manufacturers to establish 10 used paint collection centres in the Greater Vancouver Regional District. A retail chain of hardware stores has also recently embarked on a program to accept used household paint in British Columbia.

Hazardous waste programs are generally sponsored by government agencies and administered by private contractors. Costs associated with hazardous waste collection programs are not known. There may be several legal issues associated with the collection, transport and disposal of hazardous waste. Despite the potential difficulties associated with implementation, a hazardous waste collection program offers the public a mechanism by which they can practice the groundwater protection measures learned through the educational programs.

4.1.11 Technical Assistance

Technical assistance involves providing guidance to target groups in order to reduce the risk of groundwater contamination. The assistance commonly involves the use of a professional who travels to a site and provides an assessment of the situation.

In most cases, technical assistance is used to protect groundwater from agricultural-related activities. For example, the Swedish government provided free agro-consultants to educate farmers regarding the sequencing of chemical applications to reduce the loading effects on groundwater from fertilizers. Another example is a community in the U.S. that is setting up a volunteer master gardener program whereby experienced gardeners in the community provide free advice to homeowners regarding organic (chemical-free) gardening techniques. The purpose of the program is to reduce the risk of groundwater contamination from the overuse of fertilizers and pesticides in residential areas.

Less frequently, technical assistance may involve providing guidance to commercial or industrial facilities regarding waste reduction or facility upgrading to allow a greater degree of groundwater protection. Another form of technical assistance may involve training of local building inspectors to identify abandoned wells and underground storage tanks.

Technical assistance provides an effective means of working directly with target groups to better manage private lands and thereby protect groundwater. It can be more effective than a general public education program because it offers a site-specific, “show them” rather than “tell them” approach (Reference #247).

4.1.12 Land Acquisition

Land acquisition involves the acquisition of a parcel of land by purchase, exchange or donation. While land acquisition has been associated with the protection of surface water supplies for some time, it is more recently being employed as a groundwater protection measure. As discussed in Appendix II, land acquisition is a popular means of groundwater protection in Prince Edward Island. The Town of Amherst, Nova Scotia purchased 1,500 acres of land surrounding their new wellfield to protect their groundwater water supply. Land acquisition has also been used by several American communities, including Long Island, New York; Acton, Massachusetts; Crystal Lake, Illinois; the Pinelands, New Jersey; and Chelsea, Maine.

Land acquisition is considered one of the most effective means of non-regulatory groundwater protection because it allows total control over the property. It is relatively easy to implement and is most effective in rural areas where there is little existing development. However, the costs of land acquisition usually are high, which limits the amount of land that can be purchased.

4.1.13 Purchase of Development Rights

Purchase of development rights involves purchasing the right to develop a parcel of land while retaining the property in private ownership. The property owner is paid the difference between the current value and the development value of their land. This allows the property owner to continue his or her current use while limiting future development. The purchase of development rights is a relatively new concept and no examples of its application in Canada were identified during our literature review. Programs are reportedly underway in the U.S. in Massachusetts, New York, Maryland, New Hampshire, Connecticut, Rhode Island, Washington and New Jersey (Reference #247). Most of these involve agricultural lands.

The purchase of development rights offers a relatively high degree of groundwater protection and is less costly than land acquisition.

4.1.14 Conservation Easements

A conservation easement is a voluntary, legal agreement that a property owner makes to restrict the type and amount of development that may take place on his or her property (Reference #247). An owner may agree to give away certain rights such as the right to construct buildings, to subdivide land, to restrict access, or to harvest timber (Reference 247).

The primary advantage of a conservation easement program is that it permits the control of future land use without the associated purchase costs. Because conservation easements require the voluntary consent of the property owner, the success of the program is dependent on the degree of public acceptance and the goodwill of the property owner. As such, implementation of a protection plan in a targeted area using conservation easements would be difficult.

No specific case studies were identified where this method of groundwater protection has been used.

4.1.15 Cluster Development

Cluster development involves promoting and concentrating development in less sensitive areas outside of groundwater protection zones. Clustering of residential development facilitates the use of cost-effective sewering systems, restricts open lawns, reduces highway needs (and therefore highway runoff) and allows for the retention of large tracts of natural vegetation.

The promotion of clustering is under consideration in Long Island, New York (Reference #177); Idaho's Panhandle Health District (Reference #103); New Jersey Pinelands (Reference #177), and Thurston County, Washington (Reference #247). In Spokane, Washington, efforts are underway to encourage development in areas that are expected to be supplied with sewer service within the next 10 years (Reference #286).

4.2 Groundwater Protection Measures That May Be Implemented Through Either Regulatory or Non-Regulatory Means

4.2.1 Storm Water and Sewage Control

Most groundwater protection plans include measures to control storm and sewage discharge (Table 6). Emphasis on control of these sources may be related to the fact that, as shown by the inventory of contaminant sources in Spokane, Washington, a significant percentage of groundwater contamination can be related to storm and sewage discharge. Regulatory controls include registration, permitting, testing, collection, containment and treatment of storm water and sewage discharges. Other measures, that could be

TABLE 6
Use of Groundwater Protection Measures That Could be Implemented Through Either Regulatory or Non-Regulatory Means

	Stormwater & Sewage Controls	Septic System Controls	Agricultural Controls	Roadsalt Controls	Transportation Controls	Well Drilling & Abandonment	Geotechnical Controls	Forest Management	Market Approaches	Groundwater Guidelines
1. Selected Protection Plans										
Dayton, Ohio	x		x						x	
Waterloo, Ontario	x			x	x	x				
Amherst, Nova Scotia	x		x	x	x			x		
South Fredericton, NB	x				x		x		x	
Regina, Saskatchewan	x	x		x		x	x			
Spokane, Washington	x	x			x					
Peel, Ontario										
Palm Beach, Florida	x								x	
Long Island, New York		x								x
2. Other Protection Plans										
Acton, Massachusetts	x	x		x						
Austin, Texas	x	x								
Biola Comm. Ser. Distr., California			x			x				
Brookings County, South Dakota			x	x						
Chelsea, Maine										
Cheyenne & Arapoho Tribes, Oklahoma										
Clark County, Washington	x	x	x			x			x	
Clinton Township, New Jersey	x	x								
Clover/Chambers Creek, Washington	x	x	x			x				
Crystal Lake, Illinois	x	x								
Dade County, Florida	x	x								
Danbury, Connecticut										
Descanso Comm. Ser. Distr., California			x							
Dorchester, Ontario			x							
Elkhart County, Indiana	x									
El Paso, Texas	x	x							x	
Falmouth, Massachusetts	x	x							x	x
Idaho's Panhandle Health District		x								
Issaquah, Washington										
Julian Comm. Ser. Distr., California			x							
Nantucket Island, Massachusetts										
Newcastle County, Delaware	x									
Olmstead County, Minnesota		x								
Pinelands, New Jersey		x							x	x
Renton, Washington	x	x							x	
Southington, Connecticut	x			x						
Thurston County, Washington	x	x	x	x	x					

X = groundwater protection measure that has been implemented or is under consideration

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TABLE 7
Evaluation of Groundwater Protection Measures That Could be Implemented Through Either Regulatory or Non-Regulatory Means

Groundwater Protection Measure	Extent to Which Proactive	Degree of Protection	Implementation Effort	Relative Cost	Staffing Requirements	Public Acceptability	Flexibility
Storm Water & Sewage Control	M	H	H	M	M	M	M
Septic System Controls	M	H	H	H	H	L	M
Agricultural Activities	M	H	H	H	H	L-M	M
Roadsalt	M	M	M	L	L	M	M
Transportation Controls	M	L	H	L	L	M	M
Well Drilling & Abandonment	M	M	M	L	L	L	M
Geotechnical Controls	M	M	H	M	M	L	M
Forest Management	M	M	H	H	H	H	M
Market Approaches	L-H	M	H	L-H	M	L-H	L
Groundwater Guidelines/Regulations	L-H	M	H	M	M	L-H	M

L = Low
M = Medium
H = High

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implemented through either regulations or guidelines (non-regulatory means), include regular maintenance, inspection and upgrading of storm and sewage utilities. The degree of control that should be implemented depends on the discharge source and the sensitivity of the area.

Several examples of storm water and sewage control are provided in the groundwater protection plans. Washington State has emphasized the need for stringent subdivision rules to regulate road drainage and runoff in protected areas (Reference #103). Dayton, Ohio and Southington, Connecticut have prohibited dry wells in groundwater protection areas, and Palm Beach, Florida has prohibited infiltration trenches. In a new residential development adjacent to a major public water supply well field in Newcastle County, Delaware, a double-lined storm water retention pond has been constructed to prevent infiltration (Reference #196). Fredericton, New Brunswick has implemented a program for regular inspection, repair, upgrading and replacement of storm sewer catch basins and pipes in their downtown area. Amherst, Nova Scotia has recommended that all stormwater systems be directed away from their well field. Acton, Massachusetts carried out an inventory of all industrial and commercial discharges containing hazardous materials (Reference #247). Spokane, Washington has made extensive efforts to extend the area served by public sewer systems (Reference #286). Clark County, Washington has recommended the development of a comprehensive stormwater management manual and a coordinated, county-wide approach to implementing it (Reference #247). Austin, Texas has implemented numerous stormwater management controls, including: isolation and treatment of “first flush” or first 1/2 inch (1.3 cm) of a storm event, requirements for on-site storage and treatment systems, requirements for developers to pay a fee per lot for the City to assume the responsibility of on-site systems, submission of erosion and sedimentation-grading plans, requirements for vacuum street sweeping three times per week for commercial parking lots over 5000 square feet (460 square metres) and requirements for leak-proof sewer construction (Reference #247).

Storm water and sewage design and maintenance controls are an effective means of groundwater protection. However, similar to other source controls, these measures may only be successful if implemented by regulatory rather than non-regulatory means. Implementation of controls would be easier for new utilities than existing ones, and would require a moderate level of inspection and enforcement.

4.2.2 Septic System Controls

Numerous groundwater protection plans included measures to protect groundwater from contamination from on-site septic systems. Some communities prohibit the use of on-site septic systems in sensitive areas. For example, Renton, Washington requires all new developments (both residential and non-residential) to connect to a central sanitary sewer system (Reference #083). Dade County, Florida prohibits in-ground sewage disposal within subzone 1 (within 100 feet or 30 m of a water supply well) (Reference #195). Crystal Lake, Illinois prohibits septic systems in outwash soil areas (Reference #247). Regina, Saskatchewan is considering the use of holding tanks rather than underground disposal where there is no protective overburden.

Another common means of controlling groundwater contamination from septic systems is to impose minimum lot size restrictions to reduce septic system density. For example, Austin, Texas requires a minimum lot size of one acre for on-site sewage disposal (Reference #247); Long Island, New York requires two acres (Reference #177); Dade County, Florida requires either one acre or 2.5 acre lot sizes, depending on the proximity to water supply wells (Reference #242); Pinelands, New Jersey has 3.2 acre lot size restriction based on requirements for a maximum concentration of 2 ppm nitrate at the property boundary (Reference #177); and Idaho's Panhandle Health District requires a five acre minimum lot size (Reference #103).

Other measures include tighter controls on the siting, design and operation of in-ground systems. For example, Thurston County, Washington has an operational permit for some septic systems for a three-year period that is revokable if the system is found to be polluting (Reference #247). Spokane County, Washington requires that septic systems be constructed with dry line sewers so that houses could be connected to public sewers when they become available (Reference #286).

Although septic systems can effectively treat and dispose of most domestic wastewaters, they do not have the capability to remediate solvents and other hazardous wastes that may be disposed in septic systems. To address this issue, Dade County, Florida is attempting to prevent improper disposal in septic systems by light industry. Similarly, Clover/Chambers Creek Basin, Washington is imposing pretreatment requirements on commercial establishments that may handle, store or dispose of hazardous chemicals (Reference #140). Clark County is considering several measures aimed at better controlling the siting, design and operation of septic systems, including the following (Reference #139):

- encouraging a ban on the manufacture, sale and/or use of septic system cleaners that contain chlorinated organic solvents;
- increasing educational programs to assist property owners to better protect, operate and maintain their septic systems;
- requirements for septic system inspection and maintenance prior to property transfer;
- extending sewer services to areas of high septic density, or areas of aquifer susceptibility; and
- development of a county-wide mandatory septic system maintenance program.

Most of the protection measures outlined above are regulatory in nature and would require significant administrative effort and expense to implement. However, if implemented, they would offer an effective means of groundwater protection. Non-regulatory measures could take the form of guidelines, public educational programs and free inspections of existing systems. Non-regulatory measures would likely be less effective than regulatory measures, but less expensive and more readily accepted.

4.2.3 Agricultural Controls

Control of agricultural activities is a common means of groundwater protection. For some communities, it may consist of prohibition of agricultural activities within a sensitive area. For example, Amherst, Nova Scotia prohibits agricultural land use within Zones 1 and 2 of its groundwater protection area. Similarly, Brooking County, South Dakota prohibits feedlots within its groundwater protection area (Reference #103).

More commonly, agricultural activities are permitted within protected areas but are controlled through the use of restrictions and guidelines. Several communities restrict the amount and types of chemicals that can be stored on farms. For example, Dayton, Ohio will only allow storage of a one-year supply of agricultural chemicals for on-site application; Dorchester, Ontario prohibits bulk storage of chemicals, fertilizers and petroleum products other than those to be used in the normal operation of the farm (Reference #199); Amherst, New Brunswick restricts manure storage, and Germany has regulations regarding the storage of fertilizers.

In addition to storage restrictions, there are regulations and guidelines controlling the use of agricultural chemicals. Amherst prohibits the use of biocides in Zones 1 and 2 and restricts the use of biocides in Zone 3 of its protection area to those with a total degradation life of less than 50 years; Clark County is considering the regulation of pesticide and fertilizer use (Reference #139), and Germany has regulations controlling the metal content in sludge and the use of sludge, fertilizers and manure.

Another means of protecting groundwater from agricultural activity is to control the sequencing of chemical application through regulations, guidelines and educational programs. For example, Brookings County, South Dakota will only allow application of nitrogen fertilizer in the autumn (Reference #103), while Sweden controlled the sequencing of chemical application by providing free agro-consultant advice to farmers.

Another means of agricultural control is to require farmers to report on their activities. Farmers in Dayton, Ohio are required to report the types and amounts of chemicals applied on an annual basis. The reports are used to determine appropriate monitoring locations and analytical protocol for groundwater sampling. Clark County, Washington is considering a notification program that would require applicators to provide public notification of pesticide applications.

Controls to limit the number of livestock on agricultural land are in place in Dorchester, Ontario and Amherst, Nova Scotia.

Non-regulatory forms of groundwater protection include research into agricultural practices and groundwater monitoring. Clark County is considering research into best management practices for animal waste disposal and research into pesticide and fertilizer use patterns. Integrated pest management programs (IPM) are being promoted in three community service districts in California (Reference #150). These programs involve monitoring climatic events and crop diseases to better target the use of chemicals and to minimize their use. Alternative biological pest controls and the use of chemicals characterized as having lower persistence in the environment are also being encouraged in these districts.

Another form of non-regulatory groundwater protection is to provide education and technical assistance for farmers. Both Clark County and Clover/Chambers Creek Basin are considering educational programs that will improve pesticide and fertilizer application practices (Reference #140). As described in Appendix II, Sweden educates farmers on agricultural practices through the use of free agro-consultants. As discussed in Section 4.1, Farm-A-Syst programs are underway across the United States to help farmers evaluate possible sources of contamination on their properties and implement appropriate protection measures.

In British Columbia, members of the dairy industry have formed a working group known as the Dairy Producers' Conservation Group (DPCG). The DPCG publishes a quarterly newsletter (The News Spreader) that presents an annual Dairy Farmer Conservation Award, provides Best Agricultural Waste Management Plans, organizes field days and tours, and makes presentations at various workshops and courses (Reference #295). In 1994, the DPCG published two booklets entitled "Nitrogen Management for Silage Corn Production in South Coastal British Columbia" and "Guidelines for Preparing you own Environmental Farm Plan" (Reference #295).

Given the relatively high contribution of agricultural activities to groundwater contamination, any degree of agricultural control should provide a measure of groundwater protection. However, because agricultural contaminant sources are commonly non-point sources, the effectiveness of the controls may be difficult to assess. As discussed above, agricultural controls may be implemented by either regulations or guidelines. Guidelines may be just as effective as regulations and better accepted if accompanied by educational and technical assistance programs.

4.2.4 Roadsalt

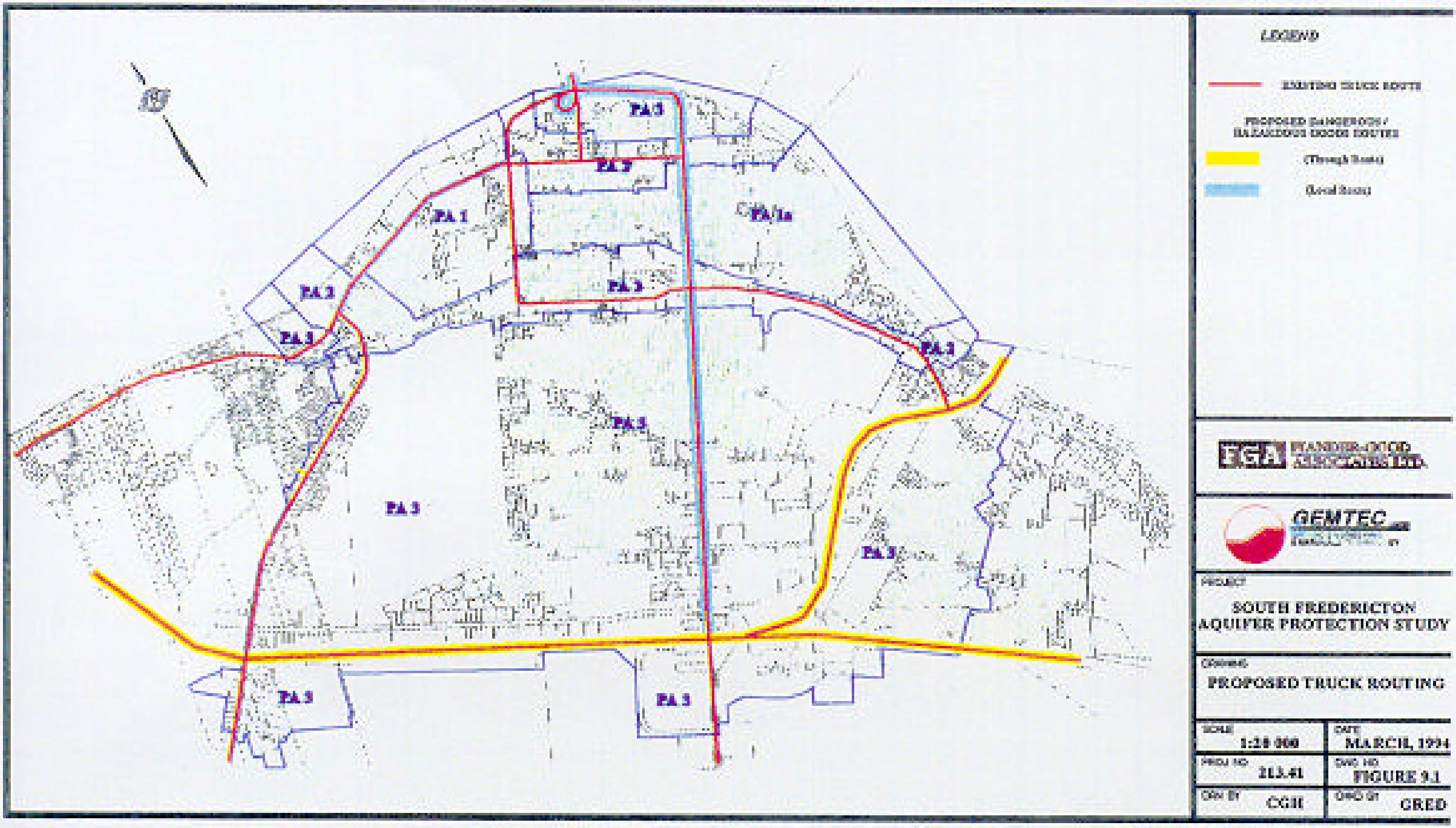
Several groundwater protection plans include measures to control groundwater contamination from roadsalt. Acton, Massachusetts; Waterloo, Ontario; Thurston, Washington and Regina, Saskatchewan have implemented, or are considering, prohibition or restriction of application of roadsalt. Southington, Connecticut prohibits storage of road salt within its groundwater protection area (Reference #247), while Brookings County, South Dakota requires that all roadsalt storage be covered (Reference #103). Amherst, New Brunswick recommends that roadsalt be mixed with sand to reduce contaminant potential.

Controls for roadsalt may be implemented through regulations or guidelines. Roadsalt control is a relatively inexpensive measure that is easy to implement and offers a moderate degree of groundwater protection.

4.2.5 Transportation Controls

A select number of groundwater protection plans include controls for transportation over aquifers. Of these, the measures under consideration by Fredericton, New Brunswick appear to be the most comprehensive. Fredericton has identified an alternative trucking route outside of its groundwater protection area for all trucks carrying dangerous goods, hazardous wastes or other compounds exceeding designated critical quantities (Figure 17). They have also designated a preferred rail route for railcars containing similar materials. For trucks that are required to enter the groundwater protection area for delivery purposes, a designated route has been identified. Consideration is being given to reduced speed limits, posting of warning signs to encourage driver caution and more attention to road maintenance and repairs along this route. Other measures include training of emergency response personnel on response procedures in the event of chemical spills along the transportation route, and educating delivery personnel regarding the need for caution during delivery. Spokane, Washington, is considering a similar program to control the impact of chemical releases along transportation routes. Waterloo is also considering rerouting vehicle traffic carrying hazardous material away from the immediate vicinity of its well fields.

Figure 17
Designated Transportation Routes For South Fredericton, New Brunswick



From: Figure 9.1, Draft South Fredericton Aquifer Protection Study, A Summary Report, Gemtec Ltd., March 1994.

Transportation controls are relatively inexpensive and can be implemented with moderate ease. Because they are preventative measures, their benefits are not easily quantifiable.

4.2.6 Well Drilling and Abandonment

Water wells that have been improperly constructed or inappropriately sited may be susceptible to contamination from surface or shallow groundwater sources. To reduce the potential for groundwater contamination by this means, guidelines for well siting, construction and maintenance could be provided to drillers and property owners. None of the protection plans examined included guidelines for well drilling. However, guidelines, information brochures and regulations on well drilling are available at the provincial level. Development of guidelines on well drilling would be relatively inexpensive.

Although none of the groundwater protection plans included provisions for well drilling, several communities are considering the implementation of measures to ensure proper well abandonment. Improperly abandoned water wells or environmental monitoring wells can provide direct conduits to an aquifer that may lead to groundwater contamination. Current practice in the well drilling industry is to partially backfill with loose cuttings, insert a surface plug, or to simply weld a steel cap on top of an abandoned well. In the environmental industry, often no measures are taken to properly abandon former monitoring wells. Conceivably, guidelines or regulations for proper grouting of abandoned wells could be adopted. Regulations are currently in effect for proper abandonment of water wells at a provincial level in most provinces.

Better tracking of abandoned wells may be facilitated with a well inventory program. Clark County, Washington, is considering the development of a process to assess the presence of abandoned wells on properties prior to transfer of ownership. They also want to establish and implement a procedure that requires proponents of development to evaluate building sites for the presence of abandoned wells as a condition of site plan approval. Another measure under consideration is training building inspectors to identify wells and ensure proper abandonment (Reference #139).

4.2.7 Geotechnical Controls

Similar to abandoned water wells and environmental monitoring wells, building piles and testholes drilled for geotechnical purposes can provide pathways for contaminant migration to lower aquifers. Regina, Saskatchewan and Fredericton, New Brunswick are considering requirements for proper sealing of geotechnical testholes and building piles. Landstripping, excavations, ditching and trenching may also affect aquifer sensitivity. Regina has recommended that excavations into the overlying protective clays be minimized in areas where the overburden is less than 5 m and that excavations be restricted to less than 5 m in areas where the overburden is less than 10 m thick.

Although geotechnical controls may be exercised through guidelines, successful implementation would likely require some form of regulatory control.

4.2.8 Forest Management

Amherst, Nova Scotia is the only groundwater protection plan that included provisions for forestry controls. Because forestry is one of the few activities permitted in their groundwater protection zone, Amherst has implemented stringent forestry controls. Their groundwater protection plan requires that a forest management plan be developed and approved for anyone planning to harvest more than 20 chords of wood from the groundwater protection area. Elements to be incorporated into the plan include the control of activities around streams, restricting cutting to one block at a time, prohibition of whole tree cutting, proper location and construction of haul roads, skid trails and log landings, management to minimize the risk of fire, control of pesticides and herbicides, and posting of performance bonds. Forest harvesting within Zone 1 is restricted to select cutting only.

Presumably, although guidelines for forestry practice could be issued, successful implementation of forestry controls may require regulatory control.

4.2.9 Market Approaches

Market approaches involve the use of taxes, subsidies, marketable pollution permits and insurance bonds to encourage groundwater protection. These measures may be either regulatory or non-regulatory.

The regulatory market approach involves adopting a "polluter pays" principle, whereby the costs of contamination are passed on to the dischargers. Examples include requiring facilities to post bonds of credit for pollution prevention (Palm Beach, Florida, Reference #177), and the use of penalties for facilities that do not comply with zoning or permitting requirements. Renton, Washington has penalties of up to $500 per day for facilities that violate its groundwater ordinance (Reference #083).

Non-regulatory market approaches involve the use of financial incentives to achieve groundwater protection. Examples include the use of tax credits for retaining private land as open space and the use of land credit exchange programs to encourage development out of protected areas and into those areas designated for development (New Jersey Pinelands, Reference #177). In Dayton, Ohio, businesses are eligible for grants and loans from the City's well field protection fund to finance corrective actions required by the well field protection program (Reference #256). Fredericton, New Brunswick is considering incentive programs to encourage local residents to convert from heating oil to alternative heating methods to reduce the need for heating oil tanks. The City is currently deciding on a means of compensating dry cleaning businesses who are required to relocate their facilities as a result of the groundwater protection plan.

Non-regulatory market approaches allow some control over future land use. However, because they require the voluntary consent of the property owner, the programs may be difficult to implement in a targeted area and the properties could always be removed from the program at a later date. In addition, such programs would require significant resources.

4.2.10 Groundwater Quality Guidelines and Regulations

Another form of groundwater protection consists of the establishment of site-specific thresholds for groundwater quality. These thresholds may take the form of non-regulatory groundwater guidelines or groundwater regulations. Establishment of groundwater guidelines or regulations provides a means of protecting groundwater and minimizing groundwater degradation to acceptable levels. For some areas, this may involve adopting a policy of non-degradation, whereby the quality of groundwater is not permitted to decline below existing levels. For example, Long Island, New York adopted a policy of non-degradation in order to maintain the high ambient quality of groundwater in their groundwater recharge area (Reference #177). In other areas, a limited degradation policy may be adopted. The intent of limited degradation policies is to preserve groundwater quality above certain specified standards. For example, Falmouth, Massachusetts (References #103 and #177) and the New Jersey Pinelands (Reference #177) have established specific nitrogen concentration standards for their groundwater protection areas.

Establishment of site-specific groundwater quality guidelines or regulations requires sound technical support. Establishment of groundwater quality regulations, rather than guidelines (non-regulatory), may be required for the measure to be effective.

4.3 Regulatory Groundwater Protection Measures

4.3.1 Zoning

Zoning involves the regulation of land use and/or hazardous materials in sensitive areas. It is one of the most common regulatory means of groundwater protection. Zoning controls are commonly implemented using “Groundwater Overlay Zones”, which identify the boundaries of the protection area. The overlay zone is superimposed on the existing zoning map. Selected examples where zoning is used to control land use include: Amherst, Nova Scotia, where forestry, agriculture, open fires, waste disposal, highway salting and other activities are restricted; Brookings County, South Dakota, where new feedlots, uncovered road salt storage and car washes are prohibited (Reference #103); and Acton, Massachusetts, where residential and septic system densities are controlled (large lot zoning) (Reference #247). Zoning ordinances were the

TABLE 8
Use of Regulatory Groundwater Protection Measures

	Zoning	Facility Siting, Design, Operation	Hazardous Materials Restrictions	USTs & Pipelines	Above-Ground Storage Tanks	Sand & Gravel Controls	Permitting	Inspection & Compliance
1. Selected Protection Plans								
Dayton, Ohio	x	x	x	x		x		x
Waterloo, Ontario		x						x
Amherst, Nova Scotia	x							
South Fredericton, NB	x		x				x	x
Regina, Saskatchewan	x		x	x	x			
Spokane, Washington	x	x	x	x				
Peel, Ontario								
Palm Beach, Florida	x		x				x	x
Long Island, New York	x	x						
2. Other Protection Plans								
Acton, Massachusetts	x		x				x	
Austin, Texas	x		x	x				
Biola Comm. Ser. Distr., California								
Brookings County, South Dakota	x	x						
Chelsea, Maine	x					x		
Cheyenne & Arapoho Tribes, Oklahoma								
Clark County, Washington		x	x	x	x		x	x
Clinton Township, New Jersey	x		x	x				
Clover/Chambers Creek, Washington		x	x	x				
Crystal Lake, Illinois	x							
Dade County, Florida	x	x	x	x				
Danbury, Connecticut								
Descanso Comm. Ser. Distr., California								
Dorchester, Ontario	x		x			x		
Elkhart County, Indiana		x						
El Paso, Texas		x	x	x			x	
Falmouth, Massachusetts	x	x	x	x			x	
Idaho's Panhandle Health District								
Issaquah, Washington	x						x	
Julian Comm. Ser. Distr., California								
Nantucket Island, Massachusetts								
Newcastle County, Delaware			x					x
Olmstead County, Minnesota								
Pinelands, New Jersey	x							
Renton, Washington	x	x	x				x	x
Southington, Connecticut	x	x	x	x				
Thurston County, Washington	x		x				x	

X = groundwater protection measure that has been implemented or is under consideration

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TABLE 9
Evaluation of Regulatory Groundwater Protection Measures

Groundwater Protection Measure	Extent to Which Proactive	Degree of Protection	Implementation Effort	Relative Cost	Staffing Requirements	Public Acceptability	Flexibility
Zoning	M	H	H	H	H	L-M	M
Facility Siting, Design & Operation	M	H	H	H	H	L-H	M
Toxic & Hazardous Materials Restrictions	M	H	H	H	H	L-H	M
USTs & Pipelines	M	H	H	H	H	L	M
Above Ground Storage Tanks	M	M	H	M	M	M	M
Sand & Gravel Mining Controls	M	M	H	M	L	M	M
Permitting	M	H	H	H	H	L	M
Inspection	M	H	H	H	H	L	M

L = Low
M = Medium
H = High

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primary mechanism for the control of hazardous substances in Dayton, Ohio. Another form of zoning is large-lot zoning, which involves the use of minimum lot sizes as a means of controlling septic system densities.

Always implemented by local governments, zoning is a well accepted method of groundwater protection and can be easily adopted to the unique circumstances of a local community (Reference #247). Zoning is most effective for regulating new developments or preventing problems. It is very difficult to implement new regulations or change zoning in areas that have already been developed. The use of grandfathering clauses, whereby non-complying uses are permitted to continue within a groundwater protection zone, is an unacceptable approach to groundwater protection. Zoning controls may not always be perceived as necessary and may be challenged legally if the zoning boundaries are based solely on arbitrary delineation.

4.3.2 Facility Siting, Design and Operation Controls

Often associated with zoning, several groundwater protection plans include measures to control the siting, design and operation of various industrial and municipal facilities. Most of these controls are regulatory in nature. However, it may be possible to exercise some control through guidelines rather than regulations.

Siting, design and operating controls may be required for some of the following facilities in areas underlain by sensitive aquifers: airports, auto repair shops, car washes, cemeteries, dry cleaning establishments, laboratories, landfills, gas stations, golf courses, railyards, manufacturing facilities, recycling facilities, surface impoundments, transfer stations, waste treatment and storage facilities, underground storage facilities and other commercial and industrial facilities.

Forms of regulatory control include siting restrictions, design and construction standards, permitting, licensing and fees. Another measure, which may be either regulatory or non-regulatory, is the development of best management practices. Examples of best management practices include operational requirements, implementation of discharge standards, regular maintenance and inspection, monitoring (for example landfill sites in Clark County, Washington), secondary containment for liquid waste disposal (Brookings

County, South Dakota, Reference #139), preparation of contingency plans for inadvertent discharges of contaminants (Brooking County, South Dakota), development of closure plans and employee training. Control of facility siting, design and operation is often the best way of controlling specific point sources of groundwater contamination.

4.3.3 Hazardous Materials Restrictions

A select number of groundwater protection plans have focused their efforts on the control of types and quantities of toxic and hazardous materials within groundwater protection areas rather than placing restrictions on land use. Toxic and hazardous waste restrictions form the basis of the groundwater protection plans for Dayton, Ohio; Fredericton, New Brunswick, and Palm Beach, Florida. This regulatory approach is the best means of protecting groundwater in areas that have already been developed, while at the same time minimizing the economic impacts to local businesses.

In addition to restrictions on the quantity and types of hazardous materials, other controls, such as registration and tracking, and proper storage, handling and disposal of hazardous materials can be implemented using regulations or guidelines (non-regulatory means). An example of a non-regulatory means of control is in Fredericton, New Brunswick, where guidelines may be developed to instruct service stations in the proper storage and disposal of car care products such as antifreeze, solvents and other compounds.

4.3.4 Underground Storage Tanks (USTs) and Pipelines

A number of groundwater protection plans make provisions for the control of underground storage tanks (USTs) and one plan (Dade County, Florida, Reference #195) regulates underground pipelines. Control of USTs may involve the prohibition of USTs or the adoption of performance standards or guidelines for use of USTs in protected areas. Regina, Saskatchewan and Clinton, Township, New Jersey (Reference #063) have prohibited USTs in sensitive areas, while Dayton, Ohio is implementing a plan to phase out all USTs containing regulated substances other than vehicle lubricants and fuel for heating over a five-year period. Fredericton, New Brunswick is considering incentive assistance programs to encourage conversion from heating oil to alternative heating methods.

Examples of performance standards or guidelines for USTs include requirements for permitting, secondary containment, pressure testing and groundwater monitoring. Clover/Chambers Creek Basin, Washington is carrying out an inventory of existing USTs and educating tank owners of their responsibilities. They are also considering establishing a fee for new tanks and an annual tank fee to assist with their funding (Reference #140).

Control of USTs and pipelines is an effective means of groundwater protection. There are guidelines, such as those recently released by the Alberta government, that may have some application to the control of USTs; however, adequate control of USTs may only be successful through regulatory means. Some communities, such as Palm Beach, Florida, were not able to gain jurisdiction over USTs and therefore could not exercise any control. Another difficulty with the control of USTs is that, in the case of Dayton, Ohio, there may be a conflict with fire code regulations since prohibition would require the storage of flammable materials be relocated to above-ground facilities. Another problem associated with the relocation of materials to above-ground facilities is the increased vulnerability of the facilities to vandalism and corrosion. Regulation of USTs would require moderate administrative support for inspection and enforcement.

4.3.5 Above Ground Storage Tanks

Only two of the groundwater protection programs examined (Regina, Saskatchewan and Clark County, Washington) made specific reference to the control of above-ground storage tanks; however other plans may have addressed this issue through facility design and construction controls. Above-ground storage tanks would be controlled by similar means to USTs. Measures may include permitting and secondary containment using liners and dykes.

Similar to USTs, regulatory controls over above-ground storage tanks would be more effective than non-regulatory controls. Public acceptance of controls for above-ground storage tanks may be better than for USTs because the risk of contamination from above-ground tanks may be more readily understood by the non-professional. Administrative support for inspection and enforcement would be moderate.

4.3.6 Sand and Gravel Mining

Sand and gravel mining frequently occurs in areas where the sand and gravel provide a shallow, productive aquifer and high groundwater yields. In many cases, mining may remove near surface layers of soils and geological deposits that would otherwise provide a level of protection to the underlying groundwater (Reference #137). In addition, many sites from which sand and gravel is extracted are later used as landfills or as sites for asphalt plants.

Three groundwater protection plans included provisions for the control of sand and gravel mining. Chelsea, Maine is considering gravel mining restrictions (Reference #064) and Dorchester, Ontario imposed restrictions to sand and gravel mining through the Pits and Quarry Control Acts (Reference #199). Dayton, Ohio permits gravel mining but requires drainage control and the provision of security to prevent unauthorized access and possible illegal dumping.

The control of sand and gravel operations may reduce the risk of groundwater contamination from existing operations but would not address the risk of contamination from the numerous abandoned sand and gravel pits where illegal dumping is common. Control of sand and gravel mining is most effective through regulatory means.

4.3.7 Permitting

Permitting is used to restrict uses within groundwater protection zones that may cause groundwater contamination if left unregulated (Reference #103). Permitting can be used to control numerous activities, including commercial and industrial activities, municipal and industrial waste discharges (Acton, Massachusetts), septic systems (Thurston County, Washington), wells, USTs, landfills and forestry activities. Fredericton, New Brunswick wishes to use their existing building permitting system as a mechanism by which aquifer protection mechanisms would be triggered.

Permitting is a well recognized method of controlling land uses within groundwater protection zones. It requires a case-by-case analysis to ensure equal treatment of applicants, and a detailed understanding of the area's sensitivity by the permit granting authority.

4.3.8 Inspection and Compliance

Inspection is a necessary means of ensuring compliance with zoning and permitting measures. Inspections should be undertaken for any facilities that are controlled by zoning and permitting requirements, such as septic systems, USTs, pipelines, and landfills. Dayton, Ohio employs five full-time professional staff to inspect the over 700 businesses in its groundwater protection area. Fredericton, New Brunswick has recommended random inspections and enforcement to ensure compliance with its plan. Clark County, Washington is considering the use of inspections at the time of real estate transfer that would include abandoned wells, USTs, hazardous waste, and the condition of septic systems (Reference #139).

5.0 IMPLEMENTATION OF A GROUNDWATER PROTECTION PLAN

The most effective means to implement the groundwater protection measures described in Chapter 4 is to first develop site-specific groundwater protection plans at the municipal level. A municipality is best suited to develop its own groundwater protection plan based on local hydrogeologic conditions, land uses, and political and economic conditions. This chapter presents 10 steps for developing a groundwater protection plan. The steps provide a simple, structured approach that communities with little or no experience in groundwater protection or hydrogeologic methods can implement with some technical assistance from provincial and federal governments and groundwater consultants.

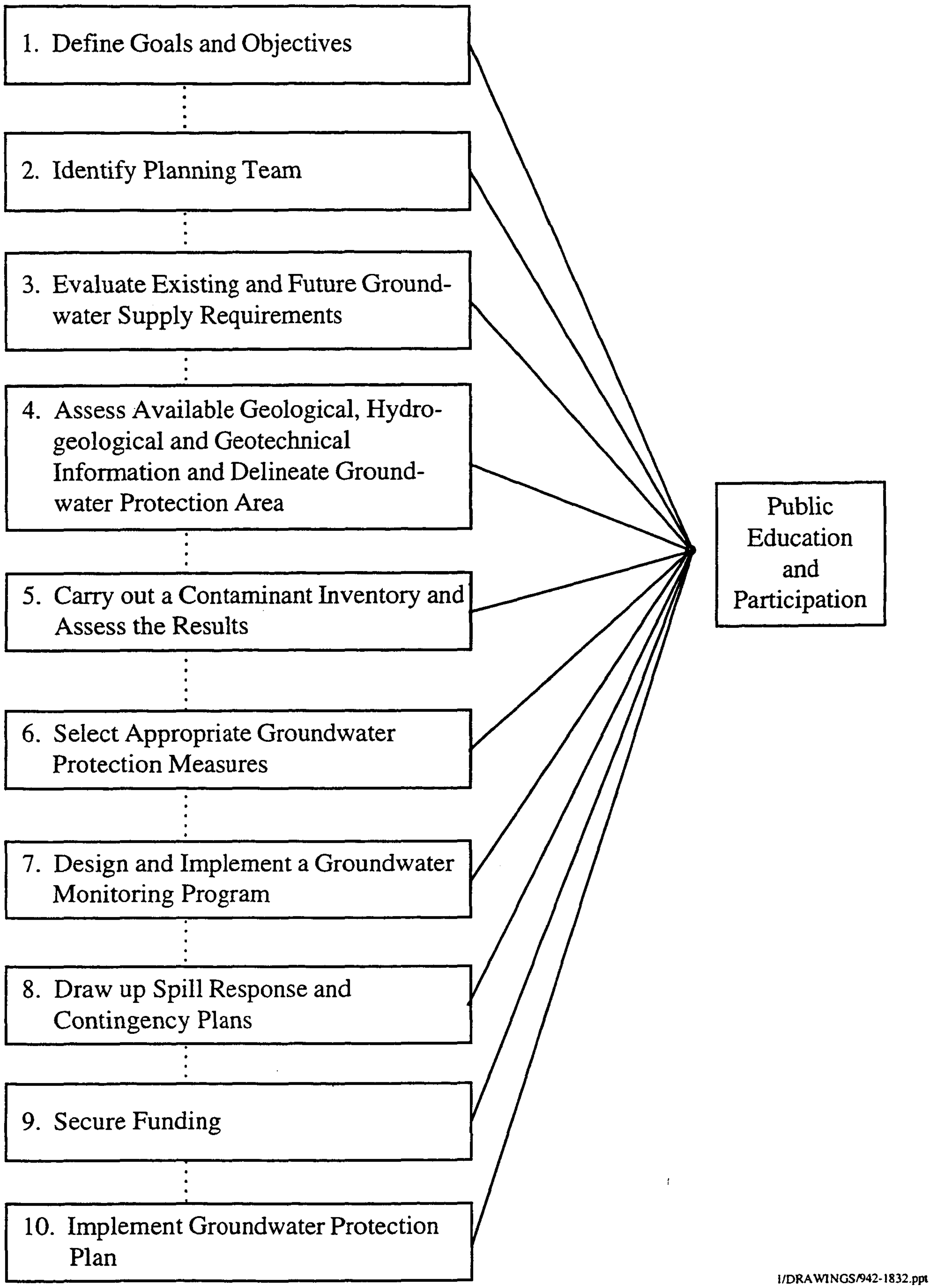
In our discussions with other municipalities that have implemented protection plans, they have indicated that the process of developing and implementing a protection plan is a highly valuable experience. It provides the municipality an opportunity to gain more knowledge about its local aquifers and to identify priorites for groundwater management, and raises public awareness about the need for groundwater protection.

The steps in the development of a groundwater protection plan are presented in Figure 18 and discussed below.

5.1 Define Goals and Objectives

The first step in the development of a groundwater protection plan is to define the long-term goals and objectives of the municipality, and to recognize that they may require revision and expansion as the program develops. Most groundwater protection plans are designed to prevent future contamination of groundwater. Others also include provisions for clean up of existing groundwater contamination. Long-term goals should include the delineation of the area to be protected and the development of a protection plan to control activities within this area. Protection measures may be implemented for a particular aquifer, a number of aquifers, or an individual well field.

FIGURE 18
Steps in the Development of a Groundwater Protection Plan



5.2 Identify Planning Team

Once the goals and objectives of a protection plan are established, a planning team should be identified that will be reponsible for the development and implemention of the plan. The planning team should consist of representatives from local, provincial and federal governments, and groundwater consultants. Other agencies, including public service organizations, businesses, farmers, developers, drillers, first nations peoples and environmental groups should also be involved in the planning process.

When selecting the planning team, it is important to involve individuals who have a first-hand knowledge of issues related to groundwater protection; for example, local health inspectors who are in the field dealing with problems related to septic systems. Since groundwater does not correspond to political boundaries, several juristictions may be involved in the implementation of the plan and cooperation between these juristictions is essential to the success of the plan. Similarly, most protection measures do not clearly fall under the responsibility of a single government agency, and therefore an interdepartmental approach is required. Whatever the makeup of a planning team, it is essential to have a strong and continuous committment from the members. Our review indicates that the most important element of a successful management plan is the selection of a dynamic, pro-active leader to spearhead the project.

5.3 Evaluate Existing and Future Groundwater Supply Requirements

The development of a groundwater protection plan must include an assessment of groundwater resources. The assessment should include an evaluation of both existing and future domestic, municipal, agricultural and industrial groundwater and surface water supply requirements, along with an evaluation of groundwater recharge required for the maintenance of wetlands, streams and lakes.

5.4 Assess Available Geological, Hydrogeological and Geotechnical Information and Delineate Groundwater Protection Area

Once an assessment of groundwater resources has been completed, a protection area should be delineated on the basis of local hydrogeological conditions. As described in Sections 4.1.2 through 4.1.4, various techniques can be employed to delineate a groundwater protection area. Methods range from the traditional “wellhead protection” approach, which defines the protection area based on travel times, to the delineation of the protection area based on vulnerability mapping and/or aquifer classification. Once defined, a protection area may consist of a municipal well field, an entire aquifer, or several aquifers. Much of the information on local hydrogeological conditions that is needed to carry out protection area delineation is already available from existing geological, hydrogeological and geotechnical reports. A summary of some of the available sources of information is provided below.

- Environment recently developed a map-based aquifer classification system and is currently applying the system to selected areas of the Fraser Basin. So far over 200 aquifers, including 73 aquifers in the Fraser Lowland, have been delineated and classified (Reference #272).

- The Geological Survey of Canada published a series of 23 maps of unconfined aquifers at a 1:250,000 scale for the entire Fraser River Basin (Reference #306).

- Groundwater mapping has been carried out in the Fraser Valley by Armstrong and Brown (1953) (Reference #307), and Halstead (1986) (Reference #308).

- B.C. Environment recently issued a report on the Groundwater Resources of British Columbia (Reference #301).

- A series of hydrogeological fence diagrams and well location maps for the Fraser Lowland have been published by Environment Canada (Reference #299).

- Other sources of hydrogeological information are contained within published and unpublished reports prepared by, or for, the federal and provincial governments as well as reports by private consultants.

- The Groundwater Section of B.C. Environment maintains a computerized data base of well records that are submitted to the province by drillers on a voluntary basis. Basic groundwater information from the water well records is available from the data base via the internet.

- The Geological Survey of Canada has recently developed a data base containing information from about 4,300 water wells in the Fraser Lowlands (Reference #297). The data is being used to develop two-dimensional hydrostratigraphic cross-sections and subsurface maps, and three-dimensional models of aquifers.

- The Groundwater Section of B.C. Environment operates some 149 groundwater observation wells throughout the province. Water-level information is available from some of these wells.

- Information on water quality is available from several sources including the SEAM data base, Provincial Ministry of Health, the Groundwater Section of B.C. Environment, Environment Canada and site specific studies carried out by private consultants.

- Environment Canada issued a report on Nitrates and Pesticides in the Abbotsford Aquifer in 1992 (Reference #90).

- A review of groundwater mapping and assessment in British Columbia and preparation of criteria and guidelines for a consistent approach to groundwater mapping and assessment has been carried out on behalf of the Resources Inventory Committee Earth Science Task Force (Reference #091).

5.5 Carry Out a Contaminant Inventory and Assess the Results

A contaminant inventory should be carried out to identify past, present and potential point and non-point sources of groundwater contamination within a protection area. The groundwater protection plan can then be tailored to address the most serious risks identified by the inventory. Tables 1 and 2 provide a summary of common sources of contamination that should be considered when carrying out the contaminant inventory.

Sources of information for a contaminant inventory are listed in Section 4.1.5. As a cost saving measure, private volunteers (for example, senior citizens) could assist with the inventory. An example of a contaminant inventory survey form that could be completed by volunteers is provided in Figure 16. A data management system should be established to organize the contaminant inventory and the inventory should be updated on a regular basis.

5.6 Select Appropriate Groundwater Protection Measures

Once the groundwater protection area has been delineated and potential sources of contamination have been identified, appropriate groundwater protection measures should be selected for implementation. The selection of appropriate measures will depend on the location and area of the protection zone, the results of the contaminant inventory, the mechanisms available for implementation, and available funding. A protection plan must include provisions for the protection of groundwater against accidental spills; however, the plan should not focus on spills to the exclusion of other less dramatic events. Rather, a sound protection plan focuses on routine, common sense prevention activities that have been developed from experience (Reference #286). Our review indicates that the success of a protection plan is not necessarily related to the number of protection measures implemented, but rather the selection of the most appropriate protection measures.

Table 10 presents a detailed check list of all groundwater protection measures discussed in Chapter 4 for consideration. The protection measures are listed in order from the most simple and inexpensive to the more complex and costly. Tables 4, 7 and 9 present a summary of groundwater protection measures ranked according to the extent to which the practice is proactive, the degree of protection offered, cost, staffing requirements, public acceptability and flexibility. Summaries of protection practices compiled by others are provided in Appendix IV.

5.7 Design and Implement a Groundwater Monitoring Program

A groundwater monitoring program should be designed and implemented as part of a protection plan. It should involve monitoring of both groundwater chemistry and the physical groundwater flow regime. Monitoring should be carried out at water supply wells and downgradient of known or potential sources of contamination to provide early warning of impending water quality problems. A data management system should be developed to process the monitoring data. It is important that, in addition to the collection of data, sufficient resources be allocated to the interpretation and assessment of the data to ensure the effectiveness of the program.

5.8 Draw up Spill Response and Contingency Plans

Spill response and contingency plans should be prepared as part of the groundwater protection plan. A spill reponse plan should identify measures that should be implemented to protect groundwater in the event of a spill or accident. A contingency plan should identify alternative drinking water supplies in the event that a wellfield

TABLE 10
Detailed Summary of Groundwater Protection Measures

A. Non-Regulatory Groundwater Protection Measures

1.	Public involvement	✓ Public information meetings ✓ Groundwater issues survey ✓ Newspapers, television, magazine and radio features ✓ Distribution of magazines, bulletins, pamphlets and maps ✓ Provision of signs at strategic locations ✓ Telephone information lines ✓ Posters, information booths and slide shows ✓ School educational programs ✓ Assistance programs
2.	Wellhead Protection Area Delineation	✓ Arbitrary fixed radii ✓ Calculated fixed radii ✓ Simplified variable shapes ✓ Analytical models ✓ Hydrogeological mapping ✓ Numerical flow and transport models
3.	Vulnerability Mapping	✓ i.e. DRASTIC
4.	Aquifer Classification	
5.	Contaminant Inventory	✓ Use private volunteers ✓ Establish a data management system
6.	Well Inventory	
7.	Groundwater monitoring	✓ Groundwater chemistry monitoring ✓ Water-level monitoring ✓ Monitoring of water-supply wells ✓ Monitoring groundwater downgradient of landfills, industrial sites, USTs and agricultural lands ✓ Surface water monitoring ✓ Establish a data management system

8.	Spill Response planning	✓ Prepare a spill response plan ✓ Install signs at strategic locations with emergency phone numbers ✓ Training for emergency response personnel ✓ Flag addresses within the protection area in the 911 system ✓ Require facilities handling hazardous materials to prepare spill response plans ✓ Standing contract with a cleanup contractor ✓ Contingency fund
9.	Contingency Plans	✓ Short-term water supply ✓ Long-term water supply
10.	Hazardous Waste Collection	✓ Drop-off at central depot ✓ Mobile units that travel to various locations ✓ Collection days once or twice per year
11.	Technical Assistance	✓ Volunteer master gardener program ✓ Training building inspectors to recognize abandoned wells and USTs ✓ Agricultural consultants ✓ Septic system consultants ✓ Training for commercial and industrial facilities
12.	Land Acquisition	✓ Donation ✓ Land exchange ✓ Land purchase ✓ Purchase and lease back
13.	Purchase of Development Rights	
14.	Conservation Easements	
15.	Cluster Development	✓ Encourage development in less sensitive areas ✓ Encourage development where sewer extension is planned

B. Groundwater protection measures that may be implemented through either Regulatory or Non-Regulatory means

1.	Storm Water and Sewage Control	✓ Stormwater management plan ✓ Design standards for drainage systems and catch basins ✓ Regular inspection and maintenance ✓ Upgrading and replacement ✓ Testing of stormwater and sewage discharges ✓ Permitting of stormwater and sewage discharges ✓ Containment and treatment of discharges ✓ Subdivision controls ✓ Prohibit dry wells and infiltration trenches
2.	Septic System Controls	✓ Educational programs ✓ Technical assistance ✓ Water conservation ✓ Siting control ✓ Prohibition in sensitive areas ✓ Minimum lot size requirements ✓ Design control ✓ Restrict use by industry ✓ Extend sewer system ✓ Use holding tanks ✓ Operational permits ✓ Regular inspection program and maintenance program ✓ Inspection prior to property transfer ✓ Ban cleaners with organic solvents
3.	Agricultural Controls	✓ Educational programs (working groups) ✓ Technical Assistance ✓ Best Management Practices ✓ Restrict amount and type of chemicals stored ✓ Pesticide/fertilizer application control ✓ Prohibit/restrict agricultural activities in sensitive areas ✓ Reporting requirements ✓ Research

4.	Roadsalt Controls	✓ Mix roadsalt with sand ✓ Covered storage ✓ Prohibit roadsalt in sensitive areas
5.	Transportation Controls	✓ Designated truck route ✓ Designated rail route ✓ Warning signs ✓ Speed limits ✓ Education of delivery personnel ✓ Training for emergency response personnel ✓ Road and maintenance repair
6.	Well Drilling and Abandonment	✓ Siting guidelines/regulations ✓ Construction guidelines/regulations ✓ Maintenance guidelines/regulations ✓ Guidelines/regulations for well abandonment ✓ Identification of abandoned wells as a condition of site plan approval/property transaction
7.	Geotechnical Controls	✓ Guidelines/regulations for grouting boreholes ✓ Limit depth of excavations in sensitive areas
8.	Forest Management	✓ Forest management plan ✓ Management to reduce the risk of fire ✓ Control of activities around streams ✓ Cutting restrictions ✓ Design controls for haul roads, skid trails and log landings ✓ Control of pesticides and herbicides ✓ Performance bonds
9.	Market Approaches	✓ Performance bonds ✓ Surcharge on water use ✓ Penalties/fines for non-compliance ✓ Financial incentives through tax credits ✓ Financial incentives through grants and loans
10.	Groundwater Quality Guidelines/Regulations	✓ Non-degradation policy ✓ Limited degradation policy

C. Regulatory Groundwater Protection Measures

1.	Zoning	✓ Overlay zones ✓ Prohibition of hazardous materials ✓ Prohibition of land uses ✓ Aquifer-wide protection area ✓ Protection area around a well field ✓ Large-lot zoning
2.	Facility Siting, Design and Operation Controls	✓ Best management plan ✓ Siting Restrictions ✓ Design and construction standards (i.e., secondary containment) ✓ Operating standards ✓ Permitting and licensing ✓ Regular inspection and maintenance ✓ Contingency plan
3.	Hazardous Materials Restrictions	✓ Control type and quantity of hazardous materials ✓ Registration and tracking controls ✓ Storage and handling controls ✓ Disposal controls
4.	Underground Storage Tanks and Pipelines	✓ Operations standards ✓ Secondary containment ✓ Pressure testing ✓ Groundwater Monitoring ✓ Permitting ✓ Fees ✓ Prohibition in sensitive areas

5.	Above-ground Storage Tanks	
		✓ Operations standards ✓ Secondary containment ✓ Pressure testing ✓ Groundwater Monitoring ✓ Permitting ✓ Fees ✓ Prohibition in sensitive areas
6.	Sand and Gravel Mining	✓ Security requirements ✓ Drainage control ✓ Mining restrictions ✓ Prohibition in sensitive areas
7.	Permitting	
8.	Inspection and Compliance	

cannot be used, or additional water supplies are required. Examples of spill response and contingency plans are presented in Section 4.1.8 and 4.1.9, respectively.

5.9 Secure Funding

The implementation of a protection plan will require a source of funding. There may be opportunities for cost sharing between the municipalities and the provincial and federal governments. Other potential funding sources include property taxes or surcharges on water use.

5.10 Public Education and Participation

Public involvement is essential to the success of a groundwater protection plan and should be carried out during each step of the development. The public should participate in the development and implementation of the plan, and should be educated regarding the importance of the plan and the steps they can take to protect groundwater. Successful interaction with the media is critical to gaining public support for the program.

Public education should be continued long after the protection program is first implemented. This ensures that groundwater protection measures are followed and helps to secure a continual source of funding. It also serves to educate people who have recently moved into the area. Public interest in groundwater protection may be low in areas where there is a perceived lack of problems with groundwater quality. In these areas, it may be necessary to be more proactive in seeking public support. A more detailed discussion of public education and participation is provided in Section 4.1.1.

5.11 Implement Groundwater Protection Plan

Implementation of groundwater protection measures may be carried out through either an incremental approach, starting with the most simple and cost-effective protection measures and progressing to more complex measures; or by a uniformed approach, whereby all measures are implemented at once.

5.12 Summary

In summary, the review has indicated that the Fraser Basin is well suited to the implementation of groundwater protection plans managed at the municipal level. Provided the above steps are followed, the implementation of a protection plan will help a community to ensure a clean, economical source of groundwater for years to come.

GLOSSARY

Alluvium. A general term for uncolsolidated material deposited by a stream or other body of running water.

Aquifer. A porous, permeable geologic unit capable of transmitting groundwater in sufficient volumes for development under normal hydraulic gradients.

Aquitard. A porous, normally fine grained geologic unit not capable of transmitting groundwater in sufficient volumes for development under normal hydraulic gradients. Can provide a natural protective layer for aquifers.

Attenuation. The removal of contaminants from a solution passing through a porous medium by natural mechanisms such as ion exchange, chemical precipitation, absorption and filtration.

Baseflow. Represents groundwater discharge to a river or stream. Baseflow is particularly important during extended dry periods or drought as it may contribute significantly to the maintenance of streamflow quantity and quality.

Bedrock. The consolidated or unweathered rock mass underlying the soil or other unconsolidated geologic material.

Best Management Practices (BMP). A set of "operating guidelines" that prescribe procedures to be followed to minimize the risk that these activities may pose to the water resource.

By-law. A form of subordinate legislation made by an authority subordinate to a legislature for the purpose of regulation, administration, or control.

Catchment. See Watershed.

Cone of depression. The depression of hydraulic heads around a well caused by the withdrawal of water.

Confined aquifer. An aquifer saturated with water and bounded above and below by beds having a distinctly lower hydraulic conductivity than the aquifer itself.

Contaminant plume. An elongated and mobile column or band of a pollutant moving through the subsurface.

Contaminants. All solutes introduced into the hydrologic environment as a direct result of human activities (Freeze and Cherry, 1979).

Database. A collection of interrelated information, usually stored on some form of mass-storage system such as magnetic tape or disk.

Discharge Area. An area characterized by an upward component of flow from the water table; normally occurs in topographically low areas. Discharge areas are typically smaller than recharge areas.

Drainage basin. The land area from which surface runoff drains into a stream system.

Drawdown. The decline in groundwater level at a point caused by the withdrawal of water from an aquifer.

Ecosystem. An environment containing a community of adapted organisms interacting in such a manner that there is a transfer of energy through the system and recycling of material resources within the system.

Freshwater. Water containing only small quantities (generally less than 1,000 mg/L) of dissolved minerals.

Geographic Information System (GIS). A computer-based land resource information system for the collection, storage, retrieval, transformation and display of spatial data.

Glacial drift. A general term for material transported by glaciers and deposited directly on land or in the sea.

Groundwater divide. A ridge in the water table or potentiometric surface from which groundwater moves away at right angles in both directions. The line of highest hydraulic head in the water table of potentiometric surface.

Groundwater flow. The movement of water through the pore spaces of geologic materials in response to variations in the potential energy of the water. Groundwater moves in the direction of decreasing potential and can vary from rates of between several centimetres per year to several hundred metres per year.

Groundwater. Generally, water occurring below the water table that moves through the saturated subsurface materials due to pressure gradients.

Hazardous Waste. Means any waste present in sufficient quantities to present a danger -

(i) to life or health of living organisms when released into the environment

(ii) to the safety of humans or equipment in disposal plants if incorrectly handled

Hazardous substances may possess toxic, carcinogenic, mutagenic or teratogenic characteristics as well as flammability, chemical reactivity, infectious or other biologically damaging properties (including radioactivity).

Hydraulic conductivity. The capacity of a rock to transmit water; expressed as the volume of water that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Hydraulic gradient. The slope of the water table or potentiometric surface; that is, the change in water level per unit of distance along the direction of maximum head decrease. Determined by measuring the water level in several wells.

Hydraulic head. In groundwater, the height above a datum plane (such as sea level) of a column of water. In a groundwater system, it is composed of elevation head and pressure head.

Hydrogeology. Branch of science dealing with groundwater, and the geological controls on its occurrence and movements, its availability and chemistry.

Hydrologic cycle. The exchange of water between the Earth and the atmosphere through evaporation and precipitation.

Leachate. The liquid effluent associated with seepage from a landfill.

Nonpoint source. Pollution from water runoff over the surface of the land.

Overburden. The sequence of unconsolidated or “loose” geologic materials that lie above the consolidated or bedrock surface.

Permeable. Having a texture that permits water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Point source. A discrete readily definable source of pollution such as a pipe or wastewater treatment plant.

Policy. A definite course of action developed to meet identified needs and to address existing and emerging issues.

Pollution. A state of contamination for which the water quality has deterioriated to a point where the ability of the water to support or maintain the existing or potential uses is diminished.

Potable. Water which is fit for human consumption.

Recharge Area. An area characterized by a downward component of flow away from the water table; normally occurs in topographically high areas but can occur in closed depressions.

Saltwater intrusion. The movement of saltwater into a part of an aquifer formerly occupied by freshwater.

Saturated zone. The zone (below the unsaturated zone) in which interconnected openings contain only water.

Stormwater Infiltration. A concept whereby storm runoff is collected and allowed to infiltrate into the soil materials as a means of enhancing natural groundwater recharge. Careful designs are necessary to prevent surface contaminants from being introduced into the groundwater environment.

Till. General term for a wide variety of poorly sorted sediments, ranging in size from clay sized particles to boulders, that were deposited by glaciers.

Time of travel. The amount of time it takes for water to reach a well from a certain distance.

Unconfined aquifer. An aquifer that contains both an unsaturated and a saturated zone (i.e., an aquifer that is not full of water).

Unsaturated zone. The subsurface zone, usually starting at the land surface, that contains both water and air.

Vulnerability. A relative evaluation of the potential exposure of a groundwater resource to contamination from planned and unplanned sources.

Water Quality Standards. Standards developed by a number of agencies, throughout the world, that are used as a basis to assess water for various different uses: such as human consumption, livestock consumption, etc.

Water Resources Protection Strategy. A framework for preventing or minimizing the impacts on water quality and water quantity arising from land use practices or other activities that have the potential to degrade water supplies. The framework provides strong technical support for the many initiatives required to protect water resources.

Water table. The plane which forms the upper surface of the zone of saturation.

Watershed. The area or basin over which all surface water collects; normally bounded between adjacent watersheds by a "divide"; also termed catchment.

Zone of Capture. The zone of capture of a pumping well is the land area over which groundwater is diverted to a pumping well.

APPENDIX I

OBJECTIVES, METHODOLOGY AND APPROACH

1.0 PROJECT OBJECTIVES

The overall objective of the study was to review non-regulatory groundwater protection practices in other jurisdictions for unconfined aquifers and recharge areas that could be applicable to the Fraser River Basin. The study recommends strategies for potential application in the Fraser River Basin to support or supplement proposed groundwater quality protection legislation.

The specific objectives of the study, based on Environment Canada's Terms of Reference dated February 21, 1994, were:

- a thorough compilation and review of information on groundwater quality protection strategies for unconfined aquifers and recharge areas, used in other jurisdictions;
- a description of the goals and objectives of these groundwater protection practices;
- an evaluation and comparison of the existing practices, guidelines or strategies and of the degree to which various components of these approaches may be appropriate for the Fraser River Basin in B.C.;
- a description of the strengths and weaknesses of the representative strategies;
- recommendation of protection strategies for potential application in the Fraser River Basin.

2.0 METHODOLOGY AND APPROACH

Golder's review of groundwater quality protection practices was carried out through a series of tasks outlined below;

- Task 1 - Compilation of Groundwater Protection Practices in Other Jurisdictions
- Task 2 - Project Kick-off Meeting
- Task 3 - Groundwater Protection Practices Review
- Task 4 - Classification, Evaluation and Summarization of the Various Groundwater Protection Practices
- Task 5 - Recommendations
- Task 6 - Interim Progress Meeting
- Task 7 - Groundwater Protection Guideline Recommendations, Documentations and Report Preparation
- Task 8 - Presentation of Draft Report
- Task 9 - Preparation and Presentation of Final Report

The methodology and approach used to complete these tasks is described below.

2.1 Task 1 - Compilation of Groundwater Protection Practices in Other Jurisdictions

Task 1 consisted of gathering information on groundwater protection practices used in other jurisdictions. To complete this task, Golder used its worldwide network of offices located across Canada, the United States, Europe and Australia to assemble information from government representatives, members of the groundwater community and Golder's project files. Communication was carried out by electronic mail, telephone and letters. Among its inquiries, Golder contacted government representatives from all Canadian provinces and from each of the 10 Environmental Protection Agency (EPA) regions in the United States. In addition, a representative from Golder's Waterloo, Ontario office attended a Groundwater Protection Symposium held in Waterloo in June 1994 and provided information for incorporation into the review.

2.2 Task 2 - Project Kick-Off Meeting

A project kick-off meeting attended by groundwater representatives from Environment Canada, the British Columbia Ministry of Environment and Golder Associates Ltd. was held on May 3, 1994. The purpose of the meeting was to review and discuss Golder’s approach for evaluating groundwater protection practices.

2.3 Task 3 - Groundwater Protection Practices Review

Over 300 documents were received in response to Golder's inquires. All documents were subjected to a “broad brush” review by Golder and were organized into a project database under a database document number and descriptors. The title, publisher, author and jurisdiction of the document were entered into the database under the document number. Each document was categorized in terms of its intended scope (i.e., aquifer protection plan, government strategy, public information brochure) and where possible, a brief summary of the contents of the document was provided.

2.4 Task 4 - Classification, Evaluation and Summarization of the Various Groundwater Protection Practices

Following a “broad brush” review of all documents and information received (Task 3), a select number of groundwater protection plans considered to be most relevant to the Fraser Basin in British Columbia were chosen for detailed evaluation. The groundwater protection plans were evaluated to identify strengths and weaknesses of the representative strategies.

2.5 Task 5 - Recommendations

Task 5 consisted of developing a range of feasible options for a non-regulatory approach to groundwater quality protection of unconfined aquifer and recharge areas, and proposing recommended strategies on the basis of the evaluation conducted under Task 4.

2.6 Task 6 - Interim Progress Meeting

An interim progress meeting attended by groundwater representatives from Environment Canada, the British Columbia Ministry of Environment and Golder Associates Ltd. was held on July 20, 1994. The purpose of the meeting was to discuss protection options and to allow the Federal and Provincial agencies to provide further direction prior to proceeding with the development of project draft report.

2.7 Task 7 - Groundwater Protection Guideline Recommendations, Documentation and Report Preparation

Task 7 consisted of developing a draft report for review by Environment Canada and the British Columbia Ministry of Environment. The draft report was issued on November 18, 1994.

2.8 Task 8 - Presentation of the Draft Report

The draft report was presented to a joint meeting of Federal and Provincial groundwater representatives on November 24, 1994.

2.9 Task 9 - Preparation and Presentation of Final Report

This final report represents Task 9 of Golder's review of groundwater protection practices. The report is presented in five chapters and five appendices. Background information on groundwater resources within the Fraser Basin is presented in Chapter 2. A discussion of common sources of groundwater contamination is presented in Chapter 3. Chapter 4 presents a review of groundwater quality protection measures that could be implemented at municipal levels through either regulatory or non-regulatory means. Chapter 5 outlines the steps involved in the development of a municipal groundwater quality protection plan. An outline of the methodology used for the preparation of this report is provided in Appendix I. Appendix II presents an overview of groundwater quality protection practices in western developed nations. Appendix III presents a detailed evaluation of nine selected groundwater protection plans that have been implemented at a municipal level. Summaries of groundwater protection practices compiled by others are provided in Appendix IV and the database of document references is presented in Appendix V.

APPENDIX II

OVERVIEW OF GROUNDWATER PROTECTION PRACTICES

1.0 OVERVIEW OF GROUNDWATER PROTECTION PRACTICES

1.1 General

Information on groundwater protection in jurisdictions outside of British Columbia was gathered using Golder's worldwide network of offices. An effort was made to obtain guidelines, policies and strategies regarding non-regulatory groundwater quality protection practices. Among its findings, the search revealed that groundwater protection is rarely handled in a solely non-regulatory manner, but is almost always associated with some degree of regulatory control. An overview of the status of groundwater protection in the United States, Europe, Australia, Barbados and Canada is presented below.

1.2 USA

Groundwater is recognized as an important natural resource in the United States, where more than 50 percent of the population relies on groundwater for home water supply (Reference #012). The United States has made significant efforts towards groundwater protection over the past decade and a half through a detailed regulatory approach. Groundwater protection legislation is administered and enforced by the U.S. Environmental Protection Agency (EPA) through 10 EPA regions across the country. Implementation is carried out on a state by state basis.

Early efforts towards groundwater protection by the EPA involved the release of their initial Groundwater Protection Strategy under Section 106 of the Clean Water Act (Reference #108) in 1984. In response to this program, all states, U.S. Territories and the District of Columbia developed statewide groundwater management strategies. Several states passed legislation incorporating elements of, or entire state strategies. Elements common to many of the strategies included the adoption of aquifer classification systems, wellhead protection programs and non-degradation policies (Reference #118).

Although the development of groundwater protection strategies by each state served to emphasize the need for groundwater protection, more significant steps towards the protection of groundwater resources were achieved through the passage of the 1986 federal “Safe Drinking Water Act Amendments” (Section 1428). This legislation required that each state submit and obtain approval of a groundwater Wellhead Protection Plan. As of late 1993, and in response to available federal funding, over 20 states had submitted such plans, and several have been approved. The EPA has issued several guidance documents to assist the states in developing their plans (References #104, #105, #106, #110 and #111).

Recent efforts towards groundwater protection by the EPA have involved the release of its Groundwater Protection Strategy for the 1990s in July 1991 and release of the National Program Guidance for Comprehensive State Ground Water Protection Program (CSGWPP) in January 1993 (Reference #283). As of the winter of 1994, at least one state in each of the 10 EPA regions had embarked upon the development of a Comprehensive State Groundwater Protection Program (CSGWPP) (Reference #074). According to Reference #074, key components in the development of the state CSGWPP programs have been the previous development and implementation of groundwater classification systems that serve as the foundation on which other groundwater programs are built, and an increased emphasis on data management and pollution prevention.

Currently, the EPA is combining the essential elements of the Wellhead Protection Program and the CSGWPP criteria and goals under their proposed Source Water Protection (SWP) Program.

Although groundwater protection strategies, wellhead protection plans and CSGWPP's have been developed, or are currently being developed, on a state level, actual implementation of aquifer and wellhead protection plans most commonly occurs at the municipal level. Aquifer management plans that have been implemented and have been found to be particularly successful are examined in Appendix III. Many of the successful groundwater protection plans have been implemented under the Sole Source Aquifer program. The Sole Source Aquifer (SSA) program is a federal program that allows a community to petition the EPA to designate an aquifer as the sole or principle drinking water source for an area where there are no reasonably available alternative sources should the aquifer become contaminated. The primary benefit of the SSA designation is that proposed federal financially-assisted projects that have the potential to contaminate the aquifer are subject to EPA review. The SSA designation also helps to increase public awareness, enhances the communities' ability to receive state funding, and allows the community to receive technical support from the EPA.

In addition to federal, state and local governments, numerous organizations exist in the U.S. that are actively involved in groundwater protection. For example, the League of Woman Voters has issued several educational publications on groundwater protection (Reference #233) and recently organized a national town meeting to discuss issues of groundwater protection (Reference #234). The National Groundwater Foundation is currently sponsoring a Groundwater Guardian Program designed to support and recognize communities protecting their groundwater. Nine communities representing six U.S. States and one Canadian province are taking part in this year's program. Other organizations include the National Rural Water Association and the Nebraska Groundwater Foundation.

1.3 Europe

Groundwater is highly valued in Europe because it is used as a drinking water source by half the European population (Reference #174). There has been a long-standing tradition of groundwater protection in Europe in response to pressures from intensive land practices, large population centres and large water demands. In contrast to the United States, where much of the effort has focused on the cleanup of existing contamination through Superfund type projects, efforts in Europe have been directed towards the prevention of future contamination of water supply (Reference #172). In addition to water quality issues, European countries have also been concerned with issues of allocation and optimal groundwater usage (Reference #114).

Most European groundwater protection schemes have been modelled after the German system and consist of the establishment of well-head protection zones based on distance and travel times. A general summary of the protection zones is presented below.

> Zone I: Land use is restricted to water supply equipment (i.e. pump house and piping) only. No other development is permitted.
>
> Zone II: Land use restrictions are placed on most industrial and agricultural activity.

Zone III: Limited restrictions are placed on certain types of industries, and on the storage and use of certain types of oils and chemical compounds.

A country by country comparison of groundwater protection zones for Europe compiled by the International Association of Hydrogeologists (Reference #096) and updated by Golder's Italian office, is presented in Table II-1.

One of the criticisms of the classical European approach to well head protection is that in many cases, little distinction is made between different aquifer systems and associated variations in flow and attenuation characteristics (Reference #096). Similarly, the wellhead protection scheme may not apply to sensitive lands located outside of the well-head protection zones (Reference #021). In response to these concerns, vulnerability mapping, which consists of ranking areas based on hydrogeological characteristics and susceptibility to contamination, is becoming increasingly popular in Europe. The UK has recently embarked on a four-year groundwater vulnerability mapping project. The National Research Council in Italy has published a “Unified Legend for the Aquifer Pollution Vulnerability Maps” (Reference #039). The status of groundwater protection in some key European Countries is described in further detail below.

1.3.1 Germany

The concept of a time-distance integrated groundwater protection program was developed in Germany as far back as the 1930s and as a result, the German scheme serves as a model for many other European programs (Reference #135). More than 70 percent of the public drinking water supply and almost all private water supply are derived from groundwater in Germany. Federal legislation requires groundwater protection through wellhead protection measures in all provinces. The delineation and enforcement of the wellhead protection zones are the responsibility of each province. The most effective wellhead protective programs appear to be run by the provinces of Lower Saxony, located in northern Germany, where mostly unconfined aquifers are present, and Baden-Wuerttemberg, located in southern Germany, where most groundwater is derived from bedrock sources.

One of the major threats to groundwater resources in Germany is the contamination of groundwater by agricultural activities. Approximately 50% (in 1989) of the drinking

TABLE II-1
Summary of Groundwater Protection Zones in European Countries

Prohibitions	Fed. Rep. Germany	Austria	Belgium	Finland	The Netherlands	France	Switzerland	Csechoslovakia	Hungary	Sweden	Great Britain	Norway	DDR	URSS	Italy
Only Water supply activities allowed	Zone I Well field 10 m	Immediate Protection area	Immediate Protection zone	Intake area ????	Well field	Immediate protection (10 - 20 m)	Zone I 5 - 20 m	First sanitary production zone 10 - 50 m	Protection zone	Well area	Zone I 50 m	Well site (10 - 30 m)	Zone 1 (5 - 100 m)	Zone I (15 - 50 m)	Zone of absolute defence (> - 10 m)
Prohibition on building Agricultural restrictions	Zone II 50 days	Protection area 50 days	100 m 24 hrs. Inner protection area (300 - 1000 m) 50 days	Inner protection zone 60 days	Catchment area (> 30 m) 50 - 60 days	Inner protection area ????	Zone II 10 days > 100 m	Internal second sanitary protection zone ????	50 days ???	Inner protection zone > 60 days > 100 m	Zone II 400 days	60 days	Zone II 60 days	Zone II 100 - 400 days	Zone of observance (> - 200 m)
Restrictions on certain industries, storage and transport of certain chemicals and oil	Zone III A 2 km	Partial protection area	Remote protection area	Outer protection zone	Protection area 10 years delay (>800 m) Protection area 20 years delay (>1200 m)	Remote protection area	Zone III >200 m Zone A	External second sanitary protection zone	Hydro geological protection area	Outer protection area	Zone III complete catchment area	Zone of input	Zone III A 10 years Zone III B	Zone III as a function of the time	Zone of protection
	Zone III B				Far recharge area		Zone B		25 - 100 year delay regional protection				25 years		
						OUTER BOUNDARY OF RECHARGE AREA									

Adapted from Table 6.1, Overview of the Protection of Groundwater Quality, H.G. van Waegeningh; from Theoretical Background, Hydrogeology and Practice of Groundwater Protection Zones, International Association of Hydrogeologists, Volume 6, 1985.

water in Germany has been affected by pesticides and an estimated 0% to 8% of public water supply systems and 50% of private supply systems have nitrate levels above the German drinking water limit of 50 mg/l as NO_3 (Reference #135). Among other guidelines, the Water Authority of Lower Saxony has developed guidelines to reduce groundwater contamination through agriculture-related substances. The guidelines include limits on the metal content in sludge that can be applied as fertilizer to agricultural land; regulations regarding the storage of fertilizers, and references to the maintenance of pasture land surfaces, crop rotation, plant coverage of soil, use of fertilizers and manures, agricultural work and irrigation.

1.3.2 Sweden

Approximately 15% of the population of Sweden uses private water wells and 50% of the urban population uses groundwater (Reference #129). Over 60% of groundwater is obtained from shallow, unconfined sand and gravel deposits contained within glacial eskers (personal communication, Golder Sweden).

A federal Water Law that restricts land use within a given distance of water wells has been in place in Sweden since 1897. The law is administered through the municipalities. As of 1991, approximately 40% of groundwater supplies in Sweden were protected through zoning restrictions (Reference #129). Groundwater protection measures have typically been developed in municipalities where larger populations are present. Federal guidance on groundwater protection is provided through the Grand Reservoir Protection System (the Swedish Environmental Protection Act or EPA). In 1991, the Law of Natural Resources (NRL) was adopted which serves to link the EPA and the Water Law through a permitting process. The NRL was modelled after the Californian system and has a strong emphasis on environmental impact assessment. The law requires localization studies prior to all development projects. Developers are then required to undertake groundwater protection measures before a permit is granted.

A large effort is currently underway towards groundwater protection at Stockholm's main airport. A new runway is being constructed on a delta system supplying groundwater to 50,000 inhabitants. Due to concerns over contamination of the aquifer by de-icing chemicals, the developer has been required to install a liner beneath the entire runway to protect the groundwater. Another recent groundwater quality issue in Sweden is the concern over salt water intrusion. Rapid development in coastal areas has lead to salt water intrusion in many existing shallow wells. Strict regulations have been imposed on groundwater allocation in these areas. Household water-saving measures such as prohibiting bathtubs (showers only) and requiring low-pressure showers have been imposed. Sweden has made efforts towards the protection of groundwater from agricultural activities using non-regulatory measures such as public education. For example, many farmers were applying fertilizers before the spring flood. A measure of groundwater protection was achieved by educating farmers to change the sequencing of chemical application. Free agroconsultants were made available to provide guidance to the farmers.

1.3.3 United Kingdom

Groundwater provides approximately 35 percent of the total public water supply for the UK. Groundwater protection in England and Wales is currently under the sole regulatory authority of the National Rivers Authority (NRA), which came into being in 1989 as the result of the 1989 Water Act. Prior to that time, groundwater protection was under the jurisdiction of 10 regional Water Authorities, each with its own groundwater protection policy. The NRA's jurisdiction extends to all "controlled waters", including groundwater, surface water, esturial waters and coastal waters. The NRA issued a groundwater policy document in 1992 entitled "Policy and Practice for the Protection of Groundwater" (Reference #050). The NRA's groundwater policy document is non-statutory and is not legally enforceable; however, there are legislative provisions through which the policies can be implemented. So far, the policies have been relatively well received by industry, with the exception of gasoline retailers and wholesalers, who are concerned with the restrictions pertaining to underground storage utilities.

The groundwater protection policies include provisions for the control of groundwater abstractions; physical disturbance of aquifers and groundwater flow; waste disposal to land; contaminated land; disposal of sludges and slurries to land; discharges to underground strata via soakaway pits, permeable lagoons, septic systems and sewage treatment plants; diffuse pollution, and additional threats to groundwater supply. The key to enforcement and regulation of the policies is based on zonation of sources and resources. The NRA is currently involved in a groundwater vulnerability mapping program based on an eight-fold groundwater vulnerability classification scheme. The NRA is also engaged in a nation-wide program of mapping groundwater protection zones for 750 major water supply sources. Three groundwater protection zones have been recognized based on distance and groundwater travel times (Table 1).

1.4 Australia

Groundwater is used as a source of domestic water for approximately 1 million people, or 18 percent of the population of Australia. Perth, located in Western Australia, is the only major urban centre relying on groundwater for its drinking water supply, with over two-thirds of the Perth population deriving their drinking water from groundwater. Most of the groundwater resources in the Perth area are located in shallow, unconfined sands of the coastal plain. In other areas of Australia, groundwater is used primarily by rural communities.

Groundwater protection in Australia falls under the jurisdiction of the State and Territorial governments. In 1992, the Australian Water Resources Council (AWRC) published a set of “Draft Guidelines for Groundwater Protection” (Reference # 174) as part of their National Water Quality Management Strategy. It is our understanding that these guidelines have not been well received because rather than providing federal policy statements on groundwater protection, the guidelines provide guidance on the steps each state and territory should take to develop their own policies and strategies for groundwater protection.

To date, the only significant efforts made towards groundwater protection appear to have occurred in Western Australia, where groundwater is more widely used and, because most is derived from unconfined sources, is most vulnerable to potential contamination. The Geological Survey of Western Australia recently completed vulnerability mapping of the Perth Basin (extending a distance of 900 km from Augusta to Geralton) using a five-fold ranking scheme based on the DRASTIC system (Reference #204). The Water Authority of Western Australia has designated several “Underground Water Pollution Control Areas” in the Perth Metropolitan area and has assigned three levels of protection to these areas (Priorities 1,2 and 3) based on existing ownership and zoning, proximity to water supply wells and groundwater flow paths and levels of threat (Reference #041). Public information brochures have been issued describing these zones (Reference #209) and groundwater protection measures that could be adopted by the general public to protect groundwater (Reference #208). No aggressive measures towards groundwater protection in the Perth area appear to have been implemented. A groundwater management plan was developed for the Cockburn area, located near Perth (Reference #207). Although the plan highlighted significant areas of groundwater contamination in Cockburn, the plan excluded any provisions for groundwater protection and simply addressed the issue of groundwater allocation.

Recently, a draft State Environmental Protection Policy (Groundwaters of Victoria) was issued by the State of Victoria, located in southern Australia (Reference #289). The policy sets out beneficial uses of groundwater that are to be protected, water quality objectives, proposed actions and a monitoring program.

1.5 Barbados

The regulatory programme of groundwater protection adopted by the Government of Barbados is one of the earliest plans in existence (1963) (Reference #092). The source of most potable water in Barbados is groundwater obtained from deep wells in coral aquifers. Development of a plan was essential because of groundwater contamination problems related to the high population density, the absence of wastewater collection systems and the high permeability of the coral limestone aquifers. The program consisted of restrictions on development and waste disposal practices through the establishment of five control zones. The control zones were delineated based on travel times.

Potential risks to groundwater quality in Barbados are primarily from saltwater intrusion and wastewater from private residences, industry and agriculture. The 1963 plan included the restriction of all development within Zone 1, immediately surrounding all existing and potential water supply wells. This represented an area of approximately 7085 acres across Barbados, much of which was highly desirable for development. A water resources study of Barbados, carried out in 1978, included an assessment of ways that the area of zone 1 could be reduced in response to pressures from developers.

Alternatives included 1) the provision of sewers in Zone 1; 2) improved treatment at each well; 3) improved design of in-ground septic systems, and 4) reduction in the size of Zone 1 from 300 travel days to 100 travel days based on pollution survival times. The study also recommended reducing the number of control zones from five to three to allow easier application and management of the zones. Currently, the government of Barbados is commissioning another study to update the status of water resources on the island.

1.6 Canada

Groundwater is the source of water supply for over 26% of Canadians (Reference #291). The use of groundwater for household and industrial use in Canada has increased dramatically over the past 20 years and is expected to continue to grow, particularly outside of large cities where groundwater is often readily available and more economical to develop (Reference #172). A recent report summarizing the status of groundwater issues and research in Canada prepared by a Task Force appointed by the Canadian Geoscience Council (Reference #256) stated that "Canada needs to make major advances in areas such as groundwater inventory, protection and research in order to achieve responsible and effective management of this important freshwater resource." As stated by the Task Force, reasons cited for the relative lack of action in Canada with regard to groundwater management included the following:

"1. *Ownership* of groundwater beneath provincial land is primarily in the hands of provincial governments.

2. Groundwater is used by a minority (7 - 8 million) of Canadians for domestic water supply. In contrast, federal politicians take a more active concern for groundwater issues in Europe, the United States, Mexico and in many other regions, where groundwater is the primary source of water supply for the majority or near-majority of the populations.

3. An *abundance mentality* regarding groundwater has developed in Canada, because we have been so richly blessed with water resources. As a result, we are blind to the possibility of ultimate limitations to groundwater resource quantity and quality.

4. Groundwater poses administrative problems for the federal government because few groundwater issues fit entirely within the mandate of a single department or even a single directorate in one department."

Among 21 other recommendations, the Task Force report recommended the establishment of a federal groundwater protection office for disseminating information about groundwater protection. Currently, groundwater protection in Canada falls under the jurisdiction of the provinces, each of which has developed its own set of policies and procedures (Reference #091). A summary of the status of groundwater protection on a province-by-province basis is provided below.

1.6.1 British Columbia

Statistics compiled in 1981 by the British Columbia Ministry of Environment showed that 22% of British Columbia's population depended on groundwater for their water supply. Groundwater accounts for 12% of the total water consumption in the province and represents 22% of all groundwater extracted in Canada. The largest use of groundwater in British Columbia is by industry (55%), followed by agriculture (20%), municipal (18%) and rural domestic use (7%) (Reference #291).

Some of the more accessible and economic groundwater resources in British Columbia, such as those in the Fraser and the Okanagan Valleys, are also from unconfined aquifers, which are more vulnerable to pollutants arising from industrial and agricultural activities. The detection of pesticides and elevated nitrates in the Abbotsford Aquifer (Environment Canada, Liebscher et. al, 1992) and areas of the Fraser Valley (Reference #90) have become a highly publicized health concern for the residents of these areas. Such concerns have led to the development of the community-based group, Enviro-health, established under the Upper Fraser Valley Union Board of Health. In addition to the "non-point" pollution sources from agricultural land use practices, unconfined aquifers are subjected to a variety of other non-point and point loadings from historic and current practices such as "soak-away pits" (dry wells), point loadings from poultry and other livestock manure piles, and other human and animal wastes, leaking underground storage tanks (LUSTs) and infiltration lagoons, among other sources. Further, groundwater quality may be compromised through inadequate well construction and well abandonment techniques, a lack of resources and inadequate groundwater legislation.

British Columbia has existing legislation and regulations that have a degree of indirect control over groundwater protection (i.e., the Waste Management Act, Health Act, Municipal Act and Pesticide Control Act); however, British Columbia is the only province in Canada that does not have some form of direct groundwater legislation. The existing provincial Water Act does not apply to groundwater supplies. B.C. Environment recently released a comprehensive discussion paper titled “Stewardship of the Water” (Reference #258) as part of a major policy review aimed at updating the Water Act. The paper proposes that the new Water Act be expanded to include groundwater. Associated proposals that, once adopted, would aid in the protection of groundwater include:

- the designation of groundwater management areas to regulate well drilling and groundwater use by means of permitting of new wells and test wells, licensing of existing wells, certification and licensing of well drillers and pump installers, approval for groundwater investigations;
- mandatory submission of well records;
- enhanced data collection, inventory and aquifer classification;
- standards for well construction, maintenance and closure;
- standards of operations for specified land use activities to prevent pollution of groundwater;
- the designation of sensitive groundwater recharge/discharge areas and protection zones around major wells;
- development of aquifer management plans; and
- the regulation of high risk activities in and around wells.

Non-regulatory groundwater protection measures currently in place in British Columbia consist of a set of “Guidelines for Minimum Standards in Water Well Construction”, that were published by B.C. Environment in 1982 (Reference #257) and are currently under revision, along with an approved training program for well drillers. Recent initiatives for groundwater protection included a “Wellhead Protection Seminar” (January 12, 1994) sponsored by B.C. Environment, which served to highlight the inadequacies of current practice, and the need to develop effective groundwater management plans.

In a report prepared for Environment Canada through the Fraser River Action Plan ("Groundwater Mapping and Assessment in British Columbia", Piteau Associates Engineering Ltd. and Turner Groundwater Consultants Ltd., October 1993), recommendations were made that identified the need for improved access to groundwater information and increased public awareness of groundwater issues. Since then, B.C. Environment developed an aquifer classification system and is applying the system to selected areas in the Fraser River Basin. So far, over 200 aquifers have been delineated and classified on a 1:50,000 scale (Reference #272). The province, in partnership with Environment Canada, intends to follow up with vulnerability mapping on a 1:20,000 scale. In addition, the Geological Survey of Canada recently launched a three-year comprehensive regional mapping program aimed at delineating and characterizing aquifers and groundwater flow in the Greater Vancouver and Lower Fraser Valley regions (Reference #249).

1.6.2 Alberta

Groundwater is used as a drinking water source by approximately 27% of the Alberta population (Reference #291). Groundwater in Alberta is managed by Alberta Environmental Protection and is regulated under the Environmental Protection and Enhancement Act (Reference #273) and the Water Resources Act. Regulations currently in place include licensing of drillers, regulations for well construction and abandonment, and permitting of wells supplying over 3000 Imperial gallons per day.

Most of Alberta is covered with a mantle of low-permeability clay deposits that have provided a degree of natural protection against groundwater contamination. As a result, there appears to have been little emphasis on groundwater protection in Alberta. No guidelines are in place that serve to protect groundwater, with the exception of the recent guidelines pertaining to storage tanks. The provincial government has undertaken a significant number of regional groundwater studies; however, the emphasis of those studies has been more on water supply than water quality. The province has also prepared groundwater protection maps which have reportedly been adopted by the oil field industry to prevent contamination of useable groundwater zones. A groundwater information guide (Reference #274) that lists measures to prevent pollution of groundwater is also available through the provincial government. Other steps towards groundwater protection have involved increased restrictions on well drillers in counties located outside of Calgary, where development is occurring at a rapid rate.

1.6.3 Saskatchewan

Fifty-four percent of Saskatchewan residences depend on groundwater for their drinking water supply (Reference #291). Water quality issues in Saskatchewan fall under the jurisdiction of Saskatchewan Environment, while water resource issues are addressed by the crown corporation, Sask Water. Although it has no regulatory control over groundwater, the Saskatchewan Research Council (SRC) maintains the provincial observation well network and provides staff and resources for groundwater studies. Groundwater is regulated under the Groundwater Conservation Act (Reference #018) and the Water Corporation Act (Reference #014). These acts are presently under review and are expected to be revised and consolidated into one act in 1995.

Several regulations are in place under the two acts that allow the province some control over the protection of groundwater. Given the relatively dry climate in Saskatchewan, the issue of groundwater allocation, rather than groundwater protection, appears to have been the driving force behind the development of these regulations. A three-step approval process is currently in place for the development of non-domestic groundwater supplies, which involves obtaining separate permits for groundwater investigation, well construction and well operation. This process allows Sask Water the opportunity to impose restrictions at various stages of the project on a case-by-case basis. For example, before Sask Power was recently permitted to develop a new groundwater supply, they were required to conduct an inventory of 100 neighbouring wells and establish a monitoring network of some 30 stations. Other existing regulations include mandatory submission of well logs and geophysical logs to the provincial government, licensing of drilling rigs, and requirements for the abandonment of test holes and wells.

Although no guidelines exist on a provincial level that specifically protect groundwater, several related guidelines are in place that indirectly protect groundwater. These include guidelines for monitoring well installation, numerous guidelines related to agricultural practices, and guidelines related to pipelines, storage tanks and mineral exploration.

Sask Water has undertaken a series of aquifer management plans for three aquifer systems in the province that are under considerable pumping stress. These aquifer systems include the Regina, Yorkton and Southeast systems. The intent of the plans is to more accurately define the aquifers, quantify the groundwater resources available, quantify the demand, and establish an aquifer management plan to ensure that the groundwater resources are protected from contamination and over-allocation (Reference #013). The management plan for the Regina aquifer, which has been developed the furthest, is discussed in detail in Appendix III.

1.6.4 Manitoba

Approximately 24 percent of Manitoba's population relies on groundwater (Reference #291). Groundwater management in Manitoba is the responsibility of the Department of Natural Resources, while groundwater remediation is handled by the Department of Environment. Groundwater is regulated under the Groundwater and Water Well Act, which includes provisions for the licensing of well drillers and the mandatory submission of well records. The emphasis on groundwater protection in Manitoba has not involved the development of guidelines or regulations but rather, programs of groundwater mapping, monitoring and public education. In addition to numerous groundwater availability studies, the provincial government has published a series of seven groundwater pollution hazard maps of Southern Manitoba. The province currently maintains a monitoring network of almost 500 stations for monitoring groundwater chemistry and water levels. The Department of Natural Resources provides site-specific guidance on groundwater issues for individual municipalities upon request and has issued a report summarizing information and services available from the province (Reference #032).

Although the emphasis on groundwater protection in Manitoba has not involved the development of guidelines, the province, in cooperation with producer groups, recently developed draft guidelines for large-scale hog operations aimed at protecting water quality. The Department of Natural Resources is currently working on guidelines for beef producers (Reference #292).

1.6.5 Ontario

Approximately 26% of the population of Ontario obtains its domestic supply from groundwater, and water use is projected to double between 1985 and 2000 (Reference #125). Although the Ontario government has allocated considerable funds to groundwater research, relatively little progress has apparently been made towards groundwater protection (Reference #172). Regulations, including the Water Resources Act, the Environmental Protection Act and the Planning Act, are in place through which groundwater protection could be implemented; however, few protection initiatives have been undertaken by the province. Instead, groundwater protection responsibilities have been relegated to various municipalities, some of which have developed region-specific groundwater protection strategies. A comprehensive Water Resources Protection Strategy was developed by the Regional Municipality of Waterloo in 1992 (Reference #170). Implementation of the protection strategy will be carried out over the next 10 years. The Regional Municipality of Peel, located west of Toronto, initiated a wellhead protection study in the fall of 1992, and plans to implement groundwater protection measures in 1995. Both Waterloo and Peel’s programs are examined in detail in Appendix III.

One program initiated by the provincial government aimed at protecting surface water supplies is the Municipal - Industrial Strategy for Abatement (MISA) Program. The purpose of the program is to reduce discharges of toxic contaminants from industrial and municipal discharges (Reference #282 and #293).

Government efforts towards public education in Ontario have included publication of a booklet on water wells and groundwater supplies (Reference #200) and fact sheets on protection of water wells against contamination and proper well abandonment (References #201, #202 and #203). Public concerns over groundwater quality have resulted in the recent formation of Groundwater Education Ontario, a group dedicated to the education and promotion of groundwater awareness. Recent efforts towards groundwater education in Ontario include the Children's Groundwater Festival held at the Ontario Agricultural Museum in Milton, Ontario in June 1994. The event attracted 6500 school children and 1000 adults.

1.6.6 Quebec

Groundwater is used as a drinking water source by approximately 17% of the Quebec population and 31% of Quebec municipalities (Reference #291). Groundwater is managed by the Ministère de l'Environnement et de la Faune du Québec (Ministry of Environment and Fauna) and is currently regulated under the “Loi sur la Qualité de l'Environnement” (Environmental Quality Act) (Reference #259) and a set of 20 year-old groundwater regulations.

Significant efforts toward groundwater protection in Quebec are currently underway. The government has recently embarked on a four-year strategy for the protection and conservation of groundwater. As part of this strategy, new regulations entitled “Ouvrages de Captage d'eau Souterraine” (Structures for Capturing Groundwater) are being prepared to replace the 20 year-old regulations governing groundwater. The new regulations, which are expected to be adopted in the spring of 1995, pay considerable attention to the protection of groundwater. Under the new regulations, municipalities, which are currently required to submit a zoning plan every five years, will also be required to prepare a groundwater management plan. Municipalities with populations under 2500 will be eligible for provincial funding of up to 75% of the total cost of implementation. To assist municipalities with the preparation of groundwater management plans, the government has released a “Guide Pour la Détermination des Pêrimètres de Protection Autour de Captage d'Eau Souterraine” that provides technical assistance for the determination of groundwater protection zones (Reference #028).

Groundwater protection plans are already in place in three municipalities in Quebec. The mining community of Amos, located in northwestern Quebec, has requested that the Ministry grant a special permit to prohibit mining operations near their well field. In Cap-de-la-Madelaine, where groundwater is obtained from shallow sand aquifers, local zoning bylaws have been used to protect groundwater quality. A multi-million dollar project has recently been completed in the Îles-de-la-Madeleine, located in the Gulf of St. Lawrence. The Madeleine Islands, which are completely reliant on groundwater for water supply, were experiencing salt water intrusion problems. The province developed a set of regulations specific to this area to provide groundwater protection.

Other efforts by Quebec include plans for hydrogeological mapping of all groups of municipalities across the province. The maps are expected to include an aquifer classification scheme, vulnerability mapping and an inventory of groundwater resources. Existing vulnerability maps at scales of 1:50,000, 1:125,000 and 1:250,000 are referenced in References #265 through #271.

1.6.7 New Brunswick

Sixty-four percent of New Brunswick's population relies on groundwater. Groundwater is managed by the Department of Environment and is currently regulated under Clean Water Act and the Clean Environment Act (Reference #291). According to Cherry (1993) (Reference #012), New Brunswick has experienced some of Canada's most severe groundwater contamination problems for more than two decades. In response to incidents of major groundwater contamination, the province launched a Groundwater Protection Program in 1990.

The purpose of the Groundwater Protection Program is to control existing and future land use activities in an effort to protect drinking groundwater supplies. The main thrust is to create protection zones in areas of municipal wells and recharge areas (Reference #282). Seven groundwater protection studies are being carried out across the province under the Clean Water Act on an equal cost-sharing basis between the municipalities and the province. Consultants are used to conduct the protection studies and prepare draft regulations, and residents living within the protected areas are informed through public meetings. Protection zones for semi-confined/confined aquifers have been delineated using time of travel, while protection zones for bedrock aquifers have been defined on the basis of groundwater divides and mass balance approaches. As yet, no studies have been carried out on unconfined aquifers (Reference #029); however, it is likely that the criteria New Brunswick has adopted for semi-confined situations will be equally applicable for unconfined cases.

Results of the studies have concluded that the use of chlorinated solvents is incompatible with the operation of a municipal water supply. Other recommendations include limiting the quantities of petroleum hydrocarbons and organic liquids that can be stored or used within the protected areas, and restricting septic systems. Draft regulations have also been prepared aimed at controlling existing and future land uses within the protected areas (Reference #029). None of the protection plans have been fully implemented as of yet. The protection plan prepared for South Fredericton (Reference #030), which is examined in detail in Appendix III is likely to become the first fully implemented plan.

The Department has identified an additional 40 municipalities across the province where it plans to carry out groundwater protection studies. As a result of their Groundwater Protection Program, New Brunswick is considered to be at the front of provincial activities for groundwater protection in Canada.

1.6.8 Nova Scotia

Approximately 45% of the population of Nova Scotia obtains its drinking water from groundwater supplies, mostly from bedrock wells (Reference #291). Groundwater is regulated under the Well Drilling Act (Reference #024) which provides for licensing of well drillers, mandatory submission of well records and a few basic precautions to protect groundwater quality (Reference #026), and the Environmental Assessment Act. An Environmental Act has recently been drafted, with provisions for water resources not much different from the existing Well Drilling and Water Act. The Water Act (Reference #022) was originally developed for use in regulation of surface water; however, the Act, which allows the province to “designate” a water supply area (Reference #023), has recently been used for the protection of groundwater in the Amherst area. A comprehensive groundwater protection plan was recently developed for the town of Amherst and represents the province's most significant achievement towards groundwater protection. The plan is examined in detail in Appendix III. Some effort has been made by the Department of Environment towards developing a province-wide land use policy which would allow for the protection of groundwater, along with floodlands and wetlands; however, the government has been reluctant to implement such policies on a province-wide basis.

1.6.9 Prince Edward Island

Prince Edward Island (PEI) is the only province in Canada entirely dependent on groundwater as its source of domestic, municipal and industrial groundwater supply

(Reference #130). All groundwater supplies on the island are obtained from highly fractured sedimentary Permo-Pennsylvanian red bed units consisting of porous sandstones interbedded with siltstones and claystones (Reference #130).

Groundwater protection in PEI is managed through the Department of Environment. Groundwater is regulated under the Environmental Protection Act and associated regulations dealing with environmental impact assessments, water well regulations, petroleum storage tank regulations and sewage disposal regulations (Reference #130). Although there are regulations which bear directly on groundwater management, the approach to groundwater protection in PEI is largely non-regulatory in nature and is managed on a case-by-case basis by the Department of Environment. Prior to the development of community and municipal groundwater supplies, the province provides recommendations on well siting and land use activities near the well field. The community usually purchases the land around the well field and often the land is leased back to the original owner. So far, all new well fields have been sited in areas where existing land use is compatible with the province's recommendations. Because grants are commonly provided to communities to assist in the development of a groundwater supply, recommendations made by the Department of Environment are usually readily accepted by local communities without the need for regulations.

The only large capacity well fields on the island are located in the towns of Charlottetown and Summerside. Charlottetown has two existing well fields and plans to develop a third well field at some distance outside of town. The town has purchased the woodland around the new well field and plans to lease it for use as a controlled woodlot. Summerside has plans for the development of two well fields, one in the near future and another in the distant future. The town plans to hire a consultant to develop a formal groundwater protection plan similar to that developed for Amherst, Nova Scotia.

1.6.10 Newfoundland

Approximately 29% of Newfoundland's population depends on groundwater as their source of potable water (Reference #291). Greater than 90% of the 12,000 drilled wells in the province are completed in bedrock. Groundwater is regulated under the Well Drilling Act (Reference #255) under which regulations are in place for locating wells, well construction, testing and abandonment, licensing for drillers and mandatory submission of well records (Reference #254). At the present time, a Water Resources Act is not in place.

No formal guidance documents have been issued regarding groundwater protection in Newfoundland; however, the province has undertaken several non-regulatory initiatives which serve to protect groundwater. The most significant effort was the initiation and funding of groundwater protection studies for community well fields at Bager, Stephenville Crossing and St. Alban's. The studies resulted in the establishment of three groundwater protection zones around each well field based on time of travel. Implementation of protection measures is carried out by the communities. An additional groundwater protection study for Goose Bay is currently underway.

The Newfoundland and Labrador Department of Environment has issued eight hydrogeological reports covering the island portion of the province. One of these reports is provided as Reference #008. Guidance documents have been published regarding aquifer pumping tests (Reference #002) and cottage lot developments (Reference #001). Public brochures have been issued which provide information on siting and constructing wells, protecting wells from contamination, and proper pump installation (References #003, #004 and #005). Other groundwater protection measures carried out by the province include reaching an agreement with drillers to install at least one length of surface casing (6.2 m) in every well; and ongoing studies on landfill contamination, road salt contamination and well construction practices. The province has also responded to new groundwater quality issues by issuing policy statements and notifying the public through newspaper advertisements. Examples include a policy statement on the use of creosote rail ties in retaining walls and an alert published in the newspapers when old submersible pumps where reportedly leaking PCBs into wells from capacitors within the pump (Reference #006).

APPENDIX III

SELECTED GROUNDWATER PROTECTION PLANS

1.0 SELECTED GROUNDWATER PROTECTION PLANS

1.1 General

This chapter presents a detailed evaluation of six selected groundwater protection plans and a summary of three additional plans. For each plan, where information was available, a discussion of the following is provided: site background, objectives of the protection plan, extent of the groundwater protection area, contaminant inventory, protection measures that were adopted or are under consideration, control agency and staffing requirements, cost of the plan, funding sources, and an evaluation of the effectiveness of the plan.

Summaries of non-regulatory and regulatory protection measures that were implemented, or are under consideration, by the nine communities are presented in Tables 2 and 3, respectively. Groundwater protection measures implemented, or under consideration, at numerous other communities are also summarized in the tables for reference. Since publication of the documents reviewed, the groundwater protection measures listed for each community may have been enhanced with the implementation of other protection measures. Similarly, some measures may have been under consideration at the time the documents were reviewed, but may not have been incorporated into the final protection plan.

1.2 Dayton, Ohio

1.2.1 Background

The City of Dayton, Ohio is situated above the Great Miami Buried Valley Aquifer System, which is designated federally in the United States as a sole source aquifer. The City uses this resource to supply drinking water to 400,000 people in the metropolitan area. Dayton took steps to initiate a well field protection program (WFPP) in 1985 after investigations of potential pollution sources around its two well fields indicated that at that time, ten percent of the groundwater was critically contaminated and forty percent was expected to become contaminated by the year 2000 (Reference #193). A major fire in an industrial park surrounded by one of Dayton’s well fields served to heighten public awareness of the need for groundwater protection.

Dayton first implemented its WFPP in 1988. Since then, the WFPP has been widely recognized as one of the most exemplary local groundwater protection programs. As a result of its efforts towards groundwater protection, Dayton was awarded one of the national Municipal Leaque's “All-America City” awards in 1991 (Reference #103).

1.2.2 Objectives

The primary focus of Dayton’s groundwater protection efforts is on threats associated with hazardous materials and chemicals used in business and industry. The basic objectives of Dayton's wellfield protection program are two-fold (Reference #137):

- Prevent and minimize risk of groundwater contamination and
- Reduce existing risk to groundwater resources which supply Dayton's drinking water.

1.2.3 Groundwater Protection Area

The designation of the protection areas for the City's well fields was based on a one-year time-of-travel with an additional buffer zone in areas where aquifer borders encroach on the one-year boundary. Travel times were calculated from a series of groundwater flow models.

1.2.4 Contaminant Inventory

Prior to developing the groundwater protection strategy, an inventory of waste disposal and wastewater treatment sites and land use was carried out. An independent inventory of potential sources of contamination near city wells was also carried out on a voluntary basis by Sierra Club members.

1.2.5 Groundwater Protection Measures

The Dayton wellfield protection program is based on three ordinances passed by the Dayton City Commission. One ordinance establishes a wellfield overlay zoning district; a second sets up reporting and inspection procedures, and a third establishes a fund for wellfield protection activities (Reference #103). Groundwater protection measures associated with these ordinances are described below.

Land Use Control Zoning

Land use control zoning was adopted as a principal means groundwater protection. It was perceived that using zoning as the primary mechanism for the new WFPP would be preferable to the business community because of zonings' familiarity and acceptance. In order to optimize the effectiveness of the zoning, while minimizing unnecessary economic impact to local businesses, the types and quantities of hazardous chemicals (regulated substances) used by businesses are regulated rather than the type of business activity. Under the protection plan, "regulated substances" are defined as chemicals and mixtures that are classified as health hazards by the Occupational Safety and Health Administration (OSHA). The implementation of these land use control measures has resulted in the reduction of over five million pounds of hazardous chemicals within the wellfield protection area.

Underground Storage Tanks

The following groundwater protection measures have been undertaken in Dayton for underground storage tanks (USTs);

- all existing USTs must be upgraded to secondary containment and monitored systems within five years,

- USTs which contain regulated substances other than vehicle lubricants and fuel for heating must be eliminated in five years (this requirement may conflict with fire code requirements), and

- restrictions of new USTs in the wellfield protection area.

Agricultural Chemicals

Groundwater protection regulations require that no more than a one-year supply of agricultural chemicals be stored for on-site application. In addition, the types and amounts of chemicals applied must be reported on an annual basis. This information is used to aid in the selection of appropriate locations for monitoring wells.

Sand and Gravel Mining

Conditional use zoning provisions require that sand and gravel operations undertake drainage control measures and provide security to prevent possible illegal dumping.

Dry Wells

Given their susceptibility to contamination, soak away pits (dry wells) are prohibited by the wellfield protection plan.

Public Participation

Community participation was considered critical to the development of the wellfield protection plan. The media played an important role in helping increase public awareness and support for groundwater protection, particularly during the early years while the WFPP was being developed. Efforts were made to involve the public in the development of the WFPP through the City's seven existing Priority Boards, which serve as a formal mechanism for obtaining neighbourhood input for city government. Public education was carried out through meetings, slide presentations, and distribution of a series of fact sheets on various pollutant sources, such as hazardous materials, landfills, chemical lawn treatment and septic tanks. Because of the WFPP's focus on new zoning requirements, special efforts were undertaken to educate the business community. A guidebook was developed to assist new businesses starting up in the well field protection overlay district, and firms already located in the protection area were informed through a series of workshops (Reference #286).

Monitoring

The City of Dayton maintains a network of some 150 monitoring wells that are set up around production zones as an early warning system. Monitoring wells and production wells are sampled on a quarterly basis for a range of contaminants (metals, VOCs and inorganic parameters) (Reference #286). A computerized Geographic Information System (GIS) was developed to correlate groundwater quality data with chemical inventory reports.

Spill Response

The City of Dayton has a standing contract with a contractor to provide necessary services in the event of an emergency. The contract includes the provision of drilling equipment, an on-site laboratory for volatile analysis, and systems for groundwater extraction and treatment. The advantage of the City's emergency response contract is that it reduces the dependence on state and federal assistance which may be less effective and more costly. In addition to the emergency response contract, signs have been posted in key areas of the designated protected area to enhance the spill reporting process. All addresses within the designated area are also “flagged” in the 911 system so that the 911 operator will be alerted that the location of the call is within an area of public water supply concern.

1.2.6 Control Agencies and Staff Requirements

The designated wellfield protection area includes portions of three cities, two townships, a village and a U.S. Air Force base. Communication among the participating jurisdictions is maintained through a multi-jurisdictional coordinating committee and implementation is carried out by the City of Dayton Office of Environmental Protection. Five full-time professionals are employed to inspect approximately 700 businesses within the protection area. Health District employees provide inspection services in jurisdictions outside of the City of Dayton.

1.2.7 Costs and Source of Funding

The cost of development of Dayton’s well field protection plan consisted of a one-time expenditure of 1.35 million dollars (U.S.). For the population of 400,000 affected by the plan, this represented a cost of just over $3 (U.S.) per person. Development of the WFPP consisted of designation of the well field protection area, installation of monitoring wells, an inventory of existing and potential contaminant sources, and development of legislation.

The annual costs for management of the WFPP consist of approximately $445,000 (U.S.) for personnel and $100,000 (U.S.) for sampling and analysis of monitoring wells.

An important source of support for the WFPP has been the Well Field Protection Fund. The fund is supported through a one dollar surcharge per thousand cubic feet of water usage. The fund has been used to develop a $5 million (U.S.) contingency fund for emergency response purposes, and to make about $3 million (U.S.) a year available for “risk-reduction projects”. Risk reduction projects consist of 1) investigation and cleanup of spills, and 2) provision of grants or loans to the private sector to upgrade their facilities to meet the requirements of the WFPP.

Approximately 30 percent of Dayton’s water-related budget has been funded through federal grants. Dayton also received contributions from local businesses, along with funding through contracts with local jurisdictions (Reference #286).

1.2.8 Effectiveness of Protection Plan

The wellfield protection plan for the City of Dayton is considered to have been very successful. One of the keys to its success was the way in which zoning was based on regulated substances, rather than land use. This resulted in the reduction of over five million pounds of chemicals within the protection area, while at the same time, relatively little negative economic impact was experienced by the business community. Other effective elements included the use of a coordinating committee to successfully achieve consensus among the seven jurisdictions involved; the use of surcharges on the water to generate the wellfield protection fund, and a dynamic personality to spearhead the project. Mr. Douglas “Dusty” Hall, the City's Environmental Protection Manager, provided strong leadership through the promotion and implementation of the plan.

Public education and participation were also considered to be key to the successful implementation of the plan. The City found that when they relaxed their public education programs once the program had begun, some losses in funding occurred.

1.3 Regional Municipality of Waterloo, Ontario

1.3.1 Background

The Regional Municipality of Waterloo (the Region) is comprised of the Tri-Cities of Waterloo, Kitchener and Cambridge, along with the smaller communities of Elmira and

St. Jacobs. The Region, which represents the largest urban area in Canada that depends on groundwater (approximately 375,000 people) (Reference #114), obtains its municipal water supply from an integrated system of both groundwater and surface water supplies. The groundwater component consists of approximately 126 wells, including nine wells adjacent to the Grand River that are supplied through infiltration from the river. Surface water is abstracted from the Grand River and piped overland into the water distribution system. The bulk of the groundwater abstracted in the Cambridge area is derived from Paleozoic carbonate bedrock, while most groundwater abstracted in the Kitchener - Waterloo area is derived from a complex series of Pleistocene outwash sands and gravels interlayered between dense, glacial till.

In response to water supply problems and a groundwater contamination incident which forced the shut-down of wells supplying the Town of Elmira in 1989/1990, the Region retained a consultant (Golder) to assist in the development of a Strategy for Water Resources Protection in 1990. The strategy, which was issued in May 1992 (Reference #170), represented Canada's first comprehensive groundwater protection strategy. The protection strategy consists of eight elements as summarized below:

- water resources identification;
- contamination source identification;
- water quality monitoring and management;
- data management;
- integrated watershed management;
- policies and legislation for water resources protection; emergency preparedness and response; and
- community consultation and awareness.

A series of work plans were developed to facilitate the completion of these tasks. Implementation of the protection strategy will be carried out over the next 10 years.

1.3.2 Objectives

The basic objectives of the Region's strategy to protect water resources are to:

- limit the risk from historic or existing land use practices, and
- to minimize the risk from future land uses.

1.3.3 Groundwater Protection Area

The Region has recently embarked on a program to carry out initial delineation of wellhead protected areas in high priority areas. Detailed delineation of wellhead protection areas for each of the approximately 55 wells/wellfields in the region will be carried out over the period of 1996 through the year 2000. The Region has identified the need to obtain additional information regarding: 1) the location and extent of groundwater resources (particularly in recharge areas); 2) the sensitivity of regional aquifers, and 3) the relationship between surface water and groundwater supplies, prior to the delineation of wellhead protection zones. Reconnaissance-level hydrogeological studies, including capture zone analysis (from long-term well field shut down tests and pumping tests) and mapping of recharge areas, are currently underway to address some of these data gaps. The compilation of hydrogeological information will be aided by a data management system that is currently under development.

1.3.4 Contaminant Inventory

The Region intends to identify and evaluate potential sources of surface and groundwater contamination by means of an initial (reconnaissance-level) inventory of potential sources of contamination currently in progress, followed by a more detailed evaluation of contaminant sources in sensitive areas over the period of 1995 through 2000. Some of the data sources used to compile the contaminant inventory include: reports issued by the provincial government and private consultants; records of waste generators and spills maintained by Ontario Environment; inventories of fuel/oil storage facilities maintained by the Ministry of Consumer and Corporate Affairs; historical records; airphotos; fire insurance maps; well records, and maps showing the location of city sewers.

1.3.5 Groundwater Protection Measures

Development of policies and legislation for the protection of surface and groundwater resources is currently underway and is expected to be completed in 1995. Protection measures that were recommended for consideration in the Strategy for Water Resources Protection include:

- restricting the use of road de-icing chemicals in the immediate vicinity of well fields;
- inspection of storm and especially sanitary sewers to detect and repair significant leaks;
- re-routing vehicle traffic carrying hazardous materials away from the immediate vicinity of the well fields;
- abandoning unused test wells using appropriate procedures; and
- implementation of best management plans where warranted to reduce the likelihood of future contaminant releases from industrial and municipal lands.

Elements that could be considered as general groundwater protection measures that are currently underway, or planned for 1995, include: groundwater monitoring, data management, watershed management, emergency preparedness, and public consultation. These measures are described below.

Groundwater Monitoring and Management

The Region currently conducts monitoring of surface water and groundwater quality and monitors groundwater levels. Expansion of the groundwater monitoring network beyond the existing well fields has been recommended to provide an early warning capability for key parameters that pose a threat to the groundwater supply.

Data Management

Development of a data management system is currently underway as a means of compiling and managing information on water resources, geology, hydrogeology and water quality.

Emergency Preparedness and Response

The Region has an existing emergency plan that addresses a broad range of emergencies. Measures developed for the protection of water resources are being incorporated into the plan on an ongoing basis. The plan consists of measures to respond to emergencies that might threaten water resources; and for emergency water supply in the event that major water supply sources be shut-down because of contamination.

Public Consultation

A community consultation and awareness program was initiated in 1994 with the formation of the Water Resources Protection Liaison Committee. The purpose of public participation is to create awareness of the importance of protecting water resources, to reassure the public that its interests are being protected, and to develop support and participation in implementing the protection strategy. Audiences targeted for consultation include community members, industry, government agencies, environmental advisory and public interest groups, universities and professional affiliations. So far, initiatives towards educating the general public have consisted of open house meetings related to specific projects.

1.3.6 Control Agencies and Staff Requirements

A steering committee that was established in 1990 directed the preparation of the Water Resources Protection Strategy. A Water Resources Protection Liaison Committee was formed in May of 1994 to facilitate implementation of the strategy. The new Liaison Committee is composed of representatives from the Region, area municipalities, government agencies, the local business community, local environmental groups, the local agricultural association and the Waterloo Centre for Groundwater Research. Overall coordination of the groundwater protection strategies is carried out by the Region's Water Resources Protection Group, which consists of a manager, a senior hydrogeologist, two hydrogeologists and a contract hydrogeological technician.

1.3.7 Costs and Sources of Funding

Total expenditures on the Water Resources Protection Strategy over the period of 1990 through 1993 have amounted to 2.58 million dollars. Projected annual costs for protection activities are estimated to be 1.4 million dollars for 1994 and 1995, over $900,000 for 1996 through 1999, over $700,000 for the year 2000, and over $200,000 for the years 2001 through 2003 (Reference #036). For the population of 375,000 affected by the plan, this represents an annual cost of about $3.75 per person. Although the annual costs are significant, they are minimal compared with the multi-million dollar costs of abandoning the well fields and developing an alternative water supply, such as the proposal to construct a full-service pipeline from one of the Great Lakes (Reference #171).

1.3.8 Effectiveness of Protection Plan

The Region has recognized the importance of strong leadership and the need for communication with the public in order to successfully implement the Water Resources Protection Strategy. As the strategy is in its early phases of implementation, the majority of benefit from the measures remain to be realized.

1.4 Amherst, Nova Scotia

1.4.1 Background

The Town of Amherst relies on groundwater to supply water to its population of 9600. In 1983, the Town was forced to abandon two of its former seven production wells when perchloroethylene (PCE) was detected in those wells. The source of the VOCs was found to be related to Dickey Brook, a brook that flows from east to west through Amherst and is hydraulically connected to the aquifer. Dickey Brook receives discharges from industrial sources and from leaking sewer pipes. The PCE was found to originate from the disposal of drycleaning fluid in the Town's sewer system.

In response to concerns over the vulnerability of the Town's aquifer to potential contamination from these and other industrial activities, a groundwater exploration program was carried out over the period of 1985 through 1987 to identify an alternative groundwater supply. The program resulted in the identification and development of a new wellfield (the North Tyndal Wellfield) in a rural area fifteen kilometers northeast of the town. The wellfield is comprised of four production wells completed in interbedded siltstones, shales and fine sandstones of the Pictou Group. The Town of Amherst adopted a groundwater management plan and protection strategy in September 1991 to protect their newly developed wellfield (Reference #242). Implementation of the program began in October 1993 with the official opening of the wellfield.

1.4.2 Objectives

The objective of the protection strategy was to eliminate potential sources of contamination that would impair the quality of the groundwater developed and allow the continual use of the land in the area for non-contaminating activities and uses (Reference #246).

1.4.3 Groundwater Protection Area

The groundwater protection area was delineated on the basis of travel times using a publically available three-dimensional finite difference groundwater flow model developed by the U.S. Geological Survey (MODFLOW). Three zones of protection were designated on the basis of travel times. Zone 1, comprising 1,500 acres, represents the innermost zone and is based on a 10 year delay time; Zone 2, comprising 2,600 acres, represents a 50 year delay time, and Zone 3, comprising 5,200 acres, represents the long-term capture zone of the wellfield.

1.4.4 Contaminant Inventory

An inventory of existing land use and activities was undertaken during the development of the groundwater protection plan as a means of identifying potential sources of contamination. Potential sources of contamination were classified according to the following characteristics: surface or subsurface transmissions to groundwater; point or diffuse distribution; rare, sporadic or continuous release; distance from the well field, and the relative area over which the contaminant may be produced.

1.4.5 Groundwater Protection Measures

The key to Amherst's groundwater protection plan was the development of the new wellfield in a rural area where relatively few potential sources of contamination were present. Steps taken towards the future protection of groundwater within the well field included the acquisition of all land within Zone 1 and the control of activities within all three protection zones. These measures, which were undertaken through the implementation of the provincial Water Act, are described below.

Land Acquisition

Land acquisition was considered to be the most reliable means of protecting the Town's groundwater supply. As a result, the Town of Amherst purchased all of the land within Zone 1 of the protection area. In addition, they presently own approximately 800 acres within Zones 2 and 3 and intend to purchase additional land within these zones as the land becomes available.

Land Use Prohibition

Activities permitted within Zone 1 are restricted to water supply operations and forest management through select cutting. Within Zone 2, only forest resource harvesting and limited recreational activities are permitted, along with public transportation along an adjacent roadway, Tyndal Road. Recreational activities permitted within Zone 2 include hiking, hunting and fishing. Recreational activities that are not permitted within Zone 2 include the use of motorized vehicles such as ATVs, snowmobiles and motorcross, and the construction of structures and facilities such as hunting camps and recreational cottages. Within Zone 3, forestry, low density residential development, agriculture (excluding intensive activities in the form of feedlots and enclosed pig or poultry production), recreation, cemeteries, quarries and borrow pits (subject to provincial regulations) and transportation are permitted.

Forest Management

The groundwater management plan requires that a forest management plan be developed and approved for anyone planning to harvest more that 20 chords of wood from the groundwater protection area. Elements to be incorporated into the forest management plan include the control of activities around streams, restricting cutting to one block at a time, prohibition of whole tree cutting, proper location and construction of haul roads, skid trails and log landings, management to minimize the risk of fire, control of pesticides and herbicides, and posting of performance bonds. Forest harvesting within Zone 1 is restricted to select cutting only.

Biocide Prohibitions

The use of chemical biocides is prohibited in Zones 1 and 2 and restricted in Zone 3 unless the total degradation life (defined by the plan as being equivalent to five half-life reductions) can be scientifically demonstrated to be less than 50 years.

Roadsalt Restrictions

The use of road salt for de-icing along the portion of Tyndal Road that passes through the groundwater protection area is not permitted. The road salt should be replaced with a sand/salt mixture to reduce contaminant potential.

Fire Restrictions

No open fires are permitted within the groundwater protection zone.

Refuse, Waste and Discharge Restrictions

The deposit or discharge of refuse or waste is prohibited within the groundwater protection area. On-site sewage disposal and the disposal of animal waste is permitted within Zone 3.

Storm Water Drainage

Storm water systems affecting the immediate wellfield area should be directed away from the wellfield.

Agricultural Restrictions

Agricultural activities within Zone 3 are subject to controls on manure storage and application, as well as restrictions on livestock capacity. At the present time, only two farms are located within the protection zone. There is a low level of agricultural activity associated with these properties (i.e., one farmer runs a horse riding stable while the second farmer owns one donkey). As a result, there has not yet been a need to exercise agricultural controls.

Surveillance

Surveillance of the groundwater protection zone should be carried out to ensure that the groundwater management plan is being followed.

Public Education

Public awareness was considered to be key to the implementation of the protection plan. Signs were posted along access roads to the protection area and at 50 m intervals around the perimeter of Zone 1. A public information paper (Figure 3) (Reference #246) was released in October 1993 to launch the official opening of the North Tyndal Wellfield.

Monitoring

A long-term surface water and groundwater monitoring program was developed as part of the groundwater protection strategy (Reference #244) for the North Tyndal Wellfield. The program consists of quarterly sampling at seven surface water stations and annual sampling at nine groundwater monitoring well locations. Samples are to be tested for general chemistry, metals, volatile organic compounds (VOCs) and pesticides.

Spill Response

A detailed contingency plan that makes provisions for a rapid response to accidental spills of dangerous goods within the protected area was prepared (Reference #245). The contingency plan includes information regarding team leader responsibilities, reporting procedures, available resources and operational methods.

1.4.6 Control Agencies and Staff Requirements

Management of the groundwater protection zone is shared by the Town of Amherst, the Municipality of Cumberland County and the Province of Nova Scotia, with the execution of management functions conducted principally by the Amherst Water Utility. A Wellfield Advisory Committee was established by the councils of the Town of Amherst and the Municipality of the County of Comberland to advise the two councils on policy issues.

1.4.7 Costs and Sources of Funding

According to Amherst's Utility Manager, Mr. Ben Pitman, costs of the development of the groundwater management plan were approximately $200,000. This included consultants fees, survey costs, legal fees, staff time and expenses. It is understood that the Town has spent an estimated 6.5 million dollars for development of the new water supply system. Approximately $300,000 of this was used to purchase land within the groundwater protection zone, while the remainder was used to fund the water supply system piping and infrastructure. The provincial government provided about half of the funding for the development of the groundwater management plan and a quarter of the funding for the new water supply system. The remainder of the costs were covered by a fund generated from water rates. Currently, each household pays approximately $180 per year for its water.

1.4.8 Effectiveness of Protection Plan

The Town of Amherst reports that it is pleased with its newly developed groundwater protection plan. One of the keys to the successful implementation of the plan was the Town's ability to develop a new wellfield in a rural area and to control land use in that area through land acquisition. The use of signage along roads and around the perimeter of the protection area is considered to have been an effective means of raising public awareness.

1.5 South Fredericton Aquifer, New Brunswick

1.5.1 Background

The City of Fredericton, New Brunswick obtains over 95 percent of its water supply for its population of some 45,000 people from seven production wells completed in the South Fredericton Aquifer. The South Fredericton Aquifer is situated beneath the City and the adjacent Saint John River. It is comprised of glacial outwash sands and gravels that are partially confined by an overlying deposit of glaciolacustrine silt and clay, which is in turn covered by alluvium. A protection study for the South Fredericton Aquifer was recently carried out by Gemtec Limited on behalf of the New Brunswick Department of Environment and the City of Fredericton (Reference #030). A series of groundwater protection measures are proposed for the South Fredericton Aquifer that have yet to be finalized and implemented.

1.5.2 Objectives

The intent of the groundwater protection study was to designate an appropriate protection area and to institute the required controls to adequately protect the aquifer from contamination and from unregulated withdrawals.

1.5.3 Groundwater Protection Area

Three protection areas were delineated based on travel times to production wells, the presence or absence of the confining clay layer and the location of specific property lines. The locations of these areas are shown in Figure 1.

1.5.4 Contaminant Inventory

An inventory of past and present land use and chemicals associated with this land use was carried out as part of the protection study. Sources of information used included a field survey to identify fuel oil users, NBGIC property mapping and associated database, a literature review, an investigation of former land uses, a residential home heating oil survey and Department of the Environment records of petroleum storage tank locations.

1.5.5 Proposed Groundwater Protection Measures

Hazardous Materials Restrictions

Once finalized, the aquifer protection regulations will be exercised under the Clean Water Act (Province of New Brunswick, 1990) and administered by New Brunswick Environment. The basis of the proposed aquifer protection regulations is limiting the quantity and type of chemicals within the protection area rather than placing restrictions on land use. It has been proposed that chlorinated solvents not be permitted in the groundwater protection areas and that petroleum hydrocarbons, organic liquids and pesticides and preservatives be subjected to varying degrees of control. Requirements regarding the type and quantity of chemicals that may be stored and used within the groundwater protection zones will result in some businesses (two dry cleaning establishments and two bulk storage facilities) having to relocate. Businesses allowed to remain within protection zones will be subject to conditions and restrictions such as the use of alternative chemicals or compounds, and/or requirements for monitoring, record keeping and the use of secondary containment and warning systems.

Sunset Clauses

The use of "sunset clauses" in the case of non-complying uses will be used to set time limits by which regulations must be met. This will ease the financial burden on the owner and allow time for alternative solutions to be pursued.

Application and Permitting

An application and permitting system will likely be developed to provide a mechanism by which aquifer protection regulations would be triggered for building permits and rezonings.

Enforcement and Inspection

Random inspections and enforcement will be required to ensure that activities are operated in an acceptable manner with regard to aquifer protection and to ensure that allowable quantities of chemicals are not exceeded on the property.

Public Education

The federal government is currently funding an "On-Site" program which is aimed at helping unemployed professionals seek employment in the environmental field. The City of Fredericton has hired a former health inspector under this program to head up their public awareness campaign. The health inspector helps to educate and inform the public on a one-to-one basis by phone and site visits. Other public education methods that may be used in the future include (Reference #030):

- newspapers, television and radio articles and features;
- distribution of promotional literature, maps and regulations to households through mail delivery, water and sewer bills;
- promotion of dangerous chemical collection or disposal days or locations;
- provision of signs at strategic locations to educate people of the sensitive nature of the area they are entering; and
- an information line could be set up to respond to residents' questions regarding the aquifer protection program and how to properly dispose of any contaminants they may possess.

Compensation for Non-Complying Land Use

Consideration is currently being given to compensating two dry cleaning businesses that are required to relocate outside of the protection areas. Possible solutions include purchase of the properties by the City or the province, providing compensation, or a trade of lands owned by the City in exchange for the non-complying property.

The use of satellite warehouse operations located outside of the protected zone and the use of empty or limited containers in the store to provide customers with information on the products was suggested as a means of helping chemical storage facilities to comply with the requirements.

Training Programs

Owners, employees and shipping companies may be required to participate in training courses that provide information on acceptable methods for handling, storing, disposal and transportation of chemicals.

Heating Oil Tanks

Existing heating oil tanks within Protection Zone 1 must be removed or replaced within a certain time frame. Conversion to alternative heating methods may be encouraged through incentive assistance programs.

Guidelines for Storage and Disposal of Chemicals Generated by Service Stations

Recommendations were made to develop guidelines for service stations for the storage and disposal of car-care products such as antifreeze, solvents and other compounds.

Transportation Controls

A designated truck route has been recommended for the transport of hazardous chemicals through Fredericton. Implementation of the truck route may be carried out by the Department of Transport, in cooperation with the Ministry of the Environment and the City. For trucks that must travel within the protected area, provisions may be made for reduced speed limits, posting of warning signs, and attending promptly to road maintenance and repairs.

Storm Sewers

The City of Fredericton has embarked on a program to upgrade and repair their existing storm sewers and damaged or leaking catch basins and pipes. These actions will reduce the risk of aquifer contamination by storm water runoff.

Residential Compliance

Recommendations were made to investigate the storage and use of chemicals in residential areas by means of a questionnaire sent with water and sewer bills to all homeowners. Inspection and monitoring could be carried out where a contaminant was suspected or where the questionnaire indicated contaminants existed.

Monitoring

Currently, bacteriological testing is carried out on a monthly basis from each of the seven production wells, fifteen standby wells and 26 other locations within the distribution system. In addition, 29 locations, including all existing and potential raw water sources, are sampled annually for both organic and inorganic chemical analysis. More frequent sampling of a number of strategically located monitoring wells for organic analysis is recommended.

Spill Response

It was recommended that the City of Fredericton ensure that their emergency response personnel are trained in emergency response procedures for chemical spills in the specific context of aquifer protection.

1.5.6 Control Agencies and Staff Requirements

Implementation of the aquifer protection plan will be carried out by the City under their Community Planning Act, with input from the provincial Department of Environment. The Province will be largely responsible for the administration and enforcement and the City will provide some administration, inspection services and public education programs.

1.5.7 Costs and Source of Funding

The cost incurred for the development of the groundwater protection plan was on the order of $80,000. Based on a population of some 45,000 affected by the plan, this resulted in a cost of less than $2 per person. Funding was provided on an equal cost-sharing basis by the City of Fredericton and province.

1.5.8 Effectiveness of Protection Plan

The proposed protection plan for the South Fredericton Aquifer has yet to be implemented, and therefore can not be fully evaluated as of yet. Based on discussions with the Department of the Environment, the Clean Water Act grants the province significant powers to impose groundwater protection measures. While the control of hazardous substances is an effective way to protect groundwater, the province has experienced difficulties addressing the issue of existing non-complying uses. For example, under the protection plan for the South Fredericton Aquifer, the use of chlorinated solvents is incompatible with the operation of a municipal water supply. As a result, there are two dry cleaning establishments within the protection area which must be re-located. The province is currently grappling with the issue of how these businesses should be compensated. Originally, the protection plan also required that two gas stations be relocated. The two gas stations subsequently closed or re-located their operations on their own accord over the course of the study oncy they realized the implications of the impending protection plan.

1.6 Regina Region Aquifers, Saskatchewan

1.6.1 Background

Approximately 35 percent of the City of Regina's drinking water supply is derived from groundwater. Some local industries, farmers and rural home owners in surrounding communities depend on this groundwater resource for their entire needs (Reference #020). Groundwater is obtained from a complex series of five interconnected aquifers (the Regina Region Aquifers) formed by the deposition of sands and gravels in a collapse structure during the most recent periods of glaciation (Reference #283).

In 1987, the City of Regina, together with Saskatchewan Environment, Saskatchewan Research Council and the Saskatchewan Water Corporation, formed the Regina Groundwater Technical Committee (Reference #283). Since that time, the committee has helped to facilitate several initiatives towards aquifer assessment and protection. Efforts towards the development of a groundwater protection plan for the City of Regina were initiated with the commissioning of a Regina Aquifers Sensitivity Mapping and Land Use report by Saskatchewan Environment in 1990 (Reference #021). In addition, an Allocation Plan was developed on behalf of Saskatchewan Water Corporation in 1989 (Reference #020). Development of the aquifer management plan was initiated in 1993 and is still underway.

1.6.2 Objectives

The purpose of the Regina Aquifers Sensitivity Mapping and Land Use study was to map sensitive lands over the aquifers, to review the effectiveness of the existing legislation and control mechanisms currently in place, and to develop guidelines for protecting the aquifer from contamination.

1.6.3 Groundwater Protection Area

The City of Regina used sensitivity mapping to identify areas to be addressed by their aquifer management plan. As described in the Regina Aquifers Sensitivity Mapping and Land Use report, sensitivity mapping was considered more appropriate for the Regina Aquifers than the more classical wellhead protection approach for several reasons:

- “it recognizes the significance of protecting groundwater recharge areas in addition to wellhead areas;
- it lends itself to future applications in regional land use planning;
- delineating wellhead protection areas for each of the 1400 wells in the study area is not viable from a regional perspective;
- the geology of the Regina area is complex, making wellhead protection cumbersome; and
- sensitivity mapping is becoming the preferred approach for regional studies by other jurisdictions.”

Regina's aquifers were classified into four sensitivity categories (extreme, high, moderate, low), and one category of unknown sensitivity, based on the thickness and permeability of surficial materials overlying the aquifer outlined below (Figure 14).

Extreme - a major aquifer is present which extends to surface and has no protective clay or till overburden; or, a major aquifer is present beneath 0 to 5 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material.

High - a major aquifer is present beneath 0 to 5 metres of protective clay or till overburden; or, a major aquifer is present beneath 5 to 10 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material; or, a major aquifer has not been mapped but surficial sands are present which may form local unconfined aquifers of limited extent.

Moderate - a major aquifer is present beneath 5 to 10 metres of protective clay or till overburden; or, a major aquifer is present beneath no less than 10 metres of undifferentiated overburden of which the upper portion consists of silty or sandy material.

Low - a major aquifer is present beneath no less than 10 metres of protective clay or till overburden.

Unknown - no major aquifers have been mapped and the surficial material is clay or till offering a protective cover of unknown thickness; minor aquifers may be present but have not been mapped; more test hole data and mapping is required to better assess the sensitivity of these areas; at most locations sensitivity is expected to be low.

Sensitivity maps were generated using spatial analysis software (SPANS) to analyze and amalgamate existing “depth to aquifer” and geological source maps.

1.6.4 Contaminant Inventory

An inventory was carried out to identify transportation facilities, urban areas, industrial areas, sewage lagoons and landfill sites located over the Regina Aquifers. Land use activities were compiled from planning and zoning maps, rural municipality maps and 1:50,000 National Topographic Series (NTS) maps. Sewage lagoons and locations were compiled from records maintained by Saskatchewan Environment.

1.6.5 Groundwater Protection Measures

The Regina Aquifers Sensitivity Mapping and Land Use report recommended several groundwater protection measures and provided a review of existing provincial and local legislation and control mechanisms that could be used to implement those measures. A summary of the recommended groundwater protection measures is provided below.

Land Use Controls

Industrial, urban, rural, agricultural, transportation and waste management land use activities within City limits are legislated through the implementation of the “Aquifer Overlay Zone” created by ammending the City’s zoning bylaws. Efforts are still underway to address land use controls in rural areas and communities outside of the City limits.

Above-Ground and Underground Storage Tanks

The use of above-ground and underground storage tanks (USTs) is prohibited in highly sensitive areas. Liners and dykes should be used for above ground storage tanks and secondary containment and leak detection systems should be used for USTs in less sensitive areas.

Chemical Use

The use of hazardous materials and/or hazardous liquids is restricted, depending on the existing land use and sensitivity zone.

Excavations

In areas where protective overburden is thin (5 metres or less), common excavation practices such as constructing basements, trenches, road ditches and land levelling can significantly affect aquifer sensitivity by altering drainage patterns and causing ponding of water which may lead to unwanted recharge. Excavations should be kept to a minimum in highly sensitive zones and restricted to less than 5 metres in less sensitive zones.

Waste Containment

The use of liners is recommended for containment of landfills, sewage lagoons and waste storage areas in sensitive zones.

Road Salt and Manure

The application of road salt and manure must be avoided in sensitive areas and minimized in areas where overburden is thin.

Private Sewage

Holding tanks, rather than underground disposal, must be used in areas where there is no protective overburden.

Stormwater Runoff

Stormwater runoff from agricultural, rural, urban and industrial land uses must be controlled or possibly contained and treated, depending on the source of discharge and the sensitivity zone.

Spills

Spills in sensitive areas must be cleaned up (i.e., excavated) immediately.

Sealing of Wells and Testholes

Wells and testholes drilled for both water supply and geotechnical purposes must be properly abandoned in all areas by sealing the excavations with grout.

Monitoring

Design and implementation of a monitoring system was recommended as a means of providing early detection of spills and contamination. Saskatchewan Environment is currently developing a monitoring plan and database. Monitoring includes groundwater sampling, soil testing and maintaining inventories of substances received, stored or disposed.

1.6.6 Control Agencies and Staff Requirements

One of the key elements of the aquifer management plan that still must be addressed is the creation of an aquifer management body. The creation of an independent aquifer management body is required to facilitate implementation by the City of Regina and the two other rural municipalities affected by the plan. It is our understanding that while the City of Regina has adopted the plan and is commencing implementation, the protection plan has not been accepted by the two rural municipalities.

1.6.7 Costs and Sources of Funding

The province spent some $200,000 over a three to four year period for a water quality study and the development of an Allocation Plan and the Regina Aquifers Sensitivity Mapping and Land Use report.

1.6.8 Effectiveness of the Plan

Regina's plan has the potential to be very effective provided that a cooperative spirit and public awareness can be realized. One aspect of the development of the Regina protection plan that was apparently unsuccessful was that the plan was developed using a "chain approach" rather than a "team approach". As an example, at times documents were transferred from hydrogeologists to planners to lawyers with little interaction between groups. This resulted in the development of a 600-page document that is considered by some to be cumbersome and lacking in clarity and purpose. Efforts are currently underway to revise the management plan to make it a more workable document.

Another unsuccessful aspect of the Regina protection plan was that while the City of Regina adopted the plan and incorporated protection measures into its zoning bylaws, the plan was not accepted by the two nearby rural municipalities. As a result, certain industries that do not comply with Regina's new zoning bylaws are relocating to the two rural municipalities where no groundwater protection measures are in place. Some parts of these rural municipalities are located in highly sensitive recharge areas. The rural municipalities argue that implementation of groundwater protection measures would result in job losses. In retrospect, better cooperation between the City of Regina, the two rural municipalities and two provincial government departments may have been achieved through the creation of an independent aquifer management body, and/or through increased public awareness.

1.7 Spokane, Washington

1.7.1 Background

The Rathdrum Prairie - Spokane Valley Aquifer covers nearly 400 square miles in northern Idaho and eastern Washington and is a source of drinking water for nearly 400,000 people. The aquifer, which exhibits exceptionally high flow rates, is comprised of unconfined, coarse gravel. This, and the relatively shallow watertable, make the aquifer highly vulnerable to contamination. The Spokane Water Quality Management Plan was initiated in 1977 in response to citizen concerns regarding the spread of urbanization and the potential for groundwater contamination associated with development.

Implementation of the plan was facilitated following federal designation of the Rathdrum Prairie - Spokane Valley Aquifer as a “sole source” aquifer. The Sole Source Aquifer (SSA) program is a federal project that allows a community to petition the EPA to designate an aquifer as the sole or principle drinking water source for an area where there are no reasonably available alternative sources should the aquifer become contaminated. The primary benefit of the SSA designation is that proposed federal financially-assisted projects that have the potential to contaminate the aquifer are subject to U.S. EPA review. The SSA designation also helps to increase public awareness, enhances the communities ability to receive state funding, and allows the community to receive technical support from the EPA.

The Spokane Water Quality Management Plan represents one of the first groundwater protection programs in the United States (Reference #086). Protection efforts in Spokane apparently have been in place for so long that they have blended into the background, rather than being perceived as a specific program or effort (Reference #286).

1.7.2 Objectives

The two basic objectives of the Water Quality Management Plan are:

1) Non-degradation –water quality should not change over the long-term from 1977-8 levels; and

2) All contaminants should be controlled at their source of generaton – eliminate, rather than control the problem. For example, eliminate the use of chemicals or move facilities using them away from the aquifer to control the consequences of spills (Reference #286).

1.7.3 Contaminant Inventory

Prior to development of the Water Quality Management Plan, a groundwater monitoring program was carried out to identify groundwater quality trends and potential contaminant sources. The study included monitoring of over 100 wells and analyses of over 1000 groundwater samples. The results of the program indicated that about 60 percent of the contaminants reaching the aquifer were from sanitary waste discharges, 30 percent from storm water runoff and 10 percent from other sources such as household chemical disposal. This information was used to determine the appropriate level of effort required by the groundwater management plan to address the potential contaminants of concern.

1.7.4 Groundwater Protection Measures

The Water Quality Management Plan contains almost 200 recommendations for achieving their objectives. Based on the results of the contaminant inventory, the aquifer management plan was directed towards the control of sewer construction and storm water management. Chemical storage and leaking underground tanks were also targeted for action, along with the control of the impact of chemical releases during chemical transport.

Zoning and Land Use

Spokane County adopted an Aquifer Sensitive Area overlay zone to regulate land use, stormwater, on-site septic systems, and critical materials in the sensitive area. An important feature of the land use plan was to encourage development to locate in areas that were expected to be supplied with sewer service within the next 10 years (Reference #286).

Wastewater Management

A comprehensive Wastewater Management Plan was developed to coordinate the use of centralized collection and treatment facilities and on-site wastewater disposal in the urbanizing areas. Development of this plan required cooperation and agreement between the City of Spokane and Spokane County. Efforts are underway to extend sewer services to unincorporated areas on a priority basis. In areas of new development where connection to the sewer was not economically feasibile, a design-construction ordinance allowed such development to be constructed with interim septic systems, but also required that they be constructed with dry line sewers so the houses could be connected to public sewers when they became available (Reference #286).

Stormwater Management

Both the County and the City of Spokane adopted guidelines for stormwater management. These included specified construction practices for stormwater control in new developments and requirements that all developed land in the Aquifer Sensitive Area incorporate stormwater runoff treatment facilities if deemed feasible by the County engineer (Reference #286).

Hazardous Material Control

The County enacted an ordinance establishing procedures for the handling and disposal of hazardous materials used by businesses, industries and residents located over the aquifer. The ordinance requires that facilities handling such materials be connected to a control sewer system, or alternatively, employ disposal measures such sealed lagoons, holding tanks, licensed haulers, or have a permit to discharge to surface water. The ordinance also requires that facilities be designed to ensure control of any spills (Reference #286).

Public Education

Public education was considered to be an important element of the groundwater protection plan. Most efforts toward public education during the development of the plan were initiated by the Citizen Committee. The committee met with some 200 different groups to provide information about the plan, and hosted a call-in show on local television to inform the public.

Now that the plan is underway, major emphasis on citizen education is planned for the next few years as a means of raising the awareness level of new people moving into the area. On-going education efforts include the development of information materials, developing materials for use in schools, and newspaper advertising, radio spots and bus placards (Reference #286).

Groundwater Monitoring

Groundwater monitoring of 50 water supply wells is carried out on a quarterly basis for potability parameters and VOCs, and on a semi-annual basis for toxic metals. The monitoring results are reviewed by the technical advisory committee (Reference #286).

1.7.5 Control Agencies and Staff Requirements

The Water Quality Management Plan was developed by Spokane County with participation by the City of Spokane and input from a Citizen’s Representatives Core Committee (CRC) consisting of some 40 members, and a Technical Advisory Committee comprised of other local and state agencies. After the plan was developed, an Aquifer Protection Implementation Office was formed in 1980 to supply staff support and technical expertise for the implementation of the Water Quality Management Plan. The office is currently located in the Division of Engineering and Roads of the Spokane County Public Works Department and has is staffed by two full-time and one part-time people. The office helped to coordinate the efforts of the 26 federal, state and local agencies that were involved in the implementation of the plan.

1.7.6 Costs and Sources of Funding

The cost of developing of the Water Quality Management Plan was about $600,000 (U.S.). For the population of 400,000 affected by the plan, this represented a cost of approximately $1.50 (U.S.) per person. The cost of running the Aquifer Protection Implementation Office is approximately $200,000 (U.S.) per year and the groundwater monitoring program amounts to about $100,000 (U.S.) per year. Some $14 million (U.S.) has also been spent on the construction of a wastewater interceptor system.

The Aquifer Protection Implementation office is funded jointly by the City of Spokane and Spokane County through a new County Aquifer Protection Area taxing district, with additional support from the State Department of Ecology. The area has also received federal funding related to the sole source aquifer of up to $1 million per year. Some of this funding has been used to support the implementation of the groundwater management plan, including public education aspects. Other amounts have been passed through to other agencies to help fund the inspection and enforcement of UST regulations and to develop and implement chemical storage regulations. The funds have also been used to develop a better understanding of the aquifer through geographic mapping and seismic surveys (Reference #286).

1.7.7 Effectiveness of Protection Plan

One element of the Spokane Water Quality Management Plan that was considered to be particularly successful was determining the relative impacts of contaminant sources as a means of identifying the appropriate level of protection measures required. As a result of this assessment, Spokane has made an extensive effort to extend the area served by public sewer systems in addition to regulating the location and density of developments using on-site systems. Another successful element of the Plan was the cooperation achieved between Spokane County, the City of Spokane and other jurisdictions, including representatives from the State of Idaho, which is also served by the aquifer. Plan recommendations were presented in general terms so that various local government could adapt them to their particular situations (Reference #286). Another successful element was the recognition of the need for on-going public education to raise the awareness of citizens who recently moved into the protection area. A unique feature of

Spokane’s program was the creation of a new county taxing district for the aquifer protection area (Reference #286).

1.8 Regional Municipality of Peel, Ontario

1.8.1 Background

The Town of Caledon, which is located west of the City of Toronto within the Regional Municipality of Peel, relies on groundwater to service several hamlets and communities in the area. A water resources study for the Town of Caledon was carried out from 1988 to 1992. The study found the groundwater quality of the area to be generally acceptable, but identified a number of municipal wells where increasing nitrate concentrations were observed. Based on these results, a wellhead protection area study for the Town of Caledon was initiated by the Region of Peel in 1992. The study is comprised of four components:

- municipal well inventory and contaminant source inventory
- computer modelling of wellhead areas
- delineation of protection areas
- implementation and contingency planning

Computer modelling of wellhead areas is currently being completed. The next step will involve the delineation of protection areas and the development of policies and guidelines that will be integrated into the Region's Official Plan. Implementation and contingency planning is expected to be underway in 1995. Funding for the program is being provided by the Region.

1.8.2 Effectiveness of Protection Plan

Based on discussions with the Region’s consultant, one of the most important lessons learned over the course of the project was the importance of public education. At the start of their public education campaign, the Region found that there was little public interest in the wellhead protection plan, possibly due to the perceived lack of problems with the groundwater quality in the area. Because of poor attendance at open-house meetings, it was necessary for the Region to become more proactive to solicit public support through participation in major County fairs and exhibitions. The response of the public to displays at these events was considered very positive. The Region is now considering the benefits of communicating the program to the local schools in the study area.

1.9 Palm Beach County, Florida

1.9.1 Background

Approximately 80 percent of Palm Beach County's potable water supply is obtained from groundwater derived from shallow, unconfined aquifers. The water wells are operated by various public and private utilities. Although Palm Beach County supports largely urban and agricultural land use, rather than industrial activity, 37 of its water wells have been lost due to contamination. A wellfield protection plan was initiated to protect groundwater from contamination due to the use, handling or production of hazardous and toxic materials.

The plan consists of the establishment of four zones around each wellfield. Zones I, II and III are based on travel times, while the outer boundary of Zone IV corresponds to the one-foot (0.3 m) drawdown contour of the water table resulting from normal groundwater pumping. Activities within each zone are controlled by the reduction of hazardous and toxic materials (regulated substances). In general, Zone 1 is a zone of prohibition, Zone 2 is a zone of secondary containment and groundwater monitoring, Zone 3 is a zone of secondary containment and Zone 4 is a zone of daily monitoring of regulated substances. Other aspects of the plan include closure of floor drains and infiltration trenches, pressure testing of storm sewers, groundwater monitoring, and inspection.

1.9.2 Effectiveness of Protection Plan

So far, 478 of the present and proposed wells and 42 wellfields have been placed under the wellfield protection program. Under the program, over three million U.S. gallons (13 million litres) of regulated substances and 118 pollutant storage tanks were either removed or were subjected to controls such as secondary containment and monitoring. Approximately 300 facilities elected to exempt themselves from the permitting requirements of the program by reducing the amount of regulated substances handled by the facilities to volumes below an established threshold of five U.S. gallons (19 litres) or 25 pounds (11 kg).

One of the keys to the success of the wellfield protection plan was a referendum that granted the County the power to enforce the program. Public education and media support were also essential to the success of the plan. County staff who are involved in the implementation of the protection plan spend about 30 percent of their time on public education programs. Also important to the success of the plan was the omission of grandfather clauses that would otherwise allow non-complying uses to continue.

One unsuccessful element of the protection plan was that the State of Florida hindered the County's efforts by not allowing the County to have jurisdiction over underground storage tanks. Another reported problem was that the County did not secure a continuous source of funding for the groundwater protection program.

1.10 Long Island, New York

1.10.1 Background

Long Island, New York has a long history of groundwater protection. Its groundwater protection strategy is based on “Plan 208”, which was completed in 1978 and designates eight hydrogeological zones in Nassau and Suffolk Counties. The focus of the groundwater protection strategy is the protection of groundwater recharge areas rather than the wellhead. Relatively undeveloped portions of the deep flow recharge zones have been identified where there is an opportunity to preserve ambient water quality through land use controls and management practices. Consideration is being given to establishing a water surcharge to fund acquisition of critical watershed areas. Other recommendations include the transfer of development rights in conjunction with the use of zoning, clustering, and control of siting of public utilities.

1.10.2 Effectiveness of Protection Plan

Keys to the success of the Long Island Protection Strategy include:

- the program was designed by local people to meet local needs;
- there was cooperation and consensus among federal, state, and county agencies;
- there was appropriate leadership and a long-term commitment by individuals and organizations involved;
- public education was achieved through the media and schools to generate support;
- existing programs were adapted where possible;
- an infrastructure and incentives were put into place to encourage voluntary compliance.

APPENDIX IV

GROUNDWATER PROTECTION MEASURES COMPILED BY OTHERS

Table IV-1
Groundwater Protection Measures Summarized by a Consultant for the United States Environmental Protection Agency

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Regulatory: Zoning				
Overlay GW Protection Districts	Used to map WHPAs. Provides for identification of sensitive areas for protection. Used in conjunction with other tools that follow.	Community identifies WHPAs on practical base/zoning map.	Well accepted method of identifying sensitive areas. May face legal challenges if WHPA boundaries are based solely on artibrary delineation.	Requires staff to develop overlay map. Inherent nature of zoning provides "grandfather" protection to pre-existing uses and structures
Prohibition of Various Land Uses	Used within mapped WHPAs to prohibit known ground-water contaminants and uses that generate contaminants.	Community adopts prohibited uses list within their zoning ordinance.	Well recognized function of zoning. Appropriate technique to protect natural resources from contamination.	Requires amendment to zoning ordinance. Requires enforcement by both visual inspection and on-site investigations.
Special Permitting	Used to restrict uses within WHPAs that may cause ground-water contamination if left unregulated.	Community adopts special permit "thresholds" for various uses and structures within WHPAs. Community grants special permits for "threshold" uses only if ground water quality will not be compromised.	Well recognized method of segregating land uses within critical resource areas such as WHPAs. Requires case-by-case analysis to ensure equal treatment of applicants.	Requires detailed understanding of WHPA sensitivity by local permit granting authority. Requires enforcement of special permit requirements and on-site investigations.
Large-Lot Zoning	Used to reduce impacts of residential development by limiting numbers of units within WHPAs.	Community "down zones" to increase minimum acreage needed for residential development.	Well recognized perogative of local government. Requires rational connection between minimum lot size selected and resource protection goals. Arbitrary large lot zones have been struck down without logical connection to Master Plan or WHPA program.	Requires amendment to zoning ordinance.
Transfer of Development Rights	Used to transfer development from WHPAs to locations outside WHPAs.	Community offers transfer option within zoning ordinance. Community identifies areas where development is to be transferred "from" and "to".	Accepted land use planning tool.	Cumbersome administrative requirements. Not well suited for small communities without significant administrative resources.

From: The Basis of Groundwater Regulation by J. Witten, in Planning, June, 1992

Table IV-1
Groundwater Protection Measures Summarized by a Consultant for the United States Environmental Protection Agency

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Cluster/PUD Design	Used to guide residential development outside of WHPAs. Allows for "point source" discharges that are more easily monitored.	Community offers cluster/PUD as development option within zoning ordinance. Community identifies areas where cluster/PUD is allowed (i.e. within WHPAs).	Well accepted option for residential land development.	Slightly more complicated to administer than traditional "grid" subdivision. Enforcement/inspection requirements are similar to "grid" subdivision.
Growth Controls/Timing	Used to time the occurence of development within WHPAs. Allows communities the opportunity to plan for wellhead delineation and protection.	Community imposes growth controls in the form of building caps, subdivision phasing or other limitation tied to planning concerns.	Well accepted option for communities facing development pressures within sensitive resource areas. Growth controls may be challenged if they are imposed without a rational connection to the resource being protected.	Generally complicated administrative process. Requires administrative staff to issue permits and enforcement growth control ordinances.
Performance Standards	Used to regulate development within WHPAs by enforcing predetermined standards for water quality. Allows for aggressive protection of WHPAs by limiting development within WHPAs to an accepted level.	Community identifies WHPAs and establishes "thresholds" for water quality.	Adoption of specific WHPA performance standards requires sound technical support. Performance standards must be enforced on a case-by-case basis.	Complex administrative requirements to evaluate impacts of land development within WHPAs.
Regulatory: Subdivision Control				
Drainage Requirements	Used to ensure that subdivision road drainage is directed outside of WHPAs. Used to employ advanced engineering designs of subdivision roads within WHPAs.	Community adopts stringent subdivision rules and regulations to regulate road drainage/runoff in subdivisions within WHPAs.	Well accepted purpose of subdivision control.	Requires moderate level of inspection and enforcement by administrative staff.

From: The Basis of Groundwater Regulation by J. Witten, in Planning, June, 1992

Table IV-1
Groundwater Protection Measures Summarized by a Consultant for the United States Environmental Protection Agency

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Regulatory: Health Regulations				
Underground Fuel Storage Systems	Used to prohibit underground fuel storage systems (UST) within WHPAs. Used to regulate UST's within WHPAs.	Community adopts health/zoning ordinance prohibiting UST's within WHPAs Community adopts special permit or performance standards for use of UST's within WHPAs.	Well accepted regulatory option for local government.	Prohibition of UST's require little administrative support. Regulating UST's require moderate amounts of administrative support for inspection follow-up and enforcement.
Privately-Owned Wastewater Treatment Plants (Small Sewage Treatment Plants)	Used to prohibit Small Sewage Treatment Plants (SSTP) within WHPAs.	Community adopts health/zoning ordinance prohibiting SSTP's within WHPAs. Community adopts special permit or performance standards for use of SSTP's within WHPAs.	Well accepted regulatory option for local government.	Prohibition of SSTP's require little administrative support. Regulating SSTP's require moderate amount of administrative support for inspection followup and enforcement.
Septic Cleaner Ban	Used to prohibit the application of certain solvent septic cleaners within WHPAs, a known ground water contaminant.	Community adopts health/zoning ordinance prohibiting the use of septic cleaners containing 1,1,1-Trichloroethane or other solvent compounds within WHPAs.	Well accepted method of protecting ground water quality.	Difficult regulation to enforce even with sufficient administrative support.
Septic System Upgrades	Used to require periodic inspection and upgrading of septic systems.	Community adopts health/zoning ordinance requiring inspection and, if necessary, upgrading of septic systems on a time basis (i.e. every 2 years) or upon title/property transfer.	Well accepted purview of government to ensure protection of ground water.	Significant administrative resources required for this option to be successful.
Toxic and Hazardous Materials Handling Regulations	Used to ensure proper handling and disposal of toxic materials/waste.	Community adopts health/zoning ordinance requiring registration and inspection of all businesses within WHPA using toxic/hazardous materials above certain quantities.	Well accepted purview of government to ensure protection of ground water.	Requires administrative support and on-site inspections.

From: The Basis of Groundwater Regulation by J. Witten, in Planning, June, 1992

Table IV-1
Groundwater Protection Measures Summarized by a Consultant for the United States Environmental Protection Agency

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Private Well Protection	Used to protect private on-site water supply wells.	Community adopts health/zoning ordinance to require permits for new private wells and to ensure appropriate well to septic system setbacks. Also requires pump and water quality testing.	Well accepted purview of government to ensure protection of ground water.	Requires administrative support and review of applications.
Non-Regulatory: Land Transfer and Voluntary Restrictions				
Sale/Donation	Land acquired by a community within WHPAs, either by purchase or donation. Provides broad protection to the ground water supply.	As non-regulatory technique, communities generally work in partnership with non-profit land conservation organizations.	There are many legal consequences of accepting land for donation or sale from the private sector, mostly involving liability.	There are few administrative requirements involved in accepting donations or sales of land from the private sector. Administrative requirements for maintenance of land accepted or purchased may be substantial, particularly if the community does not have a program for open space maintenance.
Conservation Easements	Can be used to limit development within WHPAs.	Similar to sales/donations, conservation easements are generally obtained with the assistance of non-profit land conservation organization.	Same as above.	Same as above.
Limited Development	As the title implies, this technique limits development to portions of a land parcel outside of WHPAs.	Land developers work with community as part of a cluster/ PUD to develop limited portions of a site and restrict other portions, particularly those within WHPAs.	Similar to those noted in cluster/ PUD under zoning.	Similar to those noted in cluster/ PUD under zoning.
Non-Regulatory: Monitoring	Used to monitor ground water quality within WHPAs.	Communities establish ground water monitoring program within WHPA. Communities require developers within WHPAs to monitor ground water quality downgradient from their development.	Accepted method of ensuring ground water quality.	Requires moderate administrative staffing to ensure routine sampling and response if sampling indicates contamination.

From: The Basis of Groundwater Regulation by J. Witten, in Planning, June, 1992

Table IV-1
Groundwater Protection Measures Summarized by a Consultant for the United States Environmental Protection Agency

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Contingency Plans	Used to ensure appropriate response in cases of contaminant release or other emergencies. within WHPA.	Community prepares a contingency plan involving wide range of municipal/county officials.	None	Requires significant up-front planning to anticipate and be prepared for emergencies.
Hazardous Waste Collection	Used to reduce accumulation of hazardous materials within WHPAs and the community at large.	Communities, in cooperation with the state, regional planning commission, or other entity, sponsor a "hazardous waste collection day" several times per year.	There are several legal issues raised by the collection, transport and disposal of hazardous waste.	Hazardous waste collection programs are generally sponsored by government agencies, but administered by a private contractor.
Non-Regulatory: Public Education	Used to inform community residents of the connection between land use within WHPAs and drinking water quality.	Communities can employ a variety of public education techniques ranging from brochures detailing their WHPA program to seminars to involvement in events such as hazardous waste collection days.	No outstanding legal considerations.	Requires some degree of administrative support for programs such as brochure mailing to more intensive support for seminars and hazardous waste collection days.
Legislative:				
Regional WHPA Districts	Used to protect regional aquifer systems by establishing new legislative districts that often transcend existing corporate boundaries.	Requires state legislative action to create a new legislative authority.	Well accepted method of protecting regional ground water resources.	Administrative requirements will vary depending on the goal of the regional district. Mapping of the regional WHPAs requires moderate administrative support while creating land use controls within the WHPA will require significant administrative personnel and support.
Land Banking	Used to acquire and protect land within WHPAs.	Land banks are usually accomplished with a transfer tax established by state government empowering local government to impose a tax on the transfer of land from one party to another.	Land banks can be subject to legal challenge as an unjust tax, but have been accepted as a legitimate method of raising revenue for resource protection.	Land banks require significant administrative support if they are to function effectively.

From: The Basis of Groundwater Regulation by J. Witten, in Planning, June, 1992

Table IV-2
Regulatory Groundwater Protection Measures Examined by Thurston County, Washington

OPTION	LEGAL FRAMEWORK	MAJOR ADVANTAGES	MAJOR DISADVANTAGES
Zoning	Amend Zoning Ordinance	Provides uniform regulations by land use type (zone); special area regulations can be added for varying degrees of protection; generally well understood	Difficult to change zoning in developed areas; sometime difficult to implement new regulations or overlay standards; regulations not always perceived as necessary
Moratorium - Interim Regulations	Suspend existing ordinances; adopt temporary ordinance	Provides immediate relief to current situation; allows an opportunity to develop a long term solution; can select technique which matches the severity of the crisis	Must demonstrate that a crisis exists; temporary in nature; creates risk of legal challenge
Source Controls	Adopt special ordinance, amend zoning, health and public work ordinances	Provides uniform regulations for activities regardless of location; applies to existing and new development; able to target and prioritize problem pollution sources	Information lacking on controls (BMPs) for some pollution sources; few programs being developed by state and federal agencies; individual contribution to problem/solution not generally acknowledged
Aquifer Classification	Draft state authority	Provides means of rating ground water resources; adopts drinking water standards for most aquifers; will prohibit land use activities that impact ground water	May require years of sampling data to upgrade an aquifer; may increase pollution from current level to allowable standard; poorly connected to surface water standards or land use activities; no local control

From: Table 2, Regulatory Management Options; Management Options for Groundwater Protection in Thurston County, Washington, May, 1989, Thurston County Planning Department

Table IV-2
Non-Regulatory Groundwater Protection Measures Examined by Thurston County, Washington

OPTION	LEGAL FRAMEWORK	MAJOR ADVANTAGES	MAJOR DISADVANTAGES
Acquisition	Local authority, eminent domain	Provides complete control of lands purchased, traded, or land banked; generally simple process; easy to implement	Acquisition costs are high and may limit lands purchased; removes lands from property tax rolls; properties require long term management
Purchase of Development Rights	Local authority	Provides for simultaneously keeping property on the tax rolls and controlling land use; less costly than fee simple acquisition	Relatively new concept; difficulty in determining the true value (cost) of the rights; properties require some long-term oversight
Conservation Easements	Legal agreement between the landowner and the organization receiving the easement	Provides significant property and federal income tax benefits to property owner; limits future use of lands without purchase	Requires voluntary consent of property owner; may have piecemeal effect; difficult to implement a protection plan in a targeted area
Open Space Tax Program	State enabling legislation, amendment to county open space tax program	Provides substantial property tax reduction for enrolled properties; retains private land as open space	Requires voluntary consent of property owner; property can be removed from program; difficult to implement a protection plan in a targeted area
Technical Assistance	Governmental program	Provides technical information at low or no cost; encourages better management of private lands; field agents able to work directly with target groups	Requires voluntary action by property owner; may not assure compliance with regulations; may be difficult to measure results
Public Education	Governmental program	Provides general information on problems and solutions to a wide population; basis for informed decision making; generally nonthreatening	Requires little direct action by effected parties; process generally slow and long term; may be difficult to measure change in actions

From: Management Options for Groundwater Protection in Thurston County, Washington, May, 1989, Thurston County Planning Department

Table IV-3
Groundwater Protection Measures at Six Sites Examined by the Urban Institute

	Techniques	Cape Cod, MA	Clarke Co., VA	Dayton, OH	El Paso, TX	Pinellas Co., FL	Spokane, WA
POLICE AND REGULATORY POWERS							
	Open space districts	✓	✓		✓	✓	
	Conservation and recreation districts	✓	✓		✓	✓	
Zoning Ordinances	Aquifer recharge or wellhead protection zones	✓	✓		✓	✓	✓
	Overlay districts (aquifer or wellhead)	✓	✓	✓	✓	✓	✓
	Prohibition of hazardous materials	✓		✓	✓	✓	
	Prohibition of adverse uses	✓	✓	✓	✓	✓	
	Landfill locations	✓		✓	✓	✓	✓
Subdivision Regulations	Minimum lot sizes	✓	✓		✓	✓	✓
	Slope controls, drainage maintenance and easements	✓			✓	✓	
	Gradations in protection for vulnerable areas	✓			✓	✓	
Site Plan Reviews	Environmental review requirements	✓	✓	✓	✓	✓	✓
	Cross-checking with water/environmental departments	✓	✓	✓	✓	✓	✓
	Permit renewal documentation/site visits	✓			✓		
	Building codes	✓			✓	✓	✓
	Setback requirements	✓			✓	✓	✓
	Septic system standards	✓	✓		✓	✓	✓
Design Standards	Drainage systems, catch basins	✓	✓	✓	✓	✓	✓

From: Assessing the Experience of Local Groundwater Protection Programs, E.B. Liner and E. Morley with J. Stanger, The Urban Institute, Washington, D.C., February, 1994

Table IV-3
Groundwater Protection Measures at Six Sites Examined by the Urban Institute

	Techniques	Cape Cod, MA	Clarke Co., VA	Dayton, OH	El Paso, TX	Pinellas Co., FL	Spokane, WA
	Performance standards	✓			✓		✓
	Underground storage tanks	✓		✓	✓	✓	✓
	Sinkhole protection (for Karst topography)		✓			✓	
Operating Standards	Alternative waste treatment systems permitted	✓			✓		
	Storage and transport of hazardous materials	✓		✓	✓	✓	✓
	Best management practices	✓				✓	
	Underground storage tanks	✓			✓	✓	✓
Source Controls	Pesticide management plans	✓			✓	✓	
	Prohibited materials from zones	✓		✓	✓	✓	
	Groundwater discharge permits	✓			✓	✓	✓
	Exclusive use zones	✓		✓	✓		
Wellhead Protection Ordinances	Overlay methods	✓		✓		✓	✓
	Time of travel delineations	✓		✓		✓	
POLICIES AND PRACTICES							
	Capital or bond fund programs	✓		✓	✓	✓	
Purchase of Property or Development Rights	Easements	✓		✓	✓	✓	✓
	Restrictive covenants	✓		✓	✓		✓
	Recharge area acquisition program	✓			✓	✓	
	Leaseback of lands					✓	
	Deed restrictions	✓			✓		

From: Assessing the Experience of Local Groundwater Protection Programs, E.B. Liner and E. Morley with J. Stanger, The Urban Institute, Washington, D.C., February, 1994

Table IV-3
Groundwater Protection Measures at Six Sites Examined by the Urban Institute

	Techniques	Cape Cod, MA	Clarke Co., VA	Dayton, OH	El Paso, TX	Pinellas Co., FL	Spokane, WA
Public Education	Adult	✓		✓		✓	✓
	Schools	✓		✓	✓	✓	✓
	Media	✓		✓	✓	✓	✓
	Xeriscaping				✓	✓	✓
	Source materials guidance	✓	✓		✓	✓	
	Alternative materials guidance	✓			✓	✓	
	Pesticide/fertilizer application	✓	✓	✓	✓	✓	✓
	Best Management Practices		✓	✓			✓
Groundwater Monitoring	Monitoring wells at landfills and critical locations	✓		✓	✓	✓	✓
	Regular testing for listed contaminants	✓		✓	✓	✓	✓
	Regular testing for pathogens, viruses	✓		✓	✓	✓	
	Wastewater treatment plants	✓			✓	✓	
	Regular (annual) inspections	✓		✓	✓	✓	
	Self-monitoring reports	✓		✓	✓	✓	
Household Hazardous Waste Collection	Regular collection programs exist			✓	✓	✓	✓
Water Conservation	Distribution of flow control devices	✓		✓	✓	✓	✓
	Retrofitting efforts (toilet tank replacement)	✓			✓	✓	
	Recycling wastewater				✓	✓	
Emergency Response Plans	Interagency, intergovernmental plan	✓		✓	✓		✓

From: Assessing the Experience of Local Groundwater Protection Programs, E.B. Liner and E. Morley with J. Stanger, The Urban Institute, Washington, D.C., February, 1994

Table IV-3
Groundwater Protection Measures at Six Sites Examined by the Urban Institute

	Techniques	Cape Cod, MA	Clarke Co., VA	Dayton, OH	El Paso, TX	Pinellas Co., FL	Spokane, WA
Regional Policy Development Plan	Nitrogen loading policy	✓					
	GIS has groundwater component	✓		✓		✓	✓
	Aquifer classification	✓		✓	✓	✓	
	Wetlands delineations	✓	✓			✓	
	Transfer of development rights permitted	✓				✓	✓
	Stormwater management plan	✓	✓		✓	✓	✓
	Technical hydrogeologic analyses	✓		✓	✓	✓	✓
Other Methods: Groundwater is Protected or Conserved by:	Underground tank removal program	✓		✓	✓	✓	✓
	Water need projections/hydrologic budgets	✓		✓	✓	✓	
	Assessments in water master plans	✓					
	Assessments in economic development plans	✓		✓	✓	✓	
	Assessments in capital improvement plans	✓		✓	✓	✓	
	Aquifer management program	✓		✓	✓	✓	✓
	Assessments in growth management plans		✓		✓	✓	

From: Assessing the Experience of Local Groundwater Protection Programs, E.B. Liner and E. Morley with J. Stanger, The Urban Institute, Washington, D.C., February, 1994

APPENDIX V

DATABASE CONTAINING REFERENCE DOCUMENTS

PLEASE NOTE, APPENDIX V CONTAINS 45 PAGES, SO IN INTEREST OF MINIMIZING COSTS, IT WAS NOT PRINTED.

IF REFERENCES TO THIS APPENDIX ARE REQUIRED, PLEASE CONTACT ENVIRONMENT CANADA, VANCOUVER OFFICE AT 604-666-6711 FOR HELP OR CONTACT ENVIRONMENT CANADA LIBRARY AT 604-666-5914 FOR A COPY OF THE REQUIRED REFERENCE.