NBMCA Groundwater Study
Report

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Executive Summary

The North Bay-Mattawa Conservation Authority Groundwater Study represents an extensive compilation and evaluation of regional and local water resources information. A large percentage of the population living within the study area relies on groundwater to supply nearly all of its drinking water needs, and they are fortunate that the quantity of groundwater available is capable of meeting the current water demand and that the water is of good quality.

The North Bay-Mattawa Conservation Authority Groundwater Study was initiated to develop an improved understanding of local groundwater conditions within the context of larger regional groundwater flow systems. The area included in the North Bay-Mattawa Conservation Authority Groundwater Study is presented in Figure 1-1. The study acknowledges that the basic groundwater functions of recharging, transmitting, assimilating potential contaminants, and storing and discharging water, play an essential role in maintaining a healthy ecosystem. Understanding these regional groundwater functions is necessary to provide a secure supply of clean water to municipal and communal water systems, as well as individual groundwater users who do not have access to a municipal supply.

Existing and future land-use practices that are exercised throughout the study area, as is the case in other areas throughout Ontario, may pose threats to the sustainability of groundwater resources (quantity and quality). This study provides a more thorough understanding of local and regional groundwater resources that will aid in the development of sound groundwater management and protection measures to help ensure long-term sustainability of the resource.

The study partners reflect the regional and local relevance of groundwater in this study. They include provincial and municipal levels of government, the conservation authority, the agricultural community, rural organizations and other related agencies. The Ministry of the Environment (MOE) is the project's major funding organization and provincial partner. The City of North Bay, North Bay-Mattawa Conservation Authority (NBMCA), Town of Mattawa and Municipality of Powassan are also major partners of the study and have provided funding and in-kind contributions of technical staff and project management resources.

Previous studies and initiatives conducted across the study area have helped create an understanding, amongst a core group of people associated with the study area and the NBMCA, of groundwater processes and the importance of protective measures to help ensure that an abundant, clean groundwater supply is available in the future.

A Steering Committee was formed to represent the population within the study area, and the other major study partners. Members of the Steering Committee include members of the following organizations:

- Ontario Ministry of Agriculture and Food
- Ontario Ministry of the Environment
- City of North Bay
- North Bay and District Health Unit
- Ministry of Municipal Affairs and Housing
- Municipality of Powassan
- Town of Mattawa
- North Bay-Mattawa Conservation Authority (NBMCA)
- Ministry of Natural Resources
- Ontario Clean Water Agency

At the onset of the study, a number of different objectives were developed by the Study Partners. The objectives of the North Bay-Mattawa Conservation Authority Groundwater Study are provided below:

Objective 1: Define and map local and regional groundwater conditions.
Objective 2: Define groundwater intrinsic susceptibility.
Objective 3: Compile a contaminant source inventory.
Objective 4: Complete wellhead protection area (WHPA) mapping for the municipal well systems in Mattawa and Powassan.
Objective 5: Conduct a contaminant source assessment within the WHPAs.
Objective 6: Develop a groundwater protection strategy.
Objective 7: Promote public groundwater awareness throughout the study area through open houses, local media news releases, and a project web site.

Source water protection is an excellent term to describe the different study objectives listed above. Source water protection is the first of five barriers commonly applied to provide safe drinking water, as outlined in Report 2 of the Walkerton Inquiry (O'Connor, 2002). The other four barriers include treatment, a secure distribution system, water quality monitoring, and well-planned responses to adverse conditions.

It is important to reflect on the detail incorporated into the regional mapping presented within this report, and to consider appropriate uses for this information. A large portion of the groundwater and aquifer characterization mapping completed as part of this study was at a regional scale. The mapping utilized point information that was used to develop themes such as the depth to bedrock or aquifer vulnerability. Point information used to complete this mapping is included as very small dots on each relevant map. This has been done to remind end users of these products that although we present our mapping in a continuous manner, it was developed from point data that is not evenly distributed throughout the study area.

The quality of the point data used in the mapping has been evaluated and is considered acceptable for its purpose, however it has not been field verified. As such, it is important to remember that the mapping is a representation of the real world.

The regional maps are presented at a scale of 1:350,000. This means that a 1-mm line is accurate to within 0.35 km and a 1-cm square is accurate to within 1225 ha. This level of detail is not appropriate for site-specific interpretation, but it does provide valuable information for regional scale analyses.

This report was organized to address each of the study objectives outlined above. The sections are organized by topic to coincide with the different regional and local study objectives. The study also includes a comprehensive groundwater protection implementation strategy and provides detailed recommendations and conclusions. Brief descriptions of the topics included in each of the sections are provided in the following paragraph.

Section 2 presents the regional groundwater and aquifer characterization. This characterization was used to complete the groundwater susceptibility analysis, which is presented in Section 3. Section 4 includes the groundwater use assessment, which was completed to evaluate how groundwater is used throughout the study area, and to develop a general regional water budget. A contaminant sources inventory was completed to identify potential contaminant sources throughout the study area, and is presented in Section 5. Using the information generated in Sections 2, 3, and 4, groundwater modeling was completed to locally map time-of-travel municipal wellhead protection areas. The groundwater modeling and wellhead protection area mapping results are presented in Section 6. In Section 7, the capture zones are overlain with the groundwater susceptibility and potential contaminant sources and evaluated at a local scale. Public consultation aspects of the study are presented in Section 8. A groundwater protection strategy is outlined in Section 9 and study conclusions and recommendations are presented in Section 10. All of the figures for the study are presented under separate cover so that figures can be reviewed while reading through specific sections.

Groundwater and Aquifer Characterization

Groundwater represents one of the safest and cleanest forms of water supply, when compared with surface water. Understanding how groundwater moves through the study area and the factors that control this movement will help to manage this resource.

Information from many different data sources, including the Ministry of Environment, Ministry of Natural Resources, Ministry of Northern Development and Mines, Geologic Survey of Canada, Water Survey Canada, municipalities and towns within the study area, and the North Bay-Mattawa Conservation Authority has been incorporated into a project database and GIS. The quality of the different sources of information was evaluated and data that was deemed inaccurate was not included in subsequent analyses. As part of the regional analysis, water well locations and reliabilities (Figures 2-1 to 2-3), ground surface topography (Figure 2-4), stream gauging locations (Figure 2-5), and Quaternary geology (Figure 2-6) are presented. The geology and hydrogeology of the study area was characterized and are presented in the depth to bedrock (overburden thickness), sand and gravel thickness, bedrock geology, and bedrock topography mapping (Figures 2-17 to 2-19). The characterization was refined through the development of regional geologic cross-sections. The cross-sections depict the thin overburden overlying bedrock throughout most of the study area (Figures 2-9 to 2-16) as well as the thick localized deposits of outwash sand and gravel that the municipal wells intersect.

Additional regional mapping completed to assess the hydrogeology throughout the study area includes maps of Bedrock Equipotentials (Figure 2-21), Bedrock Recharge and Discharge Areas (Figure 2.22) and Bedrock Specific Capacity (Figure 2-23).

Groundwater quality throughout the study area was evaluated through a review of raw water quality data presented in the First Engineer's Reports for the two municipal well systems with a focus on the bacteriological parameters (total coliform, E. coli, and heterotrophic plate count).

Land use information is presented at a regional scale on Figure 2-24. The vast majority of the study area is rural with areas classified as Provincial Park land, agricultural land and urban land.

The analysis presented regarding groundwater and aquifer characterization in this report provides a regional summary of groundwater in the North Bay-Mattawa Conservation Authority

Groundwater Study. The analysis is applicable at a regional scale; however, additional site-scale investigations to refine the results will be required when a new water supply or other groundwater resource related issues emerge.

Intrinsic Susceptibility Analysis

Groundwater intrinsic susceptibility for the uppermost significant aquifer (water table) and the bedrock aquifer were assessed using information contained within the MOE Water Well Information System. The approach followed the method outlined in the MOE Technical Terms of Reference. This method considers the thickness of the different geologic strata as well as the permeability, through the use of a K-factor. Intrinsic susceptibility mapping results are presented on Figure 3-1.

Within the bedrock and water table systems, areas of low, medium, and high susceptibility were identified. A high susceptibility rating was determined for most of the study area, with limited areas of low and medium susceptibility where thick deposits of fine-grained overburden were interpreted to exist. Groundwater resources throughout the study area are quite susceptible to contamination as the vast majority of bedrock within the study area is overlain by thin overburden. This protection could however be compromised by conduits such as improperly constructed or abandoned boreholes, through which contaminants could migrate.

Groundwater Use Assessment

Information regarding groundwater use throughout the study area was compiled from a variety of different documents and databases, such as the Permit to Take Water (PTTW) database. The water use assessment was undertaken to compile existing information to obtain an accurate understanding of the distribution of water taking throughout the study area. An improved understanding of groundwater users is essential to managing the use of groundwater, evaluating different municipal well capture zones, and conducting a regional water budget.

The total groundwater use for the study area was estimated to be about 18,605 m^3/year. By comparison, the total groundwater recharge is estimated to be about 290 million m^3/year. Therefore it is interpreted that the current annual groundwater use across the study area is less than 1 percent of the annual groundwater recharge.

Potential Contaminant Sources Inventory

There are many different substances that can compromise the quality of groundwater. These contaminants include organic chemicals, hydrocarbons (benzene in gasoline), inorganic cations (iron, copper) or anions (chlorides, nitrates), pathogens (bacteria), and radionuclides (Radon) (Fetter, 1999).

From a groundwater protection and management perspective, it is important to understand the locations of potential contaminants, or known spills to help ensure the long-term sustainability of the groundwater resource. This information is best stored and maintained in a database that includes the potential contaminant source, the location (including address where available), and information about the quality of the data (metadata). If a specific contaminant were to appear in a domestic water well, the database could be used to identify possible contaminant sources. Future groundwater resource development could also utilize information about different potential contaminant sources throughout the study area.

Surface and groundwater contamination may occur via two different types of sources; point and non-point sources. These terms generally describe the localization of the source contaminant. A point source is typically a small-scale contaminant source area, such as a leaky underground fuel storage tank. Non-point sources, in contrast, are larger in scale and can be more diffuse than point source contaminants. Non-point sources are primarily related to land use practices (fertilizer spreading, road salting), whereas point sources may be related to localized contamination events (contaminant spill).

The objective of the potential contaminant sources inventory was to prepare an inventory of known and potential sources of contaminants in the North Bay-Mattawa study area. This information was compiled using existing databases and other information as discussed below.

Data for the potential contaminant sources inventory was obtained primarily from the Ministry of the Environment (MOE), with supplementary information from available digital GIS mapping. Included in the information from the MOE was a database of private and retail underground fuel storage tanks from the Technical Standards and Safety Association (TSSA) as well as information from the MOE on spill occurrences, and PCB storage in the study area.

Oil and gas wells were also considered, as incorrectly sealed or abandoned wells can act as a direct conduit for surface contaminants to rapidly migrate to a deep bedrock aquifer. Information on the locations of the wells was obtained from the Ontario Ministry of Northern Development and Mines (MNDM).

The results of the potential contaminant sources inventory are presented in Figure 5-1. It is clear that many different potential contaminant sources exist throughout the study area, however there are concentrations in the urban areas. The inventory was compiled within the project database, and should be maintained and updated as additional information is collected regarding specific contaminant sources as well as the location of records that were located with poor confidence.

Wellhead Protection Area Groundwater Modeling

Numerical models were developed, calibrated, and applied to evaluate the wellhead protection areas (WHPAs) at the municipal wells in Powassan and Mattawa. 50-day, 2-, 10-, 25-year, and steady state capture zones were delineated for the municipal wells. Additional analysis using the WHPAs, potential contaminant sources, and intrinsic susceptibility results are presented in Section 7.

In all of the models, the primary source of data used during development and calibration was obtained from the Water Well Information System (WWIS). The WHPA results represent the current best estimate of the different capture zones, however their sizes and shapes will change in the future if wells are added or removed, and as water demands change. As additional information becomes available, the validity of the different models should be evaluated to help ensure that protective measures continue to be directed in the appropriate areas. Incorporating additional geologic and pumping information into the model will not be difficult now that the models have been constructed and calibrated.

Integration of Study Results

A variety of different data layers that can be used to assess the vulnerability of each municipal well, were developed during the study. Overlaying the different themes in a GIS (Geographic Information System) allows the consideration of different aspects associated with groundwater quality simultaneously. GIS is widely used around the world as a comprehensive system capable of assembling, storing, manipulating, and displaying geographically referenced information. Figure 7-1 and 7-2 present the wellhead protection areas (described in Section 6), potential contaminant sources (described in Sections 5 and 7), and areas of medium to high vulnerability (presented in Section 3) for the municipal well systems examined during the study.

The capture zones for nearly all of the municipal wells throughout the study area intersect some land uses that are associated with potential contaminant sources. Reconnaissance work will be required to characterize the risk posed to each well. Further characterization is best directed at potential contaminant sources identified within the capture zones for the different wells. This could include a survey administered to landowners within the 10- or 25-year best estimate WHPA.

Public Consultation

Public consultation was an important component of the North Bay-Mattawa Conservation Authority Groundwater Study. To transfer study information to the public and solicit their input, a variety of different public consultation strategies were utilized. At the onset of the study it was understood that public involvement and subsequent buy-in to the importance of the Groundwater Study and its findings would be very beneficial. A more environmentally aware public that appreciates the need to protect their groundwater resource will be more likely to endorse and support future groundwater protection strategies. Information from members of the community also provided insight about specific water resource issues that were of concern to them. This information was used during the development of the groundwater protection strategy and helped to focus the study on local concerns and issues.

During public consultation, information from other agencies such as the North Bay-Mattawa Conservation Authority was incorporated. Further participation and contributions from the Steering Committee also contributed to the transfer of groundwater resource protection information and specific study results to the public.

To consult the public and make study results available to local stakeholders, the following specific strategies were implemented throughout the duration of the project:

- Regular news releases to local newspaper and media outlets about groundwater issues in North Bay-Mattawa study area and details related to the project progression;
- Public meetings timed to present preliminary results and the final study results; and,
- Development of a project web site to transfer project information to the public and to convey project progression and final results (www.nbmcagroundwaterstudy.on.ca).

Section 8 of the report includes a discussion of each strategy applied during the study.

Groundwater Protection Strategy

A Groundwater Protection Strategy is a program of risk reduction to sustain the groundwater resource, both as a source of drinking water and an integral component of the ecosystem. The strategy can incorporate a number of different tools. These tools may include a combination of land use policies, regulatory controls, best management practices, public education, monitoring, land acquisition, and spills contingency planning.

The protection of water quality and quantity depends on the collective actions of individuals, private industry, government and other agencies. Rural property owners are responsible for their own well and septic tank maintenance. Municipalities are responsible for the provision and maintenance of a safe drinking water supply in urban areas and for proper sewage collection and treatment. Conservation Authorities play an important role in low water response, flow augmentation, all aspects of water conservation and perhaps source water protection in the future. Private industry is intrinsically responsible for best management practices in the utilization of water for the goods and services they provide. The farm industry in particular, has a vested interest in securing an adequate supply of water for livestock and crop watering.

Policies, such as those in a municipal Official Plan, serve to identify the public interest in water quality and quantity. An Official Plan may establish goals, set objectives for water protection (aquifer and wellhead protection), and provide the framework for land use development and implementation measures. The policies may also provide the rationale for the use of other planning tools such as zoning and site plan control. These are regulatory mechanisms that may be used to control development on a lot-by-lot basis, or an area-wide basis. Planning applications, such as development or land use changes, largely drive the implementation process.

Many tools are not retroactive and they do not enable a municipality to rectify a pollution problem by closing down an operation or forcing the relocation of an existing land use that may have the potential to contaminate an aquifer.

Best management practices may apply to a homeowner in the use and storage of solvents, pesticides, and the disposal of household hazardous wastes. For the agricultural industry it may include measures such as stream buffering from cattle grazing and the care with which manure and other fertilizers are applied.

The municipality may also utilize other statutes to complement the land use controls under the Planning Act. The Nutrient Management Act (2001), and the associated regulations, for example, set out the requirements for the preparation of nutrient management plans and the control of intensive livestock operations. The Municipal Act may be used to enact site alteration or nutrient management by-laws.

Raising public awareness, through public educational programs, can have a major impact on water protection and may be more important than enforcement measures. It is the voluntary actions and practices of people on a day-by-day basis that will help protect water resources (i.e. proper use, storage and disposal of fuels, solvents, and pesticides, regular water well maintenance, installation of water saving plumbing fixtures etc.) Municipalities can work towards developing a ‘water ethic’ in their communities. This means instilling a collective awareness, responsibility, and commitment to protect water on an ongoing basis.

Specific recommendations regarding a future groundwater protection plan that should be considered are described in Section 9, and include:

- Establishing an organizational structure to oversee and coordinate the implementation of water protection measures.

- Amend land use planning documents to establish the policy and regulatory framework for instituting effective land use controls for future development.

- Initiate a spills and contingency plan early in the implementation process.

- Develop and maintain a database that can be used in making decisions and to incorporate new information in response to development and monitoring activities.

- Develop a public education and outreach program for the ongoing education of the public, the operation of municipal water supply infrastructure and the administration and enforcement of regulatory and voluntary controls for water protection.

- Utilize Best Management Practices where feasible as measures to minimize the potential contamination of private and municipal water supply sources.

Recommendations

Large numbers of residents within the North Bay-Mattawa Conservation Authority jurisdiction rely on groundwater to supply nearly all of their drinking water needs. The population that lives within the study area is fortunate that the quantity of groundwater available is capable of meeting the current water demand and that the water is of good quality.

Groundwater Protection Strategy

It is recommended that a Groundwater Protection Strategy that incorporates the different components described in the report be developed and implemented. A Protection Advisory Committee comprised of representatives similar to those involved during the current study should oversee the refinement and implementation of the Strategy. The knowledge gained by the current Steering Committee can be utilized during the implementation of the Strategy. A Protection Advisory Committee can provide the guidance necessary to evaluate different strategy options and to coordinate the efforts of the Municipality of Powassan, City of North Bay, and Town of Mattawa. The importance of groundwater to the rural populations within the study area underscores the need to manage the resource.

The Protection Advisory Committee should consider the following Protection Strategy components:

- Data Management
- Education
- Wellhead Protection Areas
- High Aquifer Vulnerability Areas
- Monitoring
- Best Management Practices
- Spill and Contingency Planning

These components are further discussed in Section 10.

Regional groundwater and aquifer characterization was completed across the study area. During this work information was incorporated into a project database. To help ensure that additional information is incorporated into the database in a consistent manner, the database should be maintained centrally. NMBCA should manage or oversee the management of the database to ensure that the information developed during this study will be available to other end users that may be conducting geologic and/or hydrogeologic investigations in the study area.

Municipal Wellhead Protection Areas (Capture Zones)

Based on the high susceptibility throughout most of the study area, care should be taken especially in the vicinity of the Mattawa and Powassan municipal wellheads. As discussed in Section 7, many private homes contain large above ground oil or gas tanks within the different capture zones in the study area. To help mitigate some of the risk associated with the degradation of these tanks to the municipal supply wells, further information about wells within capture zones should be collected.

Clearly this will be a very large task due to the number of homes located within the capture zones. Compilation of this information would also help educate well owners of the importance of using best management practices at their homes and of the risk posed by poorly maintained above ground storage tanks. Tracking information about such tanks within municipal capture zones can be accomplished through a variety of ways, including:

- Targeted door-to-door surveying
- General education initiatives
- Specific mailings to landowners that live within a wellhead protection area

A summary of the study recommendations is listed below:

Recommendation 1: Develop and Implement a Groundwater Protection Strategy
Recommendation 2: Ensure Groundwater Data is Properly Managed
Recommendation 3: Utilize Public Education Initiatives to Foster Groundwater Protection
Recommendation 4: Acknowledge and Protect Wellhead Protection Areas (WHPAs)
Recommendation 5: Acknowledge and Protect High Aquifer Vulnerability Areas
Recommendation 6: Monitor Groundwater Quality
Recommendation 7: Encourage the Utilization of Best Management Practices (BMPs)
Recommendation 8: Address Improperly Maintained Fuel Storage Tanks within WHPAs
Recommendation 9: Ensure Spill and Contingency Planning is in Place
Recommendation 10: Incorporate Protection Planning into Municipal Official Plans
Recommendation 11: Better Enforcement of Existing Rules and Regulations

Specific information regarding each of the recommendations is provided in Section 10 of the Report.

Acknowledgements

A study as complex and in depth as the North Bay-Mattawa Conservation Authority Groundwater Study requires the cooperation of many different organizations and individuals. As such, the Consultant Team wishes to acknowledge the commitment of the Steering Committee, and other professionals from local municipalities and private companies, who provided insight and information during the course of the study. The direction, advice and support provided by the Steering Committee were instrumental to the successful completion of the study tasks. The members of the committee are listed below.

Steering Committee Members

- Paula Scott, Project Manager North Bay-Mattawa Conservation Authority
- Brian Evans, North Bay-Mattawa Conservation Authority
- Peter Bullock, City of North Bay
- Ian Kilgour, City of North Bay
- Marc Mathon, Town of Mattawa
- Jim Latendresse, Town of Mattawa/ NBMCA
- Gary Keown, Municipality of Powassan
- Fred Busch, Municipality of Powassan/ NBMCA
- Claude Ploquin, Ministry of Agriculture and Food
- Chuck Poltz, North Bay and District Health Unit
- Dennis Wilson, Ministry of Natural Resources
- Brian Carre, Ministry of Municipal Affairs and Housing
- George Terry, Ontario Clean Water Agency

Consultant Team

The Consultant Team for the North Bay-Mattawa Conservation Authority Groundwater Study comprised a number of talented individuals, encompassing a wide variety of technical expertise. The consulting firms and task leaders are listed below.

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- **Tunnock Consulting**
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  Glenn Tunnock, Groundwater Protection Planning

Public Participation

The Consultant Team appreciates the time and effort of the citizens of the North Bay-Mattawa study area throughout the public consultation activities (e.g. public open houses, water use surveys and contaminant source surveys). Their participation provided constructive feedback on the progress of the study, and was helpful in completing a number of key components of this groundwater study.

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1 Introduction

The North Bay-Mattawa Conservation Authority, in partnership with the City of North Bay, Municipality of Powassan, Town of Mattawa, and the Ontario Ministry of the Environment, retained the consultant team led by Waterloo Hydrogeologic, Inc. to undertake the North Bay-Mattawa Conservation Authority Groundwater Study. This study was completed in accordance with the MOE Technical Terms of Reference, dated November 2001. The information and analysis presented in this report represents the first phase of groundwater protection. It will assist in developing future environmental policy and will support the development of a local and regional groundwater protection strategy.

The study area includes the urban and rural areas within the jurisdiction of the North Bay-Mattawa Conservation Authority and Callander and Powassan. The area encompassed by the study is presented in Figure 1-1, and stretches from the City of North Bay in the northwest, to the Town of Mattawa in the east, and south including Pentland and Wilkes Townships in Algonquin Park. The study area comprises a total area of over 4,600 km^2.

The study partners acknowledge that the basic groundwater functions (recharging, transmitting, assimilating potential contaminants, storing, and discharging water) play an essential role in maintaining the health of an ecosystem. Understanding these regional groundwater functions is necessary to provide a secure supply of clean water for all groundwater users in the study area.

The study was completed using compiled regional geological and hydrogeological data sets and information from previous hydrogeological studies completed at regional-scale and local-scales within the various municipalities. Previous initiatives helped to develop an understanding of groundwater processes and the importance of protective measures required to ensure an abundant clean groundwater supply is available in the future.

A Steering Committee was formed and met several times to review and advise on the technical analyses and the public consultation aspects of the study. It included representatives from the following:

- North Bay-Mattawa Conservation Authority
- City of North Bay
- Municipality of Powassan
- Town of Mattawa
- Ministry of Agriculture and Food
- North Bay & District Health Unit
- Ministry of Natural Resources
- Ministry of the Environment
- Ministry of Municipal Affairs and Housing
- Ontario Clean Water Agency

The names of Steering Committee members are listed in the study Acknowledgements.

1.1 Study Objectives

The main reasons for the Ministry of the Environment to commission the North Bay-Mattawa Conservation Authority Groundwater Study were to obtain an information base to enable appropriate policy development that can:

- Limit or eliminate the risk of groundwater contamination from historical, existing, and future land uses;
- Manage groundwater quantities to promote sustainable uses, and;
- Promote water conservation and good well management and decommissioning practices.

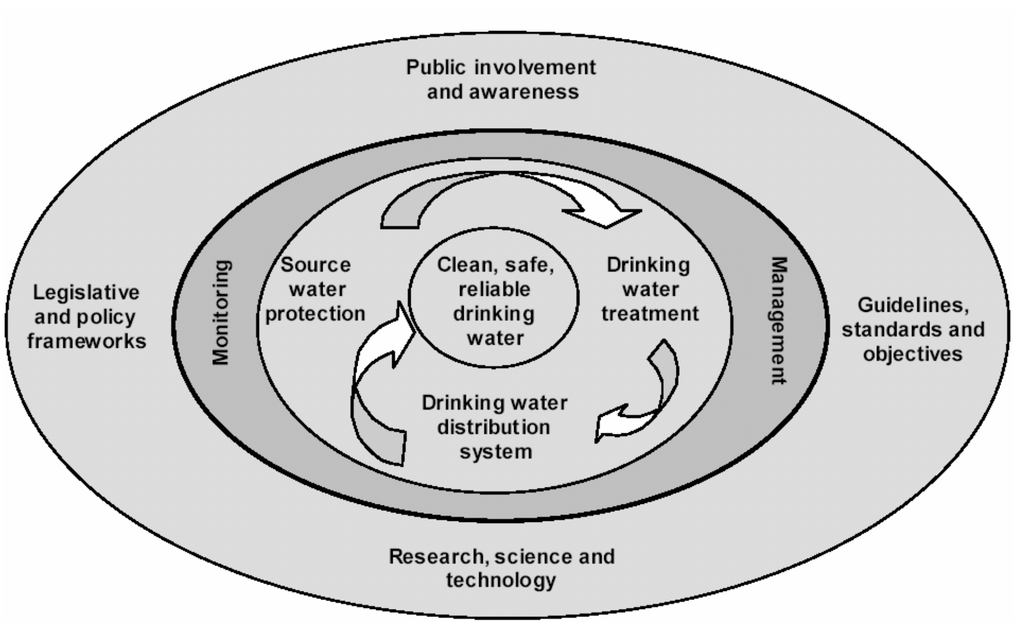
These reasons are directly related to groundwater study objectives within the NBMCA study area that include:

- Groundwater and aquifer characterization for the region;
- Wellhead Protection Area (WHPA) delineation for the Municipality of Powassan and the Town of Mattawa;
- Development of an inventory of potential contaminant sources, and assessment of the potential for aquifer contamination within the WHPAs;
- Quantification of the groundwater uses throughout the area, and establishment of a regional water budget; and,
- Development of a groundwater protection plan that includes wellhead protection areas to help ensure a clean, safe water supply in the future.

Each study objective is addressed in different sections of this report.

1.2 Multi-Barrier Approach to Water Protection

The multi-barrier approach is an integrated system of procedures, processes, and tools that collectively prevent or reduce the contamination of drinking water from source to tap, in order to reduce risks to public health (Canadian Council of Ministers of the Environment, 2002). The illustration below presents the multi-barrier approach schematically, highlighting three key processes: source protection, treatment, and distribution.



A Multi-Barrier Approach to Water Protection (CCME, 2002)

Similarly, source protection is the first of five barriers that can be applied to provide safe drinking water, as outlined in the Part Two Report of the Walkerton Inquiry (O'Connor, 2002). The other four barriers included treatment, a secure distribution system, water quality monitoring, and well-planned responses to adverse conditions.

Source protection is typically less costly than end-of-pipe treatment options, or developing alternative drinking water supplies. Developing source protection strategies is dependant on local willingness to implement various protection strategies, which can range from best management practices to legislation that influences land uses in sensitive source water areas.

1.3 Notes Regarding the Regional Mapping

It is important to consider the detail incorporated into the regional mapping presented in this report and to consider appropriate uses for this information. A large portion of the groundwater and aquifer characterization mapping developed for this study was completed at a regional scale. The mapping utilized point information that was used to develop themes such as the depth to bedrock, water table elevation, and groundwater susceptibility. Point information used to complete this mapping is included as very small dots on each relevant map. This has been done to remind end users of these products that, although the mapping presents continuous surfaces, it was developed from point data that is not evenly distributed throughout the study area.

The quality of the point data used in the mapping has been evaluated and is considered acceptable for its purpose; however, it has not been field verified. As such, it is important to remember that the mapping is a representation of the interpreted data.

The regional maps are presented at a scale of 1:350 000. This means that a line that is 1 mm thick is accurate to within 350 m (i.e. the real world width of the 1 mm line is 350 m). Similarly, a 1 cm by 1 cm square is accurate to within 1225 ha (i.e. the real world size of a 1 cm by 1 cm square is 1225 ha). This level of detail is not appropriate for site-specific interpretation, but provides a reasonable scale for regional-level analyses.

1.4 Report Organization

This report is organized to address each of the study objectives. The sections are organized by topic to coincide with the different regional and local study objectives. The report also includes a comprehensive groundwater management and protection strategy and provides detailed recommendations and conclusions. Brief descriptions of the topics included in each of the sections follow.

Section 2 presents the regional groundwater and aquifer characterization. This characterization was used to complete the groundwater susceptibility analysis, which is presented in Section 3. Section 4 includes the groundwater use assessment, which was completed to evaluate how groundwater is used throughout the study area, and to develop a general regional water budget. Section 5 presents the results of potential contaminant sources identified within the study area, and Section 6 focuses on the wellhead protection area groundwater modeling in Mattawa and Powassan. Section 7 presents the integration of wellhead protection area results. Public consultation aspects of the study are presented in Section 8, and a groundwater management and protection strategy is outlined in Section 9. Study conclusions and recommendations are presented in Section 10, a glossary is provided in Section 11, and report references are presented in Section 12. All figures are presented in a separately bound document.

2 Regional Groundwater and Aquifer Characterization

2.1 Overview

The focus of this study was to incorporate available data from provincial and conservation authority sources to develop a conceptual understanding of the water resources in the study area. The data was interpreted using a Geographical Information System (GIS), to develop a regional, conceptual, geologic model. Aquifer thickness, estimated yield from individual wells in an aquifer, and aquifer vulnerability from potential sources of environmental impacts were estimated from the basic conceptual picture in the GIS database.

2.2 Methodology/Data Sources

During the regional groundwater and aquifer characterization, information from many different data sources was synthesized to develop a regional understanding of the groundwater flow system. The data layers used in this study, as presented in Table 2.1, include the following:

Table 2.1 SOURCES OF INFORMATION AND DATA LAYERS

	Data Layer	Type of Data	Source
1	Digital Elevation Model (DEM)	Topographic Elevation	Ministry of Natural Resources
2	Cadastral Fabric	Lots & Concessions	Ministry of Natural Resources
3	Quaternary Geology	Quaternary Geology	Ministry of Natural Resources, Geological Survey of Canada
4	Water Well Information System (WWIS)	Well Completion and Geologic Information	Ministry of Environment
5	Permits to Take Water	Permitted Water Takings	Ministry of Environment
6	Potential Contaminated Sites Databases	Landfills, Fuel Storage Tanks, Spills	Ministry of Environment
7	Surface Water Monitoring Locations (Staff gauges/ Flow monitoring stations)	Surface Water Stage Elevation and Flows	Water Survey Canada
8	Engineering Terrain Mapping	Surficial Sediments	Ministry of Natural Resources, Ontario Geological Survey, Ministry of Northern Development and Mines
9	Base Mapping	Map Reference Features	Ministry of Natural Resources, Ministry of Environment
10	Bedrock Geology Mapping	Bedrock Geology	Ministry of Northern Development and Mines, Geological Survey of Canada

The MOE Water Well Record database provides an excellent source of data for regional hydrogeologic mapping. This database contains information regarding:

Well location (easting, northing, and ground surface elevation); geologic units encountered with depth; water bearing zones and general water quality observations; well construction details; static water level for screened interval; pumping test information indicating aquifer & well performance (specific capacity); water use; date of well construction; driller code; and other details about the well.

This information provides data that can be used to develop geologic/hydrogeologic maps, hydraulic conductivity estimates (from lithology), specific capacity estimates, water levels within aquifer units, hydraulic gradients and groundwater flow paths. Using the information at each well location, continuous mapping can be developed to characterize the geology/hydrogeology between well locations.

In Ontario, water well information is stored and managed in the Water Well Information System (WWIS). A well record must be submitted to the Provincial Ministry of Environment (MOE), in hardcopy format, when a new well is drilled. This process has been used since 1946. The location of the well is recorded in the form of Township, Lot and Concession, and includes a site drawing. The water well record also includes information about the lithology, water bearing zones, static and pumped water levels, and well construction. The MOE enters this information into their database system from the hardcopy they receive. Prior to 1986, the location of the well (Universal Transverse Mercator or UTM, easting and northing) and its ground elevation were assigned by checking Lot/Concession information on a topographic map. After 1986, no attempt was made to assign UTM coordinates or ground elevations to well records. As of 1999, the database consists of 492,898 wells. Of this total, 336,064 wells have been assigned coordinates, and 156,864 wells exist without eastings, northings, or elevations.

In many cases it is difficult to correlate geologic observations between well logs because each driller has a unique style of data recording and geologic interpretation. The MOE allows a maximum of 3 descriptors for each lithologic unit recorded in the well record, and there are 82 possible descriptors. As a result, there are 500,000 possible lithological names. Inconsistencies in lithologic reporting create difficulties for conceptual model development. Lithologic units are often described differently by various drillers (i.e. each driller may use 3 different descriptors to describe the same unit). For example, differentiating between the different tills throughout the study area is very difficult to do using the water well records. Sand and clay, gravel and clay, and hardpan are terms that may be used by water well drillers to describe a silty or clayey till.

Another source of error in this database results from the manual entry of hardcopy information into electronic format. Manual data entry errors are common in well location and elevation fields. These data represent point anomalies, which can sometimes be recognized through point inspection and well-to-well correlation. Section 2.2.1 (Data Reliability) includes the methodology that was developed to address these types of errors in the Ontario WWIS such that the information can be used for regional scale hydrogeologic analyses. The processes used to evaluate the data in the WWIS are presented schematically in Appendix B.

Another challenge associated with using information from the WWIS is the data density and distribution throughout different parts of Ontario. In the North Bay – Mattawa groundwater study area, well record data is concentrated along roads and settlements. As such there are large areas with few wells from which to distil geological information for regional mapping. These areas were identified and alternative approaches to mapping geological features in these areas were used, as discussed in the following sections.

2.2.1 Data Reliability

Prior to developing a conceptual model for the hydrogeologic systems within the NBMCA study area, all available WWIS data were reviewed and evaluated for reliability and quality (well location, elevation) prior to inclusion in the modeling or mapping analysis. The North Bay-Mattawa database contained a total of 5121 wells prior to inactivating wells due to poor reliability.

Prior to transmitting the WWIS data to the NBMCA, the MOE updated the location reliability codes for each record. It is understood that some wells in the database have such a large margin of error associated with their coordinates, they plot outside the study area, or township cited on the record. These wells were visually isolated and made inactive. All of the water wells that remained active in the database that were used in the development of the mapping products are shown in Figure 2-1.

Wells with UTM (location) reliability codes greater than 6 (margin of error greater than 1km) were made inactive due to their poor location reliability (Figure 2-2a), following the technical terms of reference for the study. In total, 2368 wells fell into this category, with the majority having unknown UTM coordinates. The remaining wells in the study area have a fair UTM reliability with an estimated margin of error ranging from 30 to 300 m.

The ground surface elevation recorded for each well record was also considered during the data quality analysis (Figure 2-2b). The database was queried to compare the reported well elevations to the ground surface elevation in the digital elevation model (DEM). In cases where the difference between the well elevation and the ground surface elevation from the DEM differed by more than 10 m, the wells were made inactive.

The histogram in Figure 2-3a shows the elevation difference between the value recorded for the well record and the DEM. Most well records have elevations that are very similar to the DEM. The well elevations for all of the active well records were updated to reflect the information in the DEM.

In the North Bay-Mattawa study area, the location and elevation data are of poor quality. The majority of the elevation data (~80%) has been interpreted from topographic maps with 50-foot (15 m) contour intervals as shown in Figure 2-2b. Figure 2.3b presents the well completion date for all of the water wells within the study area. The greatest number of wells was drilled in the 1970s.

Figure 2-1 shows the active bedrock and overburden wells located throughout the study area. Over 90% of the wells are completed in bedrock (1942) with the remainder completed in overburden sediments (123). Many of the water wells drilled in the study area are located near Lake Nipissing, with smaller clusters focused around North Bay, Trout Creek, Powassan, and Mattawa, and along major roadways, and surface water. The well database includes two records for wells completed in Algonquin Park, and few wells drilled north of the Mattawa River, which limits the hydrogeologic interpretation in these areas.

2.3 Population

The total population living within the study area at the time of the 2001 census was 70,700 people. This represents a decrease of 1,099 people between 1996 and 2001, an average annual decrease of approximately 0.3% per year over that time period.

The City of North Bay is the largest urban center in the study area, with a population of approximately 52,771 people (2001 Census). The communities of Callendar (population 3168), Mattawa (population 2270), and Powassan (population 1124), are centers of concentrated population within the study area (Statistics Canada, 1996 and 2001 Census).

The rural lands of North Bay-Mattawa are utilized for recreation, farming, or the production of wood products. Mixed farming is predominant in the area although east of Mattawa, in specific sandy areas, potatoes are raised as an exclusive cash crop (Harrison, 1972).

2.4 Climate

Mild summers, cold winters, and fairly reliable precipitation characterize the climate of the North Bay-Mattawa area within northeastern Ontario. Climatic fluctuations from one year to the next, and from one location to the next are anticipated due to the spatial variations caused by the topography and varying exposure to the prevailing winds in relation to area lakes.

Figures showing the long-term monthly precipitation and air temperature for selected climate stations within and surrounding the study area are given in several texts (Brown et al., 1974; Hare, 1979; OMNR, 1984). These figures show the typical variability in rain and snowfall amounts and spatial variations in mean annual precipitation, snowfall and air temperature.

The mean annual precipitation in North Bay is approximately 900 mm, of which approximately 30% appears as snowfall (or 268 cm in depth). The total precipitation is fairly evenly distributed across the study area (OMNR, 1984).

The 30-year climate norm data (discussed in Section 4.3) shows that on an annual average, the wettest months of the year are August and September, while February and March are the driest months. The lowest total precipitation occurs in February, whereas the highest precipitation amount occurs in September.

The mean annual evapotranspiration in the watershed is about 450 mm as deduced from regional Ministry of Natural Resources mapping (OMNR, 1984). Locally, the evapotranspiration may be higher because of significant amounts of water available in ponds, swamps and marshes, or held in soil-water storage.

2.5 Previous Studies

The Ontario Geological Survey published one report on the Quaternary geology of the North Bay-Mattawa Region (Harrison, 1972). The detailed Quaternary geology mapping performed by Harrison used aerial photographs, surface exposures, well logs and auger holes. This information was combined with the topographic expression, soil cover, and photographic characteristics to create map units. Two reports on the Engineering geology of the study area (Gartner and VanDine, 1980; Gartner, 1980) provide information on the surficial and bedrock geology in the study area. Additional reference resources include the Geology of Ontario (Ontario Geological Survey, Vol. 4, Parts 1 and 2), providing detailed descriptions of the bedrock units within the North Bay-Mattawa area as well as the surficial Quaternary overburden. There are also selected journal articles that have investigated the origin and distribution of the bedrock geology throughout portions of the study area, including the Town of Mattawa.

Localized studies related to the geology and hydrogeology of the area have previously been completed. For instance, a First Engineer's Report was completed by Dennis Consultants (2001) for the Mattawa Wells, and Totten Sims Hubicki (2001) completed a report for the Powassan municipal supply wells. Section 12 contains a list of all reference material gathered and compiled as part of this groundwater study.

2.6 Surface Features

2.6.1 Surface Topography

Figure 2-4 is a map of ground surface elevation generated using the Digital Elevation Model (DEM) provided by the Ministry of Natural Resources. Surficial topographic relief in the North Bay – Mattawa area is divided into three distinct regions; the Algonquin Highlands, the Northern Uplands, and the Nipissing - Mattawa Lowland. Topographic relief in the study area is largely the result of glacial deposition (moraines, eskers) and bedrock erosion (river valleys) during the Quaternary Period.

The Algonquin Highlands in the southern portion of the study area are a topographically variable area with relief up to 260 m asl and elevations in excess of 520 m asl. Hills are thinly mantled with glacial till, while the low relief areas are occupied by swamps or lakes (Harrison, 1972). The Northern Uplands are bounded by a scarp to the south and have a moderate relief of approximately 100 m asl and elevations ranging from approximately 400 m asl to 490 m asl. The higher elevations in the upland area also have a thin till cover, and Precambrian bedrock outcrops in many areas (Harrison, 1972). The Nipissing - Mattawa Lowland is an area that lies at elevations less than 325 m asl and this area is associated with extensive lake sediments around and between bedrock outcrops. The lake sediments consist chiefly of varved clays with some rhythmically banded sands (Harrison, 1972). Minor ridges and several large end moraine segments, drumlins, and eskers are important elements of the surface topography (Harrison, 1972).

Surface elevations are lowest along the Mattawa River (Nipissing - Mattawa Lowland), which cuts through the central portion of the study area, and rise significantly north or south of the River. The higher elevation areas to the north correspond to the Northern Uplands and the upland areas in the southern portions of the study area correspond to the Algonquin Highlands.

2.6.2 Surface Water and Stream Flow

The North Bay-Mattawa Conservation Authority (NBMCA) lies primarily within the Ottawa River watershed, with a portion draining to Georgian Bay via Lake Nipissing and the French River. This area is characterized by frequent small, creeks, ephemeral streams and small lakes. Surface water features of primary interest within the study area include Lake Nipissing and Trout Lake in the west and the Mattawa River that cuts east-west through the centre of the study area.

Lake Nipissing was formed during the Wisconsin ice age. It is the 4th largest lake in Ontario with an average depth of 4.5 m and a maximum depth of 52 m near the mouth of the French River, and drains westward into Georgian Bay.

The Mattawa River is a natural passage through the Algonquin Highlands between Lake Nipissing and the Ottawa River. It rises 3.5 km east of Lake Nipissing, and flows east along an ancient fault line into the Ottawa River. The Mattawa River begins in Trout Lake just east of Lake Nipissing, 198.5 metres above sea level, and drops 50 metres over the 43 km distance to the Ottawa River. Its watershed is 117,000 hectares of forested Canadian Shield. The confluence between the Mattawa and Ottawa Rivers is at the Town of Mattawa.

Within the Powassan area, the South River and Genesee Creek are the dominant surface water features. The South River includes two chutes: Elliot Chute and Bingham Chute, both of which host small hydroelectric generating stations. Immediately south of Elliot Chute is the South River Reservoir, which is maintained at a mean water level of approximately 265 m asl. There is a smaller reservoir above Bingham Chute that is maintained at a mean water level of 252 m asl.

The study area has gauging stations that have recorded flow rates throughout the area on streams and rivers (see Table 2.2). The locations of these stations are presented in Figure 2-5. Data collected at these stations were used to obtain stream flow measurements in the respective rivers and streams.

Table 2.2 STREAM GAUGING STATIONS

Station Name	WSC ID	Avg July Flow*	Avg Aug Flow*	Avg Sept Flow*	Drainage Area (km^2)	Record Length	Area Average Flow Rate (mm/yr)
Chippewa Creek at North Bay	02DD014	0.396	0.141	0.227	14.4	1974-2003	119.2
La Vase River at North Bay	02DD013	0.156	0.122	0.238	27.2	1974-2003	54.6
Mattawa River below Bouillon Lake	02JE020	7.022	9.033	6.003	360	1972-1998	203.0
Mattawa River near Rutherglen	02JE014	9.502	7.055	4.814	2040	1962-1971	74.4

* Flow is measured in cubic meters per second

The area-averaged flow rate in the North Bay-Mattawa study area during the summer months varies widely from 55 to 203 mm/yr. This value was obtained by dividing the monthly flow averages during July, August, and September by the corresponding drainage area of the river or stream. These values were used in the calculation, as they can be indicative of stream base flow, or the flow to the stream that is derived from groundwater discharge.

2.7 Geology

2.7.1 Quaternary Geology

Deposits formed by, or in connection with, continental glaciers are of particular hydrogeologic importance in the North Bay-Mattawa region. Continental scale glaciers repeatedly advanced over the study area throughout the last two million years, leaving behind a variety of glacial, glaciofluvial, and glaciolacustrine sediments.

With the exception of steep bedrock outcrop exposures and rock knob features, the North Bay-Mattawa region is predominately overlain by subglacial till deposited during the last glacial ice advance. The till matrix varies in texture from fine grained silts and sands with clasts ranging from small grains to large boulders. The till is red- grey in colour, lacking of carbonate clasts, and there is a low percentage of fine-grained material (Harrison, 1972). The till forms a thin, discontinuous veneer over the bedrock surface and thickens considerably in the valleys (Harrison, 1972; Figure 2-6).

Organic deposits are found throughout the region and cover sand and gravel outwash plains, glaciolacustrine deposits, and Precambrian bedrock. Most coarse-grained deposits in the region are comprised of sand, gravel and boulders associated with kames, eskers, and moraines. Well-rounded, and well-sorted fluvial sands and gravels form large flat areas or terraces west of the Mattawa and Ottawa valleys (Harrison, 1972). Beach sands are also well-sorted and well-rounded and form raised beaches or scarps (Harrison, 1972).

Glacial outwash is widespread throughout the region. Immediately north of North Bay a large area of sandy gravel, gravelly sand, or sand, blankets the Precambrian bedrock. In some places the overburden is over 30 m thick, but it is generally 3 to 5 m thick over the bedrock (Gartner, 1980). Immediately north of the Mattawa River, outwash deposits are found along Highway 533 from the Town of Mattawa northwest into Antoine Township (Gartner and VanDine, 1980). The Town of Mattawa is underlain by a large east-west trending ground moraine on the western edge of town, and a sand and gravel outwash plain upon which most of the town is built (Ontario

Geological Survey, 1980). Larger and deeper outwash deposits have good potential for groundwater supplies (Harrison, 1972). The Town of Powassan is underlain by coarse sands and gravels in the western portion of the town that are locally covered by a thin (5 to 6 m veneer of “silty clay and clay with sand streaks” (Hydroterra Limited, 2001) in the vicinity of the town’s two municipal wells. Numerous rock outcrops are visible east of Powassan.

End and medial moraines are scattered throughout the Nipissing– Mattawa lowland area east of Lake Nipissing. These moraines consist of bouldery silty sand till, and they occur as subordinate landforms in the rock knob terrain throughout most of the area (Gartner and VanDine, 1980).

The Rutherglen moraine (south of Rutherglen) and the Genesee moraine (15 km east of Powassan) are the two major moraines formed during the last ice recession (Harrison, 1972; Figure 2-6). They formed when ice flowed from the east through the Mattawa Valley lowland. The Rutherglen Moraine extends approximately 11 km from the Mattawa River southward towards Algonquin Park. The moraine, which many consider to be an esker, consists of five segments each with unique composition ranging from sand and gravel, to till and clay (Harrison, 1972). The Genessee Moraine is a large end moraine that lies parallel to the Algonquin Highlands (Figure 2-6). This moraine is more than 8 km long, and up to 3 km wide in some places, and is composed primarily of sand and gravel (Harrison, 1972).

Eskers are sand and gravel deposits that are formed from meltwater channels within or below a glacier. These long ridges of sand and gravel are well developed in the study area. In the Mattawa region, the eskers trend in a southerly direction, with the largest located north of the Town of Mattawa (Gartner and VanDine, 1980). One esker located in the Bonfield Township forms a single ridge and in most places rises 10 to 15 m above the surrounding landscape (Harrison, 1972).

Kames are ice-contact deposits that are typically laid down at the front of melting glaciers and they are also a common landform on the rock knob terrain of the study area (Harrison, 1972). Many kames extend from Lake Talon to the southern margin of the North Bay area, a distance of approximately 35 km (Gartner, 1980). Kames are common in the Powassan area and southeast of Mattawa (Gartner, 1980).

Glaciolacustrine sediments are present in a number of localities in the North Bay area and are especially concentrated along the north shore of Lake Nipissing. East of Bonfield Township the glaciolacustrine sediments range in texture from silty sand, to silt and clay, and usually overlie bedrock or till (Gartner, 1980). Glaciolacustrine deposits near Powassan consist of sand and silt with minor clay (generally where rock knobs are less prominent) (Gartner, 1980). In the region of Mattawa, the glaciolacustrine plains consist of clayey silt and lie at elevations of 260 to 275 m immediately south of the Mattawa and Ottawa Rivers (Gartner and VanDine, 1980).

2.7.2 Bedrock Geology

The bedrock geology of the North Bay-Mattawa study area is part of the Central Gneissic Belt of the Grenville Province of the Canadian Shield. Much of the study area consists of 1.8 to 1.6 billion year old gneisses that have been intruded by 1.4 to 1.5 billion year old granitic and monzonitic plutons (Thurston et al., 1991), but also includes metamorphosed mudstones (metagreywacke), sandstones (quartzite), and limestone (crystalline limestone/ marble).

Structural features trend in a predominantly northeastern direction within the study area and include faults of the Ottawa-Bonnechere graben system (Thurston et al., 1991). The Mattawa River flows along one such fault (the Mattawa River Fault). Similarly, the Nipissing Fault is interpreted to cut through Powassan and appears to follow Genesee Creek through the town itself (Ontario Department of Mines and Northern Affairs, 1971).

Three major batholiths (large igneous intrusive granitic rocks) have been delineated in the North Bay-Mattawa area:

1.) Mulock Batholith (northern part of study area)
2.) Bonfield Batholith (east of North Bay)
3.) Powassan Batholith (southeast of Lake Nipissing)

These batholiths are composed predominantly of pink and grey granites and gneisses of variable composition (Ontario Department of Mines and Northern Affairs, 1971). Between the batholiths are paragneisses (metamorphosed granites) and some instances of marble (Thurston et al., 1991).

In the Mattawa area the rock knob terrain also dominates the area. North of the Mattawa River the local relief is high with bedrock hills often exceeding 60 m in height (Gartner and VanDine, 1980). Local till thickness reaches 5 to 10 m in several areas north of the Mattawa River along Highway 17 on the south side of the Ottawa River. Organic terrain commonly occurs between the bedrock hills as a less important landform within the rock knob terrain (Gartner and VanDine, 1980). Bedrock underlying the North Bay area has been strongly metamorphosed, folded, and intruded by igneous rocks. The oldest and most abundant rocks of the metamorphic complex are the metamorphosed silica-rich sandstones and siltstones (Gartner, 1980). The Powassan area is dominated by the Powassan Batholith and bedrock in this area is predominantly granite and monzonite.

2.7.3 Regional Cross-Sections

Details of the subsurface geologic and hydrogeologic conditions in the North Bay-Mattawa area were evaluated through the development of six regional cross-sections that crosscut the study area. The locations of the regional cross-sections are shown in Figure 2-8, with the individual cross-sections presented in Figures 2-9 to 2-16.

Additional local cross-sections through both Mattawa and Powassan were also completed during the WHPA modeling phase of the study. These cross-sections are smaller scaled than the regional sections and provide local geologic information at and near the municipal wells. These results are presented in Section 6.

CSMapper was utilized to query the project database to create cross-sections for the NBMCA Groundwater Study. A brief description of CSMapper is provided below.

<u>Description of CSMapper</u>

CSMapper is a Windows based application that resides within the MapInfo GIS environment as an add-on application. CSMapper utilizes the many standard GIS tools available for selecting and querying data. In addition, all GIS data are available to CSMapper, allowing spatial data such as topography (digital elevation model), or borehole metadata to be directly displayed on the cross-sections. A GIS is used to manage and visualize large information databases, make and confirm interpretations on-screen, and store layer definitions for use in model development.

Application of CSMapper is a three-step process:

Select the boreholes to be displayed on the cross-section and the straight-line segment that the boreholes will be projected onto within the standard GIS windows; Choose "*Build Cross-Section*" from the pull-down menu and select the appropriate options; and Interpret the appropriate geologic structure in the cross-section window and save the interpretation back to the linked "*Interpretation Database*".

Once the "*Interpretation Database*" has been populated, these data can be readily used within the GIS for interpolation of model layers.

One of the key advancements of CSMapper is the way in which cross-section interpretations are completed. The user is presented with the interpretations for any boreholes already interpreted on intersecting cross-sections. Interpretations of the current cross-section are completed by drawing a series of lines across the cross-section, just as one would on a piece of paper. The current interpretations are stored in the linked database table, and updated immediately. Consequently, there cannot be two intersecting cross-sections with different interpretations.

The data used to generate the cross-sections and store the interpreted layer structure are all contained as relational tables within the project MS ACCESS database. This database is linked to the GIS, enabling updates to be immediately reflected on the cross-sections.

Standard GIS functionality is used to draw the interpretations on-screen, query the borehole data to display the original lithologic description, draw interpolated surfaces on the cross-section, etc.

<u>Cross-Section Application</u>
The cross-sections primarily use water well records from the WWIS to interpret the bedrock geology. Wells included in each cross-section have been projected onto the cross-section lines shown in Figure 2-8. As such, wells can be located hundreds of metres from the cross-section line, resulting in geologic interpretations shown on the cross-sections that do not correlate precisely with the boreholes. For instance, the bedrock elevation presented in each cross-section represents the bedrock elevation along the cross-section line, while the wells that have been projected onto this line will typically have bedrock elevations that are similar, but not the same, as the interpreted elevation.

Cross-section A-A' (Figure 2-9) extends from the northern portion of the study area (east of Lake Nipissing) to the south end of the study area (in Trout Creek). The cross-section is approximately 32 km in length, and crosses through the towns of Callander, Powassan and Trout Creek. Overburden is typically thin (10 to 30 m) and is composed of sands and gravels, with minimal silts and clays noted in the well logs. Water wells 4800971, 4803981, and 4801646 in the south contain thick beds (as much as 100 m) of sands and gravels deposited in a bedrock depression.

Cross-section B-B' (Figure 2-10) is aligned northeast to southwest, beginning in Powassan and passing north of Wasi Lake, through Lake Nosbonsing and Bonfield, and ending north of Rutherglen on the southern shore of Lake Talon. This cross-section is approximately 39 km long and shows more silt and clay in the overburden, which alternates with sands and gravels with thicknesses of up to 50 m.

Cross-section C-C’ (Figure 2-11) is approximately 40 km long, oriented perpendicular to section A-A’. This cross-section begins north of Highway 654 in Nipissing Township and passes near the southern edge of Callander, aligned north of Astorville, and through Bonfield. Depths to bedrock along this transect range from less than 10 m to 80 m. Sand and gravel beds predominate the subsurface geology, however, occasional beds of silt and clay are also present

Cross-section D-D’ (Figure 2-12) is aligned in an east-west direction, passing through North Bay, parallel to the Trans-Canada Highway, and stopping at the boundary between East Ferris and Bonfield Townships. This cross-section is approximately 25 km long, and shows that overburden is very thin in this section of the study area.

Cross-section E-E’ is oriented in an east-west direction, along the Trans-Canada Highway through the eastern half of the study area (including Mattawa) and is approximately 50 km long (Figure 2-13). This section includes the only water well (4303625) in which limestone/dolomite was noted. This well was logged to contain approximately 200 m of either limestone or dolostone, while the surrounding water wells are logged as granite. Although marble is noted in the geology of the area (see Section 2.7.2), it is unlikely that such a thick bed of carbonate rock could be present in such an isolated area and not observed in other wells in the area, therefore it is inferred that the rock formation was misinterpreted or the record was incorrectly entered into the WWIS. This cross-section also shows a definite transition from clay and silt overburden in the west to the sands and gravels of the outwash plains around Mattawa. The sands and gravels are observed to reach thicknesses of up to 50 m in this area.

Cross-section F-F’ runs southwest- northeast through the northwestern portion of the study area (Figure 2-14). This section is approximately 27 km long, from North Bay to Feronia. This cross-section shows that overburden thicknesses and lithologies are highly variable, ranging from thin caps of silt and clays to over 100 m thick beds of sands and gravels.

Cross-section G-G’ has a north-south orientation from Lake Nipissing southwards to Trout Creek. This cross-section illustrates the large increase in topography from the low-lying lake level near Lake Nipissing, to the Algonquin Highlands in the southern portion of the cross-section. This cross-section is very similar to other cross-sections as there are relatively thin overburden deposits, with only a few wells recording substantial thickness of sands and gravels. The thickest deposits of sands and gravels appear to exist at the base of the bedrock outcrops, most likely where paleodrainage occurred during the Quaternary period.

Cross-section H-H’ runs roughly northwest to southeast from the Northern Highlands in the north (north of North Bay) to the Algonquin Highlands in the south. This cross-section clearly shows the thin overburden cover throughout the study area. As with the other regional cross-sections, there do not appear to be any regional overburden aquifers, and the only aquifer that could be identified, as a regional aquifer is the fractured bedrock.

<u>Interpreted Overburden Geology at Municipal Wells</u>

The four municipal wells in the NBMCA study area pump water from sand and gravel overburden aquifers. The two wells in Powassan intersect a deep and coarse grained sand aquifer, and the two operating wells in Mattawa also intersect a deep fluvial sand and gravel aquifer that is interpreted to be alligned parallel to the Mattawa River. Table 2.3 below presents completion details for each of the municipal wells where the information has been available.

Table 2.3 WELL COMPLETION INFORMATION FOR MUNICIPAL WELLS

Municipality	Well	Easting	Northing	Total Depth (m bgs)	Well Completion
Mattawa	Well 1	676210[1]	5131526[1]	26.6	including a 4.6 m long screen
	Well 2	676210[1]	5131526[1]	23.6	Including a 3 m long screen
Powassan	Well 1	625874[2]	5104525[2]	23.2	including a 3.8 m long screen
	Well 2	625890[2]	5104590[2]	18.6	including a 7.6 m long screen

[1] UTM NAD 27, Zone 17
[2] UTM NAD 83, Zone 17

2.7.4 Bedrock Topography

Glacial ice has striated, and polished most of the exposed bedrock in the area, in turn removing much of the pre-glacial or interglacial overburden sediment (Easton, 1992). This resulted in a rock knob terrain that is common throughout this area with numerous organic deposits in low lying areas (Gartner, 1980). Much of the bedrock terrain is low-lying and undulating, but becomes more rugged, steep, and complex east of Lake Nipissing. Thus, the bedrock surface in the NBMCA normally follows ground surface, as the overburden in this area is generally sparse, except in low-lying areas. WWIS data for wells in the study area was used to interpret the position of the bedrock surface within the NBMCA. This information was then contoured in Figure 2-17, which shows the interpreted topography of the bedrock surface beneath the study area.

Areas to the north and south could not be interpreted, as there is no bedrock data available to contour the bedrock surface at these locations. To facilitate mapping in these areas, the bedrock was assumed to be buried beneath 0.5 m of Quaternary-aged sediments. Areas with no data are shown with cross-hatching on the figure. The bedrock surface has a maximum elevation of approximately 405 m asl in the northwest regions of the study area north of North Bay and in areas of the Algonquin Uplands east of Trout Creek. The bedrock surface dips to an elevation of approximately 125 m asl in the central portion of the study area along the Mattawa River.

A general slope of 18 m/km exists between the bedrock topographic high and low. However, a comparison of this slope with (Figure 2-4) shows that there is an inconsistency between the bedrock slope and that observed for surface topography (a general slope of 20 m/km). This discrepancy exists because the bedrock surface is interpreted using WWIS information, and water wells are preferentially installed in areas with access (i.e. along roadways) and where topography is less steep. This means that rock knobs and hills are likely to be absent of water wells (and thus bedrock contact information). This is discussed further in Section 2.7.5. From a regional perspective, the bedrock surface dips down at the Mattawa River and rises on either side of the river valley.

2.7.5 Overburden Thickness

The North Bay-Mattawa area has substantial areas where there is less than a metre of overburden, however it also includes areas with more than 100 m of overburden overlying the Proterozoic bedrock. WWIS data for wells in the study area was used to interpret the position of the bedrock surface within the NBMCA. This information was then contoured in Figure 2-18, which shows the interpreted distribution of overburden thickness across the study area. As noted previously, areas to the north and south of the Mattawa River could not be interpreted, as data is unavailable to interpret the overburden thickness at these locations. Areas with no data are shown with cross-hatching on the figure. Overburden is thickest on the north side of the Mattawa River in Olrig, and Mattawan Townships, and south of the Mattawa River in Boyd, and Pentland Townships.

Overburden is thinnest (<5 m) in the western portions of the study area near Lake Nipissing in East Ferris and areas southeast of North Bay. There a few minor glacial moraines located within the study area and these are identified on Figure 2-6 and Figure 2-17. They generally correspond to areas of thicker overburden in comparison to the surrounding area, however their surface expression may be subdued due to the limited amount of data (ie. few water wells). These moraines include the Rutherglen Moraine and the Gennessee Moraine, which are discussed in Section 2.7.1 above.

Sand and gravel thickness throughout the study area is presented in Figure 2-19. Using the water well records in the WWIS, the total thickness of sand and gravel at each bedrock well was determined. The thickness of sand and gravel at each point location was subsequently interpolated across the study area. As shown in Figure 2-19, sand and gravel thickness trends exist throughout the conservation authority jurisdiction. Areas near the Genesee and Rutherglen Moraines, near Powassan and Rutherglen respectively, are interpreted to contain thicker sequences of sand and gravel. Increased sand and gravel thickness can also be correlated in the Mattawa River near the town of Mattawa. Outwash sand and gravel deposits in this location, and near the town of Powassan also result in thicker sequences of sand and gravel than other portions of the study area.

The remainder of the study area is interpreted to have limited total thickness of sand and gravel. Most of the wells throughout the center of the study area have very little to no significant sand and gravel.

Areas with thick sand and gravel deposits are more likely to include regional overburden aquifers. Overburden and bedrock aquifers in these areas may be under increased risk of contamination where surface water can laterally circumvent protective tills through sand and gravel lenses. As with previously presented maps, areas without data are identified with a cross-hatch pattern on the figure.

2.8 Hydrogeology

2.8.1 Introduction

The North-Bay Mattawa area can be conceptualized as a three layer hydrogeologic model with an upper fine to coarse grained overburden layer, a middle thin weathered bedrock aquifer layer, and a thick lower fractured bedrock aquifer. The 3-layer model represents all areas within the North Bay-Mattawa study area on a regional basis.

Details of the subsurface hydrogeologic conditions in the study area were determined from examination of 7 regional cross-sections and many local area cross-sections (discussed in Section 6 of this report). The locations of the cross-sections are presented on Figure 2-8, with the regional cross-sections presented in Figures 2-9 to 2-16.

2.8.2 Water Table

A regional water table elevation map is presented in Figure 2-20. WWIS data provided the depth to water for wells within the NBMCA area. At each well, the static water level recorded when the well was drilled was used to interpolate groundwater levels throughout the study area. Although static water levels may change over time, groundwater extractions have not changed dramatically, and therefore the static water levels are considered acceptable for the purpose of mapping regional water table elevations. All wells completed to less than 15 m depth were considered in this analysis. As discussed previously, WWIS data is sparse in both the northern and southern portions of the study area. In these areas, additional control points were added along surface water bodies where it was assumed that the water table would coincide with such features.

Generally, the water table follows the surface topography; groundwater flows out of the highlands in the north and south, draining to the Mattawa River and eventually to the Ottawa River, or Lake Nipissing. Water level elevations range from 404 m in the north and south, to 120 m near Lake Nipissing, and the Mattawa and Ottawa Rivers. Overburden wells that exist scattered throughout the study area intersect localized kames, eskers or outwash sands and gravels. These wells may not reflect the elevation of the water table.

Interpreted bedrock equipotentials for the study area are presented on Figure 2-21. The bedrock equipotentials have the same trend as the water table map (Figure 2-20) with groundwater flow in the bedrock trending towards the major surface water bodies.

2.8.3 Regional Aquifers

Regional aquifers in the overburden are difficult to characterize as the majority of the overburden aquifers within the study area are associated with glacial or periglacial landforms. These aquifers, including the fluvial sand deposits in Mattawa, and the sand plains in Powassan, are discontinuous and highly variable, often interrupted by the uneven bedrock topography. More than 90% of all the wells drilled in the NBMCA area are completed in bedrock, which suggests that the bedrock is an important regional aquifer despite its igneous origin. Wells may be preferentially completed in bedrock despite the presence of productive overburden aquifers, because of the higher costs associated with the stainless steel screens required for overburden aquifers in comparison to open-hole well completions in rock aquifers.

The municipal wells in Powassan are completed in the sand plain, which has an estimated hydraulic conductivity of $1x10^{-4}$ m/s, and is reported to have excellent water quality (Totten Simms Hubicki, 2001). The WWIS indicates that most of the residential wells are completed in bedrock. Wells completed in the overburden are scattered across the study area and generally do not follow any trends in topography or their relation to other physical features. It is unknown how many dug wells exist within the study area, and information regarding dug wells is poorly documented.

Harrison (1972) states that “probably the largest source of untapped groundwater in the North Bay-Mattawa Region is in the Town of Mattawa”. This is because of the deeply incised valley carved into the bedrock adjacent to, and beneath, the Mattawa River. This valley is estimated to be 30 to 35 m below ground surface and predominately infilled with highly permeable sand and gravel. Harrison (1972) also notes that the bedrock is nearly impervious and that the probability of developing wells with satisfactory production rates in the bedrock diminish rapidly when wells extend more than 45 m into the rock.

2.8.4 Recharge and Discharge Areas

To differentiate areas where bedrock is being recharged by water moving downward through the overburden, from areas where water is moving upwards from the bedrock to the overburden, bedrock recharge and discharge areas were mapped. This mapping was done by comparing the bedrock water levels with the ground surface elevation. Locations where the bedrock water levels are higher, water is assumed to be moving upwards towards the lower water levels. Conversely, areas were the bedrock water levels are below the ground surface, recharging conditions are interpreted to exist.

Figure 2-22 presents the bedrock recharge and discharge areas using the approach described above. As shown in the figure, bedrock discharge areas are predominantly limited to river and stream valleys. This is expected, since in many of these areas groundwater is providing base flow to rivers or streams. The upland areas in the northern and southern limits of the study area are defined as recharging areas, or areas where groundwater is interpreted to flow in a downward direction. The lowland areas surrounding the Mattawa River and Lake Nipissing are interpreted to be discharge areas, or areas where groundwater flows in an upward direction from the bedrock to the overburden.

2.8.5 Specific Capacity

To evaluate the productivity of the bedrock aquifer throughout the study area, a specific capacity thematic map was developed (see Figure 2-23). Specific capacity was calculated at each bedrock well in the WWIS using the pump test conducted at the time the well was installed. Specific capacity was calculated by dividing the pumping rate during the test by the observed drawdown. Specific capacity can be correlated to bedrock transmissivity, and provides a general estimate of the capacity of the bedrock aquifer at a specific location. For instance, a specific capacity of 1 m^2/day means that for every cubic metre pumped per day the water level in the well will drop one metre. The specific capacity map does have limitations, for instance the length of the screened interval and the diameter of the well are both not incorporated into the calculations. These factors contribute to the large variance observed in the specific capacity thematic map, as discussed below.

Figure 2-23 shows that specific capacity is highly variable across the study area. Higher specific capacity trends are difficult to identify, however, wells completed in coarse grained overburden are likely to have higher values of specific capacity than wells completed in the crystalline bedrock. Variability in the specific capacity mapping is consistent with mapping completed in other jurisdictions using WWIS data, and should be used solely to infer general trends in aquifer productivity. Further detailed testing would be required to generate specific capacity contour mapping.

2.8.6 Regional Groundwater Quality

The Ontario Drinking Water Standards (MOE, 2001b) were designed to protect public health through the provision of safe drinking water. Water intended for domestic use should not contain disease-causing organisms, or unsafe concentrations of toxic chemicals or radioactive substances. Water should be aesthetically acceptable, and parameters such as taste, odour, turbidity and colour should be controlled.

Drinking water quality criteria must take into consideration several factors that may impact the quality of drinking water, public health, and technology available to treat the water. In the Ontario Drinking Water Standards (MOE, 2001b), standards and objectives are outlined. If a parameter is assigned a ‘standard’ there is a maximum acceptable concentration (MAC) assigned to the parameter. The MAC is a health-related standard established for parameters which, when present above a certain concentration, are known or suspected to cause adverse health effects. In contrast, 'objectives' (aesthetic objectives or operational guidelines) are established for parameters that may impair the taste, odour or colour of the water, or may interfere with good water quality control practices.

Regional groundwater quality was evaluated using information contained in the First Engineer's Reports for each of the municipal wells. Included in the evaluation were chemical parameters (nitrate, and fluoride), as well as parameters not directly related to health (colour, hardness and iron). Bacteriological parameters, including total coliform, E. coli, and HPC (heterotrophic plate count) were also examined.

Information was distilled from the First Engineer's Reports regarding groundwater quality within the study area. All of the results reflect tests conducted on raw water samples (prior to treatment and distribution). Some tests were conducted once, while others represent the maximum result obtained over a year or more of monthly, or bimonthly sampling. For reference, the Ontario Drinking Water Standard (ODWS) limits and guidelines are also provided in this table.

Mattawa Water Supply System

Between 1999 and 2001 there were a few instances where the water quality deviated from, or exceeded, the Ontario Drinking Water Standards (ODWS). Total coliform was detected on 3 separate occasions (out of 48 samples) in raw water samples at the well; June. 28, 1999, Sept. 1, 1999, and November 1, 1999. Total coliform bacteria were also identified on several occasions, with one exceedance with a count greater than 200 (May 3, 1999; Dennis Consultants, 2001).

According to the First Engineers Report for Mattawa (Dennis Consultants, 2001), approximately 6% of the groundwater samples taken from the distribution system contained counts of microbiological contamination (report published Mar. 2001). In general, deviations from the ODWS occurred when the total coliform count ranged from 1 to 2 coliform forming units (CFU) per 100 mL (where the objective is 0).

It was also noted by Dennis Consultants (2001) that nitrate was detected on separate sampling occasions in water supply wells. Nitrate is of concern, as it is known to cause methemoglobinemia (blue baby syndrome) in infants. Nitrates can originate from several sources including septic systems or agricultural fertilizers. According to the First Engineers Report, nitrate was detected in the water supply wells, with historical concentrations up to and above 4.0 milligrams per litre (Dennis Consultants,s 2001). The drinking water MAC for nitrate is 10 mg/L.

Powassan Water Supply System

Totten Sims Hubicki (2001) completed a First Engineers Report in 2001 and detailed the bacteriological results between 1998 and 2000. Four hundred and seventy-four (474) samples were taken from the distribution system and of these, 20 exceedances were reported for total coliforms, 3 for E. Coli, and 9 for background bacteria. This amounts to exceedances in approximately 4% of the samples tested. Despite these exceedances, TSH (2001) concluded that the bacteriological raw water quality is very good.

2.9 Land Use

Land use throughout the NBMCA study area is presented in Figure 2-24. Information to complete this mapping was completed using Natural Resource Values Information System (NRVIS) GIS layers. The land uses have been divided into five categories:

- Wetlands
- Woods
- Mining Areas
- Lakes
- Provincial Parks

There are few large urban areas within the study area, with North Bay being the most built up urban area. Callander, Powassan and Mattawa also act as localized population centres within a study area dominated by rural land. As Figure 2-24 shows, the vast majority of the central portion of the study area is covered by wood land, especially areas south of the Mattawa River. There are several Provincial Parks within the study area as well, including Algonquin Park, which covers a large area of land in the southern portion of the study area.

A few areas denoted as mining areas were also identified within the study area. These mining areas correspond to areas where surficial and underground mining activities are taking place.

2.10 Summary

Groundwater represents one of the safest and cleanest forms of water supply, when compared with surface water. Understanding how groundwater moves through the study area and the factors that control this movement will help to manage this resource.

Information from many different data sources, including the Ministry of Environment, Ministry of Natural Resources, Ministry of Northern Development and Mines, Geologic Survey of Canada, Water Survey Canada, and the North Bay-Mattawa Conservation Authority has been incorporated into a project database and GIS. The quality of the different sources of information was evaluated and data that was deemed inaccurate was not included in subsequent analyses. As part of the regional analysis, water well locations and reliabilities (Figure 2-2 and 2-3), ground surface topography (Figure 2-4), stream gauging locations (Figure 2-5), and Quaternary geology (Figure 2-6) are presented.

Regional geologic cross-sections show the presence of thin fine-grained overburden overlying bedrock across the vast majority of the study area (Figures 2-8 to 2-16). Regional cross-sections also show the presence of thick sand and gravel outwash units in areas including Powassan and Mattawa.

The geology and hydrogeology of the North Bay-Mattawa area was investigated and is presented in the depth to bedrock (overburden thickness; Figure 2-18), sand and gravel thickness (Figure 2-19), bedrock geology (Figure 2-7), and bedrock topography (Figure 2-17) mapping.

Groundwater quality was analyzed through a review of raw water and distribution water quality presented in the First Engineer's Reports for both the municipal water supply systems. Chemical and bacteriological parameters were considered in this analysis and it was determined that with the information available groundwater quality in Mattawa and Powassan appears to be good.

Land use information is presented at a regional scale. The vast majority of the study area is rural woodlands, with a large portion of the study area in the south classified as Provincial Park Land (Algonquin Park).

The analysis presented in this report provides a regional summary of groundwater in the North Bay-Mattawa Conservation Authority jurisdiction. The analysis is applicable at the regional scale, however, additional site-scale investigations to refine the results will be required when a new water supply or other groundwater resource related issues emerge.

2 Regional Groundwater and Aquifer Characterization

2.1 Overview

The focus of this study was to incorporate available data from provincial and conservation authority sources to develop a conceptual understanding of the water resources in the study area. The data was interpreted using a Geographical Information System (GIS), to develop a regional, conceptual, geologic model. Aquifer thickness, estimated yield from individual wells in an aquifer, and aquifer vulnerability from potential sources of environmental impacts were estimated from the basic conceptual picture in the GIS database.

2.2 Methodology/Data Sources

During the regional groundwater and aquifer characterization, information from many different data sources was synthesized to develop a regional understanding of the groundwater flow system. The data layers used in this study, as presented in Table 2.1, include the following:

Table 2.1 SOURCES OF INFORMATION AND DATA LAYERS

	Data Layer	Type of Data	Source
1	Digital Elevation Model (DEM)	Topographic Elevation	Ministry of Natural Resources
2	Cadastral Fabric	Lots & Concessions	Ministry of Natural Resources
3	Quaternary Geology	Quaternary Geology	Ministry of Natural Resources, Geological Survey of Canada
4	Water Well Information System (WWIS)	Well Completion and Geologic Information	Ministry of Environment
5	Permits to Take Water	Permitted Water Takings	Ministry of Environment
6	Potential Contaminated Sites Databases	Landfills, Fuel Storage Tanks, Spills	Ministry of Environment
7	Surface Water Monitoring Locations (Staff gauges/ Flow monitoring stations)	Surface Water Stage Elevation and Flows	Water Survey Canada
8	Engineering Terrain Mapping	Surficial Sediments	Ministry of Natural Resources, Ontario Geological Survey, Ministry of Northern Development and Mines
9	Base Mapping	Map Reference Features	Ministry of Natural Resources, Ministry of Environment
10	Bedrock Geology Mapping	Bedrock Geology	Ministry of Northern Development and Mines, Geological Survey of Canada

The MOE Water Well Record database provides an excellent source of data for regional hydrogeologic mapping. This database contains information regarding:

Well location (easting, northing, and ground surface elevation); geologic units encountered with depth; water bearing zones and general water quality observations; well construction details; static water level for screened interval; pumping test information indicating aquifer & well performance (specific capacity); water use; date of well construction; driller code; and other details about the well.

This information provides data that can be used to develop geologic/hydrogeologic maps, hydraulic conductivity estimates (from lithology), specific capacity estimates, water levels within aquifer units, hydraulic gradients and groundwater flow paths. Using the information at each well location, continuous mapping can be developed to characterize the geology/hydrogeology between well locations.

In Ontario, water well information is stored and managed in the Water Well Information System (WWIS). A well record must be submitted to the Provincial Ministry of Environment (MOE), in hardcopy format, when a new well is drilled. This process has been used since 1946. The location of the well is recorded in the form of Township, Lot and Concession, and includes a site drawing. The water well record also includes information about the lithology, water bearing zones, static and pumped water levels, and well construction. The MOE enters this information into their database system from the hardcopy they receive. Prior to 1986, the location of the well (Universal Transverse Mercator or UTM, easting and northing) and its ground elevation were assigned by checking Lot/Concession information on a topographic map. After 1986, no attempt was made to assign UTM coordinates or ground elevations to well records. As of 1999, the database consists of 492,898 wells. Of this total, 336,064 wells have been assigned coordinates, and 156,864 wells exist without eastings, northings, or elevations.

In many cases it is difficult to correlate geologic observations between well logs because each driller has a unique style of data recording and geologic interpretation. The MOE allows a maximum of 3 descriptors for each lithologic unit recorded in the well record, and there are 82 possible descriptors. As a result, there are 500,000 possible lithological names. Inconsistencies in lithologic reporting create difficulties for conceptual model development. Lithologic units are often described differently by various drillers (i.e. each driller may use 3 different descriptors to describe the same unit). For example, differentiating between the different tills throughout the study area is very difficult to do using the water well records. Sand and clay, gravel and clay, and hardpan are terms that may be used by water well drillers to describe a silty or clayey till.

Another source of error in this database results from the manual entry of hardcopy information into electronic format. Manual data entry errors are common in well location and elevation fields. These data represent point anomalies, which can sometimes be recognized through point inspection and well-to-well correlation. Section 2.2.1 (Data Reliability) includes the methodology that was developed to address these types of errors in the Ontario WWIS such that the information can be used for regional scale hydrogeologic analyses. The processes used to evaluate the data in the WWIS are presented schematically in Appendix B.

Another challenge associated with using information from the WWIS is the data density and distribution throughout different parts of Ontario. In the North Bay – Mattawa groundwater study area, well record data is concentrated along roads and settlements. As such there are large areas with few wells from which to distil geological information for regional mapping. These areas were identified and alternative approaches to mapping geological features in these areas were used, as discussed in the following sections.

2.2.1 Data Reliability

Prior to developing a conceptual model for the hydrogeologic systems within the NBMCA study area, all available WWIS data were reviewed and evaluated for reliability and quality (well location, elevation) prior to inclusion in the modeling or mapping analysis. The North Bay-Mattawa database contained a total of 5121 wells prior to inactivating wells due to poor reliability.

Prior to transmitting the WWIS data to the NBMCA, the MOE updated the location reliability codes for each record. It is understood that some wells in the database have such a large margin of error associated with their coordinates, they plot outside the study area, or township cited on the record. These wells were visually isolated and made inactive. All of the water wells that remained active in the database that were used in the development of the mapping products are shown in Figure 2-1.

Wells with UTM (location) reliability codes greater than 6 (margin of error greater than 1km) were made inactive due to their poor location reliability (Figure 2-2a), following the technical terms of reference for the study. In total, 2368 wells fell into this category, with the majority having unknown UTM coordinates. The remaining wells in the study area have a fair UTM reliability with an estimated margin of error ranging from 30 to 300 m.

The ground surface elevation recorded for each well record was also considered during the data quality analysis (Figure 2-2b). The database was queried to compare the reported well elevations to the ground surface elevation in the digital elevation model (DEM). In cases where the difference between the well elevation and the ground surface elevation from the DEM differed by more than 10 m, the wells were made inactive.

The histogram in Figure 2-3a shows the elevation difference between the value recorded for the well record and the DEM. Most well records have elevations that are very similar to the DEM. The well elevations for all of the active well records were updated to reflect the information in the DEM.

In the North Bay-Mattawa study area, the location and elevation data are of poor quality. The majority of the elevation data (~80%) has been interpreted from topographic maps with 50-foot (15 m) contour intervals as shown in Figure 2-2b. Figure 2.3b presents the well completion date for all of the water wells within the study area. The greatest number of wells was drilled in the 1970s.

Figure 2-1 shows the active bedrock and overburden wells located throughout the study area. Over 90% of the wells are completed in bedrock (1942) with the remainder completed in overburden sediments (123). Many of the water wells drilled in the study area are located near Lake Nipissing, with smaller clusters focused around North Bay, Trout Creek, Powassan, and Mattawa, and along major roadways, and surface water. The well database includes two records for wells completed in Algonquin Park, and few wells drilled north of the Mattawa River, which limits the hydrogeologic interpretation in these areas.

2.3 Population

The total population living within the study area at the time of the 2001 census was 70,700 people. This represents a decrease of 1,099 people between 1996 and 2001, an average annual decrease of approximately 0.3% per year over that time period.

The City of North Bay is the largest urban center in the study area, with a population of approximately 52,771 people (2001 Census). The communities of Callendar (population 3168), Mattawa (population 2270), and Powassan (population 1124), are centers of concentrated population within the study area (Statistics Canada, 1996 and 2001 Census).

The rural lands of North Bay-Mattawa are utilized for recreation, farming, or the production of wood products. Mixed farming is predominant in the area although east of Mattawa, in specific sandy areas, potatoes are raised as an exclusive cash crop (Harrison, 1972).

2.4 Climate

Mild summers, cold winters, and fairly reliable precipitation characterize the climate of the North Bay-Mattawa area within northeastern Ontario. Climatic fluctuations from one year to the next, and from one location to the next are anticipated due to the spatial variations caused by the topography and varying exposure to the prevailing winds in relation to area lakes.

Figures showing the long-term monthly precipitation and air temperature for selected climate stations within and surrounding the study area are given in several texts (Brown et al., 1974; Hare, 1979; OMNR, 1984). These figures show the typical variability in rain and snowfall amounts and spatial variations in mean annual precipitation, snowfall and air temperature.

The mean annual precipitation in North Bay is approximately 900 mm, of which approximately 30% appears as snowfall (or 268 cm in depth). The total precipitation is fairly evenly distributed across the study area (OMNR, 1984).

The 30-year climate norm data (discussed in Section 4.3) shows that on an annual average, the wettest months of the year are August and September, while February and March are the driest months. The lowest total precipitation occurs in February, whereas the highest precipitation amount occurs in September.

The mean annual evapotranspiration in the watershed is about 450 mm as deduced from regional Ministry of Natural Resources mapping (OMNR, 1984). Locally, the evapotranspiration may be higher because of significant amounts of water available in ponds, swamps and marshes, or held in soil-water storage.

2.5 Previous Studies

The Ontario Geological Survey published one report on the Quaternary geology of the North Bay-Mattawa Region (Harrison, 1972). The detailed Quaternary geology mapping performed by Harrison used aerial photographs, surface exposures, well logs and auger holes. This information was combined with the topographic expression, soil cover, and photographic characteristics to create map units. Two reports on the Engineering geology of the study area (Gartner and VanDine, 1980; Gartner, 1980) provide information on the surficial and bedrock geology in the study area. Additional reference resources include the Geology of Ontario (Ontario Geological Survey, Vol. 4, Parts 1 and 2), providing detailed descriptions of the bedrock units within the North Bay-Mattawa area as well as the surficial Quaternary overburden. There are also selected journal articles that have investigated the origin and distribution of the bedrock geology throughout portions of the study area, including the Town of Mattawa.

Localized studies related to the geology and hydrogeology of the area have previously been completed. For instance, a First Engineer's Report was completed by Dennis Consultants (2001) for the Mattawa Wells, and Totten Sims Hubicki (2001) completed a report for the Powassan municipal supply wells. Section 12 contains a list of all reference material gathered and compiled as part of this groundwater study.

2.6 Surface Features

2.6.1 Surface Topography

Figure 2-4 is a map of ground surface elevation generated using the Digital Elevation Model (DEM) provided by the Ministry of Natural Resources. Surficial topographic relief in the North Bay – Mattawa area is divided into three distinct regions; the Algonquin Highlands, the Northern Uplands, and the Nipissing - Mattawa Lowland. Topographic relief in the study area is largely the result of glacial deposition (moraines, eskers) and bedrock erosion (river valleys) during the Quaternary Period.

The Algonquin Highlands in the southern portion of the study area are a topographically variable area with relief up to 260 m asl and elevations in excess of 520 m asl. Hills are thinly mantled with glacial till, while the low relief areas are occupied by swamps or lakes (Harrison, 1972). The Northern Uplands are bounded by a scarp to the south and have a moderate relief of approximately 100 m asl and elevations ranging from approximately 400 m asl to 490 m asl. The higher elevations in the upland area also have a thin till cover, and Precambrian bedrock outcrops in many areas (Harrison, 1972). The Nipissing - Mattawa Lowland is an area that lies at elevations less than 325 m asl and this area is associated with extensive lake sediments around and between bedrock outcrops. The lake sediments consist chiefly of varved clays with some rhythmically banded sands (Harrison, 1972). Minor ridges and several large end moraine segments, drumlins, and eskers are important elements of the surface topography (Harrison, 1972).

Surface elevations are lowest along the Mattawa River (Nipissing - Mattawa Lowland), which cuts through the central portion of the study area, and rise significantly north or south of the River. The higher elevation areas to the north correspond to the Northern Uplands and the upland areas in the southern portions of the study area correspond to the Algonquin Highlands.

2.6.2 Surface Water and Stream Flow

The North Bay-Mattawa Conservation Authority (NBMCA) lies primarily within the Ottawa River watershed, with a portion draining to Georgian Bay via Lake Nipissing and the French River. This area is characterized by frequent small, creeks, ephemeral streams and small lakes. Surface water features of primary interest within the study area include Lake Nipissing and Trout Lake in the west and the Mattawa River that cuts east-west through the centre of the study area.

Lake Nipissing was formed during the Wisconsin ice age. It is the 4th largest lake in Ontario with an average depth of 4.5 m and a maximum depth of 52 m near the mouth of the French River, and drains westward into Georgian Bay.

The Mattawa River is a natural passage through the Algonquin Highlands between Lake Nipissing and the Ottawa River. It rises 3.5 km east of Lake Nipissing, and flows east along an ancient fault line into the Ottawa River. The Mattawa River begins in Trout Lake just east of Lake Nipissing, 198.5 metres above sea level, and drops 50 metres over the 43 km distance to the Ottawa River. Its watershed is 117,000 hectares of forested Canadian Shield. The confluence between the Mattawa and Ottawa Rivers is at the Town of Mattawa.

Within the Powassan area, the South River and Genesee Creek are the dominant surface water features. The South River includes two chutes: Elliot Chute and Bingham Chute, both of which host small hydroelectric generating stations. Immediately south of Elliot Chute is the South River Reservoir, which is maintained at a mean water level of approximately 265 m asl. There is a smaller reservoir above Bingham Chute that is maintained at a mean water level of 252 m asl.

The study area has gauging stations that have recorded flow rates throughout the area on streams and rivers (see Table 2.2). The locations of these stations are presented in Figure 2-5. Data collected at these stations were used to obtain stream flow measurements in the respective rivers and streams.

Table 2.2 STREAM GAUGING STATIONS

Station Name	WSC ID	Avg July Flow*	Avg Aug Flow*	Avg Sept Flow*	Drainage Area (km^2)	Record Length	Area Average Flow Rate (mm/yr)
Chippewa Creek at North Bay	02DD014	0.396	0.141	0.227	14.4	1974-2003	119.2
La Vase River at North Bay	02DD013	0.156	0.122	0.238	27.2	1974-2003	54.6
Mattawa River below Bouillon Lake	02JE020	7.022	9.033	6.003	360	1972-1998	203.0
Mattawa River near Rutherglen	02JE014	9.502	7.055	4.814	2040	1962-1971	74.4

* Flow is measured in cubic meters per second

The area-averaged flow rate in the North Bay-Mattawa study area during the summer months varies widely from 55 to 203 mm/yr. This value was obtained by dividing the monthly flow averages during July, August, and September by the corresponding drainage area of the river or stream. These values were used in the calculation, as they can be indicative of stream base flow, or the flow to the stream that is derived from groundwater discharge.

2.7 Geology

2.7.1 Quaternary Geology

Deposits formed by, or in connection with, continental glaciers are of particular hydrogeologic importance in the North Bay-Mattawa region. Continental scale glaciers repeatedly advanced over the study area throughout the last two million years, leaving behind a variety of glacial, glaciofluvial, and glaciolacustrine sediments.

With the exception of steep bedrock outcrop exposures and rock knob features, the North Bay-Mattawa region is predominately overlain by subglacial till deposited during the last glacial ice advance. The till matrix varies in texture from fine grained silts and sands with clasts ranging from small grains to large boulders. The till is red- grey in colour, lacking of carbonate clasts, and there is a low percentage of fine-grained material (Harrison, 1972). The till forms a thin, discontinuous veneer over the bedrock surface and thickens considerably in the valleys (Harrison, 1972; Figure 2-6).

Organic deposits are found throughout the region and cover sand and gravel outwash plains, glaciolacustrine deposits, and Precambrian bedrock. Most coarse-grained deposits in the region are comprised of sand, gravel and boulders associated with kames, eskers, and moraines. Well-rounded, and well-sorted fluvial sands and gravels form large flat areas or terraces west of the Mattawa and Ottawa valleys (Harrison, 1972). Beach sands are also well-sorted and well-rounded and form raised beaches or scarps (Harrison, 1972).

Glacial outwash is widespread throughout the region. Immediately north of North Bay a large area of sandy gravel, gravelly sand, or sand, blankets the Precambrian bedrock. In some places the overburden is over 30 m thick, but it is generally 3 to 5 m thick over the bedrock (Gartner, 1980). Immediately north of the Mattawa River, outwash deposits are found along Highway 533 from the Town of Mattawa northwest into Antoine Township (Gartner and VanDine, 1980). The Town of Mattawa is underlain by a large east-west trending ground moraine on the western edge of town, and a sand and gravel outwash plain upon which most of the town is built (Ontario

Geological Survey, 1980). Larger and deeper outwash deposits have good potential for groundwater supplies (Harrison, 1972). The Town of Powassan is underlain by coarse sands and gravels in the western portion of the town that are locally covered by a thin (5 to 6 m veneer of “silty clay and clay with sand streaks” (Hydroterra Limited, 2001) in the vicinity of the town’s two municipal wells. Numerous rock outcrops are visible east of Powassan.

End and medial moraines are scattered throughout the Nipissing– Mattawa lowland area east of Lake Nipissing. These moraines consist of bouldery silty sand till, and they occur as subordinate landforms in the rock knob terrain throughout most of the area (Gartner and VanDine, 1980).

The Rutherglen moraine (south of Rutherglen) and the Genesee moraine (15 km east of Powassan) are the two major moraines formed during the last ice recession (Harrison, 1972; Figure 2-6). They formed when ice flowed from the east through the Mattawa Valley lowland. The Rutherglen Moraine extends approximately 11 km from the Mattawa River southward towards Algonquin Park. The moraine, which many consider to be an esker, consists of five segments each with unique composition ranging from sand and gravel, to till and clay (Harrison, 1972). The Genessee Moraine is a large end moraine that lies parallel to the Algonquin Highlands (Figure 2-6). This moraine is more than 8 km long, and up to 3 km wide in some places, and is composed primarily of sand and gravel (Harrison, 1972).

Eskers are sand and gravel deposits that are formed from meltwater channels within or below a glacier. These long ridges of sand and gravel are well developed in the study area. In the Mattawa region, the eskers trend in a southerly direction, with the largest located north of the Town of Mattawa (Gartner and VanDine, 1980). One esker located in the Bonfield Township forms a single ridge and in most places rises 10 to 15 m above the surrounding landscape (Harrison, 1972).

Kames are ice-contact deposits that are typically laid down at the front of melting glaciers and they are also a common landform on the rock knob terrain of the study area (Harrison, 1972). Many kames extend from Lake Talon to the southern margin of the North Bay area, a distance of approximately 35 km (Gartner, 1980). Kames are common in the Powassan area and southeast of Mattawa (Gartner, 1980).

Glaciolacustrine sediments are present in a number of localities in the North Bay area and are especially concentrated along the north shore of Lake Nipissing. East of Bonfield Township the glaciolacustrine sediments range in texture from silty sand, to silt and clay, and usually overlie bedrock or till (Gartner, 1980). Glaciolacustrine deposits near Powassan consist of sand and silt with minor clay (generally where rock knobs are less prominent) (Gartner, 1980). In the region of Mattawa, the glaciolacustrine plains consist of clayey silt and lie at elevations of 260 to 275 m immediately south of the Mattawa and Ottawa Rivers (Gartner and VanDine, 1980).

2.7.2 Bedrock Geology

The bedrock geology of the North Bay-Mattawa study area is part of the Central Gneissic Belt of the Grenville Province of the Canadian Shield. Much of the study area consists of 1.8 to 1.6 billion year old gneisses that have been intruded by 1.4 to 1.5 billion year old granitic and monzonitic plutons (Thurston et al., 1991), but also includes metamorphosed mudstones (metagreywacke), sandstones (quartzite), and limestone (crystalline limestone/ marble).

Structural features trend in a predominantly northeastern direction within the study area and include faults of the Ottawa-Bonnechere graben system (Thurston et al., 1991). The Mattawa River flows along one such fault (the Mattawa River Fault). Similarly, the Nipissing Fault is interpreted to cut through Powassan and appears to follow Genesee Creek through the town itself (Ontario Department of Mines and Northern Affairs, 1971).

Three major batholiths (large igneous intrusive granitic rocks) have been delineated in the North Bay-Mattawa area:

1.) Mulock Batholith (northern part of study area)
2.) Bonfield Batholith (east of North Bay)
3.) Powassan Batholith (southeast of Lake Nipissing)

These batholiths are composed predominantly of pink and grey granites and gneisses of variable composition (Ontario Department of Mines and Northern Affairs, 1971). Between the batholiths are paragneisses (metamorphosed granites) and some instances of marble (Thurston et al., 1991).

In the Mattawa area the rock knob terrain also dominates the area. North of the Mattawa River the local relief is high with bedrock hills often exceeding 60 m in height (Gartner and VanDine, 1980). Local till thickness reaches 5 to 10 m in several areas north of the Mattawa River along Highway 17 on the south side of the Ottawa River. Organic terrain commonly occurs between the bedrock hills as a less important landform within the rock knob terrain (Gartner and VanDine, 1980). Bedrock underlying the North Bay area has been strongly metamorphosed, folded, and intruded by igneous rocks. The oldest and most abundant rocks of the metamorphic complex are the metamorphosed silica-rich sandstones and siltstones (Gartner, 1980). The Powassan area is dominated by the Powassan Batholith and bedrock in this area is predominantly granite and monzonite.

2.7.3 Regional Cross-Sections

Details of the subsurface geologic and hydrogeologic conditions in the North Bay-Mattawa area were evaluated through the development of six regional cross-sections that crosscut the study area. The locations of the regional cross-sections are shown in Figure 2-8, with the individual cross-sections presented in Figures 2-9 to 2-16.

Additional local cross-sections through both Mattawa and Powassan were also completed during the WHPA modeling phase of the study. These cross-sections are smaller scaled than the regional sections and provide local geologic information at and near the municipal wells. These results are presented in Section 6.

CSMapper was utilized to query the project database to create cross-sections for the NBMCA Groundwater Study. A brief description of CSMapper is provided below.

<u>Description of CSMapper</u>

CSMapper is a Windows based application that resides within the MapInfo GIS environment as an add-on application. CSMapper utilizes the many standard GIS tools available for selecting and querying data. In addition, all GIS data are available to CSMapper, allowing spatial data such as topography (digital elevation model), or borehole metadata to be directly displayed on the cross-sections. A GIS is used to manage and visualize large information databases, make and confirm interpretations on-screen, and store layer definitions for use in model development.

Application of CSMapper is a three-step process:

Select the boreholes to be displayed on the cross-section and the straight-line segment that the boreholes will be projected onto within the standard GIS windows; Choose "*Build Cross-Section*" from the pull-down menu and select the appropriate options; and Interpret the appropriate geologic structure in the cross-section window and save the interpretation back to the linked "*Interpretation Database*".

Once the "*Interpretation Database*" has been populated, these data can be readily used within the GIS for interpolation of model layers.

One of the key advancements of CSMapper is the way in which cross-section interpretations are completed. The user is presented with the interpretations for any boreholes already interpreted on intersecting cross-sections. Interpretations of the current cross-section are completed by drawing a series of lines across the cross-section, just as one would on a piece of paper. The current interpretations are stored in the linked database table, and updated immediately. Consequently, there cannot be two intersecting cross-sections with different interpretations.

The data used to generate the cross-sections and store the interpreted layer structure are all contained as relational tables within the project MS ACCESS database. This database is linked to the GIS, enabling updates to be immediately reflected on the cross-sections.

Standard GIS functionality is used to draw the interpretations on-screen, query the borehole data to display the original lithologic description, draw interpolated surfaces on the cross-section, etc.

<u>Cross-Section Application</u>
The cross-sections primarily use water well records from the WWIS to interpret the bedrock geology. Wells included in each cross-section have been projected onto the cross-section lines shown in Figure 2-8. As such, wells can be located hundreds of metres from the cross-section line, resulting in geologic interpretations shown on the cross-sections that do not correlate precisely with the boreholes. For instance, the bedrock elevation presented in each cross-section represents the bedrock elevation along the cross-section line, while the wells that have been projected onto this line will typically have bedrock elevations that are similar, but not the same, as the interpreted elevation.

Cross-section A-A' (Figure 2-9) extends from the northern portion of the study area (east of Lake Nipissing) to the south end of the study area (in Trout Creek). The cross-section is approximately 32 km in length, and crosses through the towns of Callander, Powassan and Trout Creek. Overburden is typically thin (10 to 30 m) and is composed of sands and gravels, with minimal silts and clays noted in the well logs. Water wells 4800971, 4803981, and 4801646 in the south contain thick beds (as much as 100 m) of sands and gravels deposited in a bedrock depression.

Cross-section B-B' (Figure 2-10) is aligned northeast to southwest, beginning in Powassan and passing north of Wasi Lake, through Lake Nosbonsing and Bonfield, and ending north of Rutherglen on the southern shore of Lake Talon. This cross-section is approximately 39 km long and shows more silt and clay in the overburden, which alternates with sands and gravels with thicknesses of up to 50 m.

Cross-section C-C' (Figure 2-11) is approximately 40 km long, oriented perpendicular to section A-A'. This cross-section begins north of Highway 654 in Nipissing Township and passes near the southern edge of Callander, aligned north of Astorville, and through Bonfield. Depths to bedrock along this transect range from less than 10 m to 80 m. Sand and gravel beds predominate the subsurface geology, however, occasional beds of silt and clay are also present

Cross-section D-D' (Figure 2-12) is aligned in an east-west direction, passing through North Bay, parallel to the Trans-Canada Highway, and stopping at the boundary between East Ferris and Bonfield Townships. This cross-section is approximately 25 km long, and shows that overburden is very thin in this section of the study area.

Cross-section E-E' is oriented in an east-west direction, along the Trans-Canada Highway through the eastern half of the study area (including Mattawa) and is approximately 50 km long (Figure 2-13). This section includes the only water well (4303625) in which limestone/dolomite was noted. This well was logged to contain approximately 200 m of either limestone or dolostone, while the surrounding water wells are logged as granite. Although marble is noted in the geology of the area (see Section 2.7.2), it is unlikely that such a thick bed of carbonate rock could be present in such an isolated area and not observed in other wells in the area, therefore it is inferred that the rock formation was misinterpreted or the record was incorrectly entered into the WWIS. This cross-section also shows a definite transition from clay and silt overburden in the west to the sands and gravels of the outwash plains around Mattawa. The sands and gravels are observed to reach thicknesses of up to 50 m in this area.

Cross-section F-F' runs southwest- northeast through the northwestern portion of the study area (Figure 2-14). This section is approximately 27 km long, from North Bay to Feronia. This cross-section shows that overburden thicknesses and lithologies are highly variable, ranging from thin caps of silt and clays to over 100 m thick beds of sands and gravels.

Cross-section G-G' has a north-south orientation from Lake Nipissing southwards to Trout Creek. This cross-section illustrates the large increase in topography from the low-lying lake level near Lake Nipissing, to the Algonquin Highlands in the southern portion of the cross-section. This cross-section is very similar to other cross-sections as there are relatively thin overburden deposits, with only a few wells recording substantial thickness of sands and gravels. The thickest deposits of sands and gravels appear to exist at the base of the bedrock outcrops, most likely where paleodrainage occurred during the Quaternary period.

Cross-section H-H' runs roughly northwest to southeast from the Northern Highlands in the north (north of North Bay) to the Algonquin Highlands in the south. This cross-section clearly shows the thin overburden cover throughout the study area. As with the other regional cross-sections, there do not appear to be any regional overburden aquifers, and the only aquifer that could be identified, as a regional aquifer is the fractured bedrock.

<u>Interpreted Overburden Geology at Municipal Wells</u>

The four municipal wells in the NBMCA study area pump water from sand and gravel overburden aquifers. The two wells in Powassan intersect a deep and coarse grained sand aquifer, and the two operating wells in Mattawa also intersect a deep fluvial sand and gravel aquifer that is interpreted to be alligned parallel to the Mattawa River. Table 2.3 below presents completion details for each of the municipal wells where the information has been available.

Table 2.3 WELL COMPLETION INFORMATION FOR MUNICIPAL WELLS

Municipality	Well	Easting	Northing	Total Depth (m bgs)	Well Completion
Mattawa	Well 1	676210[1]	5131526[1]	26.6	including a 4.6 m long screen
	Well 2	676210[1]	5131526[1]	23.6	Including a 3 m long screen
Powassan	Well 1	625874[2]	5104525[2]	23.2	including a 3.8 m long screen
	Well 2	625890[2]	5104590[2]	18.6	including a 7.6 m long screen

[1] UTM NAD 27, Zone 17
[2] UTM NAD 83, Zone 17

2.7.4 Bedrock Topography

Glacial ice has striated, and polished most of the exposed bedrock in the area, in turn removing much of the pre-glacial or interglacial overburden sediment (Easton, 1992). This resulted in a rock knob terrain that is common throughout this area with numerous organic deposits in low lying areas (Gartner, 1980). Much of the bedrock terrain is low-lying and undulating, but becomes more rugged, steep, and complex east of Lake Nipissing. Thus, the bedrock surface in the NBMCA normally follows ground surface, as the overburden in this area is generally sparse, except in low-lying areas. WWIS data for wells in the study area was used to interpret the position of the bedrock surface within the NBMCA. This information was then contoured in Figure 2-17, which shows the interpreted topography of the bedrock surface beneath the study area.

Areas to the north and south could not be interpreted, as there is no bedrock data available to contour the bedrock surface at these locations. To facilitate mapping in these areas, the bedrock was assumed to be buried beneath 0.5 m of Quaternary-aged sediments. Areas with no data are shown with cross-hatching on the figure. The bedrock surface has a maximum elevation of approximately 405 m asl in the northwest regions of the study area north of North Bay and in areas of the Algonquin Uplands east of Trout Creek. The bedrock surface dips to an elevation of approximately 125 m asl in the central portion of the study area along the Mattawa River.

A general slope of 18 m/km exists between the bedrock topographic high and low. However, a comparison of this slope with (Figure 2-4) shows that there is an inconsistency between the bedrock slope and that observed for surface topography (a general slope of 20 m/km). This discrepancy exists because the bedrock surface is interpreted using WWIS information, and water wells are preferentially installed in areas with access (i.e. along roadways) and where topography is less steep. This means that rock knobs and hills are likely to be absent of water wells (and thus bedrock contact information). This is discussed further in Section 2.7.5. From a regional perspective, the bedrock surface dips down at the Mattawa River and rises on either side of the river valley.

2.7.5 Overburden Thickness

The North Bay-Mattawa area has substantial areas where there is less than a metre of overburden, however it also includes areas with more than 100 m of overburden overlying the Proterozoic bedrock. WWIS data for wells in the study area was used to interpret the position of the bedrock surface within the NBMCA. This information was then contoured in Figure 2-18, which shows the interpreted distribution of overburden thickness across the study area. As noted previously, areas to the north and south of the Mattawa River could not be interpreted, as data is unavailable to interpret the overburden thickness at these locations. Areas with no data are shown with cross-hatching on the figure. Overburden is thickest on the north side of the Mattawa River in Olrig, and Mattawan Townships, and south of the Mattawa River in Boyd, and Pentland Townships.

Overburden is thinnest (<5 m) in the western portions of the study area near Lake Nipissing in East Ferris and areas southeast of North Bay. There a few minor glacial moraines located within the study area and these are identified on Figure 2-6 and Figure 2-17. They generally correspond to areas of thicker overburden in comparison to the surrounding area, however their surface expression may be subdued due to the limited amount of data (ie. few water wells). These moraines include the Rutherglen Moraine and the Gennessee Moraine, which are discussed in Section 2.7.1 above.

Sand and gravel thickness throughout the study area is presented in Figure 2-19. Using the water well records in the WWIS, the total thickness of sand and gravel at each bedrock well was determined. The thickness of sand and gravel at each point location was subsequently interpolated across the study area. As shown in Figure 2-19, sand and gravel thickness trends exist throughout the conservation authority jurisdiction. Areas near the Genesee and Rutherglen Moraines, near Powassan and Rutherglen respectively, are interpreted to contain thicker sequences of sand and gravel. Increased sand and gravel thickness can also be correlated in the Mattawa River near the town of Mattawa. Outwash sand and gravel deposits in this location, and near the town of Powassan also result in thicker sequences of sand and gravel than other portions of the study area.

The remainder of the study area is interpreted to have limited total thickness of sand and gravel. Most of the wells throughout the center of the study area have very little to no significant sand and gravel.

Areas with thick sand and gravel deposits are more likely to include regional overburden aquifers. Overburden and bedrock aquifers in these areas may be under increased risk of contamination where surface water can laterally circumvent protective tills through sand and gravel lenses. As with previously presented maps, areas without data are identified with a cross-hatch pattern on the figure.

2.8 Hydrogeology

2.8.1 Introduction

The North-Bay Mattawa area can be conceptualized as a three layer hydrogeologic model with an upper fine to coarse grained overburden layer, a middle thin weathered bedrock aquifer layer, and a thick lower fractured bedrock aquifer. The 3-layer model represents all areas within the North Bay-Mattawa study area on a regional basis.

Details of the subsurface hydrogeologic conditions in the study area were determined from examination of 7 regional cross-sections and many local area cross-sections (discussed in Section 6 of this report). The locations of the cross-sections are presented on Figure 2-8, with the regional cross-sections presented in Figures 2-9 to 2-16.

2.8.2 Water Table

A regional water table elevation map is presented in Figure 2-20. WWIS data provided the depth to water for wells within the NBMCA area. At each well, the static water level recorded when the well was drilled was used to interpolate groundwater levels throughout the study area. Although static water levels may change over time, groundwater extractions have not changed dramatically, and therefore the static water levels are considered acceptable for the purpose of mapping regional water table elevations. All wells completed to less than 15 m depth were considered in this analysis. As discussed previously, WWIS data is sparse in both the northern and southern portions of the study area. In these areas, additional control points were added along surface water bodies where it was assumed that the water table would coincide with such features.

Generally, the water table follows the surface topography; groundwater flows out of the highlands in the north and south, draining to the Mattawa River and eventually to the Ottawa River, or Lake Nipissing. Water level elevations range from 404 m in the north and south, to 120 m near Lake Nipissing, and the Mattawa and Ottawa Rivers. Overburden wells that exist scattered throughout the study area intersect localized kames, eskers or outwash sands and gravels. These wells may not reflect the elevation of the water table.

Interpreted bedrock equipotentials for the study area are presented on Figure 2-21. The bedrock equipotentials have the same trend as the water table map (Figure 2-20) with groundwater flow in the bedrock trending towards the major surface water bodies.

2.8.3 Regional Aquifers

Regional aquifers in the overburden are difficult to characterize as the majority of the overburden aquifers within the study area are associated with glacial or periglacial landforms. These aquifers, including the fluvial sand deposits in Mattawa, and the sand plains in Powassan, are discontinuous and highly variable, often interrupted by the uneven bedrock topography. More than 90% of all the wells drilled in the NBMCA area are completed in bedrock, which suggests that the bedrock is an important regional aquifer despite its igneous origin. Wells may be preferentially completed in bedrock despite the presence of productive overburden aquifers, because of the higher costs associated with the stainless steel screens required for overburden aquifers in comparison to open-hole well completions in rock aquifers.

The municipal wells in Powassan are completed in the sand plain, which has an estimated hydraulic conductivity of $1x10^{-4}$ m/s, and is reported to have excellent water quality (Totten Simms Hubicki, 2001). The WWIS indicates that most of the residential wells are completed in bedrock. Wells completed in the overburden are scattered across the study area and generally do not follow any trends in topography or their relation to other physical features. It is unknown how many dug wells exist within the study area, and information regarding dug wells is poorly documented.

Harrison (1972) states that “probably the largest source of untapped groundwater in the North Bay-Mattawa Region is in the Town of Mattawa”. This is because of the deeply incised valley carved into the bedrock adjacent to, and beneath, the Mattawa River. This valley is estimated to be 30 to 35 m below ground surface and predominately infilled with highly permeable sand and gravel. Harrison (1972) also notes that the bedrock is nearly impervious and that the probability of developing wells with satisfactory production rates in the bedrock diminish rapidly when wells extend more than 45 m into the rock.

2.8.4 Recharge and Discharge Areas

To differentiate areas where bedrock is being recharged by water moving downward through the overburden, from areas where water is moving upwards from the bedrock to the overburden, bedrock recharge and discharge areas were mapped. This mapping was done by comparing the bedrock water levels with the ground surface elevation. Locations where the bedrock water levels are higher, water is assumed to be moving upwards towards the lower water levels. Conversely, areas were the bedrock water levels are below the ground surface, recharging conditions are interpreted to exist.

Figure 2-22 presents the bedrock recharge and discharge areas using the approach described above. As shown in the figure, bedrock discharge areas are predominantly limited to river and stream valleys. This is expected, since in many of these areas groundwater is providing base flow to rivers or streams. The upland areas in the northern and southern limits of the study area are defined as recharging areas, or areas where groundwater is interpreted to flow in a downward direction. The lowland areas surrounding the Mattawa River and Lake Nipissing are interpreted to be discharge areas, or areas where groundwater flows in an upward direction from the bedrock to the overburden.

2.8.5 Specific Capacity

To evaluate the productivity of the bedrock aquifer throughout the study area, a specific capacity thematic map was developed (see Figure 2-23). Specific capacity was calculated at each bedrock well in the WWIS using the pump test conducted at the time the well was installed. Specific capacity was calculated by dividing the pumping rate during the test by the observed drawdown. Specific capacity can be correlated to bedrock transmissivity, and provides a general estimate of the capacity of the bedrock aquifer at a specific location. For instance, a specific capacity of 1 m^2/day means that for every cubic metre pumped per day the water level in the well will drop one metre. The specific capacity map does have limitations, for instance the length of the screened interval and the diameter of the well are both not incorporated into the calculations. These factors contribute to the large variance observed in the specific capacity thematic map, as discussed below.

Figure 2-23 shows that specific capacity is highly variable across the study area. Higher specific capacity trends are difficult to identify, however, wells completed in coarse grained overburden are likely to have higher values of specific capacity than wells completed in the crystalline bedrock. Variability in the specific capacity mapping is consistent with mapping completed in other jurisdictions using WWIS data, and should be used solely to infer general trends in aquifer productivity. Further detailed testing would be required to generate specific capacity contour mapping.

2.8.6 Regional Groundwater Quality

The Ontario Drinking Water Standards (MOE, 2001b) were designed to protect public health through the provision of safe drinking water. Water intended for domestic use should not contain disease-causing organisms, or unsafe concentrations of toxic chemicals or radioactive substances. Water should be aesthetically acceptable, and parameters such as taste, odour, turbidity and colour should be controlled.

Drinking water quality criteria must take into consideration several factors that may impact the quality of drinking water, public health, and technology available to treat the water. In the Ontario Drinking Water Standards (MOE, 2001b), standards and objectives are outlined. If a parameter is assigned a ‘standard’ there is a maximum acceptable concentration (MAC) assigned to the parameter. The MAC is a health-related standard established for parameters which, when present above a certain concentration, are known or suspected to cause adverse health effects. In contrast, 'objectives' (aesthetic objectives or operational guidelines) are established for parameters that may impair the taste, odour or colour of the water, or may interfere with good water quality control practices.

Regional groundwater quality was evaluated using information contained in the First Engineer's Reports for each of the municipal wells. Included in the evaluation were chemical parameters (nitrate, and fluoride), as well as parameters not directly related to health (colour, hardness and iron). Bacteriological parameters, including total coliform, E. coli, and HPC (heterotrophic plate count) were also examined.

Information was distilled from the First Engineer's Reports regarding groundwater quality within the study area. All of the results reflect tests conducted on raw water samples (prior to treatment and distribution). Some tests were conducted once, while others represent the maximum result obtained over a year or more of monthly, or bimonthly sampling. For reference, the Ontario Drinking Water Standard (ODWS) limits and guidelines are also provided in this table.

Mattawa Water Supply System

Between 1999 and 2001 there were a few instances where the water quality deviated from, or exceeded, the Ontario Drinking Water Standards (ODWS). Total coliform was detected on 3 separate occasions (out of 48 samples) in raw water samples at the well; June. 28, 1999, Sept. 1, 1999, and November 1, 1999. Total coliform bacteria were also identified on several occasions, with one exceedance with a count greater than 200 (May 3, 1999; Dennis Consultants, 2001).

According to the First Engineers Report for Mattawa (Dennis Consultants, 2001), approximately 6% of the groundwater samples taken from the distribution system contained counts of microbiological contamination (report published Mar. 2001). In general, deviations from the ODWS occurred when the total coliform count ranged from 1 to 2 coliform forming units (CFU) per 100 mL (where the objective is 0).

It was also noted by Dennis Consultants (2001) that nitrate was detected on separate sampling occasions in water supply wells. Nitrate is of concern, as it is known to cause methemoglobinemia (blue baby syndrome) in infants. Nitrates can originate from several sources including septic systems or agricultural fertilizers. According to the First Engineers Report, nitrate was detected in the water supply wells, with historical concentrations up to and above 4.0 milligrams per litre (Dennis Consultants,s 2001). The drinking water MAC for nitrate is 10 mg/L.

Powassan Water Supply System

Totten Sims Hubicki (2001) completed a First Engineers Report in 2001 and detailed the bacteriological results between 1998 and 2000. Four hundred and seventy-four (474) samples were taken from the distribution system and of these, 20 exceedances were reported for total coliforms, 3 for E. Coli, and 9 for background bacteria. This amounts to exceedances in approximately 4% of the samples tested. Despite these exceedances, TSH (2001) concluded that the bacteriological raw water quality is very good.

2.9 Land Use

Land use throughout the NBMCA study area is presented in Figure 2-24. Information to complete this mapping was completed using Natural Resource Values Information System (NRVIS) GIS layers. The land uses have been divided into five categories:

- Wetlands
- Woods
- Mining Areas
- Lakes
- Provincial Parks

There are few large urban areas within the study area, with North Bay being the most built up urban area. Callander, Powassan and Mattawa also act as localized population centres within a study area dominated by rural land. As Figure 2-24 shows, the vast majority of the central portion of the study area is covered by wood land, especially areas south of the Mattawa River. There are several Provincial Parks within the study area as well, including Algonquin Park, which covers a large area of land in the southern portion of the study area.

A few areas denoted as mining areas were also identified within the study area. These mining areas correspond to areas where surficial and underground mining activities are taking place.

2.10 Summary

Groundwater represents one of the safest and cleanest forms of water supply, when compared with surface water. Understanding how groundwater moves through the study area and the factors that control this movement will help to manage this resource.

Information from many different data sources, including the Ministry of Environment, Ministry of Natural Resources, Ministry of Northern Development and Mines, Geologic Survey of Canada, Water Survey Canada, and the North Bay-Mattawa Conservation Authority has been incorporated into a project database and GIS. The quality of the different sources of information was evaluated and data that was deemed inaccurate was not included in subsequent analyses. As part of the regional analysis, water well locations and reliabilities (Figure 2-2 and 2-3), ground surface topography (Figure 2-4), stream gauging locations (Figure 2-5), and Quaternary geology (Figure 2-6) are presented.

Regional geologic cross-sections show the presence of thin fine-grained overburden overlying bedrock across the vast majority of the study area (Figures 2-8 to 2-16). Regional cross-sections also show the presence of thick sand and gravel outwash units in areas including Powassan and Mattawa.

The geology and hydrogeology of the North Bay-Mattawa area was investigated and is presented in the depth to bedrock (overburden thickness; Figure 2-18), sand and gravel thickness (Figure 2-19), bedrock geology (Figure 2-7), and bedrock topography (Figure 2-17) mapping.

Groundwater quality was analyzed through a review of raw water and distribution water quality presented in the First Engineer's Reports for both the municipal water supply systems. Chemical and bacteriological parameters were considered in this analysis and it was determined that with the information available groundwater quality in Mattawa and Powassan appears to be good.

Land use information is presented at a regional scale. The vast majority of the study area is rural woodlands, with a large portion of the study area in the south classified as Provincial Park Land (Algonquin Park).

The analysis presented in this report provides a regional summary of groundwater in the North Bay-Mattawa Conservation Authority jurisdiction. The analysis is applicable at the regional scale, however, additional site-scale investigations to refine the results will be required when a new water supply or other groundwater resource related issues emerge.

3 Groundwater Intrinsic Susceptibility Analysis

3.1 Overview

The susceptibility of an aquifer to contamination is a function of the susceptibility of its recharge area to the infiltration of contaminants. Groundwater susceptibility to contamination can thus be defined as: *the tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer.* Susceptibility is not an absolute property, but a relative indication of where contamination is likely to enter the subsurface. It is also necessary to consider long-term effects on groundwater quality, perhaps over decades, in carrying out a susceptibility analysis.

A number of factors may influence the susceptibility of an aquifer. Areas of high recharge are generally more susceptible to groundwater contamination than areas where recharge is restricted. In addition, unconfined aquifers having little cover of fine-grained material are susceptible to contamination. Fractured bedrock is highly susceptible because of rapid rates of groundwater flow and less potential for attenuation of contaminants. Deeper aquifers confined by an impermeable formation are better protected than unconfined aquifers.

Water wells can act as a direct pathway for contaminants to travel from the land surface to an aquifer, if they are not constructed properly. In addition, wells intersecting two aquifers increase the chance of cross contamination between the aquifers. An important consideration in groundwater protection and the risk of contamination is the position and condition of water wells.

Overburden formations generally provide primary protection against groundwater contamination from the surface. Bacteria, sediment and other insoluble forms of contamination can become trapped or adsorbed within the soil pores. Some chemicals are absorbed or react chemically with various soil constituents, thereby preventing or slowing the migration of these contaminants into the groundwater. In addition, plants and soil micro-organisms utilize some potential contaminants, such as nitrogen, as nutrients for growth. This reduces the resultant contamination in the groundwater. These processes are known as natural attenuation processes.

These natural systems can fail if they are overloaded with pollutants. Large amounts of potential pollutants concentrated in a small area can cause localized groundwater contamination, depending on the depth and type of soil above the water table. To help protect water wells against contamination, it is important to use the natural protection that soil provides by maintaining adequate separation distances between wells and potential sources of contamination. Groundwater protection strategies aim at mitigating or minimizing the potential for aquifer contamination through proper land use and groundwater management alternatives.

It is costly and time consuming to identify and remediate groundwater contamination after an aquifer has been impacted, and aquifers may remain contaminated for years, even after the source of contamination has been removed. In some cases it is not feasible to consider groundwater remediation as a solution, particularly when the contaminants are difficult to characterize and isolate. Prevention of groundwater contamination is the key, which includes identifying the major sources of potential contamination, and controlling them.

For the North Bay-Mattawa Conservation Authority Groundwater Study, a regional groundwater susceptibility assessment was completed. In this section, a brief summary of the approach and results of the assessment are presented.

3.2 Methodology / Data Sources

The groundwater intrinsic susceptibility (GwIS) for the study area was evaluated using an Intrinsic Susceptibility Index. The Intrinsic Susceptibility Index (ISI) is a calculated value that estimates the susceptibility of the groundwater resource to contamination at a given point. It was determined, on a well-by-well basis, for each WWIS well in the study area.

The following process was used to determine the intrinsic susceptibility; the geology of each well was evaluated to determine the "uppermost significant aquifer". The water table map, presented in Figure 2-20, and the bedrock equipotential surface map presented in Figure 2-21 were used as a reference for determining the locations of these aquifers. ISI values were determined at each well by summing the multiplication of the thickness of each unit by the K-factor that represents its geology over this depth. K-factors are defined in the Technical Terms of Reference for the study (MOE, 2001). The ISI map was then interpolated across the entire study area to provide shallow and bedrock ISI maps. Following the Technical Terms of Reference, the ISI value at each well in the WWIS was classified into one of three groupings; high (<30), medium (30 to 80), or low (>80) susceptibility (MOE, 2001).

3.3 Intrinsic Susceptibility Results

The results of the bedrock intrinsic susceptibility analysis are presented in Figure 3-1. Medium and high susceptibility classes are the most important classes to consider and Figure 3-1 shows that a substantial portion of the study area is characterized by high ISI values.

High susceptibility results from the presence of high permeability overburden units with little, or no, low conductivity layers (aquitards) overlying the aquifer. This condition exists across a large percentage of the study area, where there is little overburden overlying the bedrock surface. Fractured bedrock is the dominant groundwater aquifer within the study area, with over 90% of groundwater wells intersecting the bedrock aquifer. Understanding that fine-grained overburden overlying bedrock in northern Ontario is generally thin or non-existent; the upland areas on the northern and southern extent of the study area were interpreted to also have a high ISI value.

There are very few areas of low susceptibility within the study area. These areas correspond to water wells that have reported thick deposits of clay and silt overlying bedrock. These areas do not appear to be laterally continuous, or be associated with any regional geological features within the study area. Areas where thick deposits of fine-grained sediment overlie bedrock restrict the downward movement of infiltrating surface water, making the underlying groundwater less susceptible to associated contamination than areas overlain by coarse-grained deposits.

Abandoned wells listed in the WWIS have also been included on Figure 3-1. Improperly sealed or abandoned wells pose a threat to groundwater and can greatly increase an aquifer's susceptibility to contamination. The abandoned wells located on Figure 3-1 are likely only a fraction of the total number of abandoned wells located within the study area, as private wells are seldom decommissioned properly, and the MOE is rarely notified when a well is abandoned.

3.4 Summary of Groundwater Intrinsic Susceptibility Analysis

Groundwater intrinsic susceptibility for the uppermost significant aquifer was assessed using information contained within the MOE Water Well Information System (WWIS) for the study area. The ISI mapping approach followed the method outlined in the MOE Technical Terms of Reference. This method considers the thickness of the different geologic strata, as well as their permeability, through the use of a K-factor. This facilitated an interpolation of ISI values to create an ISI map across the entire study area (Figure 3-1).

Within the uppermost groundwater flow system, areas of high, medium, and low susceptibility were identified using MOE susceptibility classes (high < 30, medium = 30 to 80, and low > 80). Areas of medium or high susceptibility result from the presence of high permeability units in the overburden with little, or no, low conductivity layers overlying the uppermost significant aquifer.

4 Groundwater Use Assessment

4.1 Overview

The groundwater use assessment was conducted considering two categories of water use: public supply and self supply. Within these categories, groundwater use in the study area can be grouped according to the following uses:

- Public supply (municipal, communal, recreational);
- Self supply (private domestic);
- Self supply (agricultural – livestock and irrigation);
- Self supply (industrial - manufacturing, commercial, and institutional); and,
- Self supply (industrial – aggregate, quarries, and mining).

To encourage sustainable growth, the rate of groundwater extraction in any area should be related to the groundwater recharge and allowable groundwater withdrawal based on maintaining satisfactory baseflow in the local streams. If groundwater use is more than the groundwater recharge, a groundwater overdraft (or "mining") will occur, which can result in impacts to streams, or wetlands, and an overall reduction of the total available groundwater resource. An understanding of the distribution of groundwater uses in the study area is essential to managing this resource. This assessment of total water use and the groundwater budget therefore assists in the determination of reasonable levels of water use.

4.2 Methodology / Data Sources

Data for the groundwater use assessment was obtained from various documents, such as MOE Permit to Take Water (PTTW) database, MOE Water Well Information System (WWIS), and Certificates of Approval. Information was also obtained from surveys of the public water supply systems and the large permitted water users, whose permitted rate of groundwater takings is greater than 200,000 L/day. A groundwater use assessment was undertaken to compile and evaluate the existing information, in order to better understand the distribution of water taking throughout the NBMCA watershed.

4.3 Population

The North Bay-Mattawa Conservation Authority lies primarily within the Nipissing District of Ontario, with small portions of the western reaches of the CA lying in the Parry Sound District. The total population of the watershed was estimated to be approximately 70,700, with roughly 52,771 of those people living within the City of North Bay, the largest urban center in the study area (see Table 4.1; Census, 2001). The following urban centers are also located within the NBMCA study area: Callendar (3,168), Mattawa (2,270), and Powassan, (1,124).

Table 4.1: POPULATION ESTIMATES OF MUNICIPALITIES IN STUDY AREA

Municipality	Urban Pop'n	Non-Urban Pop'n	Total Pop'n
North Bay	52771		52771
East Ferris		4291	4291
Chisholm		1230	1230
Mattawa (town)	2270		2270
Bonfield		2064	2064
Calvin		603	603
Papineau- Cameron		997	997
North Himsworth	3168	9	3177
South Himsworth	3184	68	3252
Nipissing (Unorganized, South Part)		51	51
Total NBMCA Population	**61393**	**9313**	**70706**

Table 4.1 includes the total populations within the NBMCA study boundary. The rural population within this area was estimated to be 9,313. As the total population for this region was estimated to be 70,706 people, and the urban population for portions of the study area are estimated to be roughly 61,393.

4.4 Groundwater Use Assessment Results

Groundwater use information for the study area was primarily obtained from the MOE's Permit to Take Water (PTTW) database. Water use in excess of 50,000 L/day (equivalent to continuous pumping at approximately 7 Imperial gallons per minute) requires a Permit to Take Water from the MOE. The PTTW database includes information associated with each permit (e.g. issue date, expiration date, location, maximum permitted pumping rates, etc.). Water takings requiring a permit can be from surface water sources (e.g. ponds, rivers or lakes), or from groundwater (e.g. wells or springs).

The locations of all current groundwater and surface water PTTWs that are in the MOE database are shown in Figure 4-1. The locations of the groundwater PTTWs in the study area classified by purpose and scaled relative to the maximum permitted rate are shown Figure 4-2. The locations of all surface water PTTWs classified by purpose and scaled to the maximum permitted rate are shown in Figure 4-3.

Within the study area, there are 3 current PTTW records for which the maximum permitted withdrawal of groundwater is greater than 200,000 L/day. These are defined by the MOE as "large users". For the groundwater use analysis, the PTTW records that were assessed include both groundwater permits and combined (groundwater and surface water) permits. Table 4.2 summarizes the total permitted rates for each category for the large users. A survey was conducted of the large users to obtain information about the actual water takings. The list of questions that were included in the survey is provided in Section 4.4.3.

The PTTW database also classifies permits based on their general purpose (e.g. water supply, commercial, industrial, agricultural, etc.), and further subdivides them into specific purpose categories (e.g. golf course irrigation, aquaculture, aggregate washing, food processing, etc.).

Table 4.2: LARGE USER PTTWS BASED ON GENERAL PURPOSE*

General Purpose	Number of Permits	Combined Maximum Permitted Rate (L/day)	Combined Maximum Permitted Rate (m^3/day)
Water Supply	3	16,809,617	16,809

Since actual water taking may be different than the permitted rates, further information from the large permitted users (> 200,000 L/day) was collected through a survey. Based on the survey results, all of the permitted users pump less than their permitted rates, These results are described in Section 4.4.1 and 4.4.3.

It is noted that if each large user were to extract groundwater at the maximum permitted rate cited in each PTTW, a total of about 16,809 m^3/day of groundwater would be taken daily from the aquifers in the study area.

4.4.1 Municipal Water Use

Municipal water use was considered during the groundwater use assessment. Two towns within the North Bay-Mattawa study area are supplied by municipal water supply systems (Mattawa and Powassan), while the remaining urban areas are serviced by surface water. The communities of Mattawa and Powassan are serviced by two overburden wells each. Further discussion regarding each water supply system is presented in Section 6.

To determine current pumping rates at each of the municipal systems and to collect and confirm information associated with each municipal well, each municipal water supply was surveyed on their water use as part of the water use assessment. The following questions were asked:

- What is the location of your well (including datum)? Or, where applicable; can you confirm that this is the location of your well?
- What was the average daily raw water flow for each of the last 5 years?
- Can you provide us with an estimate of the wells future pumping rate (are there plans to shut down the well or add an additional well? Do you anticipate an abnormal population growth or decline in the area necessitating a higher or lower pumping rate?).
- What is the MOE water well number?
- What is the Permit to Take Water number?
- What is the Certificate of Approval number?
- What is the Water works number?
- What is the elevation: at the top of the well? Top of the screen? Bottom of the screen?
- What is the population served by the municipal well?
- What is the approximate breakdown of commercial, industrial and residential users served by the well?

Table 4.3 presents the average water taking by municipal system and includes an estimated breakdown of water uses. The completed questionnaires are presented in Appendix D. Additional details about the different municipal wells are included in Sections 2 and 6.

Estimated municipal water takings, and the residential component of the municipal water use have been combined and are presented in Table 4.5.

Table 4.3: MUNICIPAL GROUNDWATER USE BY CITY/TOWN/VILLAGE

City/Town	Average Pumping Rate (m^3/day)	Breakdown of Municipal Water Use
Mattawa	420.2	90% residential, 10% commercial
Powassan	483.0	Not reported
Total	**903.2**	

4.4.2 Rural Domestic Water Use

The rural population in the study area use private wells for domestic use. The average daily flow of groundwater from private individual wells was estimated by multiplying the rural population in the study area by 175 L/person/day (MOE, 2002). The larger urban centers (North Bay, and Callander) receive their water from surface water sources, and were not included in this analysis. Domestic water use is typically not 100% consumptive, as the water is typically discharged to septic systems and much of the water is returned to the shallow groundwater system.

Table 4.2 presents the estimated net rural population using private groundwater wells and the estimated rural groundwater use.

A rural population of approximately 9,313 in the study area was estimated to use water from private groundwater wells for domestic supply. As such, domestic water use was considered an important part of the water use assessment. Rural groundwater use in the study area was estimated to be approximately 1,630 m^3/day or about 595,000 m^3/year.

4.4.3 Large-Scale Groundwater Use

The MOE Permit to Take Water database was used to estimate the groundwater use by permitted large-scale users (>200,000 L/day) and to categorize the large groundwater users (i.e. industrial, commercial, dewatering, etc.). The following information was obtained from the PTTW:

- Permit number;
- General and specific purpose;
- Maximum permitted water taking (L/day);
- Days per year of taking;
- Identify the largest water users; and,
- Conduct a survey of large users for estimates of actual water use.

The large-scale groundwater users, such as for industrial, commercial, and dewatering purposes, not including municipal water supply use, generally use private wells that are not part of municipal water systems. To further evaluate these water uses, letters were sent to individuals or companies with a large permitted rate identified using the PTTW database, and were subsequently surveyed by telephone in the fall of 2004. This was done to confirm the location of the well listed in the PTTW and the actual water takings.

A letter was sent to the sole large water user in the study area (excluding municipal groundwater users) and this permit holder was interviewed to evaluate the volume of water being pumped at these locations and to collect additional information about the location and status of the pumping well. The following questions were asked during the telephone interview:

- What is the location of your well(s)?

- What is your well currently being used for?
- Is there a secondary use for your well?
- What is the depth and diameter of the well?
- When was the well drilled?
- Who is the original owner of the well?
- What months of the year do you pump water?
- How many days a month do you pump water?
- How many hours a day do you pump water?
- What is the capacity of your pump?

The large water user is currently not using the permitted water supply well for communal use, rather they are using the well only to service their private water needs.

4.4.4 Agricultural Water Use

Agricultural water use was compiled for selected regions across the study area. The Ontario Ministry of Natural Resources commissioned R. de Loe to develop estimates of agricultural water use. These estimates are based on data from the 2001 Census of Agriculture and coefficients that relate levels of agricultural activity to water requirements. They are developed at the municipal level (CCS) and have then been extrapolated to a regional basis. The extrapolation to a regional basis has been done strictly based on area weighting. In other words, water use across a municipality is assumed to be homogeneous.

Table 4.4 summarizes the water use for the CCS's within the NBMCA study area (as estimated by de Loe, 2002). The importance of water to all agricultural activities is readily apparent from the average water use per farm. In the NBMCA study area, agriculture water use is dominated by water use for livestock operations, and irrigation purposes (especially in the summer months). The climate and soil composition in the study area is not appropriate for the production of fruit, and specialty crops (nurseries, greenhouses, sod farms, etc) are found only in East Ferris. Irrigation takes place only in East Ferris, and only in the summer months, likely for irrigation of field crops.

Table 4.4: AGRICULTURAL WATER USE (M^3/YEAR) FOR CENSUS CONSOLIDATED SUBDIVISIONS

CCS	Powassan	Calvin	Bonfield	Chisholm	East Ferris	Nipissing
# of Farms	47	29	28	41	26	41
Livestock	24241	7088.5	7455.7	12991.5	7027.5	10567.7
Field crops	111.9	50.6	71.5	104.2	24.6	55.1
Fruit crops	0.0	0.0	0.0	0.0	0.0	0.0
Vegetable crops	475.4	29.1	0.0	43.7	9156.1	708.5
Specialty crops	0.0	0.0	0.0	0.0	8562.5	18395.1
Irrigation (total)	0.0	0.0	0.0	0.0	16232.0	40812.7
Irrigation (summer)	0.0	0.0	0.0	0.0	16232.0	39084.3
Seasonal water use	2241.8	82. 6	70.3	151.7	16754.3	19660.8
Total water use	24828.9	7168.3	7527.2	13139.4	24770.7	29726.4
Average water use/ farm	528.3	247.2	268.8	320.5	952.7	725.0

Other CSSs throughout the study area were not considered by the document commissioned to assess agricultural water takings, and therefore have not been included in the analysis.

These results indicate the total estimated agricultural water use for the study area is approximately 107,161 m^3/year. If this annual amount is averaged over an entire year, the daily average is about 293.6 m^3/day. It is recognized that in almost all cases, agricultural water use is greatest during the growing season. If this annual amount were averaged over a 120-day period, the daily average would be about 893 m^3/day for the entire study area.

To estimate the total amount of groundwater used for agricultural purposes, the PTTW database was evaluated to estimate the proportion of agricultural water use that is derived from groundwater and from surface water. It must be emphasized that the absence of specific water use and unspecified locations of water taking in the PTTW database, only a subjective approximation could be made. The current database indicates that there are no groundwater PTTWs for agricultural use within the study area, however there are two surface water PTTWs for agricultural use within the study area. These two permits represent a total permitted withdrawal of surface water of about 596.9 m^3/day.

4.4.5 Other Groundwater Users

Other groundwater takers in the study area include construction projects (i.e. road building), pumping tests, and other short term pumping uses. Following the Technical Terms of Reference (MOE, 2002), these short-term groundwater extractions were disregarded as they represent relatively small water taking volumes and do not represent continuous long-term pumping.

4.5 Groundwater Use Analysis by Watershed

The estimated total groundwater taking by study area is presented in Table 4.5. The total groundwater use was calculated by combining the takings estimated above for rural domestic, municipal, large users, and agricultural across the study area.

Table 4.5: ESTIMATED TOTAL GROUNDWATER USE (M^3/DAY)

Rural Domestic	Municipal	Large Users*	Agricultural	Total
16,809	903.2	0	893	18,605

** Based on large water users survey and PTTW database

Observations that can be made based on these estimates of groundwater use by major use categories, on a watershed basis, are as follows:

- Rural domestic use represents the vast majority of groundwater use (90%);
- Agriculture water taking represents 5 percent of groundwater use (during the 120-day period).
- Municipal water taking represents the remaining 5 percent of the groundwater use

4.6 Water Budget Summary

4.6.1 The Hydrologic Cycle

The hydrologic cycle consists of four main components; precipitation, evapotranspiration, surface water resources, and groundwater resources. Water on the ground surface, in streams, or in lakes can return to the atmosphere through evaporation. Water used by plants can be returned to the atmosphere through transpiration. Collectively known as evapotranspiration, both evaporation and transpiration occur in greatest amounts during periods of high temperatures, high wind, low humidity, and bright sunshine.

When water infiltrates the ground, gravity allows the infiltration of water into the soil until it reaches the water table. This groundwater then moves very slowly through pore spaces ultimately towards surface water features such as rivers, streams, lakes, and oceans.

4.6.2 Regional Water Budget Analysis

Establishing a water budget for a natural system is a complex problem as there are many factors that influence the parameters involved, namely precipitation, runoff, recharge, and evapotranspiration. A generalized version of the water balance is as follows:

GW (in) + SW (in) + Precipitation = SW (out) + GW (out) + ET + (Net storage)

GW and SW denote groundwater and surface water respectively, (in) and (out) represent flow into and out of the study area, ET is the evapotranspiration, and Net Storage represents the amount of infiltrated water that is held in storage in the system. For instance, the positive totals for Net Storage during the winter months (e.g. December to March) represent snow on the ground, whereas the negative values during the summer months (e.g. July to August) denotes water lost from soil-water storage. When long-term inflows and outflows are considered, the Net Storage term will approach zero.

Groundwater is of primary interest in the study area; however, surface water flows should be examined with climate (precipitation) data to understand the inputs and outputs to the water budget. In addition, groundwater taking for domestic, industrial and other uses should be considered.

Since the hydrologic cycle does not follow municipal boundary lines, it is difficult to evaluate a water budget over a portion of land that spans several different watersheds (ie. Mattawa River, Ottawa River, etc). The regional water budget for the study area represents a large-scale regional estimate, and further refinement is needed to evaluate water budgets at a more local-scale. This refinement should be directed at sub-watershed scales, so that stream flow data can be better utilized.

Precipitation, evapotranspiration, and temperature data for the study area were obtained from climate norms originating from point-based weather station data acquired by Agriculture Canada. The information obtained is based on data acquired over a 30-year period (1961-1990). The data is regional in extent, and similar information exists for all of Canada. At a regional-scale, the components of the hydrological cycle provide reasonable estimates of the net available quantity of water, however small scale variations are anticipated (Agriculture and Agri-Food Canada, 1997).

The study area lies within two Ecodistricts, as defined by Agriculture Canada. The climate data collected is at an Ecodistrict scale. The portion of the study area lying north of the Mattawa River is represented by Ecodistrict 411, while the area to the south is represented by Ecodistrict 412. Precipitation (mm), temperature (^{o}C), and evapotranspiration (mm) rates for these two Ecodistricts are provided in Table 4.6.

Table 4.6: CLIMATE DATA FOR THE STUDY AREA (1961 TO 1990)

Precipitation[1]													
Ecodistrict	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
411	65.9	50.7	58.5	64.9	73.0	74.9	75.1	89.0	98.9	82.0	78.9	75.8	886.1
413	72.7	60.9	63.3	66.9	77.1	82.2	75.9	85.7	92.8	80.8	87.4	87.9	938.9

Potential Evapotranspiration[2]													
Ecodistrict	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
411	0.0	0.0	3.2	60.1	106.8	125.4	137.2	104.3	66.0	32.7	7.0	0.0	642.8

Potential Evapotranspiration[2]													
Ecodistrict	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
413	0.0	0.0	3.8	63.9	102.7	117.3	127.7	98.9	61.6	30.1	6.8	0.0	612.8

Temperature[3]													
Ecodistrict	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
411	-12.3	-10.9	-4.5	3.6	10.6	15.5	18.8	17.4	12.7	6.8	0.0	-8.4	4.2
413	-11.3	-9.8	-3.5	4.4	11.3	16.1	19.0	17.7	13.2	7.1	0.6	-7.7	4.8

[1] Refers to average monthly precipitation (snow and rain) in mm
[2] Refers to the average monthly potential evapotranspiration in mm
[3] Refers to the average monthly temperature in degrees Celsius

Based on the information in Table 4.6 and the percentage of the study area in each Ecodistrict, the average annual precipitation for the study area is calculated to be 907.2 mm. The study area has an area of approximately 4,600 km^2. Therefore, the annual volume of precipitation that falls on the study area is approximately 4,173 million m^3/year. The potential evapotranspiration in the study area is calculated to be 630.8 mm/year, which is equivalent to an annual volume of 2,902 million m^3/year.

Annual recharge to the groundwater system is estimated on the basis of the regional groundwater modeling that was completed for this study. The results of the modeling are presented in Section 6. The average annual recharge for the same area was estimated to be 460 million m^3/year. This represents an average recharge rate of 100 mm/year across the study area and is consistent with the average low flow data presented in Section 2 (54 to 200 mm/year aerially). The proportion of the precipitation that infiltrates to the groundwater system is dependent on the hydraulic conductivity of the soil, topography, vegetative cover, and land use. Therefore, estimates of potential recharge, and water budgeting in general, should be used only on a regional scale, not a local scale.

Water budget parameters for the study area on an annual basis are summarized as follows:

- Precipitation 4,173 million m^3/year
- Evapotranspiration 2,902 million m^3/year
- Recharge 460 million m^3/year
- Runoff 811 million m^3/year

Runoff was calculated as the difference between precipitation and the other components of the water budget.

The groundwater use assessment provided an estimate of total annual groundwater use in the study area. This amount was about 18,605 m^3/year, which represents less than 1 percent of the estimated annual rate of groundwater recharge across the study area.

4.7 Summary of Groundwater Use Assessment

A regional groundwater use assessment was conducted using information on municipal, agricultural and private water taking. Data for the groundwater use assessment was obtained from the MOE Permit to Take Water (PTTW) database, MOE Water Well Information System (WWIS), and Certificates of Approval. A survey was also completed of large water users (PTTW rate of more than 200,000 L/day), and municipal water works. Population estimates, which were used to estimate domestic water use, were obtained from Canadian census data.

The total groundwater use for the study area was estimated to be about 18,605 m^3/year. By comparison, the total groundwater recharge is estimated to be about 460 million m^3/year.

Current annual groundwater use across the study area is less than 1 percent of the annual groundwater recharge.

5 Potential Contaminant Sources Inventory

5.1 Introduction

A critical aspect of the groundwater study was to identify potential sources of groundwater contamination. An inventory of available databases, listings, and reports of potential contaminant sources has been completed. The potential for contamination from the identified sources has been assessed with respect to possible impacts on groundwater supplies in the area. This section provides a description of the potential contaminant sources inventory. It must be emphasized that, without exception, in every database, listing, and report there were limitations to the extent and accuracy of the data. An important aspect of this inventory was therefore to note the limitations of the data and to make recommendations for updating and/or improving the data.

5.2 Background

There are many different types of substances that can compromise the quality of groundwater. These contaminants include organic chemicals, hydrocarbons (benzene in gasoline), inorganic cations (iron, copper) or anions (chlorides, nitrates), pathogens (bacteria), and radionuclides (Radon, Strontium) (Fetter, 1999).

It is important to understand the locations of potential contaminants and known spills, to promote the long-term sustainability of the groundwater resource. This information can be used to identify areas where further monitoring work may be required to safeguard the water resource. The information is best stored and maintained in a database that includes details about the potential contaminant source, and the location (including address where available).

In the future, if a specific contaminant is identified in a water well, the database could be used to identify possible contaminant sources. Future groundwater resource development could also utilize information about different potential contaminant sources throughout the study area.

Groundwater contamination may occur from either point sources or non-point sources of contamination. These terms generally describe the localization of the contaminant. A point source is typically a small-scale contaminant source area, such as a leaky underground fuel storage tank. Non-point sources, in contrast, are larger in scale and are typically more diffuse than point source contaminants. Non-point sources are primarily related to land use practices such as fertilizer spreading and road salting.

Both point and non-point contaminant sources are capable of impacting large groundwater volumes. For example, one litre of a solvent such as trichloroethene can contaminate up to 29 million litres of groundwater. This is equivalent to the water required to fill approximately 30 Olympic sized swimming pools.

The objective of the potential contaminant inventory was to prepare an inventory of known and potential sources of contaminants in the NBMCA study area. This information was compiled using existing databases and other information as discussed below.

5.3 Methodology/Data Sources

Data for the potential contaminant sources inventory was obtained primarily from the Ministry of the Environment (MOE), drive-thru surveys, and with supplementary information from the Steering Committee members. Included in the information from the MOE was a database of private and retail underground fuel storage tanks from the Technical Standards and Safety Association (TSSA), as well as information from the MOE on spill occurrences, and PCB storage in the study area.

Incorrectly sealed or abandoned wells were also considered, as they can act as a direct conduit for surface contaminants to rapidly migrate to underlying aquifers. Information on the locations of the wells was obtained from the Ontario Ministry of the Environment's Water Well Information System.

The quality of the information available to complete the contaminant sources inventory, particularly the information in the previously compiled databases, was poor with respect to location. The UTM coordinates were not provided for spill occurrences, fuel storage sites, or waste generating or receiving sites, and therefore these locations were estimated based on limited address information. Approximately 57 percent of the potential contaminant sources from these data sets could not be mapped, due to very poor location reliabilities.

The accuracy of the information is acceptable from a regional standpoint, and has been supplemented locally throughout much of the study area. In urban areas, within the municipal well capture zones, the locations of the potential contaminants were verified (where possible) during the wellhead protection area (WHPA) contaminant sources assessment (Section 7), and in all cases, additional potential contaminant sources were identified. The field surveys were conducted to verify the presence of different land uses that could adversely affect groundwater quality. During these surveys it was impossible to verify the location of spills that occurred some time ago.

5.4 Potential Contaminant Sources Inventory Results

The compilation of potential contaminant sources from various databases is summarized in Table 5-1. Of the 969 entries in the MOE Contaminant Sources Database, 550 (57 percent) were identified within the study area, using UTM coordinates or township information (leaving 414 records that could not be plotted on a map; 308 of these being historic spill sites). The fuel storage, contaminant spill sites, hazardous waste generating and receiving sites were located using address information, such as street number or lot and concession. This information was compiled and was used in conjunction with the project GIS to plot the data (Figure 5-1). Various other potential contaminant sources including active and closed landfill sites, lumber yards, and pipelines were plotted from digital mapping of the National Topographic System map sheets (1:250,000 scale) obtained from Natural Resources Canada (http://www.cits.rncan.gc.ca/cit/servlet/CIT/site_id=01&page_id=1-005-002-001.html).

Table 5-1 summarizes the results of the contaminant sources assessment and Figure 5-1 shows the location of the potential contaminant sources that were mapped within the study area. As mentioned above, these records were mapped with a combination of UTM coordinates, Lot, Concession, Township, NRVIS roads information, and address matching using Internet mapping software.

Table 5-1: Potential Contaminant Sources

Potential Source	Number of Records		
	Located	Not Located	Total
Fuel Storage	109	48	157
PCB Storage	8	2	10
Contaminant Spill Sites	212	308	520
Hazardous Waste Generating Sites	186	46	232
Hazardous Waste Receiving Sites	5	10	15
Active Landfill Sites	13	0	13
Closed Landfill Sites	5	0	5
Waste Sites (liquid and solid)	9	0	9
Lumber Yards	6	0	6
Pipelines	2	0	2
Total	550	414	969

A discussion of the specific types of contaminant sources in the database is presented below.

5.4.1 Fuel Storage

Fuel storage tanks are large metal containers that commonly contain hundreds to thousands of litres of gasoline, fuel oil, or diesel. The storage tanks are located either above or below ground. For instance, gas stations commonly have underground storage tanks that store gasoline. Underground storage tanks are susceptible to corrosion by groundwater, and to the settling of the ground above or around the tanks. In the process of filling the tanks, there is also some risk of spillage. Holes, cracks, or fissures in tanks can cause varying amounts of fuel to enter the ground over potentially long periods of time resulting in groundwater contamination. As such, identifying the locations of underground storage tanks, as well as the location of sites where storage tanks previously existed, provides information that can be used to assess potential groundwater contaminant sources.

Locations of underground storage tanks from the TSSA database are shown in Figure 5-1. A total of 157 fuel storage tanks in the TSSA database reside within the NBMCA study boundary. 109 of these records can be reliably plotted on a map, while the remaining 62 records contained incomplete or incorrect address information. It is likely that many other private fuel storage tanks (including several above ground storage tanks) exist throughout the study area that have not been included within the database. Fuel storage tanks are identified on Figure 5-1 as green dots.

Private fuel storage tanks are not included in this database, and therefore are not shown on Figure 5-1. During the WHPA potential contaminant source assessment, residential fuel storage tanks were identified where possible, and are further discussed in Section 7. Residential fuel tanks that were identified within the capture zone areas and surrounding areas were included on Figure 5-1 as miscellaneous sources (purple dots).

5.4.2 PCB Storage Sites

PCBs (polychlorinated biphenyls) were widely from the 1930s to the 1970s, as ingredients in a number of industrial materials, including sealing and caulking compounds, inks and paint additives. More recently PCBs were used in the 1960s and 1970s to make coolants and lubricants for certain kinds of electrical equipment, including transformers, and electrical capacitors. North America banned the manufacture and import of most PCBs in 1977, when concerns about the impact of PCBs on human health and the environment began to escalate. Not included in the government ban were the electrical applications of PCBs, however the federal government is beginning to phase out these applications, and is setting strict guidelines for the storage and disposal of PCBs. PCBs are quite resistant to chemical, thermal or biological degradation, and as such they tend to persist in the environment for long periods of time.

Within the study area, a total of 10 PCB storage sites were identified in the study area and 8 of these were plotted on the map as yellow dots (Figure 5-1). These areas correspond to areas where PCBs are believed to exist within a transformer, or in areas designed as PCB storage or disposal facilities.

5.4.3 Contaminant Spill Sites

Contaminant spills are of concern to rural and urban groundwater users alike. Every spill has the potential to contaminate the environment or groundwater, however the degree to which the spill impacts the environment is dependent on the localization, the amount of contaminant spilled, as well as the type of contaminant spilled.

Spills recorded in the MOE database range from a few litres of paint spilled on a parking lot, to several hundreds of litres of heavy oil spilled on a highway. 656 spills of varying severity were recorded in the NBMCA study area with 520 of those released to the ground. The 136 spills released to the air (e.g. gases, fumes, etc), or surface water bodies were not plotted. Of the 520 groundwater spills, 212 had sufficient address information to plot the spill on a map, and the remaining 308 spills contained insufficient information (e.g. Hwy 11, North Bay) to plot. Spills that were recorded in the database with only lot/ concession information were plotted at the centroid of the lot. Spills that were plotted are found on Figure 5-1 as dark red dots.

Rail lines, and major highways are also plotted on Figure 5-1 as they are locations that are particularly susceptible to spills. Rail cars that contain chemicals and hazardous substances may pose a threat to the underlying groundwater resources in the event of a train derailment. Traffic accidents on northern highways are also common, and tractor trailers carrying chemicals or other hazardous substances also have the potential to contaminate the groundwater in such situations. It is recommended that a spills contingency plan be created to handle such spills (refer to Section 9), especially in the vicinity of the Mattawa and Powassan water supply systems.

5.4.4 Hazardous Waste Generating and Receiving Stations

The Ontario Environmental Protection Act defines a waste generating station as any facility or operation involved in the production, collection, handling or storage of regulated wastes, while a waste receiving site is defined as any facility to which waste is transferred to via a waste carrier. Examples of waste generating sites include pharmacies, hospitals, chemical laboratories (including those in high schools), factories/ manufacturing plants, and dry cleaners. The database of both registered waste receiving sites, and waste generating sites is identified by the registration number, the company name and the company address. A total of 232 waste generating sites exist in the NBMCA study area, and an additional 15 waste receiving sites exist in the study area. Of these, 186 waste generating sites (grey dots), and 5 waste receiving sites (orange dots) were plotted within the study area on Figure 5-1. The remaining sites could not be plotted due to inadequate address information.

5.4.5 Landfill Sites

Sanitary landfills and garbage dumps have the potential to act as major sources of groundwater contamination. Landfills and dumps may contain various solid waste items including food, paper, plastics, metals and toxic materials such as lead, mercury, cadmium, poisons and pesticides. These waste disposal areas can threaten groundwater as rain and moisture wash out metals and organic material, called leachate from the waste.

Landfill or waste disposal sites were located using the MOE Waste Disposal Inventory, a document that lists all the active and inactive landfills in Ontario (MOE, 1991). The report provided UTM locations for a total of 17 landfills in the NBMCA study area, of which 12 were listed as active (black triangles) and 5 closed waste disposal sites (white triangles). The 17 landfill sites listed in the report, and an additional landfill site surveyed in Mattawa, were plotted on Figure 5-1. Also included on Figure 5-1 are solid dumps (blue pentagons) and liquid dumps (red diamonds), obtained from the digital NTS mapping. Solid dumps refer to areas designated as accepting solid industrial or household waste, while liquid dumps refer to open, artificial ponds or basins that are used for storing liquids such as municipal sewage.

5.4.6 Automotive / Machinery Sites

Potential contaminant sources arising from automotive wrecking yards include the discharge of automotive fluids and used car batteries to the surface or subsurface. Potential contaminants associated with wrecking yards include gasoline (containing chemicals such as benzene, naphthalene, ethyl benzene, methyl-tert-butyl-ether), anti-freeze (contains ethylene glycol), engine and transmission oils (contains paraffin-like hydrocarbons) as well as battery acid and lead from abandoned car batteries. Information on the locations of wrecking yards across the study area was obtained from digital mapping of the NTS map sheets (scale: 1:50,000). Locations where automobiles and various types of machinery are stored were included in this category.

Automotive and machinery sites were not located and mapped regionally, and therefore are not located on Figure 5-1. However these potential sources of contamination were located during the field surveys within the capture zones, and are located on Figures 7-1 and 7-2, and discussed in Section 7.

5.4.7 Lumber Yards

Lumber yards are plants or operations that preserve, dress/ plane, and store wood products prior to distribution to the consumer. Wood products are often preserved or treated with hazardous chemicals that pose a threat to groundwater resources. Drums or large tanks full of the hazardous compounds (including chromated copper arsenicals) are often stored in lumber yards and used to treat various wood products. These wood preservatives may spill onto the ground and seep into the groundwater or nearby surface water bodies contaminating the groundwater resource.

A total of six lumber yards are denoted on the potential contaminant sources inventory map (Figure 5-1) as green squares and these locations were also identified with the digital NTS mapping. As mentioned above, there are likely additional lumber yards in the study area that are not included on Figure 5-1.

5.4.8 Pipelines

Pipelines (i.e. sewers, natural gas, petroleum products etc) have the potential to leak and release contaminants to the groundwater. Old pipelines and pipelines that are made of steel are of greatest concern as they are subject to breakdown or corrosion. Oil and gas pipelines within the NBMCA study area (2 were located) identified with the digital NTS mapping are plotted on Figure 5-1 as red lines.

5.4.9 Abandoned wells

Ontario Water Resources Act, Regulation 903, Section 21 addresses well abandonment, and it states that: "When a well is to be abandoned, it shall be plugged with concrete or other suitable material so as to preclude the vertical movement of water or gas in the well between aquifers or between an aquifer and the ground surface." Abandoned or poorly constructed wells are a threat to groundwater aquifers as they can provide a conduit for surface contaminants to travel directly to a deep aquifer in a very short period of time.

Limited information about the locations of abandoned wells is currently available. The MOE's WWIS includes a data field that denotes wells that were drilled, but were not used. These are wells that provided poor yield or provided poor quality water. Information regarding the decommissioning of these wells is not included in the database, and it is impossible to assess whether they were properly decommissioned. Since it is possible that many of these wells were not properly decommissioned, their locations are included in Figure 5-1 as small dots. In total, 121 abandoned wells are plotted.

Where possible within areas that are deemed sensitive (high vulnerability areas and within WHPAs), the abandonment status of these wells should be further evaluated.

5.4.10 Other Potential Sources

The locations of potential sources of contamination, based on available information are presented on Figures 5-1. There are a variety of other potential sources of contamination, but locations of these sources were not readily available. These potential contamination sources include:

- Septic systems;
- Urban point sources such as unreported spills;
- Residential oil tanks;
- Fertilizer, pesticide, and herbicide storage and distribution centres;
- Road salt and sand-salt storage facilities;
- Sand and gravel pits; and,
- Snow dumps.

5.5 Summary of Potential Contaminant Sources Inventory

The objective of the potential contaminant inventory was to prepare an inventory of known and potential sources of contaminants. Within the study area, there are 969 records in the MOE Contaminant Sources Database. Of these records, there are 550 known contaminant source records that could be mapped and these potential contaminant source locations are presented in Figure 5-1. Table 5-1 outlines the number of sites identified in the study area for six major categories examined in the inventory (fuel storage, PCB, spills, landfills, and waste generating and receiving sites).

Approximately 57 percent of the existing records were located using the available address or coordinate information. As additional information is collected or becomes available, the information contained in the database of potential contaminant sources should be updated. The information collected during this part of the study can be used to help identify the sources contaminants detected in the future, and can be used during the development of future water supplies.

6 Wellhead Protection Area Groundwater Modeling

6.1 Methodology

The most defensible method for delineating wellhead protection areas (WHPAs) is through the application of numerical groundwater models. The physical relationships governing the movement of groundwater can be incorporated into numerical models to simulate the existing flow system. Numerical modeling also allows integration of heterogeneous field data, which in a complex geologic environment, is very difficult to consider otherwise.

Groundwater velocities can be calculated at any point within a numerical groundwater model using the simulated heads, the calibrated hydraulic conductivity, and the porosity value. Using these velocities, pathlines of imaginary "particles" of water released at any point can be determined. The time-of-travel between any two points along the pathlines can also be calculated. Individual groundwater particles can be traced down-gradient ("forward" particles) or up-gradient ("reverse" particles). Time related capture zones for pumping wells can be calculated by releasing a number of reverse particles originating around a well in a circle.

For the delineation of WHPAs, all well fields shared the following numerical modeling approach. Well field specific details are contained in Sections 6.2 and 6.3 respectively for the two municipal systems in the NBMCA study.

<u>Conceptual Model Development</u>

The purpose of this task was to characterize the geology and hydrogeology surrounding each well field, for direct implementation into the groundwater flow model. Existing hydrogeological and engineering reports, in addition to the principal data sources listed in Table 2.1, were used to develop and characterize the following:

A series of hydrogeological cross-sections were created for both well fields (Mattawa and Powassan). Selection of wells for inclusion into the cross-sections was based on availability of data. Cross-sections locations were chosen where data was available and where the cross-sections would provide insight into the local geology of the areas. Hydrogeological interpretations were developed using previous interpretations and aquifer testing results (where available).

Using the regional mapping and local cross-section analysis, overburden thickness and bedrock surface topography were defined. Areas with potentially higher or lower recharge rates were interpreted from cross-sections and other sources of information, such as previous studies and geological maps. Hydraulic conductivity zones were determined for each aquifer based on cross-sections and other available information such as aquifer test data. Water level maps, cross-sections, and aquifer thickness maps were used to delineate the hydrogeologic boundaries for the numerical model.

Transmissivity, specific capacity, pumping rates, and hydraulic conductivities are all presented in consistent units, as follows:

- Transmissivity: m^2/day
- Specific Capacity: m^2/day
- Pumping Rates: IGPM and m^3/day
- Hydraulic Conductivity: m/s

Numerical Model Selection

For the NBMCA Groundwater Study, a single modeling package, MODFLOW (Harbaugh et al., 2000) was used for the numerical modeling. MODFLOW was selected because it can simulate groundwater flow, and with the add-on package MODPATH (Pollock, 1994), it can also display advective pathlines. Furthermore, Visual MODFLOW (WHI, 2002) provides an easy to use graphical user interface for data input and output. The MODFLOW code, developed by the United States Geological Survey (USGS), is the most frequently applied groundwater modeling code in the world.

Model Input and Boundary Conditions

MODFLOW is a finite-difference code with particle tracking support programs (MODPATH). A complete description of the code can be found in the USGS MODFLOW User's Manual (Harbaugh et al., 2000). The finite-difference approach involves discretizing the model area into 'cells' with an array of rows and columns. By discretizing the model area, the finite difference model simulates the groundwater hydraulic head level in each cell so that the volume of water entering each cell balances the volume of water exiting each cell.

MODFLOW is capable of simulating three-dimensional groundwater flow in heterogeneous, anisotropic porous media. When used with the code MODPATH, time-related pathlines and capture zones can be calculated for a wide variety of geological environments and boundary conditions.

Geological information is represented in MODFLOW by 'zones', or 'windows' corresponding to areas within the model domain that contain similar property values. Physical information related to the conceptual geological model is entered into the model, including spatially varying:

- hydraulic conductivities,
- porosities,
- bottom elevations of each model layer, and,
- thicknesses of each model layer.

Boundary conditions must be incorporated in the model to control how the groundwater model interacts with the environment outside the model area. Boundary conditions are used to represent features such as streams and rivers. MODFLOW is capable of simulating the following boundary conditions:

- spatially varying recharge and evapotranspiration rates,
- infiltration or exfiltration from surface water bodies such as streams and rivers,
- constant head cells, which may correspond to the water elevation in a lake or reservoir,
- any number of pumping or injection wells, and,
- no-flow boundaries that correspond to areas that groundwater does not flow across, such as a groundwater divide.

Model Calibration

Model calibration results in a groundwater flow model capable of simulating groundwater flow that is statistically representative of field conditions. Models can be calibrated to steady-state or transient field-measured hydraulic heads. In this study, numerical models were calibrated to a set of groundwater levels that represent steady-state groundwater flow conditions.

Prior to numerical model calibration, the range of uncertainty in the parameters contained within the conceptual hydrogeologic model was evaluated. Some parameters were known with a higher degree of certainty, such as hydraulic conductivities in well fields where aquifer testing had previously been performed.

Model calibration was conducted using an iterative process where a flow simulation was carried out, the resulting groundwater heads were compared to observed heads, and the model input parameters were re-adjusted to achieve better agreement with observed conditions. This process was repeated until a satisfactory agreement of simulated and observed heads was achieved.

The calibration data included static water level measurements taken when wells were installed contained within the MOE Water Well Information System (WWIS). This dataset was supplemented with local monitoring data where it was available. Since pumping conditions have largely remained unchanged throughout the study area, the static water levels from the WWIS are considered representative of steady-state conditions.

Measures of Calibration

Model calibration results were evaluated using quantitative measures. Calibrated models were evaluated using statistical measures that are based on the calibration residuals. Calibration residuals are calculated as the difference between the simulated and measured water levels for each calibration point. The statistical parameters used to evaluate the model calibration included:

- Mean Error (ME). The Mean Error represents the mean of all the residuals. This parameter can be misleading because the sum of a large negative residual plus a large positive residual may be equal to zero. The Mean Error provides an indication of whether residuals are biased positively or negatively.
- Mean Absolute Error (MAE). The Mean Absolute Error represents the mean of the absolute values of all the residuals. This parameter will be larger that the mean error and provides the average error associated with each calibration point in the model.
- Root Mean Squared Error (RMS). The Root Mean Squared Error represents the square root of the sum of the squares of all the residuals. Squaring the residuals increases the weighting that a poor residual will have on the overall calibration statistic. A low RMS is the best measure of a good model calibration.
- Scaled Root Mean Squared Error (Scaled RMS). The Scaled Root Mean Squared Error represents the RMS divided by the difference between the highest and lowest observed head within the model domain.

Wellhead Protection Area Delineation

A wellhead protection area, or WHPA, is the three-dimensional subsurface volume surrounding a well or well field providing water to the well, projected to ground surface. WHPAs usually receive time-of-travel designations such as 50-day, 2-yr, 10-yr, and 25-yr. These times reflect the time required for water to move to the well from different areas of the subsurface.

Because capture zones are projected to ground surface, in many instances the time-of-travel WHPA does not reflect the time required for water to travel from ground surface to the well. This is particularly true when the well pumps water from a deep aquifer that is overlain with fine-grained sediments such as silts and clays.

In consideration of the time required for water to migrate from ground surface through the overburden, this time-of-travel is presented. It is important to consider that that this time-of-travel represents groundwater flow through porous media. In cases where water moves through a conduit such as a poorly constructed well or an improperly sealed borehole, the time for water to move from the ground surface to the bedrock aquifer would be much shorter and may be considered to be nearly instantaneous in some cases.

During the WHPA delineations, municipal pumping rates were adjusted to reflect future pumping conditions within each municipality. Personnel from both Mattawa and Powassan reported that pumping is not anticipated to increase or decrease dramatically in the upcoming years. Rates were adjusted during the delineation of the 50-day capture zone however to account for larger than annual pumping rates over the 50-day period.

The delineation of WHPAs in this study was performed with the following objective:

- To delineate 50-day 2-, 10-, 25-year and steady-state time-of-travel (TOT) WHPAs using models which contain 'best estimate' values of hydrogeologic parameters,

Sensitivity was evaluated by conducting additional simulations for each WHPA. The NRA (UK National Rivers Authority, 1995) has listed the following principal factors that lead to WHPA uncertainty:

- Uncertainty in point measurements such as estimates of hydraulic conductivity at specific locations with pumping or slug tests. We recognize that in some cases, point measurements are not always available,
- Uncertainty in the accuracy of such point measurements when applied to larger areas,
- Scale errors,
- Uncertainty in the relative distribution of model parameters,
- Errors due to deficiencies in conceptual models, and
- Limitations of a model chosen to represent an aquifer system.

Uncertainties in WHPA mapping are an integral component WHPA mapping.

<u>WHPA Sensitivity Analysis Method</u>
When making predictions with a groundwater model, different combinations of parameters may result in considerable variations in WHPAs from the same pumping wells. For example, WHPAs simulated under conditions of high recharge rates, high hydraulic conductivities, and low porosity may be much larger than WHPAs simulated under conditions of low recharge rates, low hydraulic conductivities, and high porosity values. However, hydrogeologic parameters for both sets of conditions may result in an adequately calibrated numerical model, and may be within the plausible range of sensitivity associated with the parameter.

This technique for the WHPA sensitivity analysis is based on a procedure that produces different, but potentially plausible, predictions of capture zones consistent with the following:

- Simulated heads at calibration target locations are to be within target head ranges. In this study, this was evaluated using the Root Mean Squared Error of each simulation.
- Model parameters are within physically realistic ranges.
- Model boundary conditions such as recharge are within physically realistic ranges.

Two simulations were performed with a range of parameter values defined in conditions 1 and 2 above. Hydraulic conductivity, recharge, and porosity values were varied through these simulations.

For each model, simulations were performed to determine the effects of parameter changes. The WHPAs defined for each of these simulations were digitally overlain to derive envelopes defining the best estimate WHPA.

The best estimate WHPA is defined using the model simulation with the most likely combination of parameters.

Limitations of WHPA Modeling Results

The capture zones predicted using the numerical models are based on a number of assumptions, input parameters, and boundary conditions that are incorporated into each model. Each model is a representation of our understanding in the area surrounding the municipal wells, and in all cases our representation has been simplified to facilitate model development within the current time and data constraints. The WHPA modeling results represent our best estimate of the actual WHPAs, and provide excellent guidance regarding the specific water source for each well.

As additional information becomes available, the numerical models should be revised and the WHPAs should be re-evaluated. Furthermore, water taking will be different in the future, as communities grow and additional groundwater wells are developed. Each of these factors will affect the shapes and sizes of the different capture zones (and WHPAs).

Further discussion for each municipal system and the developed models is provided in the following sections.

6.2 Mattawa Municipal Well System

The Town of Mattawa is located in the Township of Mattawan and its water supply system is comprised of two wells (Figure 6-2-1) that service a total population of approximately 2400 people. Three wells exist within one pump house, however Well No. 3 was abandoned and is no longer used for water supply. Well No. 1 and Well No. 2 are utilized on a duty/ standby basis, whereby Well No. 1 operates during the day, and Well No. 2 operates in the evening.

First Engineer's Reports for the well system was completed in March 2001 (Dennis Consultants, 2001). This report noted that the wells do not appear to be under the direction influence of surface water (Mattawa River), and that nearby sewage lagoons and landfill are not believed to impact the groundwater quality at the wells. There is limited information regarding the response of the well to pumping and/or potential well capture zones.

This section presents specific details concerning the conceptual model developed for the municipal wells in Mattawa, followed by the development and application of a MODFLOW groundwater flow model (Harbaugh et al., 2000) for the delineation of time-of-travel (TOT) based capture zones. The model prediction is evaluated for the well field by altering input parameter values and observing the differences in the predicted capture zones.

6.2.1 Local Aquifer Characterization (Conceptual Model)

Figure 6-2-1 shows the locations of the pumping and calibration wells, the locations of geologic cross-sections, and the surface water features near the Mattawa pumping wells. As illustrated on Figure 6-2-1, four local cross-sections were developed to interpret the geology and hydrogeology at the Mattawa wells and the surrounding model domain (Figure 6-2-2 and Figure 6-2-3).

The cross-sections (Figure 6-2-2 and 6-2-3) are two representative cross-sections that show that bedrock is encountered at various depths throughout the study area. In some areas, the bedrock is at surface, or buried beneath a thin veneer of glacial till, and in other areas (including beneath the town of Mattawa), bedrock lies roughly 30 m below the ground surface at an elevation of approximately 130 m asl.

Bedrock water levels in the Water Well Information System (WWIS) reflect the static water level observed and reported when wells were drilled. Although these water levels may not reflect current water levels, they are the best data available at this time for establishing flow direction and determining model boundary conditions. In the vicinity of Mattawa, groundwater flow in the bedrock is towards the Mattawa River and the Ottawa River, as discussed in Section 2 (Regional Groundwater and Aquifer Characterization). Within the overburden, groundwater is also expected to flow towards the Mattawa and Ottawa Rivers.

6.2.2 Municipal Well Features

Information supplied by the Town of Mattawa is summarized in Table 6.1 and includes average production rate data, and screen information for the Mattawa wells from 1999 to 2003. During this period, average production rates have remained fairly stable.

Table 6.1 MATTAWA MUNICIPAL WELL INFORMATION

Well ID	UTM Coordinates[1]		Well Depth (m bgs)	Average Pumping Rate (m^3/day)	Elevation (m asl) at:	
	Easting	Northing			Top of Screen	Bottom of Screen
Well No. 1	676210	5131526	23.6	306.3	22	26.6
Well No. 2	676210	5131526	26.5	114.1	20.6	23.6

1 UTM projection is NAD 27, Zone 17.

6.2.3 Previous Aquifer Testing

Proctor and Redfern (Earth Tech Canada) tested Well 1 in 1994, and expressed concern that the well may not be able to maintain a constant flow. However, International Water Supply tested the well in 1998, and found the capacity to have improved to roughly 56.8 L/s. Aquifer testing information is presented in Table 6.2.

Table 6.2 MATTAWA AQUIFER TESTING INFORMATION

Source	Test Year	Well Pumped	Notes
IWS, 1998	1998	Well 1	Step test; Specific capacity of 56.8 L/s/m
IWS, 1998	1958	Well 2	Specific capacity of 29 IGM/ft (pumping at 700 IGM)
IWS, 1998	1998	Well 2	Specific capacity of 40 IGM/ft (pumping at 750 IGM)

6.2.4 Numerical Model Setup

The Mattawa numerical model was created as a three-dimensional MODFLOW model and the model domain area is shown in Figure 6-2-1. The finite difference grid spacing consisted of 140 m regionally, with refinements to 16 m in the vicinity of the wells.

Hydraulic conductivities were assigned to each of the 6 layers with the uppermost layer corresponding to the overburden, the middle layer to the bedrock/overburden contact zone (the weathered portion of bedrock), and the lower 4 layers of the model corresponding to unweathered fractured bedrock.

Aquifer recharge is variable across the model area. A value of 60 mm/year was applied to the vast majority of the model area (where clay till blankets the bedrock), with 150 mm/year applied at the base of the bedrock highs to account for increased overland flow, and interflow through the fractured bedrock.

Constant head boundary conditions were defined in the bedrock layer and overburden/bedrock contact zone layer (layers 2 and 3 of the model) where flow is conceptualised to enter or leave the model domain. Constant head cells were also used to simulate the Ottawa River, as the head in the river is interpreted to be in direct contact with the bedrock. River boundary conditions were applied to simulate the Mattawa River and its tributaries. No-flow boundaries were assigned to groundwater flow divides.

The bottom of the model was established 40 m below the bedrock/ overburden contact zone. At this boundary a no-flow condition is applied, since flow is conceptualised to be horizontal and beyond the area of influence of the well field.

6.2.5 Model Calibration

Water levels from the MOE WWIS formed the basis of the MODFLOW model calibration data. The model was calibrated such that observed water levels obtained from 48 wells lying within the model area (refer to Figure 6-2-1 for distribution) matched those simulated by the MODFLOW model to an acceptable degree, achieving a normalized root mean squared error of less than 10%. Water levels in the MOE WWIS represent approximate water levels at the time the well was drilled. As such, seasonal fluctuations are not taken into consideration and a degree of variability was anticipated. Appendix B contains a complete listing of observation wells utilized during model calibration.

Table 6.3 shows the resulting parameter values for hydraulic conductivity, recharge, and porosity for the Mattawa model. Hydraulic conductivity values for the overburden layer, the contact zone, and bedrock are consistent with those cited in literature for silty-sand tills, and fractured limestone (Dominico and Schwartz, 1998; Freeze and Cherry, 1979). An anisotropy ratio for the horizontal to vertical hydraulic conductivity values of 10:1 was used in the overburden and the bedrock, while a ratio of 1:1 was used in the contact zone.

Table 6.3 MATTAWA HYDROGEOLOGIC PARAMETERS

Parameter	Minimum Estimate	Maximum Estimate	Calibrated Value
Hydraulic Conductivity (m/s)			
- Overburden	$1x10^{-9}$	$1x10^{-3}$	$1x10^{-4}$,$1x10^{-5}$, $1x10^{-6}$
- Contact Zone	$1x10^{-8}$	$1x10^{-5}$	$1x10^{-6}$
- Bedrock	$1x10^{-9}$	$5x10^{-7}$	$1x10^{-7}$
Recharge (cm/year)	30	300	60 to 150

Parameter	Minimum Estimate	Maximum Estimate	Calibrated Value
Effective Porosity			
- Overburden	0.05	0.30	0.15
- Contact Zone	0.01	0.1	0.05
- Bedrock	0.001	0.01	0.005

Table 6.4 shows the municipal well production information and the pumping rates used for the calibration, and the capture zone delineation. The Town of Mattawa does not anticipate a significant change in population, or in pumping rates in the upcoming years. Therefore, the capture zone delineation rates are equal to the calibration period rates, and the average rates from 1999 to 2003. The pumping rates used for the 50-day capture zone are based on a 10% maximum day factor provided by Town of Mattawa personnel.

Table 6.4 MATTAWA WELL PRODUCTION DATA

Municipal Well	Pumping Rates (m^3/day)				
	Average Rate (1999/2003)	Maximum Permitted	Calibration Period Rate	Capture Zone Delineation Rates (2, 10, 25 year)	50-day Capture Zone Delineation Rates
Well 1	306.3	4582	306.3	306.3	336.9
Well 2	114.1	1964	114.1	114.1	125.5

Model calibration results are presented in Figure 6-2-4. The variability in Figure 6-2-4, statistically measured with the normalized root mean squared residuals (Normalized RMS) of 5.1 percent, is considered acceptable for a groundwater flow model calibrated to static water levels (<10%). The numerical mass balance error associated with the calibrated model was less than 0.001%.

6.2.6 Capture Zone Delineation

The capture zone, or WHPA, can be defined as the three-dimensional subsurface volume surrounding a well or well field providing water to the well, projected to ground surface. Capture zones for the Mattawa production well were determined for 50-day, 2-, 10-, and 25-year times of travel using backward particle tracking in MODPATH. As discussed above, the pumping rates used for capture zone delineation remained the same as the current pumping rates as there is no significant growth expected in the serviced population (Personal Communication, Town of Mattawa Personnel, 2004).

Since capture zones represent travel times from the well, projected to ground surface, it is important to consider the time required for water to move vertically from ground surface to the underlying aquifer. In the area of the well field, the time-of-travel from ground surface to the underlying aquifer is estimated to require more than 100 years. This time-of-travel estimate does not consider the possibility of water moving through a conduit such as an improperly sealed or abandoned borehole, in which case the time-of-travel could be considered nearly instantaneous.

6.2.7 Capture Zone Sensitivity

The approach used to address parameter sensitivity and WHPA delineation is discussed in Section 6.1 of this report. This approach involved performing backward particle tracking for two simulations, which consider variations in the model input parameters.

In the first case, hydraulic conductivities, and recharge are decreased by a factor of 1.5, and porosity is also decreased. This change in model parameters tends to create a larger capture zone that requires more time for particles to travel from the well screen to ground surface.

In the second case, hydraulic conductivities and recharge are increased by a factor of 1.5, while porosity again is decreased. This combination of parameters tends to result in larger short duration time-of-travel (2- and 10-year) WHPAs, and smaller long-duration (steady-state) WHPAs. The simulation input parameters were adjusted as follows:

Table 6.5 MATTAWA SENSITIVITY PARAMETERS

Case	Hydraulic Conductivity Adjustment	Recharge Rate Adjustment	Porosity Adjustment
0	Calibrated Value	Calibrated Value	Calibrated Value
1	Calibrated Value*1.5	Calibrated Value*1.5	Overburden – 0.25 Contact Zone – 0.01 Bedrock – 0.001
2	Calibrated Value/1.5	Calibrated Value/1.5	Overburden – 0.25 Contact Zone – 0.01 Bedrock – 0.001

For each of these scenarios, the effect on the calibration is noted in Table 6.6. Calibration statistics for Cases 1 and 2 are very similar to the Base Case, indicating that the model calibration is somewhat insensitive to parameter value changes. This reflects the joint adjustment of recharge and hydraulic conductivity in the simulations. Since recharge is not expected to vary by more than a factor of 1.5 from the calibrated value, further parameter adjustments were not considered. Additional evaluation of the WHPAs could be performed to further evaluate the overall sensitivity.

Table 6.6 MATTAWA MODEL SENSITIVITY ANALYSIS RESULTS

	Calibration Statistics		
	NRMS	ARM	RM
Best Estimate	5.109%	5.26 m	0.50 m
Case 1	5.122%	5.28 m	0.54 m
Case 2	5.098%	5.23 m	0.46 m
Notes: 1. NRMS = Normalized Root Mean Square Residual Value 2. ARM = Mean Absolute Residual Value 3. RM = Residual Mean Value			

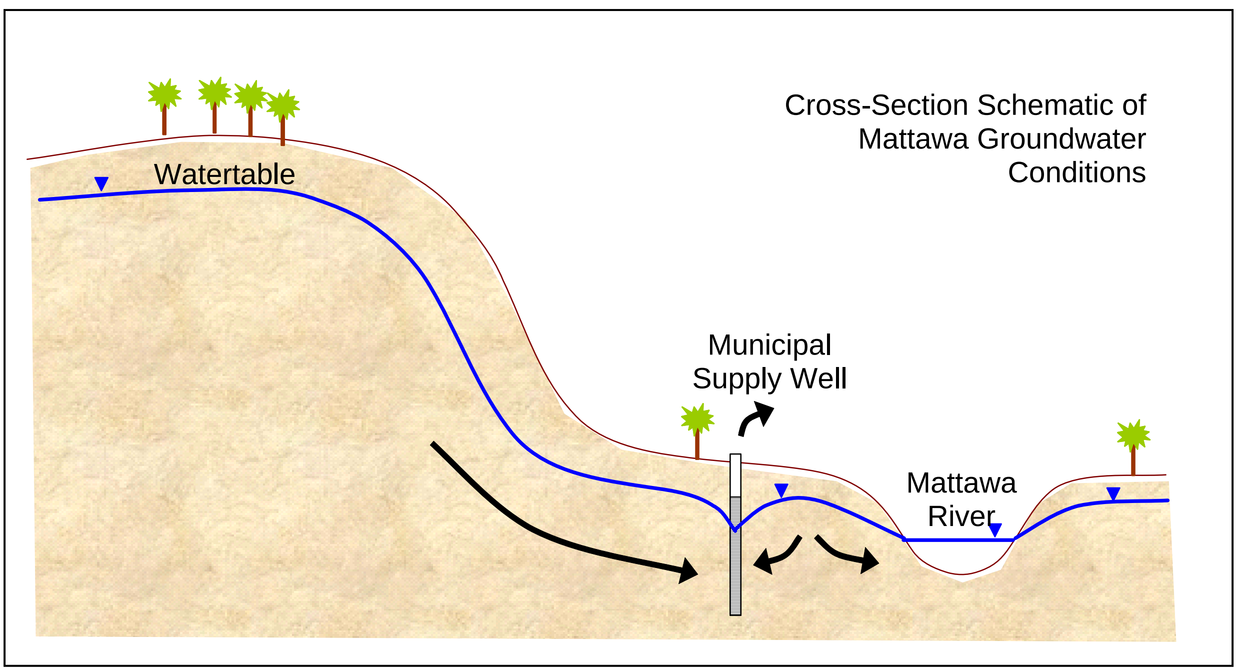
The capture zones for each of the sensitivity cases was similar to those produced for the base case calibrated conditions with only minor differences in the width of the capture zone in the 10 and 25 year cases. The largest capture zone area variations between the three simulations are due to changes in porosity values. The production well is not pumping at a high rate, and as a result, drawdown at the well field and the regional flow directions does not change significantly with conductivity value changes.

Figure 6-2-5 shows the best estimate 50-day, 2-, 10-, and 25-year, and steady-state capture zones for the Mattawa wells.

The capture zone for the Mattawa Well is quite long and narrow, especially north of the Town of Mattawa. The shape of the capture zones is primarily due to the relatively low pumping rate, and the high conductivity of the sand and gravel aquifer that the wells are screened within. Increases in the pumping rate would lead to broader, or wider capture zones. As Well 1 and Well 2 are less than 10 m apart, one capture zone was created for the two pumping wells.

The 50-day capture zone is localized around the wells, near the intersection of Bissett Street and Fourth Street on the north shore of the Mattawa River. The 2-year capture zone extends radially outward from this intersection, and the model predicts that a small amount of water is beginning to be drawn into the wells at this time. The 2-year capture zone extends west to Fifth Street and north beyond Mackenzie Street. The 10-year capture zone, extends further to the northwest beneath Brydges and Rankin Streets, and the 25-year capture zone, continues to trend northwest outside the residential areas of the Town of Mattawa. The steady state capture zone extends towards East Montreuil Lake and the topographic high north of the town of Mattawa.

The model predicts that a portion of the water flowing into the municipal wells originates from the Mattawa River and travels to the wells in approximately 2 years. Groundwater elevation data at the pumping wells; and Mattawa River elevation data, provided by the Town of Mattawa (Mark Mathon) indicates that the groundwater elevation is greater that the elevation in the Mattawa River. Under these conditions it is not possible for water from the Mattawa River to move to the municipal pumping wells. This is illustrated in the schematic below.



In the future, changing pumping conditions could alter this situation. Therefore, groundwater elevation data in the pumping wells should be monitored regularly to verify that groundwater elevations are greater than the water levels in the river. If additional geological information is collected in the area of the municipal wells, the groundwater model should be updated and the capture zone predictions refined.

The steady-state capture zones predicted in the sensitivity analysis are very similar to the capture zones produced with the base case calibrated model.

6.3 Powassan Municipal Well System

The Powassan municipal well field is located in the Town of Powassan in the Township of North Himsworth. The water supply system is comprised of two wells, which supply water to a population of approximately 1,100 people. Well 1 was drilled in 1981 and connected to the municipal distribution system in 1982. This well is located approximately 100 m north of County Road 534, and was completed at a depth of 23.2 metres below ground surface. Well 2 was added in 1983 and connected to the distribution system in 1984. This well is located about 70 m north of Well #1, near Genesee Creek, and was drilled to a total depth of 18.6 metres. Figure 6-3-1 shows the location of the 2 wells and their proximity to Genesee Creek, Highway 11, and County Road 534.

Hydroterra Limited (2001) completed a hydrogeologic assessment for the Town of Powassan water supply system, which noted that localized windows might exist in the surficial clay-rich sediments that could allow chemical or bacterial contamination of the aquifer unit. Currently there are no known bacterial sources within the area of the municipal supply wells except Genesee Creek.

This section presents specific details concerning the conceptual model developed for the Powassan well field, followed by the development and application of a MODFLOW groundwater flow model (Harbaugh et al., 2000) for the delineation of time-of-travel (TOT) based capture zones. The sensitivity of the model predictions is evaluated for the wells by altering input parameter values and observing the differences in the predicted capture zones.

6.3.1 Local Aquifer Characterization (Conceptual Model)

Four local cross-sections were developed through the Powassan area to interpret the geology and hydrogeology at the Powassan well field. Figure 6-3-1 shows the locations of the municipal and private wells, the locations of the geologic cross-sections, and surface water features near the wells. The cross-sections are presented in Figure 6-3-2 and Figure 6-3-3.

As described in Section 2, bedrock in the Powassan area is composed predominantly of granite and monzonite from the Powassan Batholith (felsic plutonic rocks) and is Middle to Late Precambrian in age. The cross-sections show that the bedrock topography is variable, ranging from 140 to 300 m asl. The overburden is predominantly glacial in origin, and varies between coarse sands and gravels in the western portion of the model area, to fine-grained clays in the central portion and numerous rock outcrops in the east (Harrison, 1972; Quaternary Geology map 3-1971).

Bedrock water levels in the Water Well Information System (WWIS) reflect the static water level observed and reported when wells were drilled. Although these water levels may not reflect current water levels, they are the best data available at this time for establishing flow direction and determining model boundary conditions. In the Powassan model area, groundwater flow in the bedrock is toward the northwest, as discussed in Section 2 (Regional Groundwater and Aquifer Characterization).

A large sand and gravel plain exists beneath, and around, the Town of Powassan, and it is locally covered by a thin (5-6 metre thick) veneer of silts and clays. Harrison (1972) notes that these sands are often associated with proglacial lakes. Raised beach scarps are apparent on the north side of the hills immediately north of Storie, as well as just south of Graham Lake, supporting this interpretation for the Powassan area. This deposit is the main unconsolidated aquifer in the area, and both of the municipal wells are completed in this unit. The majority of the private wells in the area are completed within the igneous bedrock.

6.3.2 Municipal Well Features

Information regarding the municipal supply wells was obtained from the First Engineer's Inspection Report for Water Works completed by Totten Sims Hubicki (TSH) for the Municipality of Powassan (TSH, 2001), and is summarized in Table 6.7. This table includes the average production rate, well locations, depths, and screen information for the Powassan wells. The combined average pumping rate was calculated based upon average values provided for years 1997 to 2000. During this period, average production rates have remained fairly stable.

Table 6.7 POWASSAN MUNICIPAL WELL INFORMATION

Well ID	**UTM Coordinates[1]**		**Well Depth (m bgs)**	**Average Pumping Rate (m^3/day)**	**Depth (m bgs)**	
	Easting	**Northing**			**Top of Screen[2]**	**Bottom of Screen[2]**
Well #1	625874	5104525	23.2	483	19.4	23.2
Well #2	625890	5104590	18.6		11	18.6

[1] UTM projection is NAD 83, Zone 17.
[2] Screen refers to open (uncased) borehole.

6.3.3 Previous Aquifer Testing

Table 6.8 summarizes available information on aquifer testing in the Powassan area. In 1981, aquifer testing showed that the local transmissivity of the aquifer was around 1300 m^2/day, while the regional transmissivity was much lower, at around 350 m^2/day. With an estimated aquifer saturated thickness of 10 metres, this is equivalent to a regional hydraulic conductivity of 4×10^{-4} m/s, that of a coarse sand (Hydroterra Limited, 2001). No other details of the aquifer testing were reported.

Table 6.8 POWASSAN AQUIFER TESTING INFORMATION

Source	**Test Year**	**Well Pumped**	**Transmissivity (m^2/day)**	**Notes**
Hydroterra Limited, 2001	1981	Well #1	350-1300	Lower value represents regional scale transmissivity.

6.3.4 Numerical Model Setup

The Powassan numerical model was created as a three-dimensional MODFLOW model and the model domain area is shown in Figure 6-3-1. The finite difference grid spacing consisted of 100 m regionally, with refinement to approximately 12 m near the municipal wells.

Harrison (1972) states that the probability of developing wells with satisfactory production rates in the bedrock diminishes rapidly below 45 metres. Thus, the bottom of the model was established 40 m below the bedrock/overburden contact zone. At this boundary, a no-flow condition was applied because flow is conceptualised to be horizontal and beyond the area of influence of the municipal wells.

Hydraulic conductivities were assigned to each of the 5 model layers, with the uppermost layer corresponding to the overburden, the second layer to the bedrock/overburden contact zone (the weathered portion of the bedrock), and the bottom three layers of the model corresponding to the unweathered bedrock.

Uniform hydraulic conductivities were defined across the lower four model layers, with three distinct zones applied to the uppermost layer to account for the different overburden geologic conditions in the area (rock, sand, and clay/sand/silt till). Previous Quaternary mapping (Harrison, 1972) was used to delineate the overburden hydraulic conductivity zones.

Variable recharge values were assigned to each of the three overburden units within the model area. A recharge of 100 mm/year was applied to sandy areas, 55 mm/year to clay rich and till areas, and 75 mm/year to bedrock outcrops (all defined by Harrison, 1972). These recharge rates are consistent with those applied to the Mattawa area (see Section 6.2.4).

To represent the groundwater flow conditions in the groundwater flow model, constant head boundary conditions were defined along the eastern and southern extents of the model in the lower four layers. A no-flow boundary was assigned along the northern extent of the model, perpendicular to the inferred groundwater flow direction. River boundary conditions were applied to account for the influence of both the South River and Genesee Creek on the groundwater flow system.

6.3.5 Model Calibration

Water levels from the MOE WWIS formed the basis of the MODFLOW model calibration data. The model was calibrated such that observed water levels obtained from 77 wells lying within the model area (refer to Figure 6-3-1 for distribution) matched those simulated by the MODFLOW model to an acceptable degree, achieving a normalized root mean squared error of less than 10%. Water levels in the MOE WWIS represent approximate water levels at the time the well was drilled. Appendix F contains a complete listing of observation wells utilized during model calibration.

Table 6.9 shows the resulting parameter values for hydraulic conductivity, recharge, and porosity for the Powassan model. Hydraulic conductivity values for the overburden layer, the contact zone, and bedrock are consistent with those cited in literature for clay rich tills, and fractured igneous rocks (granite) (Dominico and Schwartz, 1998; Freeze and Cherry, 1979). An anisotropy ratio for the horizontal to vertical hydraulic conductivity values of 10:1 was used in all layers.

Table 6.9 POWASSAN HYDROGEOLOGIC PARAMETERS

Parameter	Minimum Estimate	Maximum Estimate	Calibrated Value
Hydraulic Conductivity (m/s)			
- Sand	$1x10^{-5}$	$1x10^{-3}$	$1x10^{-4}$, $1x10^{-5}$
- Till	$1x10^{-10}$	$1x10^{-6}$	$5x10^{-6}$
- Weathered Bedrock	$1x10^{-8}$	$5x10^{-5}$	$1x10^{-5}$
- Bedrock (Layers 4 & 5)	$1x10^{-9}$	$5x10^{-6}$	$2.5x10^{-6}$

Parameter	Minimum Estimate	Maximum Estimate	Calibrated Value
Recharge (mm)			
- Sand overlying bedrock	125	300	100
- Till overlying bedrock	50	150	55
- Bedrock	15	125	75
Effective Porosity			
- Overburden	0.05	0.30	0.15
- Weathered Bedrock	0.01	0.1	0.05
- Bedrock	0.001	0.001	0.005

Table 6.10 shows the municipal well production information and the pumping rates used for the calibration and the capture zone delineation. The Town of Powassan does not anticipate a significant change in population or in pumping rates in the upcoming years. For this reason the capture zone delineation rates for the 2-, 10-, and 25- year capture zones are equal to the calibration period rates, and the average rates from 1997 to 2003. The capture zone delineation rate for the 50-day capture zone was 1,313 m^3/day, as this rate was almost achieved in the year 2000. This rate is also the combined maximum permitted pumping rate for the wells.

Table 6.10 POWASSAN WELL PRODUCTION DATA

Municipal Well	Pumping Rates (m^3/day)			
	Average Rate (1997/2003)	Maximum Permitted	Calibration Period Rate	Capture Zone Delineation Rates for 2, 10 and 25 years
Well 1 and 2	506.9	1,313	506.9	506.9

Model calibration results are presented in Figure 6-3-4. The variability in Figure 6-3-4, statistically measured with the normalized root mean squared residuals (Normalized RMS) of 8.2 percent is considered acceptable for a groundwater flow model calibrated to static water levels (<10%). The numerical mass balance error associated with the calibrated model was <0.01%.

6.3.6 Capture Zone Delineation

The capture zone, or WHPA, can be defined as the three-dimensional subsurface volume surrounding a well or well field providing water to the well, projected to ground surface. Capture zones for the Powassan production wells were determined for 50-day, 2-, 10-, and 25-year times of travel using backward particle tracking in MODPATH. As discussed above, the Town of Powassan does not anticipate a significant change in population or in pumping rates in the upcoming years. For this reason the 2-, 10-, and 25-year capture zone delineation rates are equal to the calibration period rates and the average rates from 1997 to 2000. The capture zone pumping rates are presented in Table 6.10.

Because capture zones represent travel times from the well projected to ground surface, it is important to consider the time required for water to move vertically from ground surface to the underlying aquifer. In the area of the well field, the time-of-travel from ground surface to the underlying aquifer is estimated to require more than 50 years. This time-of-travel estimate does not consider the possibility of water moving through a conduit such as an improperly sealed abandoned borehole or a poorly completed well, in which case the time-of-travel could be considered nearly instantaneous.

6.3.7 Capture Zone Sensitivity

The approach used to address parameter sensitivity and WHPA delineation is discussed in Section 6.1 of this report. This approach involved performing backward particle tracking for two simulations, which consider variations in the model parameters.

In the first case, hydraulic conductivities, recharge and porosity are all decreased by a factor of 2. This change in model parameters tends to create a larger capture zone that requires more time for particles to travel from the well screen to ground surface.

In the second case, hydraulic conductivities and recharge are increased by a factor of 2, while porosity is decreased. This combination of parameters tends to result in larger short duration time-of-travel (2- and 10-year) WHPAs, and smaller long-duration (steady-state) WHPAs. The simulation input parameters were adjusted as follows:

Table 6.11 POWASSAN SENSITIVITY PARAMETERS

Case	Hydraulic Conductivity Adjustment	Recharge Rate Adjustment	Porosity Adjustment
0	Calibrated Value	Calibrated Value	Calibrated Value
1	Calibrated Value x 2	Calibrated Value x 2	Sand – 0.25 Till – 0.25 Weathered Bedrock – 0.05 Bedrock – 0.05
2	Calibrated Value / 2	Calibrated Value / 2	Sand – 0.25 Till – 0.25 Weathered Bedrock – 0.05 Bedrock – 0.05

For each of these scenarios, the effect on the calibration is noted in Table 6.12. Calibration statistics for Cases 1 and 2 are very similar to the Base Case, indicating that the model calibration is insensitive to parameter value changes. This reflects the joint adjustment of recharge and hydraulic conductivity in the simulations. Since recharge is not expected to vary by more than a factor of 2 from the calibrated value, further parameter adjustments were not considered. Additional evaluation of the WHPAs could be performed to further evaluate the overall sensitivity.

Table 6.12 POWASSAN MODEL SENSITIVITY ANALYSIS RESULTS

	Calibration Statistics		
	NRMS	ARM	RM
Best Estimate	8.209%	3.5 m	0.327 m
Case 1	8.255%	3.5 m	0.575 m
Case 2	8.150%	3.5 m	0.265 m
Notes: 1. NRMS = Normalized Root Mean Square Residual Value 2. ARM = Mean Absolute Residual Value 3. RM = Residual Mean Value			

Analysis indicates the largest capture zone area variations are due to changes in porosity values. The production well is not pumping at a high rate and, as a result, drawdown at the well does not change significantly with conductivity value changes. The largest change in capture zone area occurs with extreme parameter values, (i.e. maximum conductivity and recharge values with minimum porosity value combination (creating a larger capture zone)).

Figure 6-3-5 shows the best estimate, 50-day, 2-, 10-, and 25-year, and steady-state capture zones for the Powassan wells. Both of the wells in Powassan are pumping at approximately the same rate, and the size of the capture zones for the two wells are similar. The best estimate capture zone is the smallest of the three 25-year capture zones. This is due to the higher porosity value used in the best estimate Base Case. Decreasing the porosity in the cases increases the size of the time-related capture zones, but not the shape of the steady state capture zone.

The 50-day capture zone is localized around the wells, just west of Highway 11 near Genesee Creek. The 2-year capture zone extends outward from the wells in a southeast direction towards Highway 11 and Clark Street. The capture zone extends beneath the Highway (11) in just over 2 years, however the 10-year capture zone extends completely beneath the Highway extending as far south as the intersection of Elm Street and South Street in Powassan. The 25-year capture zone continues to trend southeast, and this capture zone extends beneath the majority of the Town of Powassan towards Chiswick Line. The steady state capture zone trends southeastward beneath Chiswick Line and finally terminates in the highlands southeast of the Town.

All of the steady-state capture zones (base case, sensitivity case 1 and 2) are larger than the 25-year capture zones with the largest steady-state capture zone results arising from the conditions applied in Case 2. The second largest steady-state capture zone occurs in the best estimate Base Case, with Case 1 having the smallest WHPA. The size of the steady-state capture zone is primarily controlled by the recharge rate. Smaller recharge rates mean that a larger area must contribute water to the pumping well, resulting in larger capture zone.

6.4 Summary

Numerical models were developed, calibrated, and applied to evaluate the capture zones at the municipal wells in Mattawa and Powassan. 50-day, 2-, 10-, 25-year, and steady state capture zones are delineated for each of the municipal wells. Additional analysis using the capture zones (WHPAs), potential contaminant sources, and intrinsic susceptibility results are presented in Section 7.

In both of the models, the primary source of data used during development and calibration was obtained from the WWIS. Additional information derived from local studies at the different well fields was incorporated into the analysis. The WHPA results are the current best estimate of the different capture zones, however their sizes and shapes will change in the future if wells are added or removed, or if water demands change. As additional information becomes available, the validity of the different models should be evaluated to help ensure that protective measures continue to be directed in the appropriate areas. Incorporating additional geologic and pumping information into the model will not be difficult now that the models have been constructed and calibrated. Currently it is understood that in the near future, pumping conditions will not be changing as the populations in the municipalities and towns are not anticipated to increase dramatically in the future.

7 Integration of Wellhead Protection Area Results

7.1 Methodology/Data Sources

A variety of different data layers, that can be used to assess the security of each municipal well, have been developed during the study. Overlaying the different themes in a GIS (Geographic Information System) allows the consideration of different aspects associated with groundwater quality simultaneously. GIS is widely used around the world as a comprehensive system capable of assembling, storing, manipulating, and displaying geographically referenced information.

<u>Wellhead Protection Area (WHPA) Overlay</u>
The WHPAs for each municipal well are presented in Section 6. For each well, 50-day, 2-, 10-, 25-year, and steady state capture zones were mapped. WHPAs were generated using groundwater models for each of the two municipal systems. As discussed in Section 6, a WHPA is the three-dimensional subsurface volume surrounding a well or well field providing water to the well, projected to ground surface. As capture zones are projected to ground surface, in many instances the time-of-travel WHPA does not reflect the time required for water to travel from ground surface to the well. This is particularly true when the wells that are being evaluated pump water from a deep aquifer that is overlain by fine-grained sediments (silts and clays).

WHPAs represent the most sensitive area surrounding a municipal well when considering the security of the water supply. Water that recharges a WHPA will be pumped at the well some time in the future.

<u>Bedrock Aquifer Susceptibility Overlay</u>
Regional bedrock aquifer susceptibility mapping is presented in Section 3. The susceptibility mapping has been completed following the methodology outlined by the MOE (2001). High susceptibility areas represent zones where water is inferred to move to the bedrock aquifer more quickly than low susceptibility areas. In these areas, ground surface contamination or spills are more likely to impact the bedrock aquifer. High and medium bedrock aquifer susceptibility areas typically have shallow depths to the bedrock or have overburden material comprised of sands and gravels. High and medium aquifer susceptibility areas that lie within WHPAs are very sensitive zones from a groundwater protection perspective.

<u>Potential Contaminant Sources Overlay</u>
Regional potential contaminant source inventory mapping is presented in Section 5. Further local ground-truthing was conducted throughout each of the WHPAs mapped in Section 6 during the winter of 2004. During the ground-truthing, hydrogeologists drove through the capture zones identifying land uses that are more likely to impact groundwater quality. The specific land uses were outlined by the MOE (2001), and include:

- Dry cleaners / Laundromats
- Fuel storage and distributing operations
- Industrial manufacturers
- Automotive garages
- Salvage Yards
- Rail yards
- Landfills
- Lumber Yards

Understanding the locations of land uses that pose a greater risk to groundwater quality, in relation to high susceptibility areas and the WHPAs, provides a means of identifying sensitive areas surrounding each municipal well.

Figures 7-1 and 7-2 present point sources identified from the contaminant inventory mapping described in Section 5 with other base mapping features including the WHPAs. Each of the figures is discussed in the following sections.

7.2 Mattawa Municipal Water Supply System

The Mattawa capture zones, potential contaminant sources, and areas of medium to high vulnerability are presented in Figure 7-1. There are few potential contaminants of concern in the Mattawa capture zones. One, labeled as a ‘historic spill site’, is described in the spills inventory as a spill of an unknown quantity of raw, unchlorinated sewage spilled at the wellfield in 1998. This spill is no longer considered to be a threat to the groundwater system, however it was in the MOE spills records and therefore is included in Figure 7-1. Another potential contaminant is the school (Ecole St. Anne) located on the corner of Third Street and Brydges Street. This school is considered a potential contaminant source as it may house a chemistry laboratory with various chemicals or solvents.

Outside the capture zone there are a number of point sources identified on Figure 7-1 as miscellaneous sources. These include the liquid sewage dump sites off Moosehead Road, a medical centre located on Water Street and a few automotive or autobody shops located on John Street and Highway 17. A cemetery is also located north of the town of Mattawa west of the capture zones.

The vast majority of the capture zones for the Mattawa wellfield lie within high susceptibility zones. This is due to the thin overburden that overlies the bedrock. Despite this, the capture zones for the well field pass through a largely residential area and there do not appear to be any land uses (ie. heavy industrial) that would warrant concern from a groundwater contamination perspective. One contaminant that may be worth examining is private oil and gasoline storage tanks. Individual homes commonly have their own above ground storage tanks that have the potential to leak contaminants, including fuel or heating oil, onto the ground surface.

7.3 Powassan Municipal Water Supply Systems

The Powassan capture zones, potential contaminant sources, and areas of low, medium to high vulnerability are presented in Figure 7-2.

During the field survey, there were no known potential contaminant sources located within the 50-day or the two-year capture zone. One above ground storage tank was noted beside a barn near the municipal wells, however it was noted at the public meeting that the tank was empty and that the tank and barn may be removed in the future. It is worth noting that Highway 11 passes over the 2-year capture zone. This is significant in terms of road salt application along this stretch of the highway, and also significant in the event of a spill or accident on the highway. We recommend that a spills action plan we drawn up in case of such an event.

There is only one recorded potential source of contamination within the 10-year capture zone; an underground fuel storage tank located in Powassan, on Clark Street between Joseph St. and Edward St. There are several potential contaminant sources located within the 25-year capture zone that underlies much of Powassan. These include a funeral home, and an automotive garage on Main Street between King and Chisholm Streets (classified as Miscellaneous sources). Also located in the 25-year capture zone is another automotive garage, and a public works building with three outdoor above ground storage tanks. Both of these potential sources are located on Main Street south of South Street and are classified on Figure 7-2 as Miscellaneous sources. A railroad line also lies within the 25-year capture zone, and therefore, there is a chance that there could be a spill associated with the transport of chemicals, or other contaminants. A spills action plan should also be considered for the segment of rail that passes through the town.

The steady-state capture zone, and the uncertainty zone both come very close to a lumber yard, and an area of land with underground and above ground fuel storage tanks (the latter classified as a Miscellaneous source on Figure 7-2).

7.4 Summary

Results of the WHPA modeling, contaminant sources inventory mapping, and intrinsic susceptibility mapping were brought together on one map to examine the potential threats to the groundwater aquifers in the towns of Mattawa and Powassan. Results show that there are a few potential sources of concern in each of the towns, including Highway 11 in Powassan. The WHPAs for both Mattawa and Powassan predominately underlie residential areas of the towns. Residential areas in comparison to industrial areas, are not as great a threat to the groundwater, however, residential areas also have the ability to pollute in the form of leaky above ground fuel storage tanks. The condition and prevalence of such tanks within the capture zones in Mattawa and Powassan is not currently known, however these potential contaminant sources should not be overlooked during the implementation of future groundwater or sourcewater protection initiatives.

8 Public Consultation

8.1 Methodology

Public consultation was an important component of the North Bay-Mattawa Groundwater Study. To transfer study information to the public and solicit their input, a variety of different public consultation strategies were utilized. At the onset of the study, it was understood that public involvement and support of the North Bay-Mattawa Groundwater Study and its findings would be very beneficial. A more environmentally aware public that appreciates the need to protect their groundwater resources will be more likely to endorse and support future groundwater protection strategies. Information from members of the community also provided insight about specific water resource issues that were of concern to them. This information was used during the development of the groundwater protection strategy and helped focus the study on local concerns and issues.

During public consultation, information from other agencies such as Conservation Authorities, Ministry of the Environment, Public Health Unit, Municipal Public Works, and rural organizations were incorporated. Further participation and contributions from the Steering Committee also contributed to the transfer of groundwater resource protection information and specific study results to the public.

To consult the public and make study results available to local stakeholders, the following specific strategies were implemented during the study:

- News releases were sent to local newspapers requesting input, during the study at public meetings, and through members of the Steering Committee;
- Public meeting and open house events, located and timed to present preliminary and final study results; and,
- Development of a study website to transfer study information to the public, and to convey study progression and final results. (www.nbmcagroundwaterstudy.on.ca).

The following paragraphs provide details about the different public consultation strategies used during the study and their results.

8.2 Other Pubic Consultation Initiatives

The perception of the general public to groundwater resource related initiatives is important to understand so that public consultation initiatives can be designed to address these perceptions, and provide information that is accessible to all residents. Previous public consultation initiatives held in other jurisdictions across Ontario, and the feedback provided during these initiatives, are summarized in the following paragraphs.

Oxford County

During the Oxford County Groundwater Study a public consultation program and a county-wide survey was administered in 2000 (Monteith Planning Consultants, 2000). The goals of the household groundwater questionnaire were to obtain public input about water usage needs, water quality perceptions, water supply knowledge, the need for water conservation and protection measures, and preferences for specific protection and conservation measures. The questionnaire was administered to 389 municipally supplied households and 389 households with privately supplied water.

The survey results showed that if the County of Oxford required additional water supplies, 42% of households support the restriction of residential water use through enforced water conservation measures; 64% of respondents felt than domestic fertilizers and pesticides should be restricted; 34% felt that the County needs more lawn and garden watering restrictions; and 62% prefer water meters over flat rate billing.

The study reported that further education initiatives in Oxford County would be appropriate to provide accurate timely and more local-scale information to residents. The public requires greater information regarding sources of groundwater contamination, water efficient appliances, water testing, well and septic system maintenance, and the proper use, handling, storage, and disposal of household fertilizers, pesticides and other hazardous substances.

Perth County

The Perth County Groundwater Study (UTRCA et al., 2001) included a public consultation component that consisted of open houses in Stratford and a rural town in North Perth, as well as facilitated focus group discussions. Surveys were distributed at the open houses to help characterize the key issues of concern for residents that related to groundwater protection in Perth County. Issues included in the completed survey included:

- Abandoned wells
- Education
- Groundwater quantity
- Nutrient Management Plans
- Septic systems
- Need for regular private well testing
- Surface water/groundwater interaction
- Pesticides
- Real cost of water
- Groundwater monitoring program
- Household hazardous wastes
- Landfill sites
- Need for Province-wide protection strategy
- Sewage sludge
- Updated well records
- Use of regulations to protect groundwater
- Tile drainage
- Better understanding of groundwater resources

At the completion of the study, a number of recommendations regarding future public consultation were adopted during this study. Recommendation xi and xiv from the Perth Groundwater Study identified information dissemination to local residents (private well owners and drillers) and to other municipalities as a means to promote groundwater awareness and better information transfer between different jurisdictions.

8.3 Media News Releases

During the North Bay-Mattawa Groundwater Study, Press Releases were issued to local media outlets. Media releases provide a cost-effective means of presenting study information in a venue that is accessible by many local residents. Each release included details regarding study progress, upcoming public meetings, and general groundwater facts pertinent to residents of the North Bay-Mattawa Conservation Authority jurisdiction. The releases also included contact information for project personnel available to respond to specific project related questions.

An archive of news releases was established on the project web site (http://www.nbmcagroundwaterstudy.on.ca/results.htm).

8.4 Public Meetings

To directly interact with the public a series of public meetings were incorporated into the public consultation strategy. Drawing upon experiences gained during previously completed groundwater studies, and discussions with the Project Steering Committee, an open drop-in forum was adopted for the first set of meetings.

The first event was conducted on Monday, December 13, 2004 in the Municipal Town Hall in the Town of Mattawa. The public was encouraged (via press releases) to attend the open houses to meet with members of the Steering Committee, and the Consulting Team, and answer any questions they may have about the study. Seven people attended the open house. The second event was held on Tuesday, December 14, 2004 at the South Himsworth Hall in Powassan to present the same material as the first event, but in a different location. A total of eight people were in attendance on this date.

Information presented at the public meetings was incorporated into the study website, recognizing that every resident in the study area would not be able to attend the meetings. Furthermore, the website was promoted as a tool that residents could use during the study to monitor study progress.

The substance of public interest might best be summarized as a keen desire to be informed of the current situation (e.g. the state of the quality and quantity of groundwater resources, and the measures that might be undertaken for source protection of private individual wells in the study area). It was evident that the public wants assurance of an abundant supply of safe drinking water at an affordable cost and that quality should not be compromised through contamination, notably point source contamination (e.g. above ground fuel storage tanks, improperly abandoned wells, etc.). It may be concluded from the public consultation process, that there is pervasive support for the objectives of the study and the measures needed to provide for a consistent supply of safe drinking water.

The second set of meetings was scheduled to present the study conclusions and recommendations. Two meeting were held at the NMBCA office, to accommodate the residents across the study area.

8.5 Study Web Site (www.nbmcagroundwaterstudy.on.ca)

At the beginning of the study, a web site was developed to convey the purpose of the project and to bolster public awareness about groundwater resource issues. The web site was updated periodically throughout the study, primarily at the completion of significant study milestones.

A counter was added to the web site to monitor web traffic. The counter was designed such that a single visitor could not refresh their web page arbitrarily to inflate the number of visitors counted at the site, and therefore it provides a good indication of the traffic at the website. Since the implementation of the counter, the web site has had more than 180 visits.

The website will exist after the study has been completed, and an executive summary of the final report will reside on the website in Adobe (*.PDF) format for interested parties to access.

8.6 Summary

Public consultation aspects of the study were designed to provide an understanding of public opinion on the issues related to groundwater protection for the study area, and to transfer study related information to residents of the study area and surrounding area. The overall process was designed to provide a forum for community education and awareness and to provide a foundation for future related endeavors. Public consultation included a review of similar outreaches conducted recently, public meetings, and press releases. As part of public consultation a website was developed to convey groundwater resource related information and to transfer information about the progress of the study to interested stakeholders (www.nbmcagroundwaterstudy.on.ca).

9 Groundwater Management and Protection Strategy

9.1 Introduction

Humans can live for a month without food, but will die in less than a week without water (de Villiers, 1999). Water is continually being recycled throughout the hydrosphere. Water falls as rain or snow and serves to replenish the lakes, rivers, and groundwater systems. Water is removed from plant matter (transpiration) and surface water bodies (evaporation), to be returned once again as precipitation. During any part of this water (hydrologic) cycle, water is susceptible to the impact of human activities. As the population of any area continues to grow, the need for clean and safe water supplies also grows.

Municipalities have recognized the vulnerability of water resources that supply both individual and municipal wells within their communities. Based on provincial protocols, studies were initiated across Ontario to characterize regional aquifers, to assess their intrinsic susceptibility to contamination, to inventory contaminant sources, and to define wellhead protection areas (WHPAs). With this information, municipalities and planning authorities can design a source water protection strategy. Such strategies are based on the principle that measures to prevent contamination are less expensive than measures to treat contaminated water and remediate water supplies, and are strongly favoured by the public (O'Connor, 2002).

The protection of water quality and quantity depends on the collective actions of individuals, private industry, government, and other agencies. Rural property owners are responsible for their own well and the maintenance of their septic systems. Municipalities are responsible for the provision and maintenance of a safe drinking water supply in urban areas and for proper sewage collection and treatment. Conservation Authorities play an important role in water conservation through watershed planning and the protection of wetlands. Private industry is responsible for applying best management practices to protect and maintain water quality and quantity. The agricultural sector has a vested interest in securing an adequate supply of water for livestock and crop watering.

9.2 Groundwater Management and Protection Issues and Potential Tools

A number of the common issues that can be addressed during the development of a groundwater management and protection strategy are summarized in Table 9.1 below. This list is not intended to be exhaustive, but is intended to highlight the variety of potential risks to the health of groundwater systems. This table also provides some insight into existing policies, legislation, and/or guidelines that address specific issues regarding source protection, and if any incentive programs currently exist to aid in these initiatives.

As noted in Table 9.1, a number of policies and incentive programs exist to help protect groundwater resources. In concert with these existing initiatives, Table 9.2 outlines a number of tools that the study partners could apply to further enhance groundwater protection. A brief summary related to each tool is presented in the sub-sections that follow.

Table 9.1 Summary of Groundwater Management and Protection Issues

	Issue	Implication	Policy/ Legislation	Incentive Programs
1	Improperly Constructed and Decommissioned Wells	Conduit to aquifers	MOE Reg. 903	Healthy Futures, Clean Water Project
2	Sewage Sludge Spreading	Non-point source of nutrients	MOE	
3	Nutrient Storage	Point source of nutrients		OFA Env. Farm Plans
4	Nutrient Loading	Non-point source of nutrients	Bill 81 - Nutrient Management Act	
5	Road Salting	Non-point source of chloride		
6	Fuel/Chemical Storage	Point source of chemicals	MOE Environmental Protection Act	Local BMPs and incentives
7	Absence of Monitoring Data	Difficult to assess water quality		
8	Absence of Household Hazardous Waste Pickup	Potential point source of chemical pollution		
9	Data Management	Disorganized data that is difficult to utilize		
10	Poor Communication Between Government Levels	Poor organization and difficulty implementing programs		

Table 9.2 Groundwater Management and Protection Tools

	Tool	Applicability	Relative Value	Relative Cost
1	Education	All Issues	Medium	Low
2	Best Management Practices	Contamination risk issues	Medium	Low
3	Land Acquisition	Contamination risk and susceptibility issues	High	High
4	Municipal Site Leadership	Contamination risk issues	Medium	Medium
5	Integrated Information Management	Contamination risk and data management issues	Medium	High
6	Water Quality Monitoring	Contamination risk and data management issues	Medium	High
7	Water Conservation	Contamination risk issues	High	Low to High
8	Municipal Sewer By-Law	Contamination risk issues	Medium	Medium
9	Official Plan Amendments	Contamination risk issues	High	High
10	Spills Contingency Plan	Contamination risk issues	Medium	Low

9.2.1 Education

Many different means of communicating messages to promote awareness and responsible stewardship of groundwater resources are available. Different education-oriented initiatives include:

- Groundwater information papers that can be distributed by mail with other municipal mailings (taxes, water bills).

- Supplemental education aides can be provided to teachers throughout the study area, with a fact sheet related to the reliance on groundwater locally. Groundwater can be incorporated into the Ontario curriculum as part of the following Science and Technology Units: Air and Water in the Environment, Grade 2; Soils in the Environment, Grade 3; Rocks, Minerals, and Erosion, Grade 4; Water Systems; Grade 8 (http://www.edu.gov.on.ca/eng/document/curricul/scientec/scientec.html).
- A Children's Groundwater Festival, similar to those conducted in Waterloo Region and Oxford County, can be initiated to increase groundwater awareness. For additional information consult http://www.cwec.ca/.
- In some jurisdictions, signs labelled "Attention: Groundwater Protection Area" or "You are Entering a Wellhead Protection Area" have been constructed to promote awareness. The signs typically include a number to call in the event of a contaminant spill.
- A website, similar to the study website can be developed to provide general groundwater information and specific details about how groundwater is utilized locally.
- Workshops can be held on topical issues related to source protection such as 'How to Maintain Wells and Septic Tanks', 'Water Conservation Measures for Households and Businesses', 'Best Management Practices in Wellhead Protection Areas". These could be organized and/or sponsored by a Conservation Authority, Municipality, College or University.

9.2.2 Best Management Practices

Utilizing best management practices (BMPs) can greatly reduce the risk that different actions have on groundwater resources. Providing information about BMPs to businesses in sensitive areas can help protect groundwater resources.

9.2.3 Land Acquisition

Acquiring land in a highly sensitive area should provide complete control over the land use practices within the area. In many cases this option is not feasible due to costs and other factors. However, land can be acquired prior to the development of a new water supply, or future water supplies can be developed in areas where land is owned by the municipality.

9.2.4 Conservation Easements

A conservation easement is a voluntary agreement between a landowner and a conservation body to "conserve, maintain, restore or enhance" the natural features of a property by placing conditions on its management. The easement is a legal document that is registered on the title of the property, and binds the present owner and all future owners to the terms of the agreement. A conservation easement does not give the easement holder title to the property.

For landowners, a conservation easement is a way to protect the special attributes of their property by placing a permanent development restriction on the property, while retaining ownership. This tool has been available since 1995, when the Conservation Lands Act was revised to allow private landowners to enter into conservation easement with charitable conservation organization, municipal councils, native bands and conservation authorities. Prior to this, landowners could only enter into conservation easements with the Crown and its agencies.

9.2.5 Municipal Site Leadership

By adopting an active role and implementing BMPs at municipal sites, municipalities will have much more credibility when asking other land users to adopt similar policies. In some instances, municipal lands may be located in the most sensitive areas. An audit of these lands and the subsequent removal of potential contaminant sources can be completed to minimize risks and set an example for other landowners.

9.2.6 Integrated Information Management

An information management system is essential to incorporate all available information during decision-making. A relational database linked to a GIS can bring together water quality, Permits to Take Water, groundwater vulnerability, land uses, and potential and known contaminant sources. Information can also be served to a web application for distribution to watershed residents.

9.2.7 Water Quality Monitoring

The development of the Provincial Groundwater Monitoring Network of monitoring wells will help to provide water quality monitoring that could detect adverse water quality conditions up-gradient of private water wells. Threshold levels, with associated action plans are important facets of this groundwater management tool.

9.2.8 Water Conservation Practices

Water usage affects costs and has beneficial environmental consequences. Municipalities should be pro-active in practicing (municipal buildings) and encouraging residents and businesses to undertake water conservation practices e.g. summer watering restrictions, install water meters, use of low-flush toilets and low flow faucets, repair leaks. Reduced water consumption saves on the cost of treatment, sustains capacity for other land development and reduces the volume taken from original sources. This helps to maintain the water budget in the hydrologic cycle.

9.2.9 Municipal Sewer By-Law

A sewer by-law provides a means to control the substances that are discharged to the sewer. Sewers can leak and be a non-point source of contamination to groundwater. Furthermore, as part of the by-law, inspections could be carried out to help ensure suitable chemical storage. An inventory of chemical storage provides additional information that can be used to promote Best Management Plans.

9.2.10 Official Plan Amendments

Official Plan amendments can address specific land uses and define different sensitive groundwater zones. These zones can include areas of high intrinsic susceptibility. Restrictions, or the requirement of site-specific information prior to the approval of specific land uses, provide a direct means of controlling land uses in sensitive areas.

9.2.11 Spill Contingency Plan

A spill contingency plan would promote a quick and deliberate response to a contaminant spill. A spill contingency plan typically includes information about specific responsibilities of different individuals and organizations and contact numbers that would be needed in the event of a spill.

9.3 Groundwater Management and Protection Strategy Approach

A Groundwater Management and Protection Strategy is a program of risk reduction to sustain the groundwater resource, both as a source of drinking water supplies and an integral component of the ecosystem. The strategy can incorporate a number of different tools. These tools may include a combination of land use policies, regulatory controls, best management practices, public education, monitoring, land acquisition, and spills contingency planning.

Policies, such as those in a municipal Official Plan, serve to identify the public interest in water quality and quantity. An Official Plan may establish goals, set objectives for water protection (aquifer and well head protection), and provide the framework for land use development and implementation measures. The policies may also provide the rationale for the use of other planning tools such as zoning, site plan control, site alteration and tree cutting by-laws. These are regulatory mechanisms that may be used to control development on a lot-by-lot basis, or an area-wide basis. Planning applications, such as development or land use changes, largely drive the implementation process.

Many tools are not retroactive and they do not enable a municipality to rectify a pollution problem by closing down an operation or forcing the relocation of an existing land use that may have the potential to contaminate an aquifer.

Best management practices may apply to a homeowner in the use and storage of solvents, pesticides, and the disposal of household hazardous wastes. For the agricultural industry it may include measures such as stream buffering from cattle grazing and the care with which manure and other fertilizers are applied.

The municipality may also utilize other statutes to complement the land use controls under the Planning Act. The Nutrient Management Act (2001), and the associated regulations, for example, set out the requirements for the preparation of nutrient management plans and the control of livestock operations. The Municipal Act may be used to enact site alteration or tree cutting by-laws.

Raising public awareness, through public educational programs, can have a major impact on groundwater protection and may be more important than enforcement measures. It is through the voluntary actions and practices of people on a day-by-day basis that will help protect water resources (i.e. proper use, storage and disposal of fuels, solvents, and pesticides, regular water well maintenance, installation of water saving plumbing fixtures). Municipalities can work towards developing a ‘water ethic’ in their communities. This means instilling a collective awareness, responsibility, and commitment to protect water on an ongoing basis.

The approach to developing a protection strategy is based on a number of assumptions:

- Water is the single most important resource for a healthy community such that a preventative or proactive approach is more appropriate than a reactive approach (i.e. prevent contamination as opposed to cleaning it up);
- Water is not confined by a political boundary;
- While the focus is on groundwater protection, the linkage to surface water resources (i.e. the water cycle) necessitates a more broad-based approach;
- Existing risks to water supplies can be reduced through redevelopment or relocation of land uses;
- Water quantity (well yields) will remain constant;
- Impacts can be monitored through development decisions and the collection of data and that the strategy will be adjusted, where necessary, and;
- A source protection strategy is a risk management tool that will not provide an absolute solution, but rather, will minimize potential negative impacts over the short and long term.

9.4 Experiences in Other Jurisdictions

Source protection is not new in Ontario or other jurisdictions across North America. Groundwater protection programs are becoming more common in communities across North America due to the increased impetus to provide and protect clean drinking water. Many municipalities that rely on groundwater are taking proactive measures to safeguard the quality of their water from past, present, and future land uses.

9.4.1 Oak Ridges Moraine

The Regional Municipalities of Durham, Peel, and York, in co-ordination with the Province of Ontario, developed a conservation plan for the Oak Ridges Moraine that includes a management strategy for groundwater. The Oak Ridges Moraine Conservation Act (2001), and the associated Ontario Regulation complement the strategy by restricting land uses in WHPAs and in areas of high aquifer vulnerability. The groundwater management strategy identified 'data collection and management, data analysis and policy development and implementation' as three broad action areas. The regulation prohibits the storage of petroleum products, pesticides, inorganic fertilizers, road salt, hazardous or liquid industrial wastes, severely toxic contaminants (O.R. 347), animal manure in wellhead protection areas along with waste disposal sites, snow dumps, animal agriculture and the storage of agricultural equipment. Similar restrictions on land use activities apply to areas of high aquifer vulnerability.

9.4.2 Regional Municipality of Waterloo

The Region of Waterloo, where all communities and the rural areas are primarily dependant on groundwater for their water supply source, adopted Official Plan Amendment #12 to their Official Plan. This amendment, now approved, provides for wellhead protection through land use restrictions in four 'sensitivity areas', which correspond to the time-of-travel within each of the zones. Certain (Category A) uses are prohibited in all four sensitivity areas (i.e. lagoons, land fill sites, disposal of abattoir and rendering wastes, auto wrecking, and salvage yards). An extensive list of uses in Categories B and C are prohibited in Wellhead Protection Sensitivity Areas 1, 2 and 3. Local municipalities are not permitted to redesignate land in local Official Plans for any of the uses prohibited in the respective sensitivity areas.

9.4.3 Oxford County

An approach similar to that adopted in the Region Municipality of Waterloo has been taken in Oxford County as part of the current update of the County Official Plan. However, the scope of uses differs somewhat from the Regional Municipality of Waterloo. Activities proposed to be banned in WHPA's include earthen manure storage facilities, the bulk storage of tires, the refining of petroleum products, the bulk storage of chemicals or hazardous substances (except on-farm storage), the warehousing of cleaning products, pesticides, herbicides and fungicides, and the warehousing or bulk storage of petroleum products.

Underground storage tanks, sumps such as dry wells and machine pits and automotive repair pits would not be permitted in the two highest sensitivity rankings, while above ground storage with secondary containment would be permitted. Certain new uses would not be permitted in a WHPA, without meeting certain performance requirements including a disclosure report identifying the scope of the use, a detailed hydrogeological study with an associated mitigative plan, and a spill and contingency plan.

9.4.4 New Brunswick

New Brunswick enacted the Wellfield Protected Area Regulation under the Clean Water Act as the basis for establishing 'Protection Areas' around municipal wellfields. Protection areas (Zones A, B and C) are based on groundwater travel times of 100 to 250-days, 250-days to 5-years and 5 to 25-years. Different land uses are restricted within each protection area. Within Zone A, prohibited uses/activities include transformer substations, storage of liquid petroleum products, pesticides, fertilizers, livestock grazing or stabling, liquid or dry animal manure composting. Residential uses are permitted but they must be serviced. Existing commercial, industrial and institutional buildings are permitted but no expansions are allowed to any residential or non-residential uses.

In Zones B and C, groundwater may be extracted from the aquifer (quantity limited) by wells that are not municipal wells. Restrictions are relaxed on uses prohibited in Zone A, when they are located in Zones B and C (i.e. liquid manure may be stored, but in a clay lined pit; livestock may be grazed if fenced; limited quantities of petroleum products may be stored; pesticide use is permitted to manufacturer's specifications).

In Zone C larger quantities of chemicals may be stored, and fertilizers may be applied. New residential, commercial, and industrial buildings may be constructed if communally serviced or where the number of residents and employees serviced by septic tanks does not exceed 25 per ha. Drainage patterns for wetland areas cannot be modified without conducting an impact study on the hydrology and hydrogeology. The province has parallel restrictions to protect sensitive aquifer areas. Of interest is a maximum floor area size limit of 185 m^2 for a single detached dwelling and a prohibition against any conversion of a single to a multiple unit in the highest sensitivity area. In this area, fertilizer application is limited to inorganic applications.

9.4.5 Alberta, Newfoundland & Labrador, Prince Edward Island

Wellhead protection measures in some other provinces, such as Alberta, Newfoundland & Labrador, and Prince Edward Island, are based on minimum separation distances as opposed to land use restrictions. Distances vary for storage of petroleum tanks (15 to 50 m); septic tanks (10 to 16 m); and sewage lagoons (100 m).

9.4.6 Nova Scotia

In Nova Scotia, the Water Act has been used as the basis for establishing 'Protected Water Areas' (PWA), which are equivalent to a WHPA, tailored to individual communities. A three-zone time-of-travel system is used for a PWA. For example, within a PWA, open fires are not permitted (April to October). Restrictions on forestry operations apply on the quantity of timber removed and setbacks of the operation. Chemical pest control products are prohibited in Zone 1 and aerial spraying is barred within a 150 m radius of a wellhead. Landfill and animal waste disposal is prohibited. The use of any vehicle, except a municipal service vehicle, is prohibited in Zone 1. Peat, gravel, rock and mineral extraction, and agricultural operations are prohibited in Zone 1. Livestock operations in Zones 2 and 3 are permitted where they comply with the Provincial animal manure spreading guidelines and where the nitrogen level for all fertilizer applications does not exceed a prescribed standard.

9.4.7 The United States

Source protection in the United States falls under the Federal Safe Drinking Water Act (1986), which sets the regulatory and management framework for the activities of State governments, who are largely responsible for implementation of the upper tier legislation. Municipalities at all levels are expected to prepare protection plans, preferably on a watershed basis. The primary goal is to reduce or eliminate the potential risk to drinking water supplies within source water protection areas through federal, state, or local regulatory or statutory controls, or through voluntary measures involving the public.

Contingency planning involves water supply replacement strategies in the event of contamination. The approach typically involves the delineation of water protection areas, conducting a contaminant source inventory, and determining the intrinsic susceptibility of the source to contamination. Ordinances at the municipal level are used to govern land use activities in restricted areas. A typical Source Water Protection Plan (SWPP) includes an education and outreach campaign, a best management practices program, sign posting in the WHPA, a hazardous waste disposal program, the establishment of a water protection steering committee, and a zoning constraint overlay in the communities zoning ordinance.

The best management practices program focuses on the storage and usage of petroleum products by businesses on a voluntary or mandatory basis. A mandatory program requires a survey and compliance with the State level best management practices rules. The sign posting alerts travellers to the presence of a WHPA and how to notify emergency personnel if a contamination event should occur. In a WHPA, prohibited land uses include hazardous waste disposal facilities, solid waste landfills, outdoor storage of road salt, junkyards, snow dumps and wastewater or septage lagoons.

9.5 Developing a Groundwater Management and Protection Strategy

Measures applied as part of a groundwater management and protection strategy vary across different regions of Canada and the US. Typically, the approach that is adopted depends on local hydrologic and hydrogeologic conditions, land use activities, legislative experience and the importance of water in the public policy agenda.

The most successful approaches depend on a package of protection measures that are both voluntary and regulatory. This is essential since much of the landscape has been developed and municipalities have limited authority to implement retroactive land use controls. Also, the resources may not exist to expropriate or acquire lands or buildings that constitute a potential or actual risk to contamination or which could serve as a buffer area.

The development of a Groundwater Management and Protection Strategy (Strategy) should consist of a series of measures that provide an affordable and reasonable level of protection and can be adapted to changing circumstances.

The following Tables 9.3 to 9.9 provides a description of a diverse series of initiatives and activities that can be considered during the development of a groundwater protection strategy.

Table 9.3 Groundwater Management and Protection Strategy: Organizational Structure

Item	Scope of Activities or Options	Rationale
Objective: to establish an appropriate organisational structure for the Groundwater Protection Plan program delivery	Create a water protection advisory committee at the local municipal level to provide ongoing advice to elected officials and the community on water protection measures. Committee may review monitoring activities, may provide a co-ordinating role amongst various agencies with mandates for 'water conservation or protection' and may serve to oversee the implementation of various features of the Groundwater Protection Strategy. This may include dealing with cross-boundary controls or issues i.e. adjacent municipality.	Provides for current and ongoing responsibility for ensuring safe drinking water.
	Review the municipal management structure to ensure that it has the capability, resources and authority to implement a Groundwater Protection Strategy. This involves assigning responsibility by elected officials to their planning, public works and other staff for implementation of Groundwater Protection Strategy measures	Establishes accountability structure

Table 9.4 Groundwater Management and Protection Strategy: Data Management

Item	Scope of Activities or Options	Rationale
Objective: To provide the best possible data base on which to make decisions related to water protection	Design and maintain a community-accessible data base on water protection-related information e.g. • Updated inventory of contaminant sources. Spatial extent of known point and non-point sources and brownfields should be mapped • Water well records • Hydrological and hydrogeological studies and investigations • Nutrient management plans • Permits to take water and inventory of major water users • Septic tank re-inspections • Water quality tests • Communal systems: location/ownership/service area/size • Initiate GIS-based mapping system for data entry on water resource information	Data base will facilitate improved decision making on planning applications and other development decisions with water protection implications Provides graphic (updated) information base to support municipal/community decision making on water resource matters

Table 9.5 Groundwater Management and Protection Strategy: Education

Item	Scope of Activities or Options	Rationale
Objective: to create a greater awareness on the ongoing need for groundwater protection and to develop a community 'water ethic'	Establish vision statement and logo for Groundwater Protection Strategy at a Council or Community level	Brings a focus to all Groundwater Protection Strategy related activities and a tangible goal.
	Establish the scope of topical matters for an 'education based' water protection program to prevent the contamination of drinking water: e.g. • Maintenance of septic tanks and wells and septage disposal • Managing communal systems • Managing above and below ground storage tanks • Managing livestock wastes • Managing vehicle washing • Safe storage and usage of household solvents, chemicals, fuels and hazardous wastes • Application of agricultural fertilisers, pesticides and fungicides • Livestock grazing and watering • Safe use of household pesticides and herbicides • Safe use of road salts • Disposal of hazardous wastes • Managing pet and wildlife wastes • Managing stormwater and drainage runoff • Plugging abandoned wells • Stewardship of private wetlands and recharge areas • Clean-up of contaminated sites • Water conservation practices for households and businesses	Enables community to establish priority list of issues related to Groundwater Protection Strategy
	Initiate a newsletter or comparable news organ for distribution to householders and businesses that provides information or advice on water protection and conservation measures. Could be sent out with tax or utility bills.	One of several techniques for information dissemination
	Create a 'Safe Drinking Water Week' with several events designed to raise public awareness i.e. media campaign, trade show, demonstration projects, shopping centre displays	One of several techniques for information dissemination
	Work with school boards to develop/modify curriculum on topical issues for groundwater protection and conservation	One of several techniques for information dissemination

Table 9.5 Groundwater Management and Protection Strategy: Education

Item	Scope of Activities or Options	Rationale
	Create informational handout or 'Fact Sheet' on measures for groundwater protection. Display at municipal offices, libraries and other public places	One of several techniques for information dissemination
	Convene a Town Hall meeting in the community to discuss water protection issues and community initiatives	One of several techniques for information dissemination
	Participate/sponsor event in a community event e.g. fall fair, winter carnival, home builders show etc., that focuses on groundwater protection/conservation	One of several techniques for information dissemination
	Partner with MOE, OMAF, MNR, Conservation Authority on a householder workshop on a selected topic(s) on groundwater protection	One of several techniques for information dissemination
	Include a 'State of the Groundwater Resource' statement as part of the mayor's annual report	One of several techniques for information dissemination
	Certify and maintain municipal staff accreditation for persons who perform operational work in water treatment and distribution facilities	Ensures the qualification of assigned staff to provide for safe drinking water Ensures that there is an elevated awareness and skills level in 'city hall' for staff with responsibility for water protection other than utility operators
	Review, maintain, update reference materials and publications/videos in municipal libraries on water resource, water protection subjects	Provides accessible information to the broader public
	Build in feature to municipal websites with URL linkages on municipal water protection and conservation initiatives and consumer information sources	Highlights water as an important public policy issue

Table 9.6 Groundwater Management and Protection Strategy: High Aquifer Vulnerable Areas

Item	Scope of Activities or Options	Rationale
Objective: to protect high aquifer vulnerable areas from potential contamination	Amend Official Plans to incorporate policies for groundwater protection. Plan may include goal, objectives, policy statements and implementation measures for high aquifer vulnerable areas and wellhead protection areas (WHPA). Approach would be to describe land uses restrictions that apply to one or more sensitivity zones. See example in Appendix A	Establishes framework for variety of implementation measures municipality (ies) may use to protect groundwater
	Co-ordinate policy development and regulatory control to address cross municipal boundary issues	Ensures consistency in policy and regulatory approach and provides for uniform and universal protection
	Amend zoning by-laws for local municipalities to incorporate provisions for restricting land uses in high aquifer vulnerable areas and wellhead protection areas (WHPA).	

Table 9.7 GROUNDWATER Management and Protection Strategy: Monitoring

Item	Scope of Activities or Options	Rationale
Objective: to oversee post development impacts	Maintain an inventory of test results from monitoring of development impacts required as a condition of development approval	Enables municipality to determine development impacts and require mitigation measures where results do not meet acceptable performance standards
	Monitoring programs which generate data/information should be added to data base	Improves the information upon which subsequent applications and land use decisions will be made

Table 9.8 Groundwater Management and Protection Strategy: Best Management Practices

Item	Scope of Activities or Options	Rationale
Objective: to institute measures for groundwater protection	Review haulage routes for dangerous goods and revise routes to direct the transport of dangerous goods away from high aquifer vulnerable areas and wellhead protection areas (WHPA)	Serves to reduce the potential for a spill of a contaminant into a groundwater capture zone

Table 9.8 Groundwater Management and Protection Strategy: Best Management Practices

Item	Scope of Activities or Options	Rationale
	Review Emergency Measures Preparedness Plans to incorporate provision for dealing with a dangerous goods spill incident in a high aquifer vulnerability area and wellhead protection areas (WHPA)	Serves to reduce the potential contamination of groundwater supplies
	Review current septic tank re-inspection program in view of its application to any high aquifer vulnerability areas and wellhead protection areas (WHPA)	Serves to reduce the potential contamination of groundwater supplies
	Link current hazardous wastes collection program to the significance for source protection of high aquifer vulnerability areas and wellhead protection areas (WHPA)	Serves to reduce the potential contamination of groundwater supplies
	Review utilities rights-of-way pesticide spraying practices with utility companies where such ROWs traverse high aquifer vulnerability areas and encourage/negotiate modification of practices where necessary	Serves to reduce the potential contamination of groundwater supplies
	Encourage farm community, landscaping firms and golf course operators in high aquifer vulnerability and wellhead protection areas (WHPA) areas to review activities which might lead to releases of nutrients (fertilizers, manure), nitrogen or pesticides to groundwater or stormwater runoff	Serves to reduce the potential contamination of groundwater supplies
	Encourage clean up of ‘brownfields’ and other known or potentially contaminated sites. Remove underground (USTs) and above ground storage tanks (ASTs) that have been abandoned or are no longer used	Serves to reduce the potential contamination of groundwater supplies
	Review Property Standards by-law as a means to clean-up properties and remove derelict motor vehicles	Serves to reduce the potential contamination of groundwater supplies
	Review/enact Site Alteration By-law under the Municipal Act to govern excavation activities and other activities which may affect erosion or sedimentation that may discharge contaminants into a municipal water supply	Serves to reduce the potential contamination of groundwater supplies
	Enact a tree cutting by-law as a tool to conserve coverage in areas where sedimentation and erosion control are essential to source protection	Retains ecological effect of natural vegetation in the hydrologic cycle and in protecting water resources

Table 9.8 Groundwater Management and Protection Strategy: Best Management Practices

Item	Scope of Activities or Options	Rationale
	Review winter control de-icing policy/procedures to minimize road salting in WHPA and high aquifer vulnerability areas	Serves to reduce the potential contamination of groundwater supplies
	Review sewer use by-law for contaminant discharge standards and ensure that provision is made for grit, gas and oil interceptors in site plans for industrial and commercial uses with potential contaminant discharges	Serves to reduce the potential contamination of groundwater supplies
	Install sentry wells for industrial and commercial uses to monitor contaminant discharges where septic systems or dry wells are utilized as part of the industrial processes in the general vicinity of high aquifer vulnerability areas and wellhead protection areas (WHPA)as a condition of development or redevelopment	Serves to reduce the potential contamination of groundwater supplies
	Conserve woodlots in high aquifer vulnerability areas and wellhead protection areas (WHPA)	Enhances water retention and water quality in areas of potential recharge
	Cap unused or abandoned water wells	Serves to reduce the potential contamination of groundwater supplies

Table 9.9 Groundwater Management and Protection Strategy: Spill and Contingency Planning

Item	Scope of Activities or Options	Rationale
Objective: to respond expeditiously to spills and provide alternative water supply source	Develop a ‘Spill Response Plan’ for oil or hazardous materials. This should identify who does what at the local municipal and provincial level in reporting and responding to spills. This should include provision for minor and major spills and the identification of Transport Canada (CANUTEC) as the agency to identify unknown or the handling methods of chemicals	A clear spill response plan is necessary to guide the public and municipal officials through the process
	A spill response plan should be developed for industrial and commercial land uses as a condition of site development where the use is considered to have the potential for a spill during the transport or storage of contaminant products or as part of the processing operation	Serves to reduce the potential contamination of groundwater supplies
	A contingency plan should be developed to provide an alternative water supply where a municipal supply is at risk by a spill or contaminant on a short term basis i.e. pending acceptable clean-up. This should include provision for a bottled water supply (supplier, trucking and delivery) and implementation procedures (public notification) of a boil-water order. Consideration should also be given to a supplier for a pre-packaged water treatment system for an emergency or short-term solution. In a worst case scenario, a long term contingency option may require consideration for connection to a supply source from another community	A dependable supply of water is essential for householders and particularly for health care, social and educational institutions within the community.

9.6 Summary of Groundwater Management and Protection Strategy

Water resources management is a concern that cuts across many interests in a community, both public and private. As such, a successful approach to protecting groundwater will require a coordinated and cooperative approach on an ongoing basis. The measures put into place should be done to affect a permanent approach to groundwater protection.

Some measures will be more difficult to implement than others. However, implementation costs will likely be less costly than developing an alternative source of water. Developing a "water ethic" in the community is a paradigm where all residents will adopt water protection as routine aspects of their daily lives. The prescription of options suggested in this report will require elected officials and private authorities to establish priorities for implementation. The following recommendations should serve to provide some direction in this regard.

1. An organizational structure should be established to oversee and coordinate the implementation of water protection measures.
2. Land use planning documents should be amended to establish the policy and regulatory framework for instituting effective land use controls for future development.
3. A spills and contingency plan should be initiated early in the implementation process.
4. Provision should be made for the development and maintenance of a database that can be used in making decisions and incorporating new information in response to development and monitoring activities.
5. A public education and outreach program should be developed for the ongoing education of the public, the operation of the municipal water supply infrastructure and the administration and enforcement of regulatory and voluntary controls for water protection.
6. Best Management Practices should be utilized where feasible as measures to minimize the potential contamination of private and municipal water supply sources.

10 Recommendations

The North Bay-Mattawa Conservation Authority groundwater study was undertaken by the North Bay-Mattawa Conservation Authority, the City of North Bay, Municipality of Powassan, Town of Mattawa, and the Ontario Ministry of the Environment. The study partners acknowledge that the basic groundwater functions (recharging, transmitting, assimilating potential contaminants, storing, and discharging water) play an essential role in maintaining the health of an ecosystem. Understanding these regional groundwater functions is necessary to provide a secure supply of clean water for all groundwater users in the study area. The study area includes urban and rural areas within the jurisdiction of the North Bay-Mattawa Conservation Authority, comprising a total area of about 4,600 km^2.

At the onset, the overall objectives of the study were defined to include:

Objective 1: Define and map local and regional groundwater conditions.
Objective 2: Define groundwater intrinsic susceptibility.
Objective 3: Compile a contaminant source inventory.
Objective 4: Complete wellhead protection area (WHPA) mapping for the municipal well systems in Powassan and Mattawa
Objective 5: Conduct a contaminant source assessment within the WHPAs.
Objective 6: Develop a groundwater protection strategy
Objective 7: Promote public groundwater awareness throughout the study area through open houses, local media news releases, and a project web site.

Recommendations related to each of the study objectives are provided in the following sections.

10.1 Groundwater Protection Strategy Recommendations

Recommendation 1: Develop and Implement a Groundwater Protection Strategy

It is recommended that the Study Partners work together to develop and implement a Groundwater Protection Strategy that incorporates the different components described in the report that is funded by all municipalities. A Protection Advisory Committee comprised of representatives similar to those involved during the current study should oversee the refinement and implementation of the Strategy. The knowledge gained by the Steering Committee can be utilized during the implementation of the Strategy. A Protection Advisory Committee can provide the guidance necessary to evaluate different Strategy options and to coordinate the efforts of the member municipalities, City of North Bay and Town of Mattawa.

The Protection Advisory Committee should consider the following Protection Strategy components:

- Data Management
- Education
- Wellhead Protection Areas
- High Aquifer Vulnerability Areas
- Monitoring
- Best Management Practices
- Spill and Contingency Planning

These components are further discussed below.

Recommendation 2: Ensure Groundwater Data is Properly Managed
Data management facilitates improved decision making for planning applications and other development decisions with water protection implications. The ability to overlay different types of information within a GIS (Geographic Information System), such as WHPAs and locations of fuel storage tanks, provides decision makers with the information necessary to evaluate future planning initiatives and potential risks to groundwater resources. Where possible, data should be managed at one location, with coordination between other parties that may use the information. As additional data and metadata become available, the database should be revised to incorporate this information.

Recommendation 3: Utilize Public Education Initiatives to Foster Groundwater Protection
Education initiatives are recognized to be an excellent, cost-effective means of fostering change with regards to groundwater protection and resource management. Education promotes current and ongoing responsibility for ensuring safe drinking water. Working through different avenues, the importance of protecting groundwater can be promoted. Groundwater information should continue to be provided on the study web site, and should consider supplementing the web site with additional information to promote conservation and protection measures. The Internet provides a means for many residents within the study area to access information at their leisure. Developing groundwater information for inclusion with municipal and rural town mailings should also be considered. Reminders in mailings can be used to promote specific initiatives, and also point residents to other information sources such as the study web site and other agencies. Press releases related to specific groundwater issues, such as improperly decommissioned wells and other groundwater management initiatives, can be incorporated into education initiatives. Additional groundwater information could be provided to local teachers. Groundwater can be incorporated into the Ontario curriculum as part of the following Science and Technology Units: Air and Water in the Environment, Grade 2; Soils in the Environment, Grade 3; Rocks, Minerals, and Erosion, Grade 4; Water Systems; Grade 8.

Recommendation 4: Acknowledge and Protect Wellhead Protection Areas (WHPAs)
WHPAs represent the most critical areas surrounding a well. 50-day, 2-, 10-, and 25-year WHPAs have been delineated for the different municipal wells. Acknowledging these areas should be a part of the future Groundwater Protection Plan. Throughout most of Powassan and Mattawa, the time required for water to move from the ground surface to the well is very long, due to the extensive tills overlying the bedrock. This time can be greatly shortened if water is able to move to the bedrock through a conduit such as a poorly constructed or improperly decomissioned well.

With this in mind, the Protection Advisory Committee should consider different protection measures based on the time-of-travel for the different WHPAs. Greater protection should be established in the more sensitive (shorter time-of-travel) zones. An example of this approach is provided in Appendix F, where different types of land uses are considered for four different sensitivity zones.

Recommendation 5: Acknowledge and Protect High Aquifer Vulnerability Areas
Most of the bedrock aquifer groundwater resources within the study area have been characterized as having a high susceptibility. The Protection Advisory Committee should consider protection measures in Mattawa and Powassan where thousands of people rely on groundwater for their domestic water needs. In these areas, the bedrock and the coarse grained overburden is susceptible to contamination. This could be accomplished by defining these areas as a sensitivity Zone 2 (See Appendix A).

Recommendation 6: Monitor Groundwater Quality

Sentinel monitoring wells
Sentinel monitoring wells help to identify groundwater contaminants before they can impact a well. The Protection Advisory Committee should consider sentinel wells, located within each WHPA. Where possible, the wells should be located near the 2-year time-of-travel WHPA, and in the Town of Mattawa, this well should be installed between the Mattawa River, and the municipal wells. Sentinel well monitoring should be conducted semi-annually. Specific chemical and physical constituents to be monitored can be finalized after an initial analysis of Ontario Drinking Water Standard (ODWS) parameters is completed. Based on the review of water quality at the different municipal wells, fluoride, nitrate, heavy metals, and other chemicals related to near-by land uses should be considered in the monitoring program. Trigger levels for each monitoring well should be established to help ensure water quality concerns are identified. Triggers should address situations where a specific chemical concentration is consistently increasing or exceeds an ODWS. Chemical constituents that are non-health related (such as hardness) should be differentiated from health related parameters.

Groundwater Isotope Analysis
Groundwater isotope analysis provides a means to assess the age and source of groundwater. Wells that pump water that is very old are better protected from surface activities than wells that pump water that is young. Identifying young water versus old water can highlight wells that are more vulnerable to surface activities. Isotope analysis should be considered for each of the municipal well systems. The cost for analyzing each sample is estimated to be between $200 and $400.

Recommendation 7: Encourage the Utilization of Best Management Practices (BMPs)
Best management practices can reduce the risk that specific actions have on groundwater. Wherever possible, BMPs should be developed and encouraged. A comprehensive list of potential BMPs are provided in Section 9. Within sensitive areas, the Protection Advisory Committee should consider incentives to promote the implementation of BMPs. At wellheads, the towns and municipalities should take a leadership role by implementing BMPs. It is important that local government set an example for others to follow.

At each municipal well, the following measures should be considered:

- No application of fertilizer or pesticides.
- No vehicles within 25 m of the well (where this is not feasible, no vehicles should be permitted on the well property).
- Construct a fence surrounding the well property.
- No storage of solvents, paints, salt, or other hazardous material within 25 m of the well.
- Appropriate site grading away from all wells.
- Properly decommission any wells (pumping and observation) that have been abandoned, including Well 3 in the Mattawa system.
- Procedures to follow, with telephone numbers to call, in the event of a spill or emergency.

Where possible, the 25 m buffer distance should be enlarged to include all of the property that the municipal wells are on.

Recommendation 8: Ensure Spill and Contingency Planning is in Place

A clear spill response plan is necessary to guide the public and municipal officials in the event of a spill. A spill contingency plan promotes a quick and deliberate response to a contaminant spill. A plan should include information about specific responsibilities of different individuals and organizations and contact numbers that should be called in the event of a spill. Businesses should be encouraged to develop spill and contingency plans and information regarding who should be contacted can be distributed to all businesses or targeted to businesses that are in WHPAs.

Recommendation 9: Incorporate Groundwater Protection Planning into Municipal Official Plans

In addition to the strategies recommended for consideration above, the Protection Advisory Committee should consider incorporating groundwater resource protection policies into the Municipal Official Plans. Appendix F includes additional information and example language that could be used if the Official Plan is to be amended as part of a Groundwater Protection Strategy.

10.2 Groundwater and Aquifer Characterization Recommendations

Recommendation 9: Maintain Information in a Central Database

Regional groundwater and aquifer characterization was completed across the study area. During this work information was incorporated into a project database. To help ensure that additional information is incorporated into the database in a consistent manner, the database should be maintained centrally. The NBMCA should manage or oversee the management of the database to ensure that the information developed during this study will be available to other end users that may be conducting geologic and hydrogeologic investigations in the study area.

10.3 Groundwater Intrinsic Susceptibility Recommendations

The susceptibility of the bedrock and the water table was evaluated. Throughout most of the study area, the bedrock aquifer and water table are considered to have a high vulnerability. The susceptibility mapping is valuable when assessing the vulnerability of the municipal wells to contamination. The vast majority of the study area is classified being highly susceptible to groundwater contamination as the bedrock across much of the study area lies very close to ground surface. These areas of high susceptibility should be considered as part of the Groundwater Protection Strategy, as discussed above in Section 10.1 (Recommendation 5).

10.4 Groundwater Use Assessment Recommendations

Groundwater uses by private users and municipalities were compiled across the study area using available data and conducting water use surveys with private water-taking permit holders and municipalities.

Using the Permits to Take Water database, permitted groundwater taking is currently estimated to be 18,600 m^3/year. Based on the information collected during the groundwater use survey, actual water taking is much less than the estimated yearly recharge. Based on the study water budget, it is estimated that the study area receives approximately 460 million m^3/year of recharge. Although this indicates that at a regional scale there is an abundance of groundwater, further investigation at a more local, sub-watershed scale should be considered.

Currently, Permits to Take Water (PTTW) are contained within a different database than the Water Well Information System (WWIS). To facilitate better permit tracking, the information in the Permit to Take Water database should be linked to the WWIS. Where possible, WWIS well identification numbers have been linked to specific permits, however this should be completed at a Provincial level to ensure consistency between different jurisdictions.

10.5 Potential Contaminant Sources Inventory Recommendations

Potential contaminant sources were mapped regionally across the study area using information collected from a variety of MOE and other databases. Potential contaminant sources that were considered included spills, fuel storage, PCB storage, landfills (active and closed), and abandoned WWIS wells. Most of the records contained in the databases were plotted, and the digital information will be supplied to the Conservation Authority within the study database.

Location information was incorporated into the project databases. This data should continue to be maintained by the NBMCA. An emphasis should be directed to investigating potential contaminant sources in sensitive areas as identified by the Protection Advisory Committee.

10.6 WHPA Specific Recommendations

Field surveys were completed throughout each of the WHPAs presented in Section 6. This information has been compiled in the project database, and highlights different types of land uses that are more likely to result in groundwater contamination. This information, in addition to the capture zones and bedrock aquifer susceptibility are presented in Figures 7.1 and 7.2 for each municipal well system. Several of the capture zones intersect at least one potential contaminant source identified during the field surveys, and the susceptibility of the bedrock and overburden aquifers throughout the capture zones is high.

11 Glossary

11.1 Glossary

Aquifer – (1) A geologic formation, a group of formations, or a part of a formation that is water bearing. (2) A geological formation or structure that stores or transmits water, or both, such as to wells and springs. (3) An underground layer of porous rock, sand, or gravel containing large amounts of water. Use of the term is usually restricted to those water bearing structures capable of yielding water in sufficient quantity to constitute a usable supply. (4) A sand, gravel, or rock formation capable of storing or conveying water below the surface of the land. (5) A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquifer Capability – The maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head of the aquifer, or causing unacceptable changes to any other component of the hydrologic system. Capability is calculated at a watershed scale in terms of a water budget.

Aquifer Recharge Area – An area in which water can infiltrate the soil and replenish an aquifer relatively easily. Aquifer recharge areas allow precipitation to reach an aquifer by infiltration. Recharge areas are often much smaller than the total aquifer area and are therefore very important to the aquifer. Artificially increasing runoff in a recharge area through paving or clearing can devastate an aquifer.

Aquifer Susceptibility (or Vulnerability) – An intrinsic property of a groundwater system that depends on the sensitivity of that system to human and/or natural impacts. Intrinsic Vulnerability depends solely on the hydrogeologic properties of an aquifer. Specific Vulnerability depends on hydrogeologic properties of an aquifer and an imposed contaminant load.

Biosolids – The end product from the processes used to treat wastewater, often from municipal, industrial or institutional sources. Biosolids are primarily organic materials but can contain other trace elements such as metals.

Digital Elevation Model (DEM) – A model of terrain relief in the form of the matrix. A digital representation of the ground surface topography.

Geographic Information System (GIS) – A computer software system with which spatial information may be captured, stored, analyzed, displayed, and retrieved.

Groundwater – Water that infiltrates the earth's surface. Groundwater originates as precipitation and is suspended by the soil for varying lengths of time depending on soil type, vegetation cover, and land use. Groundwater is responsible for feeding vegetation and for recharging aquifers.

Hydraulic Conductivity (K) – A coefficient of proportionality describing the rate at which water can move through an aquifer or other permeable medium. In the Standard International System, the units are cubic meters per day per square meter of medium (m3/day/m2) or m/day (for unit measures).

Hydrogeologic – Those factors that deal with subsurface waters and related geologic aspects of surface waters.

Hydrogeology – The part of geology concerned with the functions of water in modifying the earth, especially by erosion and deposition; geology of ground water, with particular emphasis on the chemistry and movement of water.

Hydrologic Cycle (Water Cycle) – The circuit of water movement from the earth's atmosphere to the earth and back through sequential stages such as precipitation, runoff, infiltration, evaporation, transpiration, etc. The hydrologic cycle has many different variations. Typically, water vapour in the atmosphere falls to the earth as rain. It is then transported to an open body of water via streams and rivers or through runoff or aquifer discharge. It is then evaporated and returns to the atmosphere as vapour. Alternately, once water enters the soil it may be absorbed by plants and returned to the atmosphere through transpiration (evaporation of water from the leaves of a living plant).

Hydrology – The science of earth's water resources. The scope of hydrology includes water's occurrence, distribution, circulation, physical and chemical properties, and reactions with and effects on the environment.

Lithology – (Geology) (1) The scientific study of rocks, usually with the unaided eye or with little magnification. (2) Loosely, the structure and composition of a rock formation. (3) The description of rocks, especially sedimentary Clastics and especially in hand specimen and in outcrop, on the basis of such characteristics as colour, structures, mineralogic composition, and grain size.

Moraine – An accumulation of boulders, stones, or other debris carried and deposited by a glacier. Moraines, which can be subdivided into many different types, are deposits of Glacial Till. Lateral Moraines are the ridges of till that mark the sides of the glacier's path. Terminal Moraines are the material left behind by the farthest advance of the glacier's toe. Each different period of glaciation leaves behind its own moraines.

Non-Point Source Pollution (NPS) – Pollution discharged over a wide land area rather than from a specific location. Non-point source pollution actually originates from numerous small sources. It is quickly spread out and diffused, and it generally infiltrates the soil contaminating the groundwater or is deposited by runoff into rivers and lakes. NPS is much more difficult to measure and control than pollution from a specific point such as a sewer drain or a smoke stack. Agricultural chemicals and exhaust deposits in streets are examples of non-point source pollution.

Overburden – Any loose unconsolidated material, which has been deposited upon solid rock (i.e. sand or clay).

Permits to Take Water (PTTW) – Permits issued by the Ministry of the Environment for large-volume surface or groundwater withdrawals. Permit sets out the location, source maximum volume, number of days of extraction, expiry date of permit.

Pumping Test – A method used to determine the hydraulic characteristics of an aquifer whereby water is pumped from a well and the discharge from the well, and the drawdown of the water level are measured over time. These values are used in an appropriate well flow equation to quantify the hydraulic characteristics of an aquifer and the capacity of a well.

Recharge – The addition of water to the groundwater system by natural (precipitation and infiltration) or artificial processes.

Relational Database – A collection of data stored in a number of data tables that are linked by common relationships that can be easily and efficiently converted into information through database queries and other operations.

Runoff – Rainwater that does not infiltrate the soil but flows across the earth's surface into a body of water. The proportion of rainwater that penetrates the soil varies considerably depending on soil type and area covered by impervious materials. Runoff has the potential to "carry" contaminants resting on the earth's surface into streams, lakes, reservoirs, etc. A watershed with a high percentage of its area covered by impervious materials (pavement and buildings) will have a comparatively high rate of runoff. Runoff is especially problematic in agricultural areas where residues from agricultural chemicals and high concentrations of animal waste rest on the earth's surface.

Till (Glacial) – Unstratified drift, deposited directly by a glacier without reworking by meltwater, and consisting of a mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

Transmissivity – The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Water Budget - A water budget is general model of the complete hydrological cycle. For this study, the water budget provides estimates of: the quantity of water cycling through the study area (average annual precipitation); the quantity of water returned to the atmosphere by evapotranspiration, the quantity of water contributed annually to surface water resources, and the quantity of water that contributes to groundwater resources.

Water Resources – The supply of groundwater and surface water in a given area. Water resources is a general term used to describe all of the usable water in a specific geographical area.

Water Table – The level of groundwater saturation. The depth of the water table is determined by the quantity of groundwater and the permeability of the earth material and fluctuates accordingly. The water table is often the upper surface of an unconfined aquifer.

Watershed – A region or area over which water flows into a particular, lake, reservoir, stream, or river; a drainage basin. Watersheds are separated by ridges or areas of high ground. The boundary between two watersheds is a line connecting points of runoff divergence. Generally, a river or stream runs through a watershed collecting runoff. The stream then flows into another watershed downstream or into the sea.

Watershed Management – The process of analyzing and maintaining the land and water resources of a watershed in order to conserve those resources for the benefit of the watershed's residents. Since watersheds are defined by natural hydrology, watershed management is the most logical water conservation approach. Many problems are better solved at the watershed level than by addressing individual problems within a watershed. Effectively managing a watershed requires knowledge of it attainable only through thorough research. The watershed's natural resource base, health status, threats, and land use patterns as well as the needs of its residents must be understood. Good watershed management takes advantage of community resources and involves cooperation of various community organizations and residents.

11.2 List of Acronyms

AES Atmospheric Environment Service, Environment Canada
AET Actual Evapotranspiration
BMP Best Management Practice
CCS Census Consolidated Subdivision
CofA Certificate of Approval
CoA Census of Agriculture (Statistics Canada)
EC Environment Canada
GIS Geographic Information System
GSC Geological Survey of Canada
GUDI Groundwater Under the Direct Influence (of Surface Water)
ISI Intrinsic Susceptibility Index
MAC Maximum Acceptable Concentration
masl metres above sea level
MNDM Ministry of Northern Development and Mines
MNR Ministry of Natural Resources
MOE Ministry of the Environment
MUD Municipal Water Use Database (Environment Canada)
NMA Nutrient Management Act
NMP Nutrient Management Planning/Plan
NPCA Niagara Peninsula Conservation Authority
NPS Non-Point-Sources
NRVIS Natural Resource Values Information System
NTU Nephelometric Turbidity Unit
NWQPS Niagara Water Quality Protection Strategy
OBM Ontario Base Map
OFA Ontario Federation of Agriculture
OMAF Ontario Ministry of Agriculture and Food
PCB Polychlorinated Biphenyls
PTTW Permit To Take Water
PWQS Provincial Water Quality Standards
TCE Trichloroethylene
TSSA Technical Standards and Safety Association
TOR Terms of Reference
USGS United States Geological Survey
UTM Universal Transverse Mercator
WHPA Wellhead Protection Area
WSC Water Survey of Canada
WWIS Water Well Information System

11.3 Units of Measure

m/sec metres per second

mm/year millimetres per year

m^3/sec cubic metres per second

m^3/day cubic metres per day

m^3/year cubic metres per year

L/day Litres per day

km^2 square kilometres

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APPENDIX A – SAMPLE OFFICIAL PLAN POLICIES

INTRODUCTION

Policies in an Official Plan, to comply with the PPS, should contain several features:

- A recognition of the importance of aquifer and wellhead protection and the relationship between anthropogenic (human) activities and groundwater characteristics;
- Setting out measures to minimize the risk to contamination of groundwater resources including controlling or restricting land uses (new development) which have the potential to contaminate groundwater. This may include identifying the level of risk, depending on the type of land use, and its relationship to the wellhead four capture zones that have been identified in this study, which in turn, are based on Ministry of the Environment protocols. Zones with a lesser time-of-travel. For example, capture zones of with 50 days to 2 years time-of-travel, are identified as having a higher risk than zones with a more extended travel time i.e. 10 years and 25 years. Development should also be directed away from sensitive groundwater features (i.e. recharge/discharge areas, water tables, aquifers and unsaturated zones as defined by surface and subsurface hydrogeologic investigations);
- Providing measures which apply to extensions or expansion of existing uses or encouraging their relocation where such uses pose a significant threat to the groundwater resource
- Setting out measures for monitoring impacts over time
- Illustrating groundwater features and wellhead areas (capture zones) for municipal water supply on the land use schedules to the Official Plan to be protected and the measures needed to provide for that protection.

Controls For Wellhead Protection Areas

A wellhead protection area (WHPA) represents a surface protection of the entire three dimensional capture area for a municipal well. Each WHPA is divided into well capture zones to distinguish among the areas of different potential risks posed to water quality from various types of microbiological and chemical contaminants that could enter the water table and move with the groundwater flow to the well. These zones enable effective and economical management of those risks.

This variation in the risk potential throughout the WHPA results from the fact that bacteria have a limited life span and an adequate travel time from the point of entrance to the well may effectively inactivate these organisms. Similarly, over time, some chemical contaminants degrade into lower risk compounds or are adsorbed by the geological materials encountered along the flow path. On the other hand, other chemicals are unstable in a groundwater setting and the risk from their presence may only be attenuated through dilution along the flow path. Four capture zones have been identified for this study, based on Ministry of the Environment protocols:

- 50 days
- 50 days to 2 years
- 2-10 years, and
- 10-25 years

The four proposed zones provide a reasonable approach to address the potential for threatening land uses to affect municipal groundwater based drinking water supplies.

ZONE I - Bacterial Contaminant Restriction Zone

This capture zone extends from the immediate vicinity of the well to the 50-day time of travel. Groundwater contamination within this zone would be problematic since there would be a very limited opportunity to address the concern of potential contamination of the groundwater system by bacteria or viruses. New development in this zone should be severely restricted while expansion or extensions to existing uses should be very carefully controlled. None of the uses listed in the three Risk Categories of Land Uses (Table 1) should be permitted in this capture zone. Since this zone specifically relates to bacterial issues, of particular concern are land uses or activities with a bacteriological component i.e. the construction of new sewer systems, the storage and spreading of manure (including municipal biosolids), or the installation of new septic systems. New development should be permitted only where provisions are made for the containment of fuel oil storage i.e. no underground storage or outside storage that does not have a built-in secondary containment system. Expansions to existing land uses in this capture zone from any of the three Risk Categories should not be permitted. Such uses should be encouraged to relocate.

ZONE 2 - Hazardous and Toxic Contaminant Restriction Zone

This capture zone extends from the well to the 2-Year time of travel from the well. Within this zone, dissolved contaminants such as petroleum hydrocarbons or industrial solvents could arrive at the municipal well within a short time frame. As a risk avoidance strategy, it is an unacceptable risk to permit many types of industrial land uses to establish within this zone, even where the owner is committed to preventing groundwater contamination i.e. none of the three Risk Categories of Land Uses (Table 1) should be permitted in this capture zone.

ZONE 3 - Contaminant Constraint Zone

This capture zone extends from the 2 Year to the 10 Year time of travel. Further from the municipal wellhead, any groundwater contamination within this area would have some time to be attenuated and diluted in the ground as it moves towards the municipal well. Contamination detected within this zone would be sufficiently far removed from the well that a new water supply could be secured or remedial action could be undertaken prior to the contamination arriving at the municipal well. Certain land uses can be permitted with Best Management Practices. As a condition of zoning approval, certain land uses could be required to monitor shallow groundwater quality on a regular basis to monitor for degradation of the resource. Category 3 Risks (Low Risk) may be permitted in the Zone 3 Capture Zone, subject to certain performance standards being met to ensure that risks are minimized. Expansions to existing land uses in this capture zone from any of the three Risk Categories (Table 1) should be discouraged. Expansions, where permitted, should be required to meet a high standard of land use control to avoid the potential for contamination.

ZONE 4 - Contaminant Control Zone

This capture zone extends from a 10 Year Time of Travel to the limit of the capture zone i.e. 25 years. The furthest removed from the municipal well, this zone generally extends to the top of, or slightly beyond the surface watershed divide. Certain land uses will be permitted as well as expansions or extensions but will require best management practices to be implemented for groundwater protection.

Sample Wellhead Protection Policies for Official Plan

Goal for Wellhead Protection

To provide for the protection of municipal water supplies from contamination associated with certain land uses and to secure the long-term protection of a potable water supply for residents and businesses.

To prohibit land uses from establishing in Wellhead Protection Areas (WHPA) or to ensure that certain uses can be established within an acceptable level of risk to groundwater quality.

Purpose of Wellhead Protection Policies

The Municipality recognizes the importance of its groundwater resource in maintaining the quality of life of residents. Council intends to provide for a sustainable supply of drinking water through an integrated and long-term approach to the protection, improvement or restoration of the quality and quantity of water. Council intends to prohibit, restrict or manage land uses to minimize the risk to potential contamination of the groundwater aquifer. These policies will apply to a wellhead protection area (WHPA) identified on the Land Use Schedule.

WHPAs are shown on Schedule '*x*' to the Official Plan. A WHPA illustrates four time-related capture zones which were determined through a hydrogeological investigation (Municipal Groundwater Study). These include 0-50 days, 50 days -2 years, 2-10 years and 10-25 years time-of-travel (TOT) with 0-50 days being ranked as the highest level of sensitivity based on the importance of the well to the water supply and the other categories ranked on a descending basis of sensitivity.

A WHPA shall be considered as a special protection area within which certain land uses may or may not be permitted in accordance with the underlying land uses designation and the following policies.

A WHPA may be modified where the geographic extent of this area, or any of the time-related capture zone boundaries are modified through further study, or where a municipal well is abandoned. Establishment of a new WHPA shall be subject to an amendment to this Plan concurrently with the Class Environmental Assessment process.

1. **Scope of Land Use Categories**

   For the purposes of this Plan, Table 1 sets out the scope of prohibited land uses in the Wellhead Protection Area (WHPA). More specifically, uses listed as Category 'A' and Category 'B' uses are prohibited anywhere in Zones 1 and 2 of the wellhead protection area.

2. New development (non-prohibited uses) may be permitted on full municipal water and sewage services in Zone 1 or 2, where such uses are permitted in the underlying land use designation and only where provisions are made for the containment of any domestic fuel oil

storage supplies i.e. no underground storage or outside storage that does not have a built-in secondary containment system shall be permitted.

3. Category 'C' uses may be permitted in Zone 3 subject to a zoning by-law amendment and compliance with the following performance standards provided such uses are permitted in the underlying land use designation:

A. The preparation of a disclosure report specifying the nature of the proposed use, its associated required services and facilities, the activities and operations to be conducted on-site and the substances to be used or stored on-site.

B. The preparation of a detailed hydrogelogical study using protocols acceptable to the Ministry of the Environment that predicts the net groundwater and/or surface water quality impacts likely to occur on the subject property, on down gradient properties and on the municipal well. The cumulative impacts of development in the WHPA will also be addressed in the report. The study report shall include mitigation measures, where necessary, for the design, construction and post-construction monitoring of the proposed use and where the impacts of the use cannot be adequately mitigated within an acceptable risk to groundwater and (surface water) quality to the satisfaction of the Municipality, the use shall not be permitted.

C. The preparation of a spill prevention and contingency plan outlining design measures, facilities and procedures to avoid and mitigate the effects of spillage of any contaminants.

D. The cost of the disclosure report, the hydrogeological study and the spill prevention and contingency plan will be borne by the proponent.

4. Category 'C' uses may be permitted in Zone 4 subject to a zoning amendment, where the proponent uses best management practices (BMPs) to minimize the risk of contamination of groundwater provided such uses are permitted in the underlying land use designation. Examples of BMPs include: no on-site bulk storage of petroleum products, pesticides, herbicides; secondary containment for storage of raw materials and waste products; retention or installation of vegetation buffers; maintaining updated nutrient management plans.

5. Existing Uses, Enlargements, Extensions or Change of Uses

Land uses in Table 1 existing within Zones 1 and 2 of the Wellhead Protection Area at the time of the coming into force of zoning by-law amendments adopted in accordance with the policies for Wellhead Protection Areas, will be recognised as legal non-conforming uses within the zoning by-law. Once these uses cease to exist, such legal non-conforming status will be lost and such uses will no longer be permitted. Existing Category 'C' land uses in Table 1 located in Zone 3 may be expanded where they comply with the performance standards set out above.

6. Adjacent Lands

Ddespite the above policies, the municipality may limit other land uses outside of source protection areas, but in the general vicinity where they are considered to have a potential impact on source protection.

7. Zoning By-law

The zoning by-law shall incorporate appropriate requirements to implement the policies for wellhead protection. More specifically, the zoning by-law shall implement the use prohibitions and performance requirements and other policies as set out in Table 1. The By-law shall require a rezoning for any use designated as a Category ‘C’ Use in a WHPA, subject to first meeting the performance requirements and development criteria outlined above. The zoning by-law may set out minimum distance separations between a municipal well and any land use, building or structure, whether the use is located within a WHPA or is in the vicinity of a WHPA.

8. Holding By-law

The Municipality may place any property in the wellhead protection area in a holding by-law for the purposes of meeting any of the performance criteria set out above. The Holding symbol ‘H’ may be lifted by an amendment, subject to meeting the performance standard.

9. Site Plan Control

Site plan control may be imposed as a condition of the approval of any use of land within a WHPA. Site plan control shall be used as a means of incorporating mitigating and remedial measures, proper siting, containment, handling, storage or disposal of materials, or design and development of facilities, landscaping or buffering, lot grading and drainage, and site design plans identified through the development review process. As a requirement of maintenance, the Municipality may require a spills contingency plan.

Table 1 - Risk Categories by Land Use
Category A Uses (High Risk)
An On-site (private) sewage disposal system A groundwater heat pump A gas or oil pipeline A new sewage collection main Above ground storage tanks (ASTs) with secondary containment except for a permitted non-residential use Auto wrecking and salvage yards Bulk road salt storage Bulk storage of chemicals or hazardous substances, including on-farm storage for agricultural production purposes Bulk storage of tires Lagoons for sewage treatment Land application of nutrients including biosolids or septage Manure storage facilities Municipal landfills Petroleum products refining and asphalt batching Private facilities for the disposal, storage, handling, transfer, processing and/or recycling of any solid or liquid wastes, including private landfills, and excluding residential sewage systems. Snow storage and disposal facilities Underground storage tanks (USTs) and any in-ground process-related piping of chemicals and lubricants, sumps such as dry wells and machine pits, and automotive repair pits Warehousing, bulk storage of oil, gasoline or petroleum products Warehousing of cleaning products, pesticides, herbicides, fungicides and chemicals, excluding on-farm storage for agricultural production purposes
Category B Uses (Medium Risk)

Table 1 - Risk Categories by Land Use
Assembly of aircraft and aircraft parts, motor vehicles, truck, but bodies, trailers, rail cars, mobile homes, ships and boats Automobile service stations and gas stations Commercial or industrial dry cleaning of textiles and textile products Foundries non-ferrous metal smelting and refining Leather tanning and finishing Manufacturing and dyeing of textiles Manufacturing of agricultural, commercial and industrial machinery Manufacturing of cable and wire Manufacturing of chemicals, resins, paints, varnish, printing inks, adhesives, plastics and reinforced fibreglass plastic Manufacturing of electronic components such as semiconductors, printed circuit boards and cathode ray tubes Manufacturing of engines, engine parts, steering and suspension parts, wheels and brakes Manufacturing of jewellery and precious metals Manufacturing of motor vehicle wiring Manufacturing of pharmaceuticals and medicines Manufacturing of unfinished fabricated metal products and parts Manufacturing of wet electrical equipment and wet batteries Metal casting operations Metal finishing operation (electroplating, electro-coating, galvanizing, painting, application of baked enamel) Underground storage tanks (USTs) and any in-ground process-related piping of chemicals and lubricants, sumps such as dry wells and machine pits, and automotive repair pits Vehicle stamping operations Wood and wood product preservation and treatment
Category C Uses (Low Risk)

Table 1 - Risk Categories by Land Use
Abattoirs
Airports
Asphalt paving and roofing contractor yards
Automated manufacturing of soft drinks, distilleries, breweries and wine making
Automated production of baked goods, dairy, canned goods, frozen foods, processed food and meat
Cemeteries
Funeral homes
Furniture, casket, cabinet and other wood products manufacturing and assembly
Ginseng farms
Glass and glass products manufacturing
Golf courses
Intensive livestock operations and associated manure storage facilities and land application of manure
Lawn care contractors
Machinery equipment rental outlets
Market gardening farms
Manufacturing of dry batteries
Manufacturing electrical appliances, equipment, motors, lighting fixtures, lamps
Manufacturing of electric light bulbs and tubes
Manufacturing of paper, newsprint, boxes
Manufacturing of plastic and foam parts and products
Manufacturing of rubber products
Manufacturing of soaps and toiletry preparations
Medical health and other laboratories
Photographic developing facilities
Printing of newspaper, packaging and books
Rendering facilities
Repair of motor vehicles, aircraft, water craft, rail vehicles, trucks, buses and machinery
Repair of photographic equipment, electrical motors, electrical equipment, vending machines, small motors, appliances, computer equipment and jewellers
Retail sale of agricultural fertilizers and pesticides
Storage, repair yards and facilities for contractors
Tobacco farms
Transit terminals

Controls for Source Protection

Sample Source Protection Policies for Official Plan

Goal for Source Protection

To provide for the protection of groundwater water supplies from contamination associated with certain land uses and to secure the long-term protection of a potable water supply for existing residents and businesses.

To prohibit land uses from establishing in areas with known groundwater features or to ensure that certain uses can be established within an acceptable level of risk to groundwater quality.

Definition

Groundwater Feature refers to water-related features in the earth's subsurface including recharge/discharge areas, water tables, aquifers and unsaturated zones that can be defined by surface and subsurface hydrogeologic investigations.

Purpose of Source Protection Policies

The Municipality recognizes the importance of its groundwater resource in maintaining the quality of life of residents. Council intends to provide for a sustainable supply of safe drinking water through an integrated and long-term approach to the protection, improvement or restoration of the quality and quantity of water. Council intends to prohibit, restrict or manage land uses to minimize the risk to potential contamination of groundwater features. These policies will apply to areas identified as having groundwater features on the Land Use Schedule. This will not be deemed to limit Council's authority to limit development in other areas not currently identified. Other areas may be identified through hydrogeologic investigations or other means.

Identification of Source Protection Areas

Source protection areas are shown on Schedule '*x*' to the Official Plan. These areas contain sensitive groundwater features which have been identified through hydrogeologic investigations (Municipal Groundwater Study).

A source protection area shall be considered as a special area within which certain land uses may or may not be permitted in accordance with the underlying land uses designation and the following policies.

A source protection area may be amended where the geographic extent of this area is determined through further study by the Municipality or as part of an application for development. Significant changes will require an amendment to the Official Plan.

1. Scope of Land Use Categories

For the purposes of this Plan, Table 1 sets out the scope of prohibited land uses in a source protection area. More specifically, uses listed as Category 'A' and Category 'B' uses are prohibited anywhere in a source protection area.

2. New development (non-prohibited uses) may be permitted on full municipal water and sewage services in a source protection area, where such uses are permitted in the underlying land use designation and only where provisions are made for the containment of any domestic fuel oil storage supplies i.e. no underground storage or outside storage that does not have a built-in secondary containment system shall be permitted.

3. Category 'C' uses may be permitted in any source protection area subject to a zoning by-law amendment and compliance with the following performance standards provided such uses are permitted in the underlying land use designation:

A. The preparation of a disclosure report specifying the nature of the proposed use, its associated required services and facilities, the activities and operations to be conducted on-site and the substances to be used or stored on-site.

B. The preparation of a detailed hydrogelogical study using protocols acceptable to the Ministry of the Environment that predicts the net groundwater and/or surface water quality impacts likely to occur on the subject property, on down gradient properties and on the municipal well. The cumulative impacts of development in the source protection area will also be addressed in the report. The study report shall include mitigation measures, where necessary, for the design, construction and post-construction monitoring of the proposed use and where the impacts of the use cannot be adequately mitigated within an acceptable risk to groundwater and (surface water) quality to the satisfaction of the Municipality, the use shall not be permitted.

C. The preparation of a spill prevention and contingency plan outlining design measures, facilities and procedures to avoid and mitigate the effects of spillage of any contaminants.

D. The cost of the disclosure report, the hydrogeological study and the spill prevention and contingency plan will be borne by the proponent.

4. Category 'C' uses may be permitted in any source protection area subject to a zoning amendment, where the proponent uses best management practices (BMPs) to minimize the risk of contamination of groundwater provided such uses are permitted in the underlying land use designation. Examples of BMPs include: no on-site bulk storage of petroleum products, pesticides, herbicides; secondary containment for storage of raw materials and waste products; retention or installation of vegetation buffers; maintaining updated nutrient management plans.

5. Existing Uses, Enlargements, Extensions or Change of Uses

Land uses in Table 1 existing within a source protection area at the time of the coming into force of zoning by-law amendments adopted in accordance with the policies for source protection, will be recognised as legal non-conforming uses within the zoning by-law. Once these uses cease to exist, such legal non-conforming status will be lost and such uses will no longer be permitted. Existing Category ‘C’ land uses in Table 1 located in a source protection area may be expanded where they comply with the performance standards set out above.

6. Adjacent Lands

Ddespite the above policies, the municipality may limit other land uses outside of source protection areas, but in the general vicinity where they are considered to have a potential impact on source protection.

7. Zoning By-law

The zoning by-law shall incorporate appropriate requirements to implement the policies for source protection. More specifically, the zoning by-law shall implement the use prohibitions and performance requirements and other policies as set out in Table 1. The By-law shall require a rezoning for any use designated as a Category ‘C’ Use in a WHPA, subject to first meeting the performance requirements and development criteria outlined above. The zoning by-law may set out minimum distance separations between a source protection area and any land use, building or structure, whether the use is located within a source protection area or is in the vicinity of a source protection area.

8. Hholding By-law

The Municipality may place any property in the wellhead protection area in a holding by-law for the purposes of meeting any of the performance criteria set out above. The Holding symbol ‘H’ may be lifted by an amendment, subject to meeting the performance standard.

9. Site Plan Control

Site plan control may be imposed as a condition of the approval of any use of land within a source protection area. Site plan control shall be used as a means of incorporating mitigating and remedial measures, proper siting, containment, handling, storage or disposal of materials, or design and development of facilities, landscaping or buffering, lot grading and drainage, and site design plans identified through the development review process. As a requirement of maintenance, the Municipality may require a spills contingency plan.

Optional Policies for Official Plan

Education and Notification

The Municipality will notify all landowners located within a WHPA or source protection area as to the sensitivity of their land with respect to the municipal wells.

The Municipality may initiate a program of public education to inform the public of best management practices or other concerns with respect to the protection of groundwater resources.

The Municipality may post signs to identify the limits of a WHPA or source protection area and measures to be taken in the event of a spill.

Emergency Preparedness/Contingency Plan

The Municipality intends to incorporate municipal spill response in its emergency preparedness plan to address the spills of toxic or other substances in a WHPA or source protection area.

The Municipality will develop a contingency plan for the emergency replacement of a water supply should a well become seriously affected or contaminated

APPENDIX B – Groundwater Model Calibration Data

Mattawa Calibration Dataset and Residuals

Well ID	Observed Waterlevel	Calculated Waterlevel	Residual
	(m)	(m)	(m)
4300602/1	207.3	209.8	2.6
4300604/1	270.7	264.6	-6.1
4300605/1	261.5	251.9	-9.6
4300616/1	176.6	179.6	3.0
4300617/1	164.3	169.2	4.9
4300618/1	170.1	177.1	7.0
4300619/1	165.5	172.6	7.1
4301405/1	172.6	171.8	-0.8
4301498/1	239.0	239.6	0.7
4301559/1	258.2	255.6	-2.5
4301560/1	255.1	254.0	-1.2
4301612/1	261.5	255.9	-5.6
4301641/1	163.1	168.0	4.9
4301642/1	163.7	165.2	1.5
4301656/1	172.2	189.6	17.4
4301658/1	192.0	201.2	9.2
4301692/1	219.5	222.1	2.7
4301781/1	169.5	174.2	4.7
4301902/1	176.8	176.5	-0.3
4301932/1	159.5	169.3	9.8
4301949/1	163.7	170.9	7.2
4301989/1	233.2	232.2	-1.0
4302088/1	223.1	205.0	-18.1
4302116/1	176.5	174.9	-1.6
4302117/1	225.6	234.9	9.4
4302143/1	228.6	229.4	0.8
4302241/1	214.4	205.9	-8.4
4302256/1	229.5	230.9	1.4
4302395/1	198.1	202.8	4.7
4302406/1	236.3	232.5	-3.7
4302442/1	182.3	175.3	-7.0
4302638/1	171.9	173.1	1.1
4302712/1	176.8	170.1	-6.7
4302755/1	178.3	171.2	-7.1
4302759/1	267.0	261.2	-5.8
4302810/1	164.0	168.8	4.8
4302813/1	176.4	171.7	-4.7

Well ID	Observed Waterlevel	Calculated Waterlevel	Residual
4302857/1	256.6	247.7	-9.0
4302908/1	239.6	242.2	2.6
4303081/1	168.9	171.9	3.0
4303087/1	273.4	264.0	-9.4
4303178/1	225.6	231.7	6.1
4303652/1	164.6	173.6	9.0
4303708/1	172.2	170.1	-2.1
4303735/1	160.8	165.5	4.7
4303884/1	176.8	173.2	-3.6
4303889/1	209.7	213.1	3.4
PW/A	146.2	150.8	4.6

Powassan Calibration Dataset and Residuals

Well ID	Observed Waterlevel	Calculated Waterlevel	Residual
	(m)	(m)	(m)
4800752/	241.52	245.138	3.6
4800816/	258.77	261.5397	2.8
4800818/	261.51	262.0935	0.6
4800819/	263.04	258.7439	-4.3
4800820/	259.68	258.9751	-0.7
4800822/	262.71	260.175	-2.5
4800829/	250.54	260.3266	9.8
4800830/	252.98	259.8474	6.9
4800831/	250.82	258.2635	7.4
4800832/	251.42	258.734	7.3
4800834/	256.64	257.926	1.3
4800837/	263.34	258.5773	-4.8
4800846/	279.14	277.9647	-1.2
4800851/	252.67	256.367	3.7
4800854/	255.11	258.722	3.6
4800856/	266.09	260.0723	-6.0
4800857/	260.13	259.8557	-0.3
4800858/	250.7	259.0647	8.4
4800859/	239.26	239.1395	-0.1
4800973/	259.68	257.7659	-1.9
4801009/	262.73	260.2313	-2.5
4801078/	261.67	259.2388	-2.4
4801128/	264.26	259.6702	-4.6
4801140/	261.21	260.7397	-0.5
4801143/	255.09	260.1445	5.1
4801150/	245.17	248.0585	2.9
4801171/	261.21	259.1888	-2.0
4801172/	261.21	259.6129	-1.6
4801183/	241.09	243.9919	2.9
4801197/	270.66	264.0968	-6.6
4801234/	263.65	257.8681	-5.8
4801263/	258.77	257.8683	-0.9
4801268/	258.77	258.2276	-0.5
4801288/	252.06	258.7325	6.7
4801366/	262.78	259.5555	-3.2
4801386/	250.92	251.7728	0.9
4801413/	264.87	259.2388	-5.6
4801490/	260.6	259.1424	-1.5
4801491/	269.13	268.4413	-0.7
4801532/	264.26	260.4228	-3.8
4801694/	246.27	248.4519	2.2

Well ID	Observed Waterlevel	Calculated Waterlevel	Residual
4801707/	242.92	243.9919	1.1
4801732/	260.29	260.8484	0.6
4801750/	261.47	260.1548	-1.3
4801856/	241.27	244.893	3.6
4801860/	256.94	257.6182	0.7
4801865/	239.26	245.0581	5.8
4801875/	266.09	261.4976	-4.6
4801876/	242.92	244.1846	1.3
4802126/	253.04	262.5529	9.5
4802173/	264.56	257.2933	-7.3
4802199/	260.6	257.9635	-2.6
4802268/	258.77	261.6054	2.8
4802271/	260.84	257.7605	-3.1
4802272/	260.36	256.85	-3.5
4802447/	266.35	268.2195	1.9
4802449/	259.68	259.3087	-0.4
4802461/	281.94	278.5721	-3.4
4802674/	228.6	239.2013	10.6
4802676/	269.74	267.9825	-1.8
4802692/	262.73	257.8277	-4.9
4802713/	264.56	257.1812	-7.4
4802722/	260.81	259.8557	-1.0
4802785/	263.65	261.438	-2.2
4802879/	262.12	270.4738	8.4
4802901/	252.27	255.9428	3.7
4802980/	240.79	244.6103	3.8
4803100/	259	259.1258	0.1
4803194/	258.47	258.7312	0.3
4803247/	242.01	246.8826	4.9
4803248/	243.53	247.8845	4.4
4803320/	241.09	238.4368	-2.7
4803331/	270.96	262.8211	-8.1
4803732/	243.85	244.6103	0.8
4803736/	250.33	245.4319	-4.9
4803949/	245.97	251.7384	5.8
4803950/	264.56	267.0814	2.5

Technical Memorandum
North Bay – Mattawa Conservation Authority
Study Results

Prepared by:
Waterloo Hydrogeologic, Inc.

Prepared for:
North Bay Mattawa Conservation Authority

August 2006

1 Introduction

1.1 Background

Waterloo Hydrogeologic Inc. (WHI) was contracted by North Bay Mattawa Conservation Authority (NBMCA) in July of 2006, to extend existing regional mapping. The previous and revised study areas are presented in Figures 1 and 2 below. Based on Source Water Protection initiatives, the boundary of the study area was redefined and regional mapping therefore required updating. The analysis presented in this memorandum used water well records from the Ontario Ministry of the Environment (MOE) and data from the previous groundwater study which was completed in 2004 (WHI, 2004).

The revised mapping produced as part of this project is presented at the end of this memorandum. Inset figures are included within the memorandum for reference purposes only. The 11x17 figures presented at the end of this memo have been labeled and numbered in a manner that is consistent with the 2004 study so that they can be incorporated into the previous study if NBMCA wishes. The following memo describes the data sources and methodology that was applied to extend the mapping to the revised study area. WHI recommends that this memo be stored with the original 2004 report so that all information related to the regional groundwater mapping study is together.

1.2 Study Objectives

The objective of this study was to acquire the new data and extend eight of the previous regional maps based on the newly defined boundary. This mapping included Surface Topography, Bedrock Topography, Overburden Thickness (Bedrock Depth), Bedrock Groundwater Elevation, Water Table Elevation, Quaternary Geology, Bedrock Geology and Susceptibility.

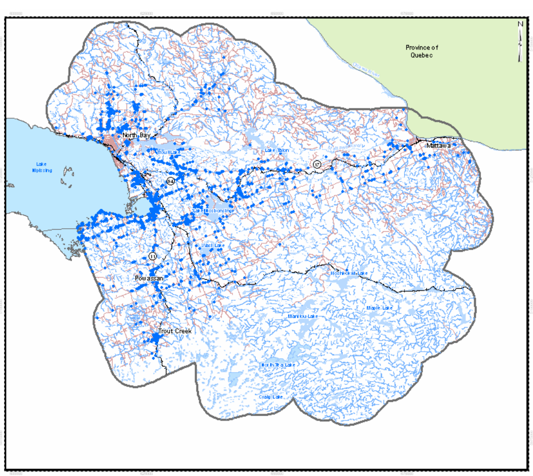

Figure 1: Previous Study Area

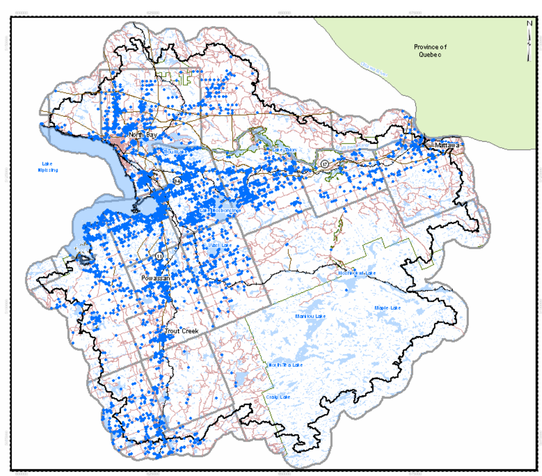

Figure 2: Revised Study Area

2 Mapping and Analysis

Analysis of the NBMCA extension study incorporated as much of the available data from the different data sources as possible. All data from the new database was used and was screened in a manner consistent with the 2004 study.

2.1 Surface Topography

Figure 2-4 is a map of ground surface elevation. This map was generated using the Digital Elevation Model (DEM) provided by the Ministry of Natural Resources. A new DEM was provided for the redefined study area, which has been interpolated using ANUDEM 4.6.3 software (Australian National University Digital Elevation Model). It uses NRVIS contour and water virtual flow information as inputs and automatically corrects sinks, which do not match stream and river locations. In this manner the DEM that is produced is considered to be more hydrologically correct.

Topographic relief in the North Bay – Mattawa area is lowest along the shoreline of Lake Nipissing and along the Mattawa River, which cuts through the central portion of the study area, and rises significantly north or south of the River. The elevations range from 142 m asl along the River to elevations in excess of 500 m asl in the southern portion of the study area. Figure 3 below is a map of the previous ground surface elevation. When comparing the previous ground surface with the hydrologically corrected DEM some differences are noted near streams and rivers.

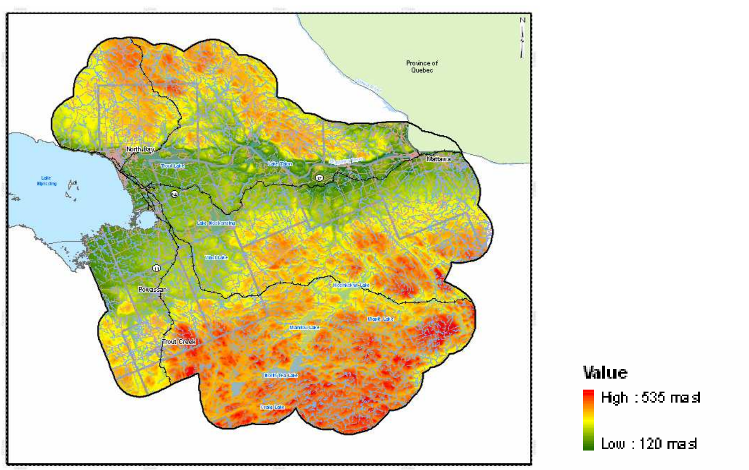

Figure 3: Previous Ground Surface Elevation

2.2 Bedrock Topography

The bedrock surface in the NBMCA generally follows the topography for ground surface. The new Water Well Record (WWR) data for wells was used to interpret the bedrock surface within NBMCA. Figure 2-17 shows the interpreted topography of the bedrock surface within the area, which dips to an elevation of around 125 m asl in the central portion to approximately over 405 m asl in the northwest regions. Areas to the north and south could not be interpreted, as information did not exist in these areas. In these regions, bedrock was assumed to be buried beneath 0.5 m of Quaternary-aged sediments, which is consistent to the approach adopted in the 2004 study. Figure 4 below shows previously interpreted bedrock topography.

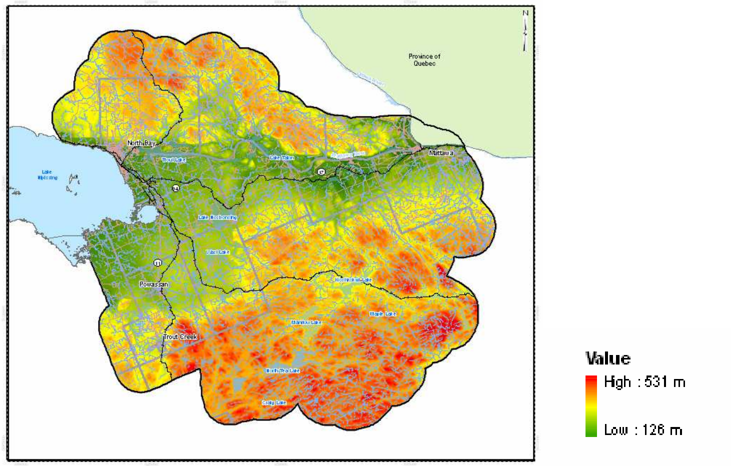

Figure 4: Previous Bedrock Topography

2.3 Overburden Thickness

WWR data for wells in the study area was used to interpret the position of the bedrock surface within the NBMCA. Figure 2-18 shows the interpreted distribution of overburden thickness across the study area. Areas to the north and south of the Mattawa River could not be interpreted, as data is unavailable to interpret overburden thickness at these locations. The thickness of overburden is observed to vary from 0 metres up to 126 metres in a small area just to the north of Mattawa. Below is Figure 5, which is the previously interpreted overburden thickness.

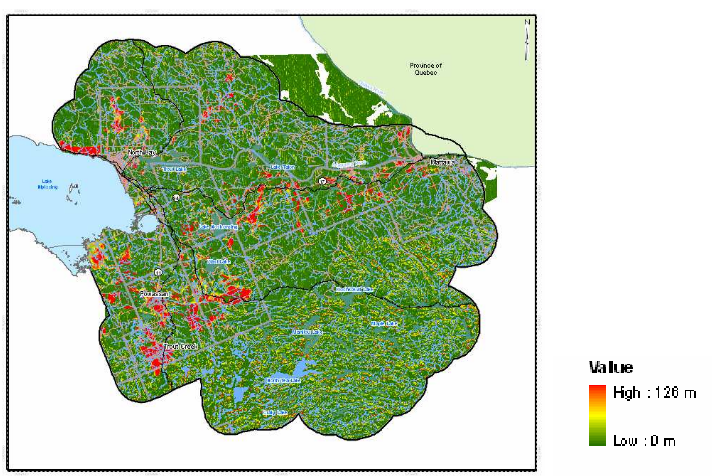

Figure 5: Previous Overburden Thickness

2.4 Water Table Elevation

The new data incorporated into the extended mapping includes the depth to water for wells within the NBMCA area. The static water level was determined by subtracting the depth of water from the DEM. This information was used to interpolate groundwater elevations throughout the study area. All wells completed to less than 15 m depth were considered in this analysis, which is consistent with the 2004 study. Data was sparse in both the northern and southern portions of the study area. To address this surface water features were considered to be representative of water table conditions, and were included in this analysis. Water table elevations range from over 400 m in the north and south, to 120 m near Lake Nipissing.

Interpreted bedrock groundwater elevations are presented in figure 2-21. The elevations range from 130 m along the Mattawa and Ottawa Rivers to nearly 400 m in the north and south. The bedrock equipotentials follow the same trend as the water table map, with flow towards major surface water bodies. Figure 6 below is the previously interpreted water table elevation.

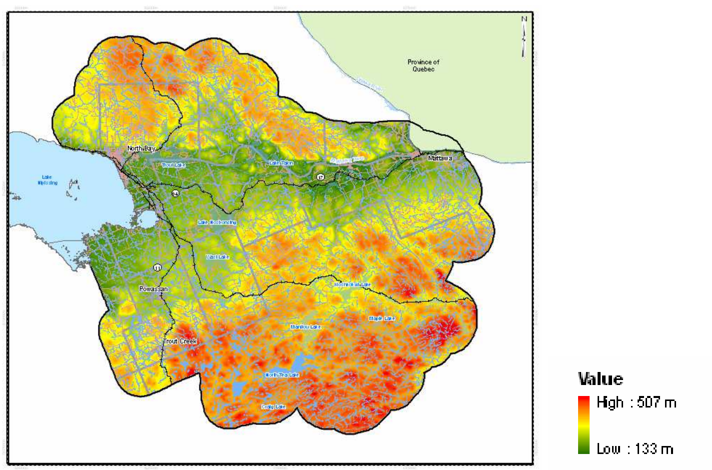

Figure 6: Previous Water Table Elevation

2.5 Quaternary Geology

Data for the quaternary geology is based on information provided by the OGS (Ontario Geological Survey, 2003). Using the newly defined boundary, the data was clipped to extract geology for the southern portion of the study area. Quaternary geology from the OGS existed for the very southern portion of the study area. Geology for the northern portion had to be generated, as it did not exist. Some areas have not been mapped and are therefore not included in Figure 2-6. This is indicated by no interpretation available in the legend.

2.6 Bedrock Geology

The bedrock geology is based on information provided by the OGS (Ontario Geological Survey, 2003). Using the newly defined boundary, the data was clipped to extract geology for the southern portion of the study area.

2.7 Intrinsic Susceptibility Analysis

Groundwater intrinsic susceptibility was assessed using information contained within the MOE Water Well Information System. The approach followed the method outlined in the MOE Technical Terms of Reference (MOE, 2001). This method considers the thickness of the geologic strata overlying the uppermost significant aquifer, as well as the permeability through the use of a K-factor. Intrinsic susceptibility mapping results are presented on Figure 3-1.

Within the bedrock and water table systems, areas of low, medium, and high susceptibility were identified. A high susceptibility rating was determined for most of the study area, with limited areas of low and medium susceptibility where thick deposits of fine-grained overburden were interpreted to exist. Groundwater resources throughout the study area are quite susceptible to contamination as the vast majority of bedrock within the study area is overlain by thin overburden.

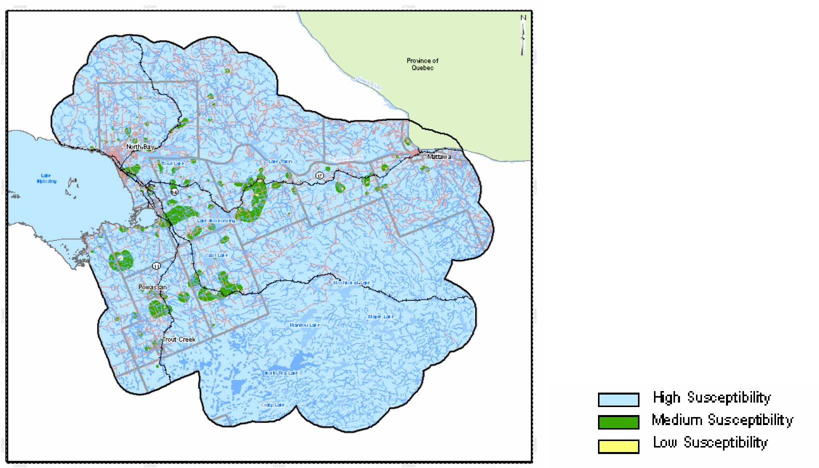

Figure 8: Previous Vulnerability

3 Recommendations

The regional mapping products developed during the original regional groundwater study (WHI, 2004) have been extended to fit to the revised source protection region boundaries for the NBMCA. Additional data was incorporated into the dataset that was compiled for the original study. The results presented within this memorandum should be kept with the original study since the work completed represents an extension of the previous study.

As additional information is collected, the maps developed as part of this study may require revision. The maps presented are regional maps and are presented at a scale of 1:350,000. These maps will need to be supplemented with site specific information for any applications that would be conducted at a land parcel scale.