WATERSHED CHARACTERIZATION REPORT
PRELIMINARY DRAFT

VOLUME I OF III
TEXT

MISSISSIPPI-RIDEAU
SOURCE PROTECTION REGION

EXECUTIVE SUMMARY

The *Clean Water Act* (CWA) was passed by the Ontario Legislature in December, 2006. The CWA is part of Ontario's response to the Walkerton tragedy of 2001 in which tainted drinking water was distributed to unsuspecting citizens. The CWA prescribes a process of watershed-based research, analysis and actions rooted in good science, public participation and sustained effort for keeping Ontario's municipal drinking water safe. The province is divided into 19 Source Protection Regions for purposes of drinking water source protection.

This *Watershed Characterization Report*, a snapshot of the drinking water source situation within the Mississippi and Rideau watersheds in Eastern Ontario, is the first product in the process. Parts of this report plus other technical "modules" (vulnerability analysis, threats inventory, water quality and quantity risk assessments) will eventually be brought together to form the *Assessment Report* detailing the issues around drinking water sources. Finally, a detailed *Source Protection Plan* for each watershed will be developed with full public participation in which current threats to municipal drinking water will be reduced and future threats will be reduced or eliminated.

This three-volume document known as the *Watershed Characterization Report for the Mississippi-Rideau Source Protection Region* (MRSPR) is the result of 18 months of exhaustive research among existing reports, government files, consultants' work and practitioners' experience. It is essentially, the most thorough, the most up-to-date and the most detailed reference book on the natural and man-made physical characteristics of the Mississippi and Rideau watersheds ever produced.

We believe it merits an important place on the reference shelf of all municipal offices in the Mississippi-Rideau Source Protection Region. This document and the multi-year efforts to follow are all about protecting municipal drinking water sources from contamination and depletion.

The *Watershed Characterization Report* covers the 8,600 square kilometres of land within the entire Mississippi and Rideau valleys. This is a huge chunk of Eastern Ontario including the two main river systems which flow east and north to empty into the Ottawa River. The report includes detailed sections on water patterns, climate, geology, where people live, land uses, vulnerable water areas and issues that we already know about within this vast area.

The MRSPR is a complicated piece of the Ottawa-St. Lawrence Lowlands. The region can be divided into two parts: about 70% bedrock outcrops covered by shallow soils and sparse overburden (western and southern portions), and about 30% surface deposits of clays and sands ranging from 10-30 m in thickness (northern and eastern portions). This pattern produces a complex network of lakes, rivers, wetlands and streams which (generally) flow from west to east/northeast. There are many local exceptions and uneven distribution of these features based on the local geology.

Detailed maps and tables explaining fascinating but little-seen features of the region are bound in Volumes 2 and 3 of this document. They include for instance the locations and water-takings from five bedrock aquifers and five overburden aquifers in the area.

There are 12 municipal drinking water systems in the MRSPR: groundwater source systems include Almonte, Kemptville, Merrickville-Wolford, three in Ottawa (Carp, Munster, King's Park in Richmond) and Westport; surface water source systems include Carleton Place, two in Ottawa (Britannia and Lemieux Island), Perth and Smiths Falls.

In terms of municipal water-taking, the Nepean sandstone aquifer is the most desirable in Eastern Ontario from the perspective of source water quantity and quality. It provides the highest sustainable yield of high quality potable groundwater and is targeted by large commercial and municipal systems including six of the seven municipal groundwater systems in the MRSPR. Almonte, Kemptville, King's Park (Richmond), Merrickville, Munster and Westport all use the Nepean sandstone aquifer as their source. Only Carp extracts groundwater from a different aquifer due to the sufficiently high volume and quality found within this local overburden deposit.

In general terms, municipal drinking water drawn from surface water sources throughout the region is good to excellent based on the monitoring of eight chemical factors, three metals and one biological characteristic over many years. Similarly, municipal drinking water drawn from groundwater wells is generally of good quality based on the data currently available. Data on the quality of the raw water used at the 12 municipal systems is presented.

The total population in the MRSPR is estimated at 865,000 people of which 730,000 are on municipal water and sewers. The remaining 135,000 people rely on private services throughout the region. There are an estimated 44,000 private wells and septic systems. The population estimates are broken down by municipality in accompanying tables.

A typical climate year in the MRSPR would include about 900 mm of precipitation, 200 cm of snow, average annual temperature of 6.3°C; January is the coldest month, February is the driest, April has the peak stream flows and July is both the hottest and the wettest.

A key goal of the *Clean Water Act* is to protect what is known as "vulnerable areas", places where water used as sources for municipal drinking water could possibly be degraded by contamination or depletion. In the case of municipal systems, the key vulnerable areas are around the wells and around the intakes from surface rivers. The areas close to these critical sites are the most vulnerable in terms of potential degradation of the raw water. As you move farther away from these sites, the threat of contamination of the municipal system diminishes. These close areas, known as Well Head Protection Areas and Intake Protection Zones, will receive a lot of attention during the upcoming additional Assessment Phase of the work.

Across the entire MRSPR, it has been calculated that as much as 89% of the region is classified as having highly vulnerable aquifers because of the large area of exposed bedrock, shallow soil or permeable overburden deposits. It means that, over large parts of the region, contaminants could travel quickly into drinking water aquifers and potentially cause real risk to users drawing drinking water from those sources. This is a concern for private wells in the rural parts of the region.

There is lots of data available and arranged here for easy viewing. At the same time, there are many data gaps. Some of the gaps are geographical; there is simply no monitoring going on in a certain area; sometimes the gap is caused by not having enough years of data to have confidence in the trends. For example, there is a lack of stream flow gauges on most of the tributaries of the Mississippi and Rideau; there are limitations in the quality of the information in the water well records database; there are known limitations in the quality of information in the Permits to Take Water database; bacterial sampling is not conducted evenly on all rivers in the region; and so on.

This *Watershed Characterization Report* concludes with a "Threats Inventory": some drinking water issues already known about in the region. All municipal drinking water systems occasionally exceed several provincial quality guidelines like colour, odour, hardness and turbidity. These are generally aesthetic or operational in nature and do not constitute real threats to the water system.

The data gaps and the issues are clearly identified in the report and flagged for future work.

The ultimate goal is to ensure, to the best of our collective ability, the security of municipal drinking water well into the future.

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Introduction

Source water is defined as the untreated surface water (streams, lakes) and groundwater (aquifers) that supplies private and public drinking water systems. The goal of drinking water source protection (DWSP) is to safeguard human health by protecting drinking water sources, the first barrier in the multi-barrier approach as defined by Justice O'Connor. Protection of the quality and quantity of our source water will result in significant economic and environmental benefits to guarantee clean water for the future.

A DWSP plan is an agreement among the people and municipalities of a watershed about how to protect water quality and quantity. In order to conduct the DWSP plan, several reference documents will be produced to provide a detailed understanding of the watershed region. The first of these reference documents will be the technical assessment report that will consist of the following components: watershed characterization, water budget, municipal water supply strategies, surface and groundwater vulnerability assessment, threats inventory and risk ranking and water quality and quantity risk assessment. Based on the results of the reference documents, the DWSP plan will be developed.

The watershed characterization document will form the introductory portion of the technical assessment report. The purposes of the watershed characterization document are to initiate the collection of relevant background data, summarize existing information and identify relevant data and knowledge gaps. This document has been prepared in accordance with the "Draft Watershed Characterization Module 1 (Province of Ontario, 2006).

The watershed description is an assessment of the natural and man-made characteristics of the watershed region. The description will compile available background information including natural characteristics, hydrology, hydraulics, geology, hydrogeology, population distribution, land uses, water quality and quantity, vulnerable areas, existing threats inventories, and identified issues and concerns.

1.0 Watershed Description

1.1 Drinking Water Source Protection Region

The Mississippi-Rideau Source Protection Region (MRSPR) is one of 19 watershed regions defined within the *Clean Water Act*. The MRSPR will consist of all of the areas of jurisdiction of the Mississippi Valley Conservation (MVC) and the Rideau Valley Conservation Authority (RVCA).

<u>MRSPR</u>

The MRSPR encompasses a number of watersheds and subwatersheds that discharge to the Mississippi River, Rideau River/Canal or Ottawa River. This area is located in eastern Ontario, with an area of 8,585 km^2. A map of the region is presented in Figure 1.1-1.

The MRSPR and adjacent lands show evidence of occupation from as early as 5,000 B.C.; however there is limited actual archaeological knowledge in the area. The area was occupied and traversed by various First Nations groups during this period. European settlers began to inhabit the region during the late 18th century. Organized military settlements in the early 19th century were responsible for the creation of the villages of Perth and Lanark. With the introduction of European settlers to the region, the initial dense virgin forests were cleared for lumbering purposes and the more fertile clay plains were developed into agricultural areas.

A prominent feature of the MRSPR is the presence of the outcropping Precambrian Shield within the western portion of the region. This area contains numerous lakes of various sizes and shapes in the western portion of the two watersheds. Within the MRSPR, this abundance of lakes and rivers means that approximately 7.5% of the total surface area is occupied by water.

In total, 20 subwatersheds have been identified within the MRSPR. Each subwatershed represents major drainage areas of the main rivers (Mississippi or Rideau) or tributaries of the Ottawa River. The subwatersheds are identified in Table 1.1-1, and their location is shown on Figure 1.1-1.

1.1.1 Watershed Vision

It is anticipated that DWSP will involve many of the various stakeholders and partners within the MRSPR. The following subsections deal with the interdisciplinary relationships that both the RVCA and MVC have currently.

1.1.1.1 Conservation Authorities

Conservation Authority Mandate

The designation of both the MVC and RVCA as Conservation Authorities (CAs) under the *Conservation Authorities Act* allows for some inherent purposes (Section 20), powers (Section 21) and responsibilities (Section 28). The objective of CAs as defined in the legislation is to establish and undertake, in the area over which it has jurisdiction, a program designed to further the conservation, restoration, development and management of natural resources other than gas, oil, coal and minerals (Section 20). The powers are documented in full in the Conservation Authorities Act Section 21. Some of the powers of the authorities, within Section 21 of the Conservation Authorities Act, are:

- To study and investigate the watershed and to determine a program whereby the natural resources of the watershed may be conserved, restored, developed, and managed;
- To survey and take levels of the land, conduct borings or trial pits;
- To acquire land;
- To erect works and structures and create reservoirs by the construction of dams;
- To control the flow of surface waters in order to prevent floods or pollution or to reduce the adverse effects thereof;
- To alter the course of any river, canal, brook, stream or watercourse;
- To use lands owned or controlled by the authority for park or other recreational purposes;
- To collaborate and enter into agreements with ministries and agencies of government, municipal councils and local boards and other organizations;
- To plant and produce trees on Crown lands and on other lands; and
- To cause research to be done.

Within the *Conservation Authorities Act*, Section 28 deals with the Development Regulation (generic regulations). The generic regulations for MVC and RVCA Development, Interference with Wetlands and Alterations to Shorelines and Watercourses are defined in O. Reg. 153/06 and 174/06, respectively.

In addition to the Conservation Authorities Act, the CAs are involved in aspects of several other provincial legislative acts:

- *Planning Act* (Provincial Policy Statement);
- *Drainage Act*;
- *Ontario Water Resources Act*; and
- *Environmental Assessment Act*.

Several memorandums of agreement (MOA) exist between the MVC, RVCA and local municipalities for the provisions of services under the *Planning Act*. The agreements involve several general areas of services to be provided to the municipalities by the CAs. The first service involves commenting on planning approval including such areas of interest as plans of subdivision or condominium, site specific official plan or zoning amendments, consent, and part-lot control bylaws. The second type of service involves a more detailed peer review of technical reports prepared by the proponent's consultant to determine if the study has been conducted in accordance with the development policies of both the municipalities and Provincial guidelines and standards. The agreements are discussed in further detail in Section 1.1.2.1 – Municipalities.

Both the MVC and RVCA are also involved in the federal *Fisheries Act*. The agreements are discussed in further detail in Section 1.1.2.3 – Federal Government.

1.1.1.2 Mississippi Valley Conservation

The MVC is a partnership of municipalities within the Mississippi Valley watershed created under the *Conservation Authorities Act* of Ontario and was formed on May 2, 1968. The boundaries of the MVC consist of all land drained by the Mississippi River system, the Carp River and a series of small streams flowing into the Ottawa River (Constance Creek, Shirley's Brook and Watts Creek) with an area of 4,352 km^2. Major tributary watersheds of the Mississippi River are Big Gull Lake, Buckshot Creek, Clyde River, Fall River and Indian River.

The generic functions of CAs, of which the MVC is one, are discussed above in Section 1.1.1.1. Environmental work conducted by the MVC involves some of the following elements: conservation awareness and visitor services, land and water management, watershed monitoring and information, and watershed planning and resource management.

<u>MVC Vision</u>

The formation of the MVC in the late 1960's has resulted in many documents being completed which have identified the vision for the MVC. The following key studies detail the vision of the MVC:

- Mississippi Valley Conservation Report (1970)
- Interim Watershed Plan – MVC (1983)
- Mississippi Valley Watershed Strategy (1993)
- Mississippi River Water Management Report (2005)

In addition, summaries of these reports are presented in Appendix 1. Detailed listing of recommendations from the reports, where applicable, is also included in Appendix 1.

For areas comprised of the Mississippi Valley, Carp River and several smaller water courses which drain directly into the Ottawa River, the main goal of the MVC is to ensure that ecological integrity is maintained and human needs are met, now and in the future, in balance with the needs of the natural environment.

The following key studies and initiatives that have existing watershed management goals or objectives have been completed:

- Shirley's Brook / Watts Creek Subwatershed Study, Final Report & Appendices (1999)
- Upper Poole Creek Subwatershed Study (1999)
- Kanata North Environmental Management Plan (2001)
- Carp River Watershed/Subwatershed Study, Volumes I & II (2004)

In addition, summaries of these reports are presented in Appendix 1. Detailed listing of recommendations from the reports, where applicable, is also included in Appendix 1.

1.1.1.3 Rideau Valley Conservation Authority

The RVCA is a partnership of municipalities within the Rideau Valley watershed created under the Conservation Authorities Act of Ontario and was formed on March 31, 1966. The boundaries of the RVCA consist of all land drained by the Rideau River system north of the Rideau Canal locks at Newboro (Rideau Valley watershed) and a series of small streams flowing into the Ottawa River (Graham Creek, Becketts Creek, Cardinal Creek, Still Water Creek, Pinecrest Creek, Greens Creek and Bilberry Creek) with an area of 4,234 km^2. Major tributary watersheds of the Rideau River are the Jock River, Kemptville Creek, Irish Creek, and Tay River.

The generic functions of CAs, of which the RVCA is one, are discussed above in Section 1.1.1.1. Environmental work conducted by the RVCA involves some of the following elements: flooding and erosion problems, research on water movement and use, community-based stewardship, advice on development-related issues, reporting on watershed conditions and trends, improving fish and wildlife habitat, providing public access to natural waterfront areas, and reducing water pollution.

<u>RVCA Vision</u>

Various documents have been compiled to identify the vision of the RVCA since its inception in the mid 1960's. The following key studies detail the vision of the RVCA:

- Rideau Valley Conservation Report (1968)
- Interim Watershed Plan – RVCA (1983)
- Rideau Valley Watershed Strategy (1992)
- Making it Happen 2006 – 2008: Three Year Strategy and Work Plan Booklet (2006)

In addition, summaries of these reports are presented in Appendix 1. Detailed listing of recommendations from the reports, where applicable, is also included in Appendix 1.

The main goal of the RVCA is to protect and improve the natural functions of the Rideau Valley watershed. The current vision of the RVCA, which incorporates both the powers authorized by the Conservation Authorities Act and the generic regulations, is provided in the Three Year Strategy and Work Plan Booklet. The main areas of focus for the RVCA are aimed at achieving: better water quality, good water supply, reduced flood risk, improved watershed habitats, conservation areas and programs, and better watershed information.

The following key studies and initiatives that have existing watershed management goals or objectives have been completed:

- Rideau Canal Water Management Plan (1994)
- Rideau Canal Management Plan – Working Towards a Shared Future (1995)
- Kemptville Creek Watershed Plan (1999)
- Jock River Watershed Management Plan (2001)
- Tay River Watershed Management Plan (2002)
- Sawmill Creek Subwatershed Study Update (2003)
- Jock River Reach 2 and Mud Creek Existing Conditions Report (2005)
- Lower Rideau Watershed Strategy (2006)

In addition, summaries of these reports are presented in Appendix 1. Detailed listing of recommendations from the reports, where applicable, is also included in Appendix 1.

1.1.1.4 Rideau Canal

The Rideau Canal, which links Lake Ontario to the Ottawa River through the Cataraqui and Rideau Rivers, was constructed between 1826 and 1832 comprising a distance of 202 km. The Rideau Canal system consists of 52 dams, 47 locks, and 16 lakes within the two above noted river basins. The Rideau Canal was constructed as a military strategy for the defense of Canada, providing an alternate route from Lake Ontario to Montreal, by way of the Canal and then the Ottawa River. The Rideau Canal is operated in a manner similar to that which it was designed in the early 19th century.

The Rideau Canal is managed by Parks Canada with the following goal: To preserve and present the Canal, its structures and natural environment as a functioning system of national historic significance, while at the same time operating and maintaining it as a waterway for recreational use. In maintaining the waterway for navigational use, lake levels are regulated to augment the summer low flows within the downstream portions of the Canal. This recreational use results in a significant amount of water movement downstream due to the lockages.

1.1.2 Stakeholders and Partners

It is anticipated that DWSP will involve many of the various stakeholders and partners within the MRSPR. The following subsections deal with the interdisciplinary relationships that both the RVCA and MVC have currently. A detailed list of all stakeholders and partners is provided in Table 1.1-2.

1.1.2.1 Municipalities

Within the MRSPR there are 23 lower tier, two single tier and seven upper tier municipalities. A list of the municipalities within the MRSPR is presented in Table 1.1-3. The municipalities within the MRSPR are also presented in Figure 1.1-1.

Several lower tier municipalities (Township of Athens, City of Clarence Rockland, Township of Edwardsburg - Cardinal, Township of North Dundas, and Township of Greater Madawaska) and upper tier municipalities (United Counties of Prescott and Russell, United Counties of Stormont, Dundas & Glengarry, and Renfrew County) have very small portions of the MRSPR within their boundaries (less than three percent of the area of each respective municipality). The majority of Athens Township is within the Cataraqui watershed region. The majority of the City of Clarence-Rockland, Township of Edwardsburg - Cardinal, North Dundas Township, United Counties of Prescott and Russell, and the United Counties of Stormont, Dundas & Glengarry are within the South Nation-Raisin watershed region.

Planning Act

Within the *Planning Act*, the regulations relating to plans of subdivision, consent applications, Official Plan amendments, Zoning Bylaws, and minor variances (O. Reg. 196-200) contain clauses that notification must be provided to the CAs. The CAs provide review for municipalities based on these development applications. This plan review involves a site-specific agreement between the CA and the municipality based upon screening criteria to review planning applications for pre-arranged hazards, such as flooding, unstable soils, etc.

Several municipalities within the MRSPR have formal agreements or MOA for the CAs to provide services or expertise to the municipalities. The following municipalities have MOAs with the CAs:

- City of Ottawa has a combined MOA with MVC, RVCA, and South Nation Conservation (SNC), collectively referred to as the Conservation Partners;
- County of Lanark has a MOA with MVC and RVCA; and
- United Counties of Leeds and Grenville have a MOA with the RVCA.

The MOAs involve several general areas of services to be provided to the municipalities by the CAs. The first service involves commenting on planning applications including such areas of interest as plans of subdivision or condominium, site specific official plan or zoning amendments, consent, and part-lot control bylaws. The second type of service involves a more detailed peer review of technical reports conducted by the proponent's consultant to determine if the study has been conducted in accordance with the development policies of both the municipalities and Provincial guidelines and standards. The technical or peer review is conducted to determine if the technical report has been conducted in accordance with the Provincial Policy Statement and that the recommendations of the study are appropriate and feasible. The exact technical review functions delivered by the CAs may vary by municipality; however, in general, the specific technical review functions conducted by the CAs for the municipalities are:

- Environmental Impact Statements for Provincially Significant Wetlands, Natural Environment Areas and Environment Features;
- Review of hydrogeological reports, terrain analysis studies to support development on private services;
- Review of hydrogeological components of site specific studies resulting from the Provincial powers Transfer of Review, such as aggregate extraction proposals;
- Studies that support applications affected by environmental constraints including organic soils, unstable slopes and unstable bedrock;
- Review of site drainage plans, storm water management plans, and sediment and erosion control plans;
- Flood plain management issues; and
- Lake capacity modeling assessments.

In addition to the above mentioned MOAs, the CAs also review proposed developments that involve natural heritage features and water quality and quantity in accordance with Sections 2.1 and 2.2, respectively, of the Provincial Policy Statement. The natural heritage features involve the following items:

- the site is within or adjacent to a wetland and/or areas of natural or scientific interest (ANSI);
- the site is adjacent to a recognized "natural environment area" as identified in municipal official plan or zoning schedules or has been identified in other sources (i.e., watershed plan); and
- the impact of proposed development may result in the harmful alteration, destruction or disturbance (HADD) of fish habitat contrary to the provisions of Section 35 of the Canada *Fisheries Act*.

The water quality and quantity features involve the following items:

- the property to which the application applies:
- abuts a watercourse or water body;
- is within 30 m of the shoreline of a watercourse including a river, stream, creek or municipal drain;
- is within 90 m of the shoreline of a lake;
- the site is in an area identified as being a potentially important recharge/discharge zone in which there may be a risk of groundwater impacts from development; or
- the proposed development of the site will involve the construction of a new drainage outlet or the enlargement of an existing drainage outlet into an existing natural water course.

In these roles, the CA is responsible for representing the "Provincial Interest" on Natural Hazards on a local scale in planning exercises where the Province is not involved.

Building Code Act

Development within Natural Hazard areas requires approval from the CAs under the *Building Code Act* with regards to the other applicable laws and portions of the act. The other applicable laws refer to the generic regulations for MVC and RVCA Development, Interference with Wetlands and Alterations to Shorelines and Watercourses are defined in O. Reg. 153/06 and 174/06, respectively.

In addition, several municipalities within the MRSPR have agreements for the CAs to provide services or expertise to the municipalities under the *Building Code Act*. The following municipalities have agreements with the CAs:

- City of Ottawa has a combined agreement with MVC, RVCA, and SNC; and
- Tay Valley Township has an agreement with MVC and RVCA.

The exact services delivered by the CAs may vary by municipality; however, in general, the agreements are to provide review of on-site sewage system applications, installation or re-installation inspections, and enforcement of septic system regulations.

Special Programs

Within the City of Ottawa and funded by the City, there is a Rural Clean Water Program which offers grants and technical assistance to rural landowners for projects and practices to protect surface water and groundwater. Specific projects include: manure storage, septic system repairs, fuel and pesticide storage, buffer strips, erosion protection, private well replacements, well upgrades and decommissioning.

In addition, for areas outside of the City of Ottawa, the RVCA has a Rideau Valley Rural Clean Water Program providing incentive grants for farmers and rural landowners. The funding for the RVCA Rural Clean Water Program is secured through private fundraising. Applicable projects for funding from the Rideau Valley Rural Clean Water Program include:

- Runoff control and treatment;
- Livestock fencing, alternate watering, small stream crossings;
- On-farm chemical / fuel / pesticide storage;
- Nutrient management plans;
- Erosion control;
- Shoreline planting / buffers and windbreaks;
- Septic system repair;
- Workshops / seminars / publications; and
- Well upgrades and decommissioning.

1.1.2.2 Provincial Agencies

Conservation Ontario

Conservation Ontario (CO) is an umbrella organization that represents all of the 36 CAs in Ontario. The general premise that CO operates on is to provide a common front for the delivery of various programs across the different CAs. CO has traditionally been involved in programs such as watershed stewardship, various pilot projects and forestry initiatives, for example.

CO has been involved with the province in the development of the draft Clean Water Act. In addition, CO has been involved with the Ministry of Environment (MOE) and Ministry of Natural Resources (MNR) in the development of the guidance documents for DWSP.

Ministry of Health and Long Term Care

The Ministry of Health and Long Term Care (MOHLTC) is the provincial ministry in charge of administering the health care system & providing services to the public. The MOHLTC provides free bacterial testing for private well water. The RVCA acts as one of the pick-up locations for sample bottles.

Ministry of Municipal Affairs and Housing

The Ministry of Municipal Affairs and Housing (MMAH) is responsible for policy direction related to land use planning and development under the *Planning Act*. As part of these duties, MMAH is responsible for the approval of the local municipal official plans.

Ministry of Natural Resources

The MNR is responsible for the protection and management of Ontario's resources. The MNR is the Provincial agency responsible for the development of flood, erosion and hazard land management policies, programs and standards. Within the MRSPR, three local MNR resource districts exist. The local MNR resource districts within the region are the Bancroft, Kemptville, and Peterborough offices. The MNR is the parent ministry for the CAs and as a result there is a close working relationship between the CAs and the MNR. Many programs have historically existed between the CAs and the MNR such as the Ontario Stream Assessment Protocol.

As a result of this mandate, several provincial statutes are administered by the MNR. These include the *Beds of Navigable Waters Act*, *Conservation Authority Act*, *Lakes and Rivers Improvement Act*, *Public Lands Act*, *Public Forests Act*, *Crown Forest Sustainability Act* and *Aggregate Resources Act*.

Ministry of Northern Development and Mines

The Ministry of Northern Development and Mines (MNDM) is responsible for policy direction related to mining under the *Mining Act*. As part of this direction, MNDM also contains the Ontario Geological Survey (OGS), which contains detailed information about the province's geology.

Ministry of the Environment

MOE is the provincial agency responsible for the protection of the environment. The MOE is the provincial agency responsible for administration of the following acts: *Ontario Water Resources Act*; *Environmental Protection Act*, *Environmental Assessment Act*, and *Clean Water Act*. In addition, the MOE also enforces the *Nutrient Management Act* and the *Drainage Act* on behalf of Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).

Similar to the MNR, several programs have historically existed between the CAs and the MOE such as the Ontario Benthic Biomonitoring Network (OBBN), the Provincial Groundwater Monitoring Network (PGMN) and Provincial Water Quality Monitoring Network (PWQMN).

Ontario Ministry of Agriculture, Food and Rural Affairs

OMAFRA is responsible for the agriculture, food and rural affairs within Ontario. As a result of this mandate, several provincial statutes are administered by OMAFRA. These include the *Drainage Act* and the *Nutrient Management Act*.

Other Conservation Authorities

Cataraqui Region Conservation Authority

The majority of the southern boundary of the RVCA is adjacent to the Cataraqui Region CA (CRCA). Common municipalities between the RVCA and the CRCA are Athens Township, Augusta Township, Elizabethtown-Kitley Township, Frontenac County, Rideau Lakes Township, South Frontenac Township, and United Counties of Leeds and Grenville.

The southern portion of the Rideau Canal, south of the Newboro locks, lies within the CRCA defined area and provides a navigable waterway link to the lands within the RVCA. The operation of the Rideau Canal is conducted by Parks Canada. As a result of these combined interests, a Rideau Waterfront Development Review Team (RWDRT) has been formed between the RVCA, the CRCA and the Rideau Canal Office of Parks Canada. The purpose of the RWDRT is to provide one stop planning and regulatory advice to approval authorities along the Rideau Canal from Ottawa to Kingston.

Quinte Conservation Authority

The southwestern boundary of both the RVCA and MVC are adjacent to the Quinte CA. Common municipalities between the MRSPR and Quinte CA are Addington Highlands Township, Central Frontenac Township, Frontenac County, Lennox and Addington County, North Frontenac Township, and South Frontenac Township.

South Nation Conservation

The eastern boundary of the RVCA is shared with the SNC. Common municipalities between the RVCA and SNC are Augusta Township, City of Clarence-Rockland, City of Ottawa, Edwardsburg Township, Elizabethtown-Kitley Township, North Grenville Township, North Dundas Township, United Counties of Leeds and Grenville, United Counties of Prescott and Russell, and United Counties of Stormont, Dundas and Glengarry.

The major population centre in the MRSPR is the City of Ottawa, which is also shared with the SNC. In order to provide consolidated services to the City of Ottawa, a MOA has been formed with the MVC, RVCA and SNC, collectively referred to the Conservation Partners and the City of Ottawa.

1.1.2.3 Federal Government

Department of Fisheries and Oceans

The federal government, through Department of Fisheries and Oceans (DFO), is responsible for the enforcement and management and protection of fish habitat. As such, DFO administers the federal *Fisheries Act* legislation.

DFO has established agreements with other government agencies (Environment Canada, Parks Canada, and provincial agencies) for administration of portions of the *Fisheries Act*. With various CAs, DFO Canada has established working agreements for undertaking review under Section 35 of the federal *Fisheries Act*, which deals with the harmful alteration, disruption or destruction of fish habitat (HADD). The various levels of review between the CAs and the DFO are as follows:

- Level I agreement: The CA conducts the initial assessment of the project to identify any impacts on fish habitat.
- Level II agreement: In addition to the above, the CA determines how the proponent can mitigate any impacts.
- Level III agreement: In addition to the above, the CA works with the proponent to prepare a compensation plan that will meet *Fisheries Act* Section 35(2) Authorization requirements.

A Level II agreement exists between both the MVC and the RVCA with DFO. The Level II agreement between DFO by the CAs has been from June 1998 to the present.

Environment Canada

Environment Canada (EC) is the federal agency responsible for the protection of the environment. As such, EC administers the *Canada Water Act*, and *Canadian Environmental Protection Act*.

In addition, EC collects information regarding the Canadian climate and surface water information. This information is collected by the Water Survey of Canada (WSC) and Atmospheric Environment Service (AES). WSC maintains and operates surface water flow gauges throughout Ontario in a Canada-Ontario agreement on the operation of a hydrometric monitoring network. AES is responsible for a network of climate stations in Canada. Several of these gauges or stations are located within the MRSPR and are discussed in further detail in Section 1.3.

National Capital Commission

Within the *National Capital Act*, the National Capital Commission (NCC) was established in 1959 for designing, building, maintaining and preserving federal assets in the National Capital Region (NCR). The NCC owns 465 km^2 of land within the NCR. In the past century, the NCC and its predecessors have protected more than 50,000 hectares (ha) of conservation land, parks and green spaces, created urban parks and connected green spaces.

As part of the NCC planning activities, the Greenbelt Master Plan was created to prevent urban sprawl within the NCR. The Greenbelt is a band of rural land, two to eight kilometers wide and 20,000 hectares in extent located in the southern part of the NCR and managed by the NCC. The Greenbelt Master Plan sets policies for:

- a connected system of natural lands;
- protected views;
- visitor interpretation and a recreational pathway system;
- sustainable farming and forestry; and
- research and high-technology campuses.

Parks Canada

Parks Canada is responsible for the protection and presentation of nationally significant examples of Canada's natural and cultural heritage. The *Department of Transport Act* has enacted regulations regarding the operation of both Canals and Historic Canals. Parks Canada is responsible for the implementation of the *Department of Transport Act* relating to canals. Within the Historic Canals Regulation, the Rideau Canal, including the Tay

Canal, is designated as a Historic Canal. As such Parks Canada is responsible for the operation of the Rideau Canal. The operation of the Rideau Canal entails that Parks Canada is responsible for maintaining the waterway in a manner that provides for navigation. The vision of the Rideau Canal is stated above in Section 1.1.1.4.

1.1.2.4 First Nations

No defined First Nation reserves exist within the MRSPR. However, several First Nations groups reside within the area and are affiliated with the Pikwàkanagàn Algonquin Reserve at Golden Lake, which is located northwest of the MRSPR. The First Nation groups within the MRSPR are:

- Ardoch Algonquins First Nation
- Ardoch Algonquins First Nation and Allies
- Sharbot Mishigama Anishinabe, Algonquin First Nation

The Pikwàkanagàn First Nation group at Golden Lake is not located within a watershed region for drinking water source protection, as the Golden Lake reserve exists outside of the defined conservation authorities within Ontario. Golden Lake is part of the Bonnechere River watershed, which is a secondary watershed of the Ottawa River, northwest of the MRSPR.

1.1.2.5 Interested Stakeholders, Engaged Public and Non-Governmental Organizations

Many varied stakeholders, public and non-governmental organizations such as lake associations, landowner groups and other interest parties have been involved in the watershed management activities within the MRSPR. A detailed list of the stakeholders within the MRSPR is presented in Table 1.1-2.

1.1.3 Water Management Initiatives

There are many water management initiatives within the MRSPR that shape the way that water is currently being managed. Many of these key water management initiatives have been conducted and facilitated since the inception of both the MVC and the RVCA. These water management studies are generally presented on three scales, consisting of the entire MRSPR, one of the MVC or RVCA watersheds, or regional subwatersheds within the MVC or RVCA. These studies are briefly described below.

1.1.3.1 Background Studies

The following background studies relating to water management initiatives have been conducted within the MRSPR.

- Rideau Valley Conservation Report (1968)

- Mississippi Valley Conservation Report (1970)
- Interim Watershed Plan – Mississippi Valley Conservation (1983)
- Interim Watershed Plan – Rideau Valley Conservation Authority (1983)
- Rideau Lakes Basin Carrying Capacities and Proposed Shoreland Development Policies (1992)
- Rideau Valley Watershed Strategy (1992)
- Mississippi Valley Watershed Strategy (1993)
- Rideau Canal Water Management Strategy (1994)
- Sawmill Creek Watershed Study (1994)
- Rideau Canal Management Plan (1995)
- Kemptville Creek Watershed Plan (1999)
- Shirley's Brook / Watts Creek Subwatershed Study (1999)
- Upper Poole Creek Subwatershed Study (1999)
- Jock River Watershed Management Plan (2001)
- Rideau River – State of the River Report (2001)
- Tay River Watershed Management Plan (2002)
- Renfrew County – Mississippi – Rideau Groundwater Study (2003)
- Sawmill Creek Subwatershed Study Update (2003)
- Carp River Watershed / Subwatershed Study (2004)
- Jock River Reach 2 and Mud Creek Subwatershed Study – Existing Conditions Report (2005)
- Mississippi River Water Management Report (2005)
- Kemptville Creek Watershed Plan Update (2006)
- Lower Rideau Watershed Strategy (2006)

Summaries of these reports are presented in Appendix 1. In addition, a detailed list of recommendations associated with the various reports is also presented in Appendix 1.

In addition, the following watershed management studies are on-going or anticipated to be undertaken in the near future.

- Rideau Lakes Watershed Plan (anticipated 2007)
- Middle Rideau River Watershed Plan (anticipated 2007-2008)
- Rideau Watershed Plan (anticipated 2007-2008)

1.2 Physical Description

The boundaries of the MRSPR are defined by the boundaries of watersheds that drain into the Rideau River, Mississippi River, and all small water courses within the City of Ottawa that drain directly into the Ottawa River and influenced by topography as opposed to geology. Geological units extend beyond the MRSPR boundary; therefore it is important to recognize the regional extent of geological units in order to better understand the local depositional environment and hydrogeological conditions.

The geological environment within the MRSPR is part of a larger physiographic region known as the Ottawa-St. Lawrence Lowland (a.k.a. Central-St. Lawrence Lowland) basin, which is a low lying area bound on the north by the Laurentian Highlands of the Canadian Shield and on the south by the Adirondack Mountains in New York State. The western boundary of this basin is the Frontenac Axis, which is a northwest-southeast trending extension of the Precambrian Shield that connects the Canadian Shield to the Adirondack Mountains and separates the sedimentary rocks of south-central Ontario from the sedimentary rocks of the Ottawa-St. Lawrence Lowlands. On the east, the Ottawa-St. Lawrence Lowland basin is bounded by a geological feature called the "Beauharnois anticline" which is situated near the confluence of the Ottawa and St. Lawrence Rivers and extends from the Canadian Shield in the north to the Adirondack Mountains in the south. Wilson (1946) and Williams (1991) provide a detailed description of the geology within this basin.

Figure 1.2-1 shows the location of the MRSPR within the Ottawa-St. Lawrence Lowland basin and that this basin encompasses parts of five Conservation Authorities (MVC, RVCA, SNC, Raisin Region Conservation Authority (RRCA), and parts of CRCA) and three MOE defined Source Protection Regions (M-R, RRCA-SNC, and CRCA watershed regions).

Generally, the geology within the entire Ottawa-St. Lawrence Lowlands basin consists of Precambrian bedrock overlain by flat-lying Paleozoic sedimentary rocks overlain by unconsolidated Quaternary deposits. The depression in the Precambrian bedrock surface forms a basin inside which the Paleozoic sedimentary rocks were deposited. The deepest point within this basin (depth to Precambrian bedrock) is estimated from Geologic Survey of Canada (GSC) borehole logs to be approximately 850 m below ground surface (mbgs) and is located near the southeastern edge of the City of Ottawa (Belanger, 2005).

The following sections describe the topography, bedrock geology, overburden geology and physiography within the MRSPR.

1.2.1 Topography

Topography within the MRSPR is highly variable and generally slopes from the southwest towards the northeast with a total relief of approximately 420 m. Figure 1.2-2 shows the ground surface topography throughout the MRSPR which can generally be divided into two regions: the western half of the MRSPR where Precambrian bedrock outcrops and ground surface elevation is generally greater than 175 meters above sea level (masl), and the eastern half of the MRSPR where Paleozoic bedrock overlies Precambrian bedrock and ground surface elevation is generally less than 175 masl.

The highest ground surface elevation within the MRSPR is at the extreme western tip of the MRSPR, south of Denbigh where ground surface is approximately 470 masl. The lowest ground surface elevation is along the shores of the Ottawa River where ground surface is approximately 40 masl. Local topographic conditions for individual physiographic regions are discussed in Section 1.2.5.

1.2.2 Geological History of MRSPR

The current geological environment that exists within the MRSPR is a present day look at a very long series of ever-changing geological processes including volcanism, sedimentation, mountain building, erosion, glaciation, deposition, etc. These processes have been occurring since the beginning of the earth, which is estimated to be over 4.6 billion years ago (Eyles, 2002). These geological processes are continuous; in other words, they are ongoing today and will continue in the future. Figure 1.2-3 summarizes the geological time scale, which describes the evolution of geological formations and is summarized below.

The core of the North American continent primarily consists of Precambrian igneous and metamorphic rocks, known as the Precambrian Shield (Precambrian basement), which date back over 500 million years ago. This time is known by geologists as the Precambrian Era. A long period of erosion occurred after the Precambrian bedrock was formed, which is evidenced by a major unconformity between the Precambrian formation and the overlying Paleozoic formations.

Following the Precambrian Era, the Precambrian Shield within Eastern Ontario became flooded by an ancient ocean from the east. Figure 1.2-1 shows the limits of advancement of this ancient ocean near the MRSPR (outlined by the Ottawa-St. Lawrence Lowland boundaries), based on geological evidence, during the Middle Ordovician and Late Ordovician time (> 400 million years ago). During this time, known as the Paleozoic Era, erosion of the Precambrian landmass followed by the deposition of conglomerates and sandstone along the shallow water shorelines formed the Covey Hill and Nepean Formations. As the ocean level increased, carbonate-rich fine-grained sediments were deposited in the deeper water environment and the March and Oxford Formations were created overlying the Nepean and Covey Hill Formations. Following the formation of these sandstone units, the ancient ocean retreated and re-flooded many times. This ultimately resulted in the formation of the limestone, dolostone, and sandstone sequences associated with the bedrock formations overlying the Nepean Sandstone Formation. Wilson (1946) offers a detailed description of the geological history for the Ottawa-St. Lawrence Lowland region, primarily after Precambrian time.

Following the formation of these Paleozoic rocks, a period of extensive faulting occurred, followed by another long period of erosion and deposition during the Mesazoic Era (> 75 million years ago). A relatively recent (in geological time) period of glaciation resulted in massive sheets of ice covering much of North America during the Quaternary Era between 1.6 million years ago to 8,000 years ago. The most recent glaciation stage in North America is known as the Wisconsin glaciation and its final retreat from the

Ottawa-St. Lawrence lowlands occurred approximately 12,000 years ago. As the ice retreated, the Atlantic Ocean invaded from the east forming a large lake known as the Champlain Sea, which encompassed the Ottawa-St. Lawrence Lowlands and deposited clays, silts and sands in low lying areas. Since this time, an erosional event has been ongoing and brings us to present time.

1.2.3 Bedrock Geology

Figure 1.2-4 shows the generalized distribution of bedrock stratigraphy throughout the proposed M-R watershed region. Generally, the bedrock geology comprises Precambrian-aged igneous and metamorphic rocks overlain by Paleozoic-aged sedimentary rocks. The Precambrian Shield exists throughout the entire MRSPR; it outcrops over the majority of the western portion of the MRSPR and is covered with Paleozoic-aged sedimentary rocks (Nepean, March, Oxford Formations) east of Perth and Almonte. The following sections describe each of the bedrock units in greater detail.

1.2.3.1 Precambrian Bedrock

The geology of Precambrian bedrock within the MRSPR is extremely complex with many faults, folds, and a mixture of rock types including: crystalline limestones, gneisses, quartzites, intruded, deformed and metamorphosed by bodies of granite, syentite and other igneous rocks (Wilson, 1946).

The Precambrian rocks within the MRSPR were formed during the youngest orogen (mountain building process) associated with Laurentia (a North American craton) and is known as the Grenville orogen (Belanger, 2005). The Grenville Province is the primary exposure of the Grenville orogen. The Grenville Province is categorized into zones with common evolutionary history (belts) and further divided by common rock types and age of development (terranes).

All of the Precambrian bedrock within the MRSPR has a common evolutionary history and are part of the Central Metasedimentary Belt. Easton (1992) provides a more detailed explanation of the portion of the Grenville Province within the MRSPR which includes the following five terranes: Bancroft, Elzevir, Mazinaw, Sharbot Lake and Frontenac.

One feature of note within the Precambrian bedrock of the MRSPR is the naturally occurring uranium mineral deposits within the Sharbot Lake terrane. As identified above the Precambrian bedrock is a complex mixture of rock types. However, within the Cross (Crotch) Lake pluton of the Sharbot Lake terrane, uranium mineralization in this area typically occurs within sills and dykes of pegmatite intrusions into the local gneiss host rock (Paulk, 1987). The specific locations of uranium mineral potential for parts of southern Ontario were put together by the Ontario Geologic Survey in 1979 (Robertson, J.A. et al., 1979). Chart G is for Lennox & Addington and Frontenac County which indicates that the area has medium uranium-thorium potential with documented occurrences of uranium.

Precambrian bedrock predominantly outcrops as a dome-shaped highland area, in the southwestern portion of the MRSPR, and is known as the Frontenac Arch. The Frontenac Arch connects the Precambrian bedrock of the Canadian Shield in Ontario to the Adirondack Mountains in New York. In addition to the western portion of the MRSPR, Precambrian bedrock is exposed at surface as a narrow band extending southeast from Galetta towards Carp and the City of Ottawa. This Precambrian bedrock ridge is locally known as the Carp Ridge and is formed as a result of a historic fault, known as the Hazeldean Fault that runs northwest to southeast, on the north side of the Carp River.

1.2.3.2 Paleozoic Geology

The Paleozoic Era comprised a time when an ancient ocean flooded the majority of the North American continent from the east. The series of sedimentary bedrock formations overlying the Precambrian basement were formed during the Paleozoic Era during several marine transgressions (advancing) and regressions (retreating) during the Cambrian to the Late Ordovician periods. Due to the higher elevation of Precambrian bedrock of the Canadian Shield, Frontenac Axis and the Adirondack Mountains, an isolated bay was formed, known as the Ottawa Embayment, which coincides with the Ottawa-St. Lawrence Lowlands (Figure 1.2-1). Wilson (1946) observed that this basin is deeper at the centre (south of Ottawa near Kemptville) than at the margins (Precambrian-Paleozoic interface), and therefore, with the exception of faulted areas, progressively younger formations are exposed in roughly concentric bands within the outer Precambrian boundary. The Paleozoic bedrock formations generally exist within the MRSPR east of the Precambrian-Paleozoic interface, which forms a divide roughly coinciding with a north-south oriented line between Pakenham and Perth.

Generally speaking, coarse-grained sediments (i.e., sandstones) are deposited near or in shallow water where wave action dominates, while fine-grained sediments (i.e., dolostones, limestones, shales) are deposited in a calmer, deeper water environment which facilitates the settling of fine-grained particles. Therefore, a sequence of sediments that become finer grained in the upper portions of the unit is indicative of a marine environment that is deepening (i.e., transgression or advancing of water). Likewise, a sequence of sediments that show coarser grains above finer grains is indicative of a marine environment that is becoming shallower (i.e., regression or retreating of water).

The Paleozoic sedimentary bedrock formations within the Central-St. Lawrence Lowlands are categorized based on similar lithologies and characteristics, which are influenced by the age of deposition and depositional environment. Three groups of Paleozoic bedrock formations exist with the MRSPR, which include the Potsdam, Beekmantown, and Ottawa Groups. Table 1.2-1, modified from Golder et al. (2003), provides a description of age, thickness and lithology for each formation of each

Paleozoic Group that exists within the MRSPR. Each Paleozoic Group and the bedrock formations associated with them are described below.

Potsdam Group (Covey Hill and Nepean Formations)

The Potsdam Group comprises coarse grained sandstones and conglomerates of the Covey Hill and Nepean Formations that were derived from erosional debris of the Precambrian quartzites and conglomerates and were deposited directly on top of the Precambrian basement. This group was formed during the Late Cambrian to Early Ordovician time periods (~500 Myrs ago), after a long erosional period of the Precambrian bedrock which resulted in an unconformity on top of the Precambrian Shield.

Covey Hill Formation

The Covey Hill Formation was the first sedimentary bedrock layer to be deposited on top of the Precambrian basement (Williams, 1991). It consists of unfossiliferous feldspathic conglomerates and coarse-grained sandstones and was formed during the Late Cambrian period near the extent of the invading flooding (furthest west, abutting Precambrian boundaries). This formation is not regionally significant; however it ranges in thickness from 0 to 13 m in isolated pockets (Williams, 1991).

Nepean Formation

The Nepean Formation has been designated as part of the Beekmantown Group of Ordovician-age by Wilson (1946); however more recent data has led Williams (1991) to classify it as part of the Potsdam Group with the Covey Hill Formation. The Nepean Formation was deposited conformably (without major erosional period in between formations) on top of the Covey Hill Formation, where it exists, and unconformably (after a long erosional period) on top of the unevenly eroded Precambrian basement throughout the majority of the Central-St. Lawrence Lowlands. It consists of well-sorted quartz sandstone and conglomerate, of both terrestrial and marine origin, that is interbedded and generally transitions from coarse-grained (conglomerates) at the bottom near the Precambrian contact to fine-grained in the upper portions of the unit. The upper reaches of the formation contain dolomitic layers which are characteristic of deeper marine environment and a period of marine transgression.

The Nepean sandstone is cream-coloured and ranges from white to light grey, brown and green and weathers to grey with mottled brown to reddish brown staining. This staining is likely due to the dissolution and oxidation of iron-rich mineral grains such as pyrite, magnetite and ilmentite which also contributes to the elevated iron content observed in groundwater originating from this formation.

The Nepean sandstone is present in the eastern half of the MRSPR and outcrops along its western contact with the Precambrian Shield. Its thickness ranges from non existent to greater than 150 m, where the thickest deposits are primarily situated within bedrock troughs or buried fault scarps. The entire bedrock unit dips to the east.

Beekmantown Group (March, Oxford and Rockcliffe Formations)

The Beekmantown Group conformably overlies the Nepean Formation of the Potsdam Group throughout the Central-St. Lawrence Lowland. In some places where the Precambrian bedrock knobs protrude above the Nepean Formation, the Beekmantown unconformably overlies the Precambrian basement (Wilson, 1946). This group was formed during the early to Middle Ordovician period (Lower and Middle Ordovician formations) and comprises interbedded sequences of sandstone, dolostone, limestone and shale which are categorized into three Formations: March, Oxford and Rockcliffe.

March Formation

The March Formation is Early Ordovician in age and consists of shallow marine carbonate and clastic sediments consisting of interbedded quartz sandstone and dolostone. This formation comprises the transition between the quartz sandstone of the underlying Nepean Formation and the dolostone of the overlying Oxford Formation. The lower contact of the March Formation is defined by the deepest occurrence of dolostone while the upper contact is defined by the first occurrence of quartz sandstone below the Oxford Formation. This formation is named after the former March Township where outcrops are noticeable (Wilson, 1946).

The colour of the March Formation varies with rock type and level of weathering, where unweathered bedrock appears as grey sandstone and sandy dolomite alternating with blue-grey dolomite and weathered bedrock of either type appears a dark reddish-brown.

The March Formation is the uppermost bedrock unit within a 10 to 30 m wide narrow band of land situated east of the Nepean Formation that falls within Drummond/North Elmsley, Beckwith, and Montague Townships of Lanark County; and Rideau Lakes, Elizabethtown-Kitley, and Merrickville-Wolford Townships of Leeds and Grenville County. Where it exists, its thickness ranges from 7 to 70 m throughout the MRSPR and it generally follows the same contour as the underlying Nepean Formation with the thickness increasing to the east (Wilson, 1946).

Oxford Formation

The Oxford Formation is also Early Ordovician in age and consists of finer-grained sediments compared to the underlying March Formation, indicating a continual increase in water depth prior to deposition. The Oxford Formation primarily comprises a dolostone unit that is weathering and exists conformably above the last sandstone layer of the March Formation. Wilson (1946) also describes some shale interbeds in the upper portions of the Oxford Formation near the eastern boundary of the MRSPR.

The colour of unweathered Oxford dolostone ranges from dark grey (higher shale content) to brownish-grey and greenish-grey while weathered units tend to appear lighter grey or reddish-brown. Near the western limits of the Oxford Formation, the dolomite exhibits a higher mud and sand content and weathers with a yellowish tinge.

The Oxford Formation is the uppermost bedrock unit east of the March Formation and primarily within the central and eastern portion of the MRSPR that falls within portions of Beckwith and Montague Townships of Lanark Country, Merrickville-Wolford, Augusta, and North Grenville Townships of Leeds and Grenville County and the southern portions of the City of Ottawa. The Oxford dolostone ranges in thickness between non existent to greater than 100 m throughout the MRSPR and it generally follows the same contour as the underlying March Formation with the thickness increasing to the east (Wilson, 1946).

Rockcliffe Formation

The Rockcliffe Formation is Middle Ordovician in age and consists of a sequence of friable shales with lenses of sandstone in the lower portions of the formation, grading to interbedded quartz sandstone interbedded with shaley limestone in the upper portions of the formation. It lies unconformably over the Oxford Formation which represents a considerable time lapse representing the complete withdrawal of the sea allowing for a time of erosion, followed by the re-advancement of the sea and the deposition of the coarser-grained Rockcliffe Formation.

The shale layers are generally light olive-green to dark grey in colour while the sandstone is fine-grained and light grey to greenish-grey. Wilson (1946) also describes occurrences of Rockcliffe Formation near the Ottawa River west of Ottawa as have a deep reddish tinge.

The existence of the Rockcliffe Formation as the uppermost bedrock unit is sporadic within the MRSPR and is limited to several unconnected areas near Ashton, Dwyer Hill and Munster, along the Ottawa River northeast of the Carp Ridge and a small section of downtown Ottawa. The maximum thickness of the Rockcliffe Formation in the MRSPR is approximately 50 m; however, a thickness of 130 m has been recorded further east near Montreal (Golder et al., 2003).

<u>Ottawa Group (Shadow Lake, Gull River, Bobcaygeon, Verulam and Lindsay Formations)</u>

The Ottawa Group of bedrock units is a sequence of Middle to Late Ordovician aged (Middle and Upper Ordovician formations) dolostone, limestone, sandstone and shale bedrock that is categorized into five formations, including: Shadow Lake, Gull River, Bobcaygeon, Verulam, Lindsay (Williams, 1991). Wilson (1946) previously grouped all of these formations together and referred to them as the Ottawa Formation. Within the MRSPR, this group primarily exists within the City of Ottawa limits, north of Carleton Place and marginally extends into the Township of Mississippi Mills (Lanark County) near the towns of Pakenham, Almonte and Ashton.

Shadow Lake Formation

The Shadow Lake Formation is the lowest member of the Ottawa Group within the Ottawa-St. Lawrence Lowland and consists of a fairly continuous thin layer (2 to 3 m) of silty or sandy dolostone with quartz sandstone interbeds and shaley partings. This formation was deposited unconformably on the Rockcliffe Formation and this contact is defined as the upper limit for shale interbeds thicker than 10 cm (Williams, 1991). The formation is generally characterized by a light-grey to green-grey colour.

The Shadow Lake Formation rarely outcrops within the MRSPR. The only known exposure of this formation is at a fault zone (Hog's Back anticline at the Prince of Wales Falls) along the Rideau River within the City of Ottawa.

Gull River Formation (Lower and Upper Members)

The Gull River Formation is a Middle Ordovician aged limestone that is locally argillaceous, silty or dolomitic and has been divided into two members: the lower and upper members. The lower member consists of interbedded limestone and silty dolostone with shale and sandstone partings. The silty dolostone beds are present in thicknesses up to 2 m (Williams, 1991). The lower member of the Gull River Formation (from bottom to top) grades from silty dolostone into siltstone and the division between lower and upper members is defined by the last occurrence of dolostone. The upper member consists of finely crystalline limestone with shaley partings.

The limestones are generally medium to dark grey to brownish grey in colour, weathering to light-medium grey to brown. The silty-dolostones are greenish grey to dark brownish grey in colour weathering to reddish brown. The thin partings of quartz sandstone are light grey to light greenish grey and the shale partings are black.

The lower member of the Gull River Formation is generally between 40 to 60 m thick within the MRSPR and generally decreases to the east. The upper member is a thinner member and averages approximately 9 m in thickness where it exists within the MRSPR.

Bobcaygeon Formation (Lower, Middle and Upper Members)

The Bobcaygeon Formation is a Middle Ordovician aged limestone with varying argillaceous content that can be divided into three members based on shale content:

lower, middle, and upper. The lower member consists of interbedded fine (lithographic) to coarsely crystalline fossiliferous limestone with shaley partings. The middle member contains a higher shale content than the lower member and consists of the same interbedded limestone (up to 35 cm thick) and undulating shaley partings. The upper member is similar to the lower member with the addition of dolomitzed zones up to 20 cm thick.

All members are light to dark grey to brownish grey in colour with the fine-grained exhibiting a darker colour compared to the coarse-grained beds. These rocks weather to a light to medium grey to brownish grey, with the more fine-grained beds weathering to a bluish grey. The thickness of this unit ranges from approximately 80 to 90 m in the northwestern portions of the MRSPR and thins towards the east, reaching a thickness of approximately 50 m near Hawkesbury. The Bobcaygeon Formation exists as the uppermost bedrock formation within small areas at a number of locations between Almonte and the City of Ottawa as well as in the northeastern limit of the City of Ottawa.

Verulam Formation

The Verulam Formation consists of very fine grained (sublithographic) to coarsely grained limestone interbedded with calcareous shale (up to 15 cm thick) and is of Middle Ordovician age. The upper and lower contacts are conformable with the overlying Lindsay Formation and underlying Bobcaygeon Formation, respectively. The upper and lower contacts define the limits where shale interbeds are greater than 5 cm thick. The limestone beds transition from fine-grained at the bottom of the formation grading to coarser-grained at the top, which characterizes a shallowing of water (regression). In addition, the shale content increases from the bottom to the top of this formation.

The limestone layers of the Verulam Formation contain more fossils, compared to the underlying Bobcaygeon Formation, and are light to dark grey to brownish grey in colour with the fine-grained exhibiting a darker colour compared to the coarse-grained beds. These rocks weather to a brown colour; with the more fine-grained beds weathering to a bluish grey. The thickness of this formation is approximately 30 m near Ottawa and increases in thickness to the east (65 m near Hawkesbury).

The Verulam Formation is the uppermost bedrock unit for a narrow stretch of land located north of Highway 417 between Carp and Kinburn and also within the City of Ottawa. The Verulam Formation is less resistant to erosion compared to the overlying Lindsay Formation; therefore natural outcrops of the Verulam Formation are typically found along escarpments capped by the protective layer of the Lindsay Formation. Areas within the MRSPR that show exposures of the Verulum Formation include the lower part of the escarpment at Rideau Falls along the Ottawa River, the Victoria Island road cut, and the Osnabruck quarry (Figure 1.2-4).

Lindsay Formation (Lower Member and Eastview (Upper) Member)

The Lindsay Formation is the uppermost formation of the Ottawa Group and is a Middle to Upper Ordovician aged limestone and shale that can be divided into two members: lower and upper (Eastview). Wilson (1946) regarded the two members as different formations: Lindsay and Eastview, however due to the similar lithology and distribution Williams (1991) grouped them together to form the Lindsay Formation lower and upper members. The fine grained lower member grading to a very fine grained Eastview member and the lack of ripple marks indicate that the Lindsay Formation was deposited in an open water environment that was deepening (i.e., transgression).

The lower member of the Lindsay Formation is characterized by very fine (sublithographic) to coarsely crystalline limestone with interbeds of shale up to 5 cm thick. Some identifying characteristics of the limestone layers include fossils, burrows, and feeding trails. The limestones are light to dark grey to brownish grey in colour with the fine-grained exhibiting a darker colour compared to the coarse-grained beds. These rocks weather to a brown colour, with the more fine-grained beds weathering to a bluish grey. The thickness of this member is approximately 20 m near Ottawa and increases in thickness to the east (125 m near Montreal).

The upper member (Eastview) of the Lindsay Formation is described by Johnson et al. (1992) as organic-rich (up to 13% total organic content) argillaceous limestone and characterized by fossiliferous calcareous shale interbedded with very fine (sublithographic) to finely crystalline limestone. The limestones are similar to the lower member and are medium to dark grey in colour weathering to a bluish grey while the shales are dark grey to dark brown in colour. The thickness of this member is approximately 5 to 10 m near Ottawa and increases to the northwest.

The Lindsay Formation only exists as the uppermost bedrock formation in a small area to the east of Ottawa south of Cumberland and Rockland. The Lindsay Formation is fairly resistant to erosion and therefore exists as outcrops in higher elevation areas. The best examples of Lindsay Formation outcrops within the MRSPR are in quarries, located east of Ottawa.

Billings Formation

The Billings Formation does not belong to a broader group due to its unique characteristics. It is an Upper Ordovician aged shale containing thin layers of finely crystalline limestone and calcareous siltstone up to 2 cm thick near the upper portion of the formation. This formation was comfortably deposited on the uppermost limestone bed of the underlying Eastview member of the Lindsay Formation under a deep water environment (Johnson et al, 1992). The lower contact is defined as the upper limit of occurrence for limestone beds with a thickness greater than 2 cm and is the transition between the calcareous shales within the Eastview member of the Lindsay Formation and the slightly calcareous to non-calcareous shales of the Billings Formation.

The shales are dark brown to black in colour, the limestones are dark grey and the siltstones are medium grey to greenish grey weathering to a reddish brown. The Billings Formation is approximately 60 m thick east of the MRSPR and thickens eastward to greater than 120 m near Montreal.

The Billings Formation is highly susceptible to weathering and therefore natural exposures are generally river cuts. It only exists as the uppermost bedrock formation in a small area on the east side of Ottawa near Mer Blue Bog.

Carlsbad Formation

The Carlsbad Formation is the youngest bedrock formation that exists within the MRSPR and consists of calcareous to non-calcareous grey shale with thin interbeds of calcareous, fossiliferous siltstone and silty limestone. The lower contact is defined as the conformable transition between the black shales of the Billings Formation and the grey shales of the Carlsbad Formation as well as the lowest siltstone or limestone bed that is greater than 2 cm thick (Williams, 1991).

The shales are dark grey in colour while the siltstones and limestones are characterized by medium grey to greenish grey, weathering to reddish brown. The siltstone and limestone beds are thinly bedded and contain evidence of flute casts and ripple marks on some beds indicating a shallow intracontinental shelf environment (Williams, 1991). There are no borehole records that show the true thickness of the Carlsbad Formation within the MRSPR, however a nearby borehole drilled by the GSC near Russell, indicates that the Carlsbad Formation is approximately 190 m thick. This formation becomes thicker towards the southeast.

The Carlsbad Formation is highly susceptible to weathering and therefore natural exposures are generally found in river valleys. It only exists as the uppermost bedrock formation in a small area on the east side of Ottawa near Cyrville Road.

Queenston Formation

The Queenston Formation is the youngest preserved Paleozoic unit in Eastern Ontario; however it does not exist within the MRSPR. Its description is included as part of this report to complete an overview of the Paleozoic bedrock formations of the Ottawa-St. Lawrence Lowland. Within the Ottawa-St. Lawrence Lowland, the Queenston Formation only exists east of the MRSPR. It is likely absent within the MRSPR due to erosion, while a down-thrust fault between the two areas has displaced the Queenston shale near Russell and protected it from erosion (Wilson, 1946).

The Queenston Formation is Upper Ordovician in age and consists of red to light greenish grey, slightly calcareous shale with interbeds of siltstone throughout the formation and thin interbeds of silty limestone in the lower portion of the formation. The predominant colour of the shales is red, with light greenish-grey colour occurring along joints and bedding planes. The red colour is likely due to the oxidation of iron deposits and the green colour to subsequent reduction (Liberty, 1969 as referenced in Williams, 1991). Although, the total thickness of the Queenston Formation has not been determined by drilling, one borehole drilled by Consumer's Gas Company shows that it is thicker than approximately 50 m near Russell. It has a low resistance to erosion and the only known exposure is in the Russell quarry.

1.2.3.3 Bedrock Topography

Figure 1.2-5 shows the topographic relief pattern of the upper most bedrock unit within the MRSPR. The highest bedrock surface elevations (greater than 400 masl) are in the extreme western limit of MVC near Denbigh and are within the area where Precambrian Shield outcrops. The bedrock surface gradually decreases towards the east of the MRSPR (Rideau River) and to the north/northeast (Ottawa River) where the lowest bedrock elevations (less than 40 masl) are found near the City of Ottawa. Due to the shallow overburden deposits within much of the MRSPR, the bedrock topography is a reflection of ground surface topography.

The current bedrock topography within the MRSPR is a reflection of the type of bedrock formation as well as numerous geological processes including faulting, glaciation, and erosion that have taken place since deposition. Due to the geological processes during rock formation, igneous and metamorphic Precambrian bedrock generally has a hummocky topography while sedimentary Paleozoic bedrock is deposited in a marine environment and is therefore generally flat lying. This is reflected in Figure 1.2-5 by the undulating topography in areas where Precambrian bedrock is the uppermost bedrock unit (western MRSPR), and the generally flatter topography where Paleozoic rocks overly the Precambrian basement in the eastern portion of the MRSPR.

As discussed below in Section 1.2.3.4, faulting is an active geological process within the northern portion of the MRSPR. In addition to the bedrock elevation changes caused by faulting, these events expose different bedrock units to the environment. Abrasion caused by the movement of ice sheets during the last glaciation followed by erosion caused by the glacier melt waters has since influenced the topography of these bedrock units. The more resistant Paleozoic units (Covey Hill, Nepean, March, Oxford, Rockcliffe, Bobcaygeon and Lindsay Formations) were not as drastically altered as the less resistant units (Shadow Lake, Gull River, Verulam, Billings and Carlsbad Formations). Therefore, the more resistant units generally outcrop in upland (higher elevation) areas while the less resistant units generally outcrop in the lowland (lower elevation) areas (Williams, 1991).

1.2.3.4 Bedrock Faults

The Earth's crust continually shifts due to natural stresses imposed on it resulting in the extension and shortening of the Earth's tectonic plates (large sections of the Earth's crust). Although Eastern Ontario is located in a stable continental region within the larger North American Plate, seismic activity (faulting) still occurs in regions of crustal weakness. The MRSPR is situated in a historically active fault zone called the Western Quebec Seismic Zone (National Resources Canada (NRC), 2006) which comprises the Ottawa Valley rift zone that spans from the St Lawrence River near Montreal to Temiscaming. The tectonic history within this area has resulted in many steeply dipping normal faults and fault zones that are evident in both the Precambrian and Paleozoic bedrock formations (Williams, 1991). According to Chapman and Putnam (1984) the Ottawa River is the only major fault that is a result of the breaking of the Paleozoic bedrock within Southern Ontario.

The Ottawa-Bonnechere graben, a down-dropped block of the earth's crust resulting from extension or pulling of the crust, is located within the northern portion of the MRSPR and is the most significant fault zone within the MRSPR. This graben was formed approximately 175 million years ago after the Paleozoic Era and therefore penetrates all of the bedrock formations within the Ottawa-St. Lawrence Lowland region resulting in abundant exposures of faults and fault zones, especially in the northern part of the MRSPR. The total displacement or down-drop of this feature is approximately 300 m as evidenced by the abrupt rise in Precambrian bedrock north of the Ottawa River (Chapman and Putnam, 1984). This graben is approximately 60 km wide and 700 km long. Intermittent earthquakes, along the same weak crustal planes within the Ottawa-Bonnechere graben, remind us that this region remains seismically active.

Williams (1991) compiled information pertaining to the relative displacement between fault blocks on the Ottawa-St. Lawrence Lowland. They reported that most faults in the MRSPR strike from the southeast to northwest and have vertical displacements exceeding 1000 m. Most of the faults have their largest displacement near the middle of their length (Wilson, 1946). A simplified version of this fault network is shown in Figure 1.2-4 which only indicates the major faults within the MRSPR. The major faults within the MRSPR which are characterized by a vertical displacement exceeding 200 m include the Pakenham, Hazeldean, Gloucester and Rigaud faults and the Ottawa River fault series.

The end result of these faults is the vertical displacement of bedrock units which is shown in three regional bedrock cross sections (Figure 1.2-6). The locations of the regional cross sections are detailed as follows:

- Regional Cross Section A-A' - Southwest to Northeast through MRSPR;
- Regional Cross Section B-B' – North to South through Richmond Area; and
- Regional Cross Section C-C' – West to East through Perth Area.

The locations of these cross sections are shown in Figure 1.2-4. This is important because the bedrock aquifer and aquitard units on either side of the fault will not necessarily be continuous and the bedrock within a fault zone typically dips towards the down-thrust side of the fault block, therefore causing complications in groundwater flow patterns. In addition, faults are commonly filled with calcite veins accompanied with minor pyrite, barite, celestite or gypsum (Williams, 1991) which would indicate that faults become less permeable; however, faults will also increase the vertical hydraulic conductivity within the fault itself. Therefore, the result of these faults on local groundwater flow environments is not clearly understood and therefore, for simplicity, the local hydraulic impact of the faults is considered to be minimal during recent Municipal Groundwater Studies (INTERA, 2003; Golder et al., 2003).

In addition, to the regional geologic bedrock cross sections, conceptual hydrogeologic cross sections have been developed for the various municipal drinking water systems within the MRSPR. The locations of the lines of cross sections for the municipal systems are also detailed on Figure 1.2-4. The locations of the conceptual hydrogeologic cross sections are detailed as follows:

- Figure 1.2-7 – Conceptual Hydrogeologic Cross Section D-D' (Carp Municipal Well);
- Figure 1.2-8 – Conceptual Hydrogeologic Cross Section E-E' (Almonte Municipal Well);
- Figure 1.2-9 – Conceptual Hydrogeologic Cross Section F-F' (King's Park – Munster Municipal Wells);
- Figure 1.2-10 – Conceptual Hydrogeologic Cross Section G-G' (Westport Municipal Well); and
- Figure 1.2-11 – Conceptual Hydrogeologic Cross Section H-H' (Merrickville – Kemptville Municipal Wells).

The conceptual hydrogeologic cross sections are discussed in more detail in Section 1.3.

1.2.4 Surficial Geology

1.2.4.1 Depositional History

The current overburden geology distribution within the MRSPR is a historical account of the geological processes (abrasion, deposition and erosion) that have occurred since the end of the last glaciation in Ontario (10,000 years ago), called the Wisconsian glaciation. During this glaciation, a continental glacier known as the Laurentian Ice Sheet covered approximately 80% of Canada and extended into the northeastern United States.

Overburden deposits can be categorized based on method of deposition, into the following four groups: till, glaciofluvial, glaciomarine and glaciolacustrine deposits. As the Laurentian glacier advanced from the north it transported eroded materials, from the Paleozoic rocks over which it traveled, and deposited them at the base of the glacier as till sheets and drumlins over low lying areas and indentations in the bedrock surface. As portions of the glacier melted, the glacial melt waters transported material from the glacier and deposited it on top of the till sheets at the edge of the glacier in the form of glaciofluvial deposits such as eskers and glacial outwash fans. Sediments that were carried by glacial melt waters and subsequently deposited in lakes that exist in the low lying areas are known as glaciomarine deposits.

The mass of this ice sheet resulted in a deformation or depression of the earth's crust throughout the area and as a result, once the glacier fully retreated, the Atlantic Ocean flowed westward and flooded most of southern Ontario. This flooding resulted in a bay of water, known as the Ottawa Embayment, covering the entire Ottawa-St. Lawrence Lowland. This body of saline water was called the Champlain Sea which deposited massive silty clay and clay, known as glaciomarine deposits, over the underlying tills and esker deposits.

As the earth's crust rebounded, the Champlain Sea drained towards the east which resulted in the exposure of the drumlin and esker deposits. The erosion and reworking of these features followed by the continual retreat of the Champlain Sea to the east resulted in a thin sand layer being deposited during the shallow water stages as it regressed. This sand layer is evident as the North Gower Sand Plain and the Edwardsburg Sand Plain physiographic regions that are discussed in greater detail in Section 1.2.5. Remnants of the Champlain Sea invasion are still evident today, such as the saline environment near the Mer Bleue bog area.

1.2.4.2 Soil Characteristics

Figure 1.2-12 shows the distribution of overburden materials throughout the MRSPR. With the exception of the northern and eastern portions of the MRSPR, bedrock generally outcrops throughout the MRSPR resulting in very sparse and disconnected overburden deposits. The following sections describe the various types of overburden deposits and their occurrence within the MRSPR.

Table 1.2-2 summarizes the types of sediments and the location of significant deposits of these sediments within the proposed MRSPR. Table 1.2-3 summarizes the surficial geology types encountered in the MRSPR.

Table 1.2-4 summarizes the various soil texture types encountered in the MRSPR. The locations of the various types of soil texture are also presented on Figure 1.2-13. The soils texture mapping was compiled from the Soils Landscapes of Canada which was completed by Agriculture and Agri-Food Canada (AAFC). The provincial soils mapping from OMAFRA for the MRSPR is incomplete. City of Ottawa and Lanark County mapping in digital format is not yet completed. A figure detailing the partial mapping for soils in the MRSPR is presented on Figure 1.2-14.

Figure 1.2-15 shows the soil type superimposed onto a map of surficial geology and Table 1.2-5 summarizes the distribution of each soil type and surficial geology. This figure and table show that the same large area of loamy sand and sandy loam is located in an area underlain by Precambrian bedrock. The Precambrian bedrock in this area generally outcrops at surface with only small, isolated pockets of sand, gravel and till. As a result, the loamy sand and sandy loam soil types are not significant deposits in the western portion of the MRSPR.

Figures 1.2-16 and 1.2-17 show conceptual geologic cross sections through significant overburden deposits within the MRSPR. The location of these cross sections is shown on Figure 1.2-12. The locations of the overburden cross sections are detailed as follows:

- Conceptual Hydrogeological Overburden Cross Section I-I' (Green's Creek); and
- Conceptual Hydrogeological Overburden Cross Section J-J' (North Gower).

Alluvium

Alluvium is described as post-glaciation deposited fine-grained sand, silt and clay and is generally found near surface watercourses. Within the MRSPR, alluvium is found along the Ottawa River and the Rideau River as well as along the post-glacial shores of the Ottawa River near Mer Bleu bog and Constance Bay.

Organic Deposits

Organic deposits are described as muck and other organic rich soils, generally found in poorly drained areas such as wetlands. These deposits exist sporadically throughout the MRSPR as thin deposits, usually less than two meters in thickness. The most predominant area of these deposits is in low lying areas of the Smiths Falls Limestone Plain throughout Leeds and Grenville and Lanark Counties and the south-central portion of the City of Ottawa.

Sand and Gravel

Coarse sand and gravel deposits exist in isolated locations throughout the MRSPR and were formed by several geological processes since glaciation, including: glaciofluvial esker and outwash fan deposits, glaciolacustrine near shore deposits and glaciomarine near shore deposits. Most sand and gravel deposits are covered with finer grained sands and silts and therefore do not outcrop at ground surface.

Sand and Gravel Esker and Outwash Deposits

Sand and gravel deposits of glaciofluvial origin were formed as linear eskers and stratified moraines at the margins of the glacial ice sheets where sediments were deposited into the Champlain Sea. As such, these features are ridge shaped and contain a core of coarse sand, gravel and boulders which becomes progressively finer outwards due to the wave action of the Champlain Sea. Gorrell (1991) mapped the locations of the sand and gravel eskers and outwash fans throughout Eastern Ontario using information from water well records, exposed gravel pits, surficial geology maps and seismic surveys. Based on this mapping, three esker systems exist within the MRSPR, as shown in Figure 1.2-12, and are identified as: the Arnprior-Kars system, the Ottawa-Kemptville system, and the Kemptville-Maitland system. The Arnprior-Kars system cuts across the northern portion the MRSPR from Arnprior, following the southern edge of the Carp Ridge, extending north of Highway 417 over to Highway 416 near Richmond and jogs down towards Osgoode. The Ottawa-Kemptville system starts near the Ottawa International Airport and runs south along the border between RVCA and SNC down to Kemptville. The Kemptville-Maitland system is just outside of the MRSPR but runs from east of Kemptville down to Maitland.

Sand and Gravel Near Shore Beach Deposits

Sand and gravel deposits of glaciolacustrine and glaciomarine origin were formed as beaches due to the wave action reworking the tills and sand and gravel deposits in shallow glacial lake and Champlain Sea environments, respectively. These deposits exist as localized pockets of sand and gravel adjacent to a larger blanket of surficial sands and are found sporadically throughout the central, southern and western portions of the MRSPR usually on the flanks of drumlins or glaciofluvial deposits.

Sand

Sand deposits exist throughout the MRSPR as both continuous sand layers and discontinuous pockets formed under glaciofluvial, glaciolacustrine, and glaciomarine environments.

Glaciofluvial environments resulted in sand deposits near ground surface and approximately 5 to 10 m in thickness, which were formed as glacial outwash plains (continuous sand layer) or post-glacial deltas (triangular shaped at mouth of rivers). The best representation of this type of sand deposit is the Russell and Prescott Sand Plains in the northeastern section of the MRSPR.

Glaciolacustrine (glacial lake) environments resulted in sands being formed near the margins of the glacial ice in low lying areas. The near shore wave action deposited the sands and carried the finer grained silts and clays into deeper water. These deposits exist as localized pockets of sand near sand and gravel beaches and are found sporadically throughout the central, southern and western portions of the MRSPR.

Glaciomarine environments existed throughout the time when the Champlain Sea flooded the Central-St. Lawrence Lowlands and the wave action during the regression of this ancient sea resulted in sands being deposited in the shallow water, usually adjacent to sand and gravel deposits of glaciofluvial origin. The best example of this type of formation is the Edwardsburg Sand Plain, located on the eastern edge of the MRSPR and extending into SNC. This sand deposit reaches thicknesses of approximately 20 m within the MRSPR and generally increases towards the east.

Clay

Clay deposits exist within the MRSPR as a discontinuous layer, primarily found in low lying areas such as bedrock valleys and between elevated features such as drumlins or bedrock ridges. These clay deposits were formed in the deeper, quieter waters when the Champlain Sea inundated the area. Therefore, the distribution of clay deposits is governed by the extent that the Champlain Sea advanced in the Ottawa embayment. The notable clay deposits are located in the eastern portion of the MRSPR between Kemptville and the City of Ottawa, with clay deposits also found along the Ottawa River valley. The thickness of clay is highly dependent on the depth of the depressions or low lying areas because during formation the Champlain Sea "filled" these depressions. Within the MRSPR, clay deposits range from non existent to thicknesses greater than 30 m and increase in thickness towards the east. Further east of the MRSPR, near Cumberland, clay thickness has been reported in excess of 50 m.

Till

Till deposits exist throughout the MRSPR as ground moraines, end moraines and drumlins and are characterized by stony and sandy with silt and clay. Till thickness ranges from non existent to ~ 10m within the MRSPR. These deposits are most notable in the form of drumlins near former Township of North Gower, which is known as the North Gower Drumlin field. During the time of the Champlain Sea, wave reworking of the exposed portions of these drumlins led to the formation of sand and gravel beaches on the west facing sides of the drumlins.

1.2.4.3 Overburden Thickness

Figure 1.2-18 shows the interpreted thickness of overburden materials based on information provided in the MOE water well records. Generally, the overburden thickness within the MRSPR is thin to non existent (less than 1 m) with the exception of areas in the northern portion of the MRSPR where bedrock valleys near the Ottawa and Rideau Rivers allow the accumulation of 10-30 m of clays and sands. East of the MRSPR, as the top of the Paleozoic bedrock drops in elevation and where the deepest portions of the former Champlain Sea were located, overburden thicknesses are much greater. Also, looking at Figure 1.2-18, overburden thickness provides further evidence that the large area in the western study region with soil types of loamy sand and sandy loam are not significant deposits.

1.2.5 Physiography

The MRSPR comprises a vast mix of landforms and physiographic regions. Chapman and Putnam (1984) have categorized the physiography of Southern Ontario, which encompasses the area of Ontario south of Lake Nipissing and the northern shore of Georgian Bay, into 55 separate and distinct regions. The MRSPR covers an area which contains seven of these physiographic regions each of which is discussed, in descending order of size, below. Figure 1.2-19 shows the distribution of these physiographic regions within the MRSPR.

The conceptual hydrogeological cross sections through the various physiographic regions within the MRSPR are presented on Figures 1.2-20 through 1.2-23. The location of these cross sections is shown on Figure 1.2.-19. The locations of the overburden cross sections are detailed as follows:

- Conceptual Hydrogeological Physiographic Region Cross Section K-K' (Britannia to Vars);
- Conceptual Hydrogeological Physiographic Region Cross Section L-L' (Ottawa to Kemptville);
- Conceptual Hydrogeological Physiographic Region Cross Section M-M' (Appleton to North Gower); and
- Conceptual Hydrogeological Physiographic Region Cross Section N-N' (Kemptville).

<u>Algonquin Highlands (40% of MRSPR)</u>

The Algonquin Highlands physiographic region, the largest area within the MRSPR, primarily covers the southwestern half of the MRSPR. This region has an approximate area of 3,400 km^2 within the MRSPR and is generally characterized by shallow to non-existent sandy or stony soils that are acidic and low in nutrients, underlain by Precambrian bedrock. The Algonquin Highlands physiographic region is also the most extensive region in all of Southern Ontario and generally includes the entire area defined by the Canadian Shield.

Topographic relief is moderate to large with rounded knobs and ridges of bedrock extending 20 to 60 m above the surrounding area. The topographic elevation within the Algonquin Highlands ranges from approximately 470 masl, located at the extreme western tip of MVC south of Denbigh, down to 102 masl, located in the middle of the MRSPR south of Perth. The valleys are typically filled with sand and gravel outwash deposits, while bogs and swamps are frequently found in low lying areas. Similarly, lakes form in the irregular depressions of the Precambrian bedrock such as Sharbot Lake, Bobs Lake and part of Big Rideau Lake and cover approximately 11% of the area.

The majority of this region is densely forested (approximately 65%) with both deciduous and coniferous trees, while only 6% is covered by wetlands. Due to shallow and poor quality soil within this physiographic region, the quality of agricultural land is generally low resulting in approximately 5% of the area used for cropland and 6% for pasture. However, there are some exceptions to this description where deeper till exists with few rock outcrops and therefore the surface of the till is smoothed as found near the Villages of Balderson, Perth and Lanark. The primary land uses in this area include forestry, agriculture, mining, and recreation. Several communities within the MRSPR that are situated within this physiographic region include Plevna, Sharbot Lake, Westport, Perth and Lanark.

Smiths Falls Limestone Plain (26% of MRSPR)

The Smiths Falls Limestone Plain physiographic region is the second largest area within the MRSPR and covers the south and central portions of the MRSPR, bordering the Algonquin Highlands. This region has an approximate area of 2,200 km^2 within the MRSPR and is generally characterized by shallow soil over limestone or dolostone bedrock. The Smiths Falls Limestone Plain physiographic region is the largest and most continuous tract of shallow soil over limestone in Southern Ontario and extends to the St. Lawrence River near Brockville.

Topographic relief within this region is small; the ground surface is generally level with a slight slope towards the northeast. The topographic elevation within the Smiths Falls Limestone Plain ranges from approximately 165 masl, located in the southwestern area near Portland, down to approximately 85 masl, located in the northeastern area nearing the City of Ottawa. Due to the flat topography and shallow soils, drainage in many depressions is poor. As a result, bogs are common features throughout this physiographic region, as evidenced in the Townships of Merrickville-Wolford, northern portion of Elizabethtown-Kitley, Drummond/North Elmsley, Beckwith and Montague. Some of the larger surface water bodies within this physiographic region include Mississippi Lake, Lower Rideau Lake, part of Big Rideau Lake and the middle part of the Rideau River.

Old marine beach deposits exist in some of the higher elevation areas, which provide some soil deep enough for cultivation. In addition, depressions in the bedrock surface are typically filled with clay deposits; therefore, a scattering of deeper soils is present but sparse. Due to shallow and poor drainage of the soil within this physiographic region, the quality of agricultural land is generally low. Approximately 20% of the land area is used for pasture, 14% for cropland, 19% covered by wetlands, only 4% covered by lakes and rivers, and much of this region is densely forested with deciduous and coniferous trees (approximately 35%). Several communities within the MRSPR that are situated within this physiographic region include Smiths Falls, Portland, Merrickville-Wolford, Munster and portions of the City of Ottawa.

Ottawa Valley Clay Plains (17% of MRSPR)

The Ottawa Valley Clay Plains physiographic region is the third largest area within the MRSPR and covers most of the northern portion of the MRSPR along the Ottawa River with a small southeastern trending arm along the Mississippi River extending as far as Carleton Place. This region has an approximate area of 1,500 km^2 within the MRSPR and is generally characterized by thick deposits of grey, silty clay interrupted by ridges of rock or sand. Outside of the MRSPR, the Ottawa Valley Clay Plains physiographic region exists throughout the Ottawa Valley, extending from Pembroke to Hawkesbury, and is approximately 10 to 20 km wide within the MRSPR near Ottawa. Some of the larger surface water bodies within this physiographic region include the Ottawa River, Lower Mississippi River, Carp River, and lower portion of the Rideau River as it discharges to the Ottawa River.

Topographic relief within this region is extremely small (120 m) with the majority of the area being flat and adjacent to the Ottawa River. The topographic elevation within the Ottawa Valley Clay Plains ranges from approximately 160 masl, located at the top of the Carp Ridge, down to approximately 40 masl, located along the Ottawa River. Although poorly drained due to the high clay content, bogs and wetlands do not cover the landscape and when artificially drained, the soil has proven to be highly productive for agricultural activities. As a result, approximately 35% of the land area is used for cropland, approximately 20% for pasture, 12% developed land, 2% covered by lakes and rivers and 23% dense deciduous and coniferous forest, and 5% covered by swamps. Several communities within the MRSPR that are situated within this physiographic region include Carleton Place, Carp and the City of Ottawa.

Georgian Bay Fringe (10% of MRSPR)

The Georgian Bay Fringe physiographic region is a broad belt that borders the eastern shore of Georgian Bay and extends as far east as the extreme southwestern corner of the MRSPR. This region has an approximate area of 860 km^2 within the MRSPR and is generally characterized by very shallow soil and bare rock knobs and ridges. The rocks knobs and ridges were formed by wave action during the time that a glacial lake, known as Lake Algonquin, existed.

The topographic elevation within the Georgian Bay Fringe ranges from approximately 400 masl, located at the western limit of MVC, down to 180 masl, located at the western tip of RVCA, near the RVCA, MVC and Quinte Conservation intersection. Very little soil cover exists throughout this region, even in the bedrock hollows between knobs and ridges. Similar to the Algonquin Highlands, lakes formed in the irregular depressions of the bedrock such as Mazinaw Lake, Crotch Lake, and Big Gull Lake.

The primary land uses in this area include forestry and recreation with approximately 70% of the land area densely forested with deciduous and coniferous trees, 16% covered with lakes and rivers, 4% covered in wetlands and <1% used for cropland or pasture. No large communities within the MRSPR are situated within this physiographic region.

Edwardsburg Sand Plain (3% of MRSPR)

The Edwardsburg Sand Plain physiographic region primarily encompasses a thin slice along the eastern edge of the MRSPR and borders the eastern edge of the Smiths Falls Limestone Plain. This region has an approximate area of 270 km^2 within the MRSPR and is generally characterized by glaciofluvial sand deposits overlying bedrock, till or clay. The overall extent of the Edwardsburg Sand Plain within the Province is relatively small (850 km^2), extending approximately 20 km to the east of the MRSPR. This physiographic region encompasses several Townships including Edwardsburgh, Augusta, North Grenville, and Elizabethtown-Kitley.

Topographic relief is relatively small (35 m) with minor undulations likely formed due to wave action during the late stages of the Champlain Sea. Although relatively level, hummocks and sand ridges or moraines are found in higher elevation areas such as east of Kemptville. The topographic elevation within the Edwardsburg Sand Plain ranges from approximately 115 masl, located near Garretton, down to 80 masl, located north of Kemptville. Due to the lack of topographic relief, and the nature of the sand deposits, groundwater is generally found close to ground surface. These saturated conditions have led to the formation of small localized areas with muck and peat bogs. The only surface water bodies found within this region include Kemptville Creek and portions of the Rideau River.

The sand deposits are acidic, deficient in nutrients, not well drained and are generally not used for cultivation, however this region has historically been used for pasture with dairy cattle. The primary land cover within this area include 25% cropland, 22% pasture, 34% densely forested, 9% covered by wetlands, and 3% covered by lakes and rivers. Several communities within the MRSPR that are situated within this physiographic region include Oxford Mills and Kemptville.

North Gower Drumlin Field (3% of MRSPR)

The North Gower Drumlin Field physiographic region is a small, localized area within the southern portions of the City of Ottawa. This region has an approximate area of 250 km^2 within the MRSPR and is generally characterized by a north-south oriented drumlinized till plain, with clay and silt deposits filling the land between the scattered drumlin formations. In addition, gravel ridges are found in some areas near Kars and Osgoode, while bare limestone plain and partially drumlinized till plain is found in Osgoode Township. The North Gower Drumlin Field is a localized feature and approximately half of its area is located within the MRSPR; the remaining half extends approximately 20 km into SNC. Drumlins extend further east of the MRSPR; however, these are found within the Winchester Clay Plains physiographic region where clay plains dominate near Winchester, Embrun and Chesterville.

The topography within this physiographic region is undulating, ranging from 115 to 80 masl, with rounded drumlins protruding up to 30 m above the surrounding area. Drainage between the drumlins is poor, however the drumlin features themselves have good drainage. The Rideau River is the only large surface water feature within this physiographic region.

The primary land cover in this area is approximately 50% cropland, 20% pasture, 20% densely forested, less than 5% wetlands, lakes and rivers. Several communities within the MRSPR that are situated within this physiographic region include Manotick, Kars, Osgoode and North Gower.

Russell and Prescott Sand Plains (1% of MRSPR)

The Russell and Prescott Sand Plains physiographic region, the smallest area within the MRSPR, only exists at the northeastern boundary of the MRSPR. The portion of this area within the MRSPR is the western extremity of the entire Russell and Prescott Sand Plains physiographic region and is situated in two separate locations: extreme northeast corner of RVCA east of Cumberland and centered around the Ottawa International Airport. This region has an approximate area of 80 km^2 within the MRSPR and is characterized by relatively thick sand deposit overlying red and grey clay. Outside of the MRSPR, the Russell and Prescott Sand Plains physiographic region extends as one continuous sand belt adjacent to and periodically separated by the Ottawa Valley Clay Plains.

Topography is relatively flat (range from 115 to 50 masl) with the majority of ground surface in the sand plains at approximately 90 masl. Regionally, the sands reach thicknesses of between 3 to 10 m with the thickest deposits found in the northern sections of this physiographic region. In addition, the texture of the sand is also variable with the coarsest sand being deposited in the northern sections of the physiographic region and grading to fine sand and silt towards the south. Due to the small area of the MRSPR included in the Russell and Prescott Sand Plains, local variations from north to south are not evident. Aside from the Ottawa River to the north, no major surface water features exist in this physiographic region within the MRSPR.

The primary land cover within this area include: 30% densely forested, 27% cropland, 20% developed, 18% pasture, and less than 4% wetlands, lakes and rivers. There are no large communities within the MRSPR situated within this physiographic region.

1.2.6 Land Cover

Figure 1.2-24 and Table 1.2-6 presents the land cover for the MRSPR. This land cover figure is a compilation of the Southern Ontario Interim Landcover (SIL) dated 2000-2002 and the Provincial Land Cover dated 2000 (PLC 2000). Both land cover datasets were produced primarily from imagery dating from 1999 to 2002. The SIL dataset was produced only for areas that were not on the Canadian Shield. This resulted in the SIL coverage being partial for the MRSPR and as a result a merged product was produced in order to have a complete land cover dataset for the MRSPR.

The largest land cover type encountered in the MRSPR is the wooded area which comprises 3,482 km^2 or 41% of the region. As presented on Figure 1.2-24, the majority of the wooded area within the MRSPR is found in the western portion of the region. The next largest land cover types are agriculture and rural land use with 18% and 17%, respectively of the MRSPR. The agricultural and rural land cover types are primarily found within the eastern portion of the MRSPR. Wetland and waterbody land cover types also contain significant portions of the MRSPR at 10% and 7%, respectively.

Developed areas represent approximately 5% of the MRSPR, with them being divided up between built-up areas (pervious and impervious) and transportation. These developed areas are primarily in the northern portion of the MRSPR in the urban areas of the City of Ottawa.

1.2.6.1 Soil Type and Land Cover

Figure 1.2-25 shows the distribution of soil type superimposed onto a map of land cover. Table 1.2-7 summarizes the distributions of these two data sets. From this figure and table it is evident that the largest area comprises of loamy sand or sandy loam in a wooded area located in the western half of the MRSPR. This figure was included in the report to meet MOE guidance requirements; however it gives the impression that this combination of land cover and soil type would provide a setting for large water holding capacity and large amounts of groundwater recharge.

1.2.6.2 Surficial Geology and Land Cover

Due to the thin overburden soils located in the western portion of the MRSPR, the surficial geology and land cover is a better representation than soil type and land cover. The surficial geology and land cover are presented on Figures 1.2-12 and 1.2-24, respectively. The fine scale of the mapping of the surficial geology and land cover datasets prevented a map presenting both features together from being assembled.

However, Table 1.2-8 presents the distribution of each surficial geology type and land cover.

The largest land cover type encountered in the MRSPR is the wooded area which comprises 3,482 km^2 or 41% of the region. As presented on Table 1.2-8, the majority of the wooded area within the MRSPR is found to reside on the Precambrian bedrock (1,818 km^2 or 52% of the wooded area), the Paleozoic bedrock (577 km^2 or 17% of the wooded area) and organic deposits (452 km^2 or 13% of the wooded area).

The next largest land cover types are agriculture and rural land use with 18% and 17%, respectively of the MRSPR. The agricultural land cover within the MRSPR is generally found on clay soils (554 km^2 or 35% of the agricultural area), diamicton (till) soils (300 km^2 or 19% of the agricultural area) and Paleozoic bedrock (262 km^2 or 17% of the agricultural area). The rural land cover type in the MRSPR is primarily found on Precambrian bedrock (585 km^2 or 40% of the rural area), Paleozoic bedrock (293 km^2 or 20% of the rural area) and diamicton soils (247 km^2 or 17% of the rural area). The surficial geology types for the rural area indicate that this land use is closer to the wooded area than the agricultural land use.

Wetland and waterbody land cover types also contain significant portions of the MRSPR at 10% and 7%, respectively. Accordingly, the majority of the wetland land cover type corresponds to the organic deposit surficial geology type at 557 km^2 or 66% of the wetland area. The majority of the waterbody land cover type is found on the Precambrian bedrock (394 km^2 or 70% of the waterbody area).

Developed areas represent approximately 5% of the MRSPR, with them being divided up between built-up areas (pervious and impervious) and transportation. These developed areas are generally found on the clay, diamicton, sand and Paleozoic bedrock surficial geology types.

1.3 Hydrology

1.3.1 Surface Water Hydrology

1.3.1.1 Major Watersheds

The MRSPR features a complex network of lakes, rivers, wetlands and streams. The upper portion of the Region, underlain by Canadian Shield, is speckled with deep glacial lake systems. The lower portion is dominated by large riverine systems. Many of these systems are controlled by numerous hydraulic structures, both natural and man-made. Flows and levels on many of these are continuously measured by a network of surface water gauges.

The MRSPR is divided into two major watersheds: the Mississippi River Watershed in the west and the Rideau River Watershed in the east (refer to Figure 1.1-1). Both watersheds are roughly the same size, the Rideau being the slightly larger and flatter of the two, while the Mississippi is longer. The MRSPR also includes the much smaller Carp River Watershed sandwiched in between the major watersheds. These three rivers, along with some smaller tributaries, drain directly into the Ottawa River, which drains into the St. Lawrence River and the Atlantic Ocean basin.

For planning purposes, the watersheds are divided into subwatersheds, the drainage areas of which are listed in Table 1.3-1 under each CAs jurisdiction. It is worthy to note that some of these subwatersheds are fairly significant, some of which are larger than some of the other Ontario watersheds.

1.3.1.2 Mississippi River

The Mississippi River watershed is 3,765 km^2 in size. It runs from at its headwaters in Mazinaw Lake at an upstream elevation of 325 masl for 212 km to a downstream elevation of 73 masl, for a total drop of 252 m or an average slope of 0.1%. These characteristics are summarized in Table 1.3-2.

The Mississippi watershed is divided into three amalgamated regions, which comprise several subwatersheds. These are described as the western, central and eastern regions, which are described below.

<u>Western Mississippi Region</u>

The Western Mississippi region is underlain by Precambrian Bedrock of the Canadian Shield and is dominated by lakes. The Western Mississippi region extends from the headwaters to the outlet of Crotch Lake. The total area of the Western Mississippi region is 1,031 km^2 and includes the following subwatersheds: Big Gull Lake, Buckshot Creek, Mazinaw Lake and Upper Mississippi.

The generalized flow network of the Western Mississippi region is described below. For additional clarification, Figure 1.3-1 also presents the surface water flow network. The Mississippi River flows from its headwaters at Birch lake south via Kilpecker Creek into Mazinaw and Marble Lakes. It then turns eastward and flows into Kashwakamak Lake. The major tributary in this reach, Buckshot Creek, flows in at the Village of Ardoch. From Ardoch, the River flows into Crotch Lake, the most significant reservoir with regards to flood mitigation and low flow augmentation. Big Gull (Clarendon Lake), a headwaters lake with little drainage area, also flows into Crotch Lake. The major control structures along this reach include the Shabomeka Lake Dam, Mazinaw Lake Dam, Mississagaon Lake Dam, Kashwakamak Lake Dam, Big Gull Lake Dam, and Crotch Lake Dam. The major control structures are presented on Figure 1.3-2. The major rapids along this reach are Whitefish Rapids and Side Dam Rapids.

Central Mississippi Region

The Central Mississippi region is also underlain by Precambrian Bedrock of the Canadian Shield. This region extends from the outlet of Crotch Lake to the outlet of Mississippi Lake. The Central Mississippi region is a transition zone with a combination of lakes and rivers. The total area of the Central Mississippi region is 1,856 km^2 and includes the following subwatersheds: Clyde River, Carleton Place (CP) Dam, Fall River and High Falls.

The generalized flow network of the Central Mississippi region is described below. Figure 1.3-1 presents the surface water flow network. The Mississippi continues eastward from the outlet of Crotch Lake through smaller lakes and the major set of rapids at Ragged Chutes - a 20 m drop - the most significant in river – and into Dalhousie Lake, the second last significant lake on the River, controlled by a natural rock outcrop. From Dalhousie Lake, the River continues eastward to the confluence of the Clyde River and the Fall River, the most significant tributaries on the Mississippi River. From here, the Mississippi River flows easterly into Mississippi Lake, which is the last lake on the Mississippi River proper. The High Falls generating station is located within the Central Mississippi region. The major control structures are presented on Figure 1.3-2.

Eastern Mississippi Region

The Eastern Mississippi region lies off the eastern edge of the Canadian Shield towards the Ottawa River. The Eastern Mississippi region is dominated by riverine systems and extends to the Ottawa River. The total area of the Eastern Mississippi region is 878 km^2 and consists of the following subwatersheds: Indian River and Lower Mississippi.

The generalized flow network of the Eastern Mississippi region is described below. The surface water flow network is presented in Figure 1.3-1. The Carleton Place Dam is located downstream of Mississippi Lake on the Mississippi River proper (not at the outlet of Mississippi Lake). From the Carleton Place Dam, the river bends northwards into the community of Appleton and continues north through the Town of Almonte. The river then flows into Pakenham and through the Village of Galetta, before emptying into the Ottawa River at Chats Lake. There are no major lakes in this last reach. There are four major waterpower generating stations in this reach including the Appleton Generating Station, the Mississippi River Power Corporation Generating Station, Enerdu Power Systems Generating Station, and the Galetta Generating Station and one major water control structure, the Carleton Place Dam. The major control structures are presented on Figure 1.3-2.

Major Tributaries of the Mississippi River

The major tributaries on the Mississippi River include Buckshot Creek, Clyde River, Fall River, Indian River, and Indian Creek. The physical characteristics of the major tributaries are listed in Table 1.3-3.

Buckshot Creek, one of the most significant tributaries on the Mississippi River, flows south-easterly into Buckshot Lake and through Plevna along a reach where several tributaries empty in, before discharging into the Mississippi River just below Ardoch. There are no human made control structures on the main channel of Buckshot Creek, although many beaver dams exist along its length. The Mississagagon Lake Dam controls Mississagagon Lake, the headwaters lake on Swamp Creek, a tributary of Buckshot Creek.

The Clyde River, the largest tributary on the Mississippi River, has numerous tributaries of its own. Its headwaters are located in the Canadian Shield and are characterized by numerous lakes (controlled – no storage available), many of which are spring fed. There is essentially no storage on these lakes. The Clyde River flows from its headwaters at Closs Lake through a series of lakes to the confluence with the Middle Branch Creek and the South Clyde River. The South Clyde flows easterly through more lakes, the largest of which are Palmerston and Canonto Lakes (both controlled). From the confluence, the Clyde River flows through Gordon Rapids and then bends southeasterly through a long stretch of smaller tributaries before finally discharging into the Mississippi downstream of Lanark and just upstream of the Fall River.

The Fall River, the second largest tributary, has three significant lakes: Sharbot and Silver (uncontrolled) and Bennett (controlled) and one significant tributary, Bolton Creek. The Fall River watershed is characterized by rolling hills, glacial deposits, and many pasture farms. It flows from the south side of the Mississippi River from its headwaters in Sharbot Lake, northeasterly through the Maberly dam (just down from where Silver Lake empties into) and Bennett Lake before discharging into the Mississippi just downstream from the Clyde River.

The Indian River flows easterly from upstream of Peterwhite Lake through Halls Mills to its confluence with the discharge from Clayton Lake, which is just downstream of Taylor Lake, two medium sized lakes in the watershed. From there it flows easterly, over a small dam, and bends north. It meets with several smaller tributaries before reaching its discharge point on the Mississippi River downstream of Almonte.

Indian Creek, an uncontrolled tributary, is located downstream of the Indian River. Indian Creek is a smaller tributary with several minor tributaries including Campbell Creek, Forsyth Creek and others. Indian Creek flows from a small lake called Marshall Lake. It flows north before bending sharply towards the east. It empties into the Mississippi River just upstream of Pakenham.

Major Lakes on the Mississippi River

The major lakes on the Mississippi River include Shabomeka Lake, Mazinaw Lake, Kashwakamak Lake, Mississagagon Lake, Big Gull (Clarendon) Lake, and Crotch (Cross) Lake. The outlets of all these lakes are all controlled by dams. They are all located in the western subwatershed. The major non-controlled lakes are Dalhousie Lake and Mississippi Lake; these lakes have a natural outlet. They are located in the central subwatershed. Characteristics of all these lakes are given in Table 1.3-4.

Major Water Control Structures on the Mississippi River

There are 23 water control structures on the Mississippi River plus a number of smaller privately owned structures. Twelve (12) of these structures were identified through the Mississippi River Water Management Plan (French et al., 2005) as having a significant affect on flows and water levels on the River. These structures are owned by MVC, Ontario Power Generation, Canadian Hydro Developers, Enerdu Power Systems Ltd., and Mississippi River Power Corporation. The major water control structures on the Mississippi River (excluding tributaries) are listed in Table 1.3-5 and presented on Figure 1.3-2.

1.3.1.3 Rideau River

The Rideau River Watershed is 3,849 km^2 in size. It runs from an upstream elevation of 163 masl at Burridge Lake for 160 km to a downstream elevation of 84 masl, for a total drop of 40 meters or an average slope of 0.05%. These characteristics are summarized in Table 1.3-6.

The Rideau River serves as the northern route of the Rideau Canal, a 175-year old, 200 km navigation route between the Ottawa River and the St. Lawrence River. The northern route of the Rideau Canal is from Newboro Locks to the entrance point at Ottawa while the southern route runs from Newboro down the Cataraqui River to Lake Ontario; the topographic divide between the two rivers lies at the Frontenac Axis of the Canadian Shield, which rises to 180 masl.

The Watershed can be divided into three regions, which are also amalgamations of several subwatersheds. The regions within the Rideau River include the Upper Rideau, Middle Rideau and Lower Rideau and are described below.

Upper Rideau Region

The Upper Rideau region starts in the headwaters and ends at Poonamalie. This section of the Rideau watershed is generally underlain by Precambrian Bedrock. Sections of Paleozoic bedrock are found south of Upper Rideau and Big Rideau Lakes. This area was subjected to glaciation leaving long narrow depressions which now form the existing lakes and watercourses and generally run in a northeasterly direction. The total area of the Upper Rideau region is 1,249 km^2 with 59 lakes and includes the following subwatersheds: Rideau Lakes and Tay River.

The generalized flow network of the Upper Rideau region is described below. The surface water flow network is also presented on Figure 1.3-1. The Rideau River starts from its headwaters in Burridge Lake and flows in an easterly direction through Wolfe Lake, Westport Lake and the Village of Westport into Upper Rideau Lake. From the Narrows Lock, it flows northeasterly through Rideau Lake to Rideau Ferry and into Lower Rideau Lake just upstream of Poonamalie. Major control structures within the Upper Rideau region are Wolfe Lake Dam, Narrows and Poonamalie on the Rideau River. The Bobs Lake Dam and Beveridges Locks are on the Tay River system. The major control structures are presented on Figure 1.3-2.

Middle Rideau Region

The Middle Rideau region of the Rideau River extends from Poonamalie to Burritts Rapids and is primarily a riverine system. This region is primarily underlain by Paleozoic bedrock consisting mainly of the Smiths Falls Limestone Plain. The total area of the Middle Rideau region is 1,274 km^2 and consists of the following subwatersheds: Kemptville Creek and the Middle Rideau River.

The generalized flow network of the Middle Rideau region is described below. The surface water flow network is presented in Figure 1.3-1. From Poonamalie the Rideau River bends east and flows through Kilmarnock. From Merrickville it flows northeast through Burritts Rapids. Major control structures within the Middle Rideau region are the Combined and Detached Locks at Smiths Falls, Old Slys Locks, Edmonds Locks, Kilmarnock Locks, Merrickville Locks, Clowes Lock and Dam, Nicholson Locks and Burritts Rapids Locks. There is also the Oxford Mills Dam on Kemptville Creek. The major control structures are presented on Figure 1.3-2.

Lower Rideau Region

The Lower Rideau region is comprised of the portion of the Rideau River downstream of Burritts Rapids and is also a riverine system. The Lower Rideau is predominantly underlain by clay soils with deposits of sand and gravel and outcroppings of limestone and sandstone bedrock. The total area of the Lower Rideau region is 1,326 km^2 and consists of the following subwatersheds: the Jock River and the Lower Rideau River.

The generalized flow network of the Lower Rideau River is described below. The surface water network is presented in Figure 1.3-1. From Burritts Rapids to Becketts Landing the Rideau River flows northeast. It bends northwest at Osgoode Station and then flows directly north from Manotick into the urban portion of the City of Ottawa. At the Hogs Back Dam, the Rideau River and the Rideau Canal diverge and follow separate paths through the urban portion of the City of Ottawa. The Rideau Canal follows a more westerly route through the City of Ottawa and transcends a series of locks immediately east of Parliament Hill to the Ottawa River. The Rideau River follows the natural course of the River and at its mouth it drops 10 meters into the Ottawa River at Rideau Falls approximately 1.5 km north of the Rideau Canal entrance to the Ottawa River. Major control structures within the Lower Rideau region are the Long Island Lock and Dam, Black Rapids Lock and Dam, Hogsback Locks, Hartwell Locks and Ottawa Locks. There are also several structures on the Jock River. The major control structures are presented on Figure 1.3-2.

Major Tributaries of the Rideau River

The major rivers that are tributary to the Rideau include (from upstream to downstream): the Tay River, Irish Creek, Kemptville Creek, Steven's Creek and the Jock River. The physical characteristics of the major tributaries on the Rideau River are given in Table 1.3-7.

The Tay River drains the western portion of the Rideau Watershed. It flows from its headwaters at Carnahan Lake through Long Lake via Fish Creek into Bobs Lake, a major storage reservoir on the Rideau Canal. Bobs Lake also receives flow from Eagle Lake and Crow Lake. From Bobs Lake, the Tay River flows northeasterly through Christie Lake till the confluence with Grants Creek at Perth. Grants Creek flows through Pike Lake and Crosby Lake upstream. Below Perth, the Tay River flows easterly into Lower Rideau Lake.

Irish Creek drains an area south of the Rideau River between Merrickville and Kilmarnock. It starts at Bellamy Pond and flows into Irish Lake and then northerly into the Rideau River at the Village of Jasper.

Kemptville Creek is located in the eastern portion of the watershed. It has two main branches. The south branch runs from Mud Lake to the hamlet of Garretton. The north branch originates at Atkin Lake, and flows through Cranberry Lake toward the confluence with the south branch between the hamlets of Bishop's Mills and Patterson's Corners. From here it runs in one unified channel northerly through Oxford Mills where it has been dammed. From the Oxford Mills Dam, Kemptville Creek flows northerly through the former Town of Kemptville and ultimately discharges into the Rideau River just downstream of Beckett's Landing.

Steven's Creek drains an area west of the Rideau River between Burritts Rapids and Manotick. It starts approximately 6 km north of Burritts Rapids and flows through North Gower and then east into the Rideau River at the Village of Kars.

The headwaters of the Jock River are located in a swampy area near the hamlet of Franktown. It flows northerly to Ashton and then easterly to south of Richmond. Along this reach Kings Creek and Nichols Creek flow into the Jock River. It then flows northeasterly through Richmond and bends east before discharging into the Rideau River at Jockvale just downstream from Manotick.

Major Lakes on the Rideau River

The principal flow control point on the Rideau Canal is at Poonamalie, which regulates levels in the Big Rideau and Lower Rideau Lakes, and regulates flow to the downstream reaches. Upstream of Poonamalie (drainage area 1,249 km^2), the canal system is formed by a series of large navigation lakes, joined by short canal sections. Big Rideau and Upper Rideau Lakes are the main navigation lakes. These lakes comprise the main route from Newboro to Poonamalie.

Wolfe Lake and Bobs Lake are the main reservoir lakes. They are controlled to augment flows downstream. Christie Lake is located downstream of Bobs Lake which has a significant surface area and no control structure. The outflow of the Tay River from Christie Lake is regulated by the flow within the Tay River / Tay Canal. The Tay Marsh also provides some storage to the Canal. The physical characteristics of the major lakes on the Rideau River are given in Table 1.3-8.

Major Water Control Structures on the Rideau River / Canal

The primary purpose of the Rideau Canal is for recreational navigation. Secondary benefits include hydroelectric power generation, lake and river recreation, tours, flood abatement and control of flows and water levels in wetlands. Flows and levels in the Rideau Canal are regulated by dams, navigation locks, and hydroelectric power generating stations. These structures are operated by the Canadian Parks Service (CPS) and Ministry of Natural Resources (MNR).

Downstream of Poonamalie (drainage area 2,600 km^2), storage in the river channel reaches represents about 11% of the storage in the entire Rideau Canal system. Any available storage is used for navigation in the canal. Here the river is effectively unregulated by lake storage and is regulated by a series of control dams and locks.

The MNR operates three control structures in the Rideau River basin including Eagle Lake, Pike Lake, and Oxford Mills. All three MNR structures are regulated for recreation, low flow augmentation, and/or flood control. RVCA operates two dams and three storage weirs in the Rideau River basin. The Motts Mills Dam and the Ashton Dam are owned by Beckwith Township and former Goulbourn Township (currently within the amalgamated City of Ottawa). The Richmond and Heart's Desire weirs are operated for fire protection and summer aesthetics plus recreation at Heart's Desire. The Bellamy Pond weir controls Bellamy Lakes in the headwaters of Irish Creek. Control structures operated by MNR and RVCA do not have a significant effect on the overall management of the Rideau Canal system.

There are three hydroelectric generating stations in the Rideau River basin. The stations are located at Smiths Falls, Merrickville, and Rideau Falls. The Rideau Falls generating station is located on the Rideau River at the outlet, not on the Canal.

The major water control structures on the Rideau River are listed in Table 1.3-9 and presented on Figure 1.3-2.

1.3.1.4 Ottawa River Tributaries

The Carp River Watershed, which is the largest of the smaller water courses, and several small streams drain directly into the Ottawa River within the MRSPR. The smaller streams include Constance Creek, Still Water Creek, Pinecrest Creek, Shirley's Brook, Watts Creek, Green Creek and Bilberry Creek. The total area drainage area to these streams is 672 km^2.

The Carp River has a drainage area of 300 km^2. The Carp River drops 48.8 m over 45.8 km for an average slope of 0.1%. The Carp River flows north-west from Stittsville through development in Kanata and farmers fields to Kinburn. At Kinburn it bends towards the north and flows towards Fitzroy Harbour. Downstream of Chats Lake the Carp River discharges to the Ottawa River at Fitzroy Harbour.

1.3.1.5 Surface Water Gauges

Surface water gauges collect water level data and stream flow data on rivers, creeks, and lakes. Level data is typically collected on lakes and reservoirs. Flows are collected where rating curves have been established on rivers and creeks. Surface water gauges are operated by a division of EC called WSC, Parks Canada, the CAs, the City of Ottawa and several private companies. Gauge locations are shown on Figure 1.3-3.

<u>Mississippi River Gauges</u>

In the Mississippi Valley, surface water gauges are operated by both WSC and MVC. There is also a gauge operated at the power generating station at High Falls by the power generating facility. WSC has eight active flow gauges plus four historic gauges. MVC has eleven active gauge locations. Gauges in the Mississippi Watershed are listed in Table 1.3-10.

<u>Rideau River Gauges</u>

In the Rideau Valley, surface water gauges are owned and operated by WSC, RVCA, Parks, Ontario Hydro, MOE/MNR, City of Ottawa, and OMYA Inc. (private company).

WSC has four active flow gauges, RVCA has one active flow gauge and OMYA owns and operates their own stream flow gauge (installed in 2003 to monitor its water takings from the Tay River). Flow data is collected by both OMYA and RVCA. Parks Canada operates nine gauges on the Rideau Canal and on lakes within the Rideau Watershed to assist with controlling levels on the Canal. Some of the historic hydrometric data (HYDAT) from these sites is available as many of these gauges (Parks) were formerly owned and operated by WSC. There are five historic surface water gauges in the Rideau Watershed. Gauges in the Rideau Watershed are listed in Table 1.3-11.

Ottawa River Gauges

WSC own and operate six surface water gauges on the Ottawa River and some of its tributaries within the jurisdiction of MVC and RVCA and outside the boundaries of the Mississippi and Rideau River Watersheds. The gauge on Sawmill Creek is a historic WSC gauge that was recently reinstated by the City of Ottawa. These gauges are listed in Table 1.3-12.

Limitations

The largest data gap is the lack of stream flow gauges representing the lower Mississippi River. There are no stream flow gauges on or near the outlet of the Mississippi River. The most downstream gauge is at Appleton, which is approximately 1/4 of the way up the River. Flows in the downstream reach are a major data gap. The Rideau River has the same issue but to a lesser degree. In terms of data at the 14 existing gauges, only 5 have 30 years of complete data (between 1974-2003). The remaining 11 gauges have gaps in data, particularly on the Tay River, where one of the largest water users (OMYA) exists in the Rideau River basin. This flow gauge only has 7 years of data. The missing data is summarized in Table 1.3-13. Data gaps are discussed in more detail in Section 1.8 and Appendix 2.

1.3.2 Groundwater and Hydrogeology

1.3.2.1 Background Studies

The following background studies relating to groundwater and hydrogeology have been conducted within the MRSPR.

- Water Resources Study – City of Kanata Rural Area (1994)
- Town of Kemptville – Municipal Well Head Protection Study (2000)
- Village of Merrickville-Wolford – Municipal Groundwater Management Study (2000)
- Preliminary Evaluation of Relative Aquifer Vulnerability – City of Ottawa (2001)
- United Counties of Leeds & Grenville – Groundwater Management Study (2001)
- Preliminary Groundwater Study – Village of Westport (2003)

- Renfrew County – Mississippi – Rideau Groundwater Study (2003)
- Water & Wastewater Alternative Servicing Solutions Study, Village of Cumberland (2003)
- Wellhead Protection Area Study – Almonte (2003)
- Wellhead Protection Study – Carp Communal Wells, City of Ottawa (2003)
- Wellhead Protection Study – Munster Hamlet and Kings Park Communal Wells, City of Ottawa (2003)
- Carp Road Corridor Groundwater Study (2004)
- Preliminary Wellhead Protection Area Study – Village of Westport (2004)
- Rural Wastewater Management Study – City of Ottawa (2004)
- Hydrogeological Evaluation of Municipal Water Supply – Village of Lanark Water Supply Study (2005)
- Village of North Gower Groundwater Study (2005)
- Vulnerability Pilot Study – Almonte Municipal Supply Wells (2005)
- Groundwater Use Characterization of the Heart's Desire Community, Ottawa, Ontario (2006)
- Village of Constance Bay Groundwater Study (2006)

Summaries of these reports are presented in Appendix 1. In addition, a detailed list of recommendations associated with the various reports is also presented in Appendix 1.

1.3.2.2 Importance of Groundwater Supplies

There are twelve municipal drinking water supplies within the MRSPR. Five of these obtain water from a surface water supply and seven are groundwater supplies. Aside from the City of Ottawa municipal supplies (two surface water and three groundwater supplies) groundwater accounts for approximately 63% of the drinking water supply within the MRSPR. Of the groundwater supplies, approximately 15% is attributed to the 4 municipal well systems while the remaining 85% is attributed to private domestic wells. Where bedrock aquifers supply groundwater, approximately 95% is for domestic water supplies and approximately 5% are used for other (i.e., municipal, commercial, industrial, institutional, etc.) water supplies. Where unconsolidated overburden deposits are used to supply water, approximately 90% is domestic and 10% for other purposes. Therefore, an understanding of the groundwater flow system is an important step in protecting the water resources.

1.3.2.3 Groundwater Flow

<u>Groundwater Flow Principles</u>

Groundwater flows through the interconnected spaces within the overburden soil (pores) and bedrock units (fractures). The relative ease that groundwater can flow through soil or rock is dependent on the porosity (size of pore spaces, opening size and density of fractures) and the permeability (measure of how well the pores or fractures are connected). Aquifers, which typically consist of gravel, sand, or fractured rocks such as sandstone/dolostone/limestone/granite, can be highly permeable (relatively large hydraulic conductivity value) and water can move through the spaces. Where they yield an adequate quantity of water, these units are most commonly used for both municipal and domestic water supply. Conversely, aquitards typically consist of clay, silt, and unfractured bedrock (limestone/shale/granite), and have a relatively low permeability (low hydraulic conductivity value) associated with them. These units are not commonly usable for water supply, however they offer protection to underlying aquifers from potential contaminant sources that originate at ground surface. Water flow direction within low permeability aquitard units is conceptualized as vertically downward, while water flow though permeable aquifer units is conceptualized as horizontal in the direction of groundwater flow.

Regional groundwater flow within the overburden and bedrock is driven by a pressure gradient influenced by the difference in relative elevations (component of hydraulic head) across the aquifer. Superimposed on this regional flow system are local flow systems driven by local changes in relative elevation, local geology, groundwater extractions (wells pumping), and surface water features (lakes, streams, wetlands, etc.).

Overall, the confidence in the flow directions is relatively high on a regional scale. The potential sources of errors will become more of a concern in areas where data is sparse such as in the western portion of the MRSPR, or if this data was used to predict groundwater elevations on a local scale. Data limitations and gaps are discussed in more detail in Section 1.8.

Similarly, the source of error associated with determining groundwater elevations for both shallow and deep aquifers using these methods is carried through into the delineation of potential recharge and discharge features. These maps should only be used as a general regional interpretation and should not be relied on for local conditions.

Shallow and Deep Groundwater Flow Systems

Figures 1.3-4 and 1.3-5 detail the regional distribution of annual shallow groundwater elevations and annual deep potentiometric surface elevations, respectively. These maps were modified from the Regional Groundwater Study (Golder et al., 2003) and are based on the well completion details and static water levels in the MOE well records. The shallow water table elevation map (Figure 1.3-4) is an interpolated surface (kriged) using a combination of surface water elevations plus static water level data from wells that were completed to depths less than 15 meters below ground surface (mbgs). The deep potentiometric surface elevation map (Figure 1.3-5) used the static water level data from wells that were completed to depths greater than 30 mbgs.

The locations and average static groundwater level of all PGMN wells within the MRSPR that have been continuously monitored with a data logger since 2003 are plotted on Figures 1.3-4 and 1.3-5. As can be seen in these regional figures, the three-year average static water levels at these locations support the regional groundwater flow directions shown.

Overall, both maps show a similar distribution of groundwater pressures (elevations) that indicate regional groundwater flow patterns which are a subdued representation of the topography and are heavily influenced by the elevation of surface water bodies (lakes, rivers, streams, etc.). The highest groundwater elevations (greater than 375 masl) are located in the southwestern portion of the MRSPR in the municipality of Addington Highlands, and the lowest (approximately 50 masl) are located along the northern portion of the MRSPR near the Ottawa River. The similarity between these two maps is expected since both maps are controlled by topography (water level measurements from ground surface) and the fact that many of the water elevation readings likely incorporate open bedrock boreholes which may connect the shallow and deep bedrock fracture zones.

The data limitations associated with the MOE water well records lower the confidence with the water elevation maps. These limitations, which include: inaccurate ground surface elevations, inaccurate water level measurements, blended groundwater pressures in open fractured rock boreholes, etc., are discussed in greater detail in Section 1.8. Therefore, any maps which are based on water elevations from MOE well records are only useful at a regional scale and should not be deemed to be accurate at a local scale.

Regional Groundwater Flow Direction and Hydraulic Gradients

Regional groundwater flows vary depending on position within the MRSPR, with water generally flowing from the highland areas to the larger surface water features (Ottawa River, St. Lawrence River) in Eastern Ontario. Figure 1.3-5 shows a general breakdown of interpreted regional groundwater flow directions, including:

- Addington Highlands the groundwater flow is generally from north to south,
- Frontenac County groundwater flow is generally from northwest to southeast,
- in the majority of the MRSPR (Lanark County, northern portion of United Counties of Leeds and Grenville, and the southern portion of the City of Ottawa) the flow direction is to the east, and
- in the northern portion of the City of Ottawa near the Ottawa River the groundwater flow direction is towards the Ottawa River.

Regional horizontal hydraulic gradients vary throughout the MRSPR however they are generally below 0.01 m/m. The lower range of values is in the flat lying Smiths Falls Limestone Plain between the Village of Lanark and Merrickville (0.001 m/m) while the higher range of values is in the steep sections within the Algonquin Highland area (0.006 m/m). The data is not sufficiently detailed to accurately calculate vertical hydraulic gradients at a local scale. However, “potential” recharge and discharge areas can be delineated based on vertical differences in hydraulic head measurements as discussed below.

Deep groundwater flow within the Nepean sandstone unit is conceptualized as flowing east-northeast across the boundary with SNC. Further detail regarding the Nepean sandstone aquifer is presented below in Section 1.3.2.5.

Local Groundwater Flow

Local groundwater flows are influenced by local topography and generally flow from higher elevations towards the surface water features in low lying areas (Mississippi River, Rideau River, major lakes, etc.) as shown in Figure 1.3-5. Local variation in geology also influences groundwater flow where groundwater connection is typically through the higher permeability units.

The depositional processes that formed the sedimentary bedrock units generally result in both horizontal and vertical fractures as opposed to the Precambrian bedrock where vertical fracturing is assumed to be predominant. Therefore, all bedrock units are conceptualized to be hydraulically connected through fracture networks, however the presence of less fractured and lower permeable bedrock layers may result in local flow barriers. Faults created in bedrock units as a result of tectonic activity may further complicate the local groundwater flow patterns. The vertical shifting of bedrock units along a fault may result in a highly permeable bedrock unit to abruptly end at a fault and be adjacent to a low permeability unit. In addition, faults can become less permeable due to the precipitation of calcite and other minerals, however, they may also increase the permeability near the fault location due to increased fracturing. Therefore, the orientation of the local fracture and joint structural pattern can greatly influence the groundwater fracture flow pattern.

Likewise, overburden aquifers are considered to be well connected except where low permeability materials (clay, silt) impede groundwater flow.

Groundwater Recharge and Discharge

Near the ground surface, the vertical direction groundwater flow becomes important in DWSP planning because areas where the dominant direction of groundwater flow is downward can provide a pathway, for contaminants that originate at the ground surface, into the underlying aquifers. These areas are considered to be under “recharge” conditions and typically exist on topographic high elevations or where a permeable surficial sand cover exists which allows the precipitation to infiltrate into the deeper groundwater aquifers. Although surface water features are typically associated with discharge features, surface water features sometimes recharge the underlying groundwater flow systems where surface water bodies are situated on top of higher permeability bedrock formations (i.e., Mississippi Lake on top of Nepean Sandstone).

Conversely, areas where the dominant vertical groundwater flow direction is upwards provide a level of protection to the underlying aquifers. These areas are considered to be under "discharge" conditions and typically exist in low lying areas and are a significant source of water for wetlands and some lakes, streams and rivers.

It is important to recognize the difference between the confined and unconfined groundwater flow systems, whereby the shallow recharge areas may not actually recharge the deeper confined aquifer. Therefore, different approaches to define significant recharge areas for shallow groundwater flow systems and deeper groundwater flow systems are warranted. The MOE (1995) approach to calculate recharge rates based on topography, soil permeability and land cover was used to define significant recharge areas for the shallow groundwater flow system. A very detailed discussion of this methodology and how it has been applied to the MRSPR for water budgeting purposes is included in the MRSPR Conceptual Water Budget Report (Proposed MRSPR, 2007). Deeper, confined aquifer recharge areas are defined in a more conceptual discussion below.

Within the MRSPR, confined aquifers exist where sand and gravel aquifers exist below a surficial clay layer such as in the northern portion of the MRSPR, and where the Nepean Sandstone aquifer is covered by lower permeability bedrock units (i.e., limestone, dolostone), in the central and east portions of the MRSPR, east of Carleton Place. In these areas, groundwater is likely recharged partially from the overlying units but also from unconfined aquifers that are hydraulically connected to the confined aquifer. For example, the water recharging the deeper confined Nepean aquifer for the Merrickville and Kemptville municipal supplies is conceptualized to partially originate a significant distance west of these communities where the Nepean aquifer outcrops (Figure 1.2-4). Similarly, where a low permeability surficial soil (i.e., clay) is covering a deeper aquifer material (i.e., sand), the recharge area for this sand aquifer is conceptualized to largely come from "windows" in the overlying confining layer and from areas further away where the confining layer does not exist. Although conceptualizing confined and unconfined aquifers attempts to simplify the understanding of groundwater recharge and discharge areas, more complicated situations exist involving multiple aquifers as well as the more common and perhaps more realistic conceptualization involving leaky aquitards and semi-confined zones.

Another method for determining recharge areas is to look at vertical gradients. Figure 1.3-6 shows interpreted areas of potential recharge and discharge as determined by Golder et al. (2003). Potential recharge conditions were assumed to exist in those areas where the potentiometric groundwater elevation in deep wells (Figure 1.3-5) is at least 5 m lower compared to the shallow water table elevation (Figure 1.3-4), therefore indicating a high possibility that a downward gradient may exist. Similarly, potential discharge conditions were assumed to exist in those areas where the deep potentiometric elevation (Figure 1.3-5) is at least 5 m greater than the shallow water table elevation (Figure 1.3-4), therefore indicating a high possibility that an upward gradient may exist.

Although this approach is useful for identifying potential recharge and discharge areas at a regional scale, there are two limitations identified with it:

- This approach assumes that the deep wells are connected to the unconfined aquifer, where it is common that confined wells or deep bedrock wells are not hydraulically connected; and
- By looking at the distribution of vertical gradients without taking into account the geologic structure and hydraulic conductivity of the material lying in the unsaturated zone, the areas identified in Figure 1.3-6 cannot be considered more than "potential" recharge and discharge areas.

Another indication of groundwater discharge features is evident in Figure 1.3-5 along the Mississippi River near Almonte and Appleton where groundwater flows in a northeasterly direction on the south side of the river and also flows in a southwesterly direction on the north side of the river. This essentially shows that this section of the Mississippi River is a sink for local groundwater and is therefore a local groundwater discharge feature. Similarly in Figure 1.3-5, several isolated high groundwater elevations with numerous accurately located groundwater wells, such as immediately north of Carp along the Carp Ridge as well as near and east of Plevna, show that water flows in all directions, therefore indicating a source to groundwater or "recharge" area.

As expected, the areas of potential recharge generally correspond with topographically high areas in the western and northern portions of the MRSPR. Similarly, the discharge areas typically correspond to low lying river valleys such as the Mississippi and Rideau as also shown by the locations of flowing well conditions. Although the distribution of recharge and discharge areas is variable within the western portion of the MRSPR where Precambrian bedrock outcrops, it corresponds to the highly variable ground surface elevations within this area.

Significant areas of groundwater recharge will be defined during the Tier 1 Water Budget for the MRSPR. The scale of the Tier 1 Water Budget is on a monthly basis and will be completed for each subwatershed.

<u>Depth to Water Table</u>

Generally speaking, domestic water wells draw groundwater from the shallowest available aquifer that produces sufficient quantity and quality of groundwater for consumption purposes; therefore, shallow wells are preferred by a residential well owner primarily from an economic perspective. In some cases, domestic water wells are drilled in areas where the bedrock is less fractured and/or where the fractures are more vertical, making them more difficult to intersect and use as a water supply. In these environments, typical where Precambrian bedrock outcrops, domestic wells tend to be deeper in an effort to access a sufficient water supply. Figure 1.3-7 shows the depth to the water table across the MRSPR. The depth to water generally ranges from 0 mbgs near surface water features to greater than 15 m in the highest topographic regions in the western portion of the MRSPR.

As discussed above, the local scale accuracy associated with Figure 1.3-7 is low. Therefore this map should only be used as a general regional interpretation and should not be relied on for local conditions. The large depth to water associated with the highest topographic regions is at least partly a function of the sparse dataset in this area and therefore the depths presented in this figure are not considered to be as realistic as those in the lower topographic areas where there are more wells. Hydrogeologic information from wells drilled in this area is a significant data gap, therefore further site specific information is needed to increase the confidence in this data. Data gaps are discussed in more detail in Section 1.8 and Appendix 2.

1.3.2.4 Hydrogeology

The hydrogeology of the MRSPR is conceptualized as consisting of 12 hydrostratigraphic units shown in Table 1.3-14.

The three regional bedrock aquitards listed in Table 1.3-14 (hydrostratigraphic units # 9, 10, and 11) are essentially the same units as the equivalent bedrock aquifers (hydrostratigraphic units #1, 3, and 4 respectively) with the exception that reduced permeability exists due to: a decrease in fracture density with depth (unit #9 vs. #1); a decreased sandstone content (unit #10 vs. #3, and unit #11 vs. #4).

Appendix 3 summarizes the best estimates for bedrock and overburden hydraulic properties (hydraulic conductivity and porosity values) for each hydrostratigraphic unit. These values are considered best estimates because they are solely based on either calculated values from field hydraulic testing studies, or integrated groundwater flow modeling assessments which, in their development, compile numerous data sources, use professional judgment and result in a single value that best calibrates the flow model taking into account various other hydrogeologic conditions. Also listed in this table is the source of the data, an estimate of unit thicknesses, and a comment on the suitability of the hydrostratigraphic unit as an aquifer or aquitard.

Figure 1.3-8 shows the conceptual distribution of water taking from each aquifer unit described above. To generate this conceptual understanding, the lowest hydrostratigraphic unit that the well intersects as described in the MOE well records or golden spike information was plotted as point data. The interpreted extent of each water supply hydrostratigraphic unit was constructed by drawing a boundary around clusters of MOE well records which were assumed to draw water from similar aquifers. This map is an approximation of aquifer usage based on reported geology within MOE water well records. Although variations in bedrock description are evident in the MOE well records database, a general trend of bedrock formations pumped correlates with the limits of the shallowest aquifer of choice. Figures 1.3-8a, 1.3-8b and 1.3-8c show the overburden, shallow bedrock and deep bedrock wells, respectively and their corresponding hydrostratigraphic unit.

Generally, domestic groundwater supply is obtained from the following aquifers:

- the western portion of the MRSPR uses the unconfined Upper Precambrian Bedrock aquifer,
- the central portion uses the unconfined Nepean Sandstone, confined Nepean Sandstone and the unconfined Oxford-March aquifers,
- the north and extreme east portions use a mixture of unconfined and confined overburden (sand and gravel) and bedrock (limestone and shale) aquifers.

Municipal Groundwater Supply Aquifer and Aquitard Distribution

Due to the high sustainable yield of high quality potable groundwater found within the Nepean sandstone aquifer, it is targeted by six of the seven municipal groundwater systems (Almonte, Munster, King's Park – Richmond, Merrickville, Kemptville and Westport). Only Carp extracts groundwater from a different aquifer (overburden sand and gravel esker deposit) due to the sufficiently high volume and quality groundwater found within this local deposit.

Figure 1.3-9 presents a summary of detailed hydrogeological studies within the MRSPR. Figures 1.2-7 through 1.2-11 show conceptual hydrogeologic cross sections views through the various municipal waster supplies in the MRSPR. The location of each cross section view is indicated on Figure 1.3-9. The locations of the hydrogeologic cross sections are detailed as follows:

- Conceptual Hydrogeologic Cross Section D-D' – Carp Municipal Well;
- Conceptual Hydrogeologic Cross Section E-E' – Almonte Municipal Well;
- Conceptual Hydrogeologic Cross Section F-F' – King's Park – Munster Municipal Well;
- Conceptual Hydrogeologic Cross Section G-G' – Westport Municipal Well; and
- Conceptual Hydrogeologic Cross Section H-H' – Merrickville - Kemptville Municipal Well.

1.3.2.5 Bedrock Aquifers and Aquitards

The MRSPR contains a mixture of confined and unconfined aquifers. Sometimes there is both a shallow and deep aquifer such as in the central portion of the MRSPR where the overlying Oxford-March Formations provide a shallow unconfined water supply and the underlying Nepean Sandstone provides a deeper confined water supply.

The bedrock units within the MRSPR that provide a sufficient quantity and quality of water for consumption purposes can be generally categorized into five groups:

Precambrian Aquifer, Nepean Formation Sandstone Aquifer, Oxford and March Formation Dolostone Aquifer, the Ottawa Group Limestone and Shale Aquifer and a Lithology-Independent Upper (Weathered) Bedrock Aquifer. Three of these units (Lower Precambrian Aquitard, Oxford and March Formation Dolostone Aquitard, and Ottawa Group Limestone and Shale Aquitard), with elevated shale content or a decreased fracture density with depth, can also be conceptualized as regional aquitards.

Groundwater flow in bedrock aquifers is dominated by flow through the existing fracture network (i.e., secondary porosity) with a much smaller component through the rock matrix (primary porosity). The bulk porosity can be estimated by taking into account the fracture density and spacing (secondary porosity) as well as the matrix porosity (primary porosity), and is frequently used as a simplistic method of conceptualizing the bedrock as a homogeneous unit. As such, the capacity of the bedrock aquifer to supply water is dependent on the connectivity of these fracture networks and the bulk porosity estimate. If the fracture networks are well connected and remain saturated, the well will yield a large flow of water (large specific yield / storage capacity). Conversely, if the fracture networks are not well connected, even though they may be saturated, a well will have a poor specific yield (low storage capacity).

The yield of an aquifer is largely dependent on the storage capacity. Therefore, bedrock aquifers with a small storage (i.e., generally fractured Precambrian bedrock) will only be able to supply a sufficient quantity of groundwater to widely spaced and low demand end users (i.e., rural domestic wells) as compared to bedrock aquifers with a large storage capacity (i.e., fractured Nepean sandstone bedrock) which is able to supply a sufficient quantity of groundwater to more closely spaced and high demand users (i.e., municipal water supply systems). However, there are several Precambrian bedrock types such as calcitic / dolomitic marbles and quartzite which may supply sufficient quantity of water to be considered bedrock aquifers for municipal systems (i.e., marble aquifer near Lanark which is proposed as a future municipal supply). The MRSPR Conceptual Water Budget report (Proposed MRSPR, 2007) provides a more detailed discussion about the implications of low storage and how this has the potential to cause water quantity issues over the short term for groundwater supplies.

Due to the random distribution of fractures and their connectivity, groundwater yield of a well completed in fractured bedrock is highly variable and dependent on the number of fractures encountered by the well. Therefore, the bedrock units that have the lowest bulk porosity are generally only useful as aquifers near fault zones or near the ground surface where a sufficient density of fractures exist to provide an adequate yield of water. For the purpose of this discussion, the term yield refers to the adequacy of the aquifer to produce a sufficient quantity of water for typical domestic purposes (i.e. able to sustain approximately 8-12 L/min and be stressed on the order of approximately 350 L/household/day or 175 L/person/day). As such, yield is described as “poor”, “adequate” or “good”.

Upper Precambrian Aquifer / Lower Precambrian Aquitard

The Upper Precambrian aquifer comprises the Precambrian bedrock units that are within approximately 50 m below ground surface. This section of Precambrian bedrock is generally more fractured than the deeper, buried portions of the Precambrian Shield and therefore is conceptualized as a local domestic water supply aquifer where other suitable water supply aquifers do not exist. Below this depth, the Precambrian bedrock is conceptualized as a regional aquitard due to the lower density of fracturing and low matrix (primary) porosity. The reported yields from the Upper Precambrian Aquifer range between 25 to 90 L/min with an average yield of 36 L/min (Golder et al., 2003). Typical water quality is good with moderate total dissolved solids (TDS) and high iron concentrations occasionally reported, however the taste is reported as very good.

Figures 1.3-8, 1.3-8b and 1.3-8c show that the majority of domestic wells that draw potable groundwater from this aquifer are located within the area delineated by Precambrian bedrock outcrops in the western half of the MRSPR. In addition, a small pocket of wells located within the City of Ottawa, in close proximity to the Carp Ridge (near Carp, Kinburn, Galetta, Fitzroy Harbour and Dunrobin) also draw water from this local aquifer.

Groundwater flow within the Precambrian aquifer is generally within the fracture network (secondary porosity). Due to spatially variable fracture densities, the range of hydraulic conductivity values for fractured igneous and metamorphic bedrock is approximately 10^{-8} to 10^{-4} m/s (Freeze and Cherry, 1979). The best estimate of hydraulic conductivity of the Upper Precambrian Aquifer is approximately $1x10^{-7}$ m/s with a bulk porosity value of 0.01 (Appendix 3). Similarly, the best estimate of hydraulic conductivity of the Lower Precambrian Aquitard is approximately $1x10^{-8}$ m/s with a bulk porosity value of 0.01. Bulk porosity takes into account primary (0.00001) and secondary porosity (0.01). It was calculated for use in numerical modeling assuming a porous media approach which incorporates a regional best estimate value.

Sandstone Aquifer (Nepean Formation)

The Sandstone aquifer primarily comprises the Nepean Formation unit with some contribution from the sandstone layers within the lower portion of the March Formation. In addition, the Covey Hill Formation, where it exists, is considered part of this aquifer unit, however it is very thin and generally not mapped in the MRSPR. The top and bottom sections of this aquifer yield the most water due to a higher number of fractures at the transition zones with the adjacent bedrock units (Raven Beck, 1994A; Brandon, 1960).

The Sandstone aquifer unit is the most desirable aquifer from a quantity and quality perspective within Eastern Ontario. It provides the highest sustainable yield of high quality potable groundwater and is therefore targeted by large commercial and municipal systems. In addition, where this bedrock unit exists within an economical depth, it is targeted by residential well drillers for domestic supply. The reported yields from the Sandstone aquifer range between 150 to 630 L/min with an average yield of 54 L/min (Golder et al., 2003). Typically, water quality from the Sandstone aquifer is reported to be good.

Figures 1.3-8, 1.3-8b and 1.3-8c show that the majority of domestic wells that draw potable groundwater from this aquifer are located within the central portion of the MRSPR where the Nepean Sandstone is generally within 40 m of ground surface. This area encompasses the Eastern portion of Lanark County; more specifically, the area east of Westport and Perth, south of Almonte and west of Merrickville. A small pocket of wells located within the City of Ottawa also draw water from this local aquifer as shown in Figures 1.3-8, 1.3-8b and 1.3-8c. In addition, with the exception of Carp, all of the municipal groundwater supply wells within the MRSPR (Almonte, Kemptville, King's Park – Richmond, Merrickville, Munster, and Westport) draw water from the Nepean Sandstone aquifer.

Although the hydraulic conductivity values associated with the Sandstone aquifer vary depending on fracture density, the matrix porosity (primary porosity) is high and therefore contributes some of the groundwater yield. This results in a more homogeneous (less variable) permeability throughout the region. Based on calibrated numerical groundwater modeling studies and field hydraulic testing of the Nepean Sandstone aquifer, the best estimate of hydraulic conductivity is approximately $1x10^{-4}$ m/s with a bulk porosity value of 0.05 (Appendix 3).

Dolostone Aquifer and Aquitard (Oxford/March Formations)

The Dolostone aquifer comprises the dolostone bedrock of the March and Oxford Formations with the inclusion of various sandstone or shale interbeds. This hydrostratigraphic unit is the most widely used bedrock aquifer for domestic well supplies due to providing adequate yields, potable water quality and the fact that it is shallower compared to the Sandstone aquifer and therefore less costly to install a well.

Groundwater flow within the Dolostone aquifer is generally within the fracture network (secondary porosity) and the dissolution of calcite and dolomite along fractures by groundwater can lead to increased permeability. Therefore, this aquifer unit is conceptualized as a regional domestic water supply aquifer.

Due to the presence of sandstone interbeds, the March Formation tends to yield more water compared to the Oxford Formation where shale interbeds exist. Generally, the Oxford Formation is only sufficiently fractured to be used as a domestic supply where it is near the ground surface and weathered. Therefore, if the fracture density is low or the fractures are not well connected, and numerous shale interbeds exist, this bedrock unit can also be conceptualized as a regional aquitard. The reported yields from the

Dolostone aquifer range between 45 to 680 L/min with an average yield of 42 L/min (Golder et al., 2003).

Figures 1.3-8, 1.3-8b and 1.3-8c show that the majority of domestic wells that draw potable groundwater from this aquifer are located within the majority of the northern and eastern portions of the MRSPR (United Counties of Leeds and Grenville and City of Ottawa) where the Nepean Sandstone is generally greater than 40 mbgs and sufficient overburden deposits do not exist, as shown in Figure 1.3-8.

Due to spatially variable fracture densities, the range of hydraulic conductivity values for the fractured Dolostone bedrock aquifer is approximately 10^{-10} to 10^{-4} m/s (GRI, 1979). Based on calibrated numerical groundwater modeling studies and field hydraulic testing of the Dolostone aquifer, the best estimate of hydraulic conductivity is approximately $1x10^{-6}$ m/s with a bulk porosity value of 0.05 (Appendix 3).

<u>Limestone / Shale Aquifer and Aquitard (Rockcliffe / Shadow Lake / Gull River / Bobcaygeon / Verulam / Lindsay / Eastview / Billings / Carlsbad Formations)</u>

The Limestone and Shale aquifer units comprise a multitude of bedrock formations including everything above the Oxford Formation Dolostone (Ottawa Group plus Rockcliffe, Eastview, Billings and Carlsbad Formations). These bedrock units are grouped together as one hydrostratigraphic unit because they all provide poor or marginally moderate yields of potable water for domestic consumption (less than 10 to 15 L/min, Golder et al., 2003) and it is difficult to distinguish between the different units based on groundwater yield. This hydrostratigraphic unit is generally only used for domestic supply in locations where none of the other aquifer units exist at an economical depth (less than 40 m).

Due to the presence of sandstone interbeds or dissolution of fractures, the Rockcliffe, Bobcaygeon, Gull River and Verulam Formations could be conceptualized as a poor domestic supply aquifer. Conversely, the presence of shale content in the Gull River, Verulam, Eastview, Billings and Carlsbad lower the potable water quality and yield from these units which usually offsets the benefits from the sandstone interbeds. Therefore, if the fracture density is low or the fractures are not well connected, and shale interbeds exist, this bedrock unit can also be conceptualized as a regional aquitard.

Figures 1.3-8, 1.3-8b and 1.3-8c shows that the majority of domestic wells that draw potable groundwater from this aquifer are located south of the Ottawa River and east of the City of Ottawa in the City of Clarence-Rockland and the former municipalities of Gloucester and Cumberland (Lindsay Formation) as well as in the former Townships of West Carleton and Goulbourn (Gull River and Verulam Formations). Based on calibrated numerical groundwater modeling studies and field hydraulic testing of the Ottawa Formation Aquifer, the best estimate of hydraulic conductivity is approximately $1x10^{-7}$ m/s with a bulk porosity value of 0.05 (Appendix 3).

Upper Weathered Bedrock Aquifer

The Upper Weathered Bedrock Aquifer comprises the upper 5 to 10 m of weathered bedrock units, independent of lithology and formation. The reason for distinguishing this aquifer from the other hydrostratigraphic units is the fact that regardless of lithology, this bedrock unit is usually highly weathered resulting in a large, uniform flow pathway through the secondary porosity network. This hydrostratigraphic unit is widely used throughout the MRSPR and is conceptualized as a regional domestic water supply aquifer.

Based on calibrated numerical groundwater modeling studies and field hydraulic testing of the Upper Weathered Bedrock Aquifer, the best estimate of hydraulic conductivity is approximately $1x10^{-7}$ m/s with a bulk porosity value of 0.05 (Appendix 3).

Overburden Aquifers and Aquitards

Groundwater flow in overburden aquifers is primarily through the spaces between soil grains (primary porosity) and therefore, by definition, overburden aquifers are delineated by the lateral extent of saturated sand and gravel deposits. Due to the relatively uniform regional depositional environment of overburden deposits, groundwater yield of a well completed in overburden sediments is conceptualized as regionally homogeneous and isotropic, with local variability.

The overburden units within the MRSPR that provide a sufficient quantity and quality of water for consumption purposes can be generally categorized into three groups: Surficial Sand Aquifer, Basal Sand and Gravel Aquifer, and Sand and Gravel Esker Aquifer. In addition, the overburden deposits within the MRSPR that are not capable of providing sufficient quantity of potable water can be grouped together and conceptualized as a Silt, Clay and Clay Till Aquitard. Each of these hydrostratigraphic units is discussed in greater detail below.

The average reported yield from wells completed in overburden aquifers is approximately 53 L/min which likely includes wells from both the Surficial Sand and Basal Sand and Gravel Aquifers (Golder et al., 2003).

Surficial Sand Aquifer

The Surficial Sand Aquifer comprises shallow sand and gravel deposits that are aerially extensive, exposed at surface and generally unconfined. Based on these characteristics, this aquifer is highly vulnerable to surface contamination and is associated with recharge areas. This aquifer ranges in thickness throughout the MRSPR from 3 m to 10 m and the water table is typically within 2 to 5 m below ground surface (Golder et al., 2003). This hydrostratigraphic unit is the most widely used overburden aquifer for domestic well supplies due to the wide distribution of surficial sand deposits formed during glaciofluvial processes. This aquifer unit is conceptualized as a regional domestic water supply aquifer, although well yield may be limited where the aquifer is thin, which reduces the available drawdown in wells. In addition, this surficial sand aquifer is conceptualized to be hydraulically connected to the bedrock aquifer and therefore transmits groundwater to the underlying bedrock where the sand is directly overlying the bedrock. Other sand features associated with outwash fans and sandy drumlins are also conceptualized to transmit water to the deeper bedrock aquifers.

Figures 1.3-8 and 1.3-8a show that the majority of domestic wells that draw potable groundwater from this aquifer are located within a few isolated pockets scattered throughout the study are and within a more continuous surficial sand unit that is located parallel to and south of the Carp Ridge and within the area delineated by the Russell and Prescott Sand Plain physiographic region (eastern portion of the City of Ottawa and around Kemptville). This aquifer unit is more highly utilized east of the MRSPR and within the SNC.

Although the hydraulic conductivity for surficial sand units varied, based on calibrated numerical groundwater modeling studies and field hydraulic testing of the Surficial Sand Aquifer, between $1x10^{-6}$ to 10^{-4} m/s, the best estimate of hydraulic conductivity is approximately $1x10^{-4}$ m/s with a bulk porosity value of 0.3 (Appendix 3). Lower values of hydraulic conductivity are common where the silt content is higher.

Basal Sand and Gravel Aquifer

The Basal Sand and Gravel Aquifer (also known as the Contact Zone Aquifer) comprises coarse-grained unconsolidated deposits (sands, gravels, cobbles, boulders, etc.) that are situated at the overburden/bedrock contact. This hydrostratigraphic unit is conceptualized as being the left over till material after extensive wave action washed away the fine sediments. It is a relatively thin layer (1 to 5 m) that is hydraulically connected to the upper weathered bedrock which it overlies and is more predominant in the eastern portion of the MRSPR where thicker overburden deposits are found.

This hydrostratigraphic unit is not well documented in the MOE well records, likely because the drillers would pass this zone and complete wells into the underlying fractured bedrock units. Therefore, Figure 1.3-8 does not show a delineation for this hydrostratigraphic unit as a water supply aquifer. The reality is that this unit likely supplies water to the shallow fractured bedrock aquifers and therefore this aquifer unit is conceptualized as a highly permeable regional domestic and municipal water supply aquifer.

Although the hydraulic conductivity for the Basal Sand and Gravel Aquifer will vary depending on sediment content, the best estimate of hydraulic conductivity is approximately $2x10^{-4}$ m/s with a bulk porosity value of 0.3 (Appendix 3). Therefore, this aquifer is considered to be more permeable compared to the Surficial Sand Aquifer.

Sand and Gravel Esker Deposit Aquifer

The Sand and Gravel Esker Deposit Aquifer comprises coarse-grained unconsolidated deposits (sands, gravels, cobbles, boulders etc.) that were formed as eskers and glacial outwash fans. This hydrostratigraphic unit is conceptualized as having a very highly permeable central core with a fining outwards to sand and silt. It is difficult to delineate the extent of this hydrostratigraphic unit because it is conceptualized as having an extremely permeable central core with a fining of sediments outwards to sand and silt, which blend in with the Surficial Sand and Basal Sand and Gravel Aquifers. However, esker complexes just east of the MRSPR have been measured to be up to 15 m thick.

Figure 1.2-12 indicates where esker complexes and outwash fans have been mapped by Gorrell (1991), however not many wells are recorded as accessing this aquifer unit. Three such Sand and Gravel Esker Aquifer systems are located within the MRSPR:

- north-south oriented system from the Ottawa airport to east of Kemptville area,
- northwest-southeast oriented system running from Arnprior to Ottawa intersecting Stittsville and Trail Road along the way,
- north-south oriented system running from Kemptville towards the community of Roebuck.

This hydrostratigraphic unit is conceptualized as a highly permeable regional municipal water supply aquifer, therefore, this is a potential source of future drinking water that could be investigated. Multiple municipalities located east of the MRSPR draw their water supplies from similar esker systems such as Vars, Embrun, Winchester, Chesterville and Chrysler.

Although the hydraulic conductivity for the Basal Sand and Gravel Aquifer will vary depending on sand and silt content, the best estimate of hydraulic conductivity is approximately $1x10^{-3}$ m/s for the esker core and $1x10^{-4}$ m/s for the finer esker deposits, with a bulk porosity value of 0.3 (Appendix 3). Personal communication with George Gorrell (2006) indicated that hydraulic conductivity of sand and gravel esker cores can be as high as 10^{-2} m/s or10^{-1} m/s. Therefore, this aquifer is considered to be the most permeable aquifer unit within the MRSPR.

Silt, Clay and Clay Till Aquitard

The Silt, Clay and Clay Till Aquitard comprises both silt and clay aquitards and clay dominated till deposits. These two aquitards are different in the fact that they were formed by different geologic processes, as discussed in Section 1.2.4, however they were grouped into the same hydrostratigraphic unit based on similar hydraulic parameter. In addition, although the hydraulic conductivity for the Silt and Clay will increase with weathering and fracturing of clay near ground surface or increased sand and gravel content of tills due to wave action, they are both conceptualized as a regional aquitard. Although till is mostly conceptualized as a aquitard, till features have also been conceptualized as a local domestic aquifer (i.e. for individual users where a large water supply is not needed) where the sand content is higher resulting in an elevated hydraulic conductivity.

As shown in Figures 1.3-8 and 1.3-8a, silt and clay units exist in the northern and eastern portions of the MRSPR where significant thicknesses of overburden deposits are mapped. This unit acts as a confining layer to underlying basal sand and gravel aquifer deposits and have has been measured up to 50 m in thickness east of the MRSPR. Clay dominated till deposits exist as a thin cover over bedrock or as elevated masses (drumlins) more than 10 m thick, such as near North Gower. Where till units have been exposed at surface they are sometimes weathered and are found as isolated deposits in bedrock depressions.

Due to the local variability of the Silt, Clay and Clay Till Aquitard, the best estimate of hydraulic conductivity of this hydrostratigraphic unit ranges between approximately $1x10^{-7}$ and $1x10^{-9}$ m/s, with an estimated bulk porosity value of 0.3 (Appendix 3).

1.3.3 Surface – Groundwater Interactions

Groundwater and surface water interaction is a highly complicated and potentially variable relationship (both spatially and temporally) that is not well understood in most watersheds. For example, a stream can have both groundwater discharge and groundwater recharge features over a short reach, which depending on seasonal fluctuations in water levels will change throughout the year. Although surface water features are typically associated with discharge features, surface water features may also be associated with recharge features or areas with no net discharge or recharge. For example, the numerous wetlands situated on top of the poorly drained, shallow bedrock area of the Precambrian Shield in the western portion of the MRSPR may recharge the underlying groundwater aquifer and therefore be a source of water for domestic water supplies in the area. On the other hand, these wetlands may not interact with the groundwater significantly and therefore may act as temporary reservoirs. An example where surface water may be recharging the underlying groundwater flow systems is where surface water bodies are situated on top of, or within, permeable bedrock formations (i.e., Mississippi Lake on top of Nepean sandstone). This lack of understanding highlights that recharge and discharge is a complicated process that relies heavily on local site specific information and forms a data gap that should be addressed in future studies. Data gaps are discussed in more detail in Section 1.8 and Appendix 2.

Base-flow monitoring is the component of surface water attributed to groundwater discharge. No long-term base-flow monitoring exists for the MRSPR.

1.3.4 Climate

1.3.4.1 Available Climate Data

Climate data, including precipitation (rain and snow), temperature, and pan evaporation data, has been collected in the MRSPR for over one hundred years. Climate data is collected by the AES division of EC, MVC, RVCA, and the City of Ottawa. The AES climate stations are shown on Figure 1.3-10.

AES Climate Stations

According to the AES climate CD (October 2003), there are 105 climate stations within or nearby the MRSPR (excluding Quebec). Eight of these sites are active and 97 are discontinued. Out of the 8 active sites, 4 are located in MVC, 3 are located in RVCA, and 1 is just outside the MRSPR. Depending on the age of the record, historical data may still be useful where there are large data gaps. A summary of the AES climate stations is given in Table 1.3-15. A list of all 105 AES climate stations can be found in Table 1.3-16.

Selected AES Climate Stations

The climate stations were reviewed to determine stations representative for the further study of the climate in the MRSPR. All climate stations that are still active and are located were selected except for North Gower as it had a very short period of record. In addition, some historic stations were selected. Stations that were more recent and had longer periods of record were selected. Some gauges (i.e., Kemptville and Brockville) have been moved to a different location within the same general area. The periods of record were combined for these stations (i.e., Kemptville – 6104025 and Kemptville CS - 6104027) to form one single station. Selected gauges for study are listed in Table 1.3-17.

MVC and RVCA Rainfall Gauges

MVC collects rain data in heated tipping buckets at all of the eight WSC stream flow gauges in the Mississippi Watershed. Manual gauges are operated by volunteer observers following EC protocol. RVCA collects rain data in tipping buckets at two locations in the Rideau Watershed. The MVC and RVCA rainfall gauges are listed in Table 1.3-18.

City of Ottawa Rainfall Gauges

The City of Ottawa operates 20 rainfall gauges in the Mississippi and Rideau Watersheds within the City limits. There are 19 other gauges that were discontinued in 2001. There is also a radar rainfall site that is not listed. The periods of record for the 20 gauges are given in Table 1.3-19.

Snow Pack Sites

Snow pack data is collected by MVC, RVCA and Parks Canada. MVC operates 14 snow sites in the Mississippi Watershed. There are 11 sites in the Rideau Watershed. RVCA operates five sites below/downstream of Smiths Falls (starting around 1977) and Parks Canada operates six sites above/upstream of Smiths Falls (starting around 1989). Snow depth cores are taken at each site. The snow cores are weighed and the snow water equivalent (SWE) is recorded based on the weight of the snow. SWE data is collected twice per month by the MVC and RVCA (starting on December 1st until the snow is melted) and four times per year by Parks Canada (starting on Feb. 1st until March 15th). Available snow data is listed in Table 1.3-20 and is presented on Figure 1.3-11.

Evaporation Data

Lake and pan evaporation data is only collected at two sites in our Region, both in Rideau Watershed: Ottawa CDA (1962 – 1998) and Kemptville (1968-1995). There is no data available in Mississippi Watershed. The next available site to the west is in Peterborough (1982-1992).

1.3.4.2 Climate Data Summary

Climate in the MRSPR consists of warm summers and cold winters. The topography, which ranges from 360 masl in the Mississippi and 240 masl in the Rideau to between 40 and 80 masl on the Ottawa River, exerts a significant influence over the temperature and precipitation.

The Canadian Hydrological Atlas (1978) provides the following information:

- mean annual precipitation is between 800 and 1,000 mm;
- mean annual snowfall is 200 cm;
- mean annual evapotranspiration is between 500 and 600 mm;
- mean annual runoff is between 200 and 350 mm.

Average precipitation for all active AES climate stations in the MRSPR over the last ten years (1994-2003) is 918 mm per year. Average annual temperature in the Region over the last ten years is 6.3°C. Preliminary analysis on the last 30 years of climate data has been completed to determine a representative station. Drummond Centre climate station was selected as representative for the Mississippi Watershed. The Kemptville AES climate station was chosen for the Rideau Watershed. Table 1.3-21 lists the average total precipitation for each month for both Watersheds using 30 years of continuous climate data. Gaps in Drummond Centre data were in-filled with data from MVC. Gaps in Kemptville data were in-filled with data from Ottawa.

July is recorded as being the wettest and hottest month of the year. February is the driest month. January is the coldest month. Peak stream flows occur in April. This is different than the peak precipitation month, which is July. Peak stream flows are caused by the spring snow melt event. An assessment of low flows is required before further conclusions can be made about the relationship between climate and stream flow. This will be completed with more analysis.

1.3.5 Climatic and Meteorological Trends

Climate change is integral to the current source protection initiatives ongoing with respect to the *Clean Water Act*. DWSP involves activities to keep drinking water sources free of contamination. This will involve the linkage between land use activities and water quality / quantity. Recent projections suggest that Ontario's climate in a hundred years will be different than today. Due to these potential climate change effects, past hydrological regimes may not be appropriate for the future hydrological regimes. As a result of these predicted changes, climate change may influence vulnerable areas, the vulnerability of future drinking water sources, and the quality of water sources that supply drinking water (de Loe and Berg, 2006).

1.4 Naturally Vegetated Areas

Naturally vegetated areas in the MRSPR refer to ecological features that perform various beneficial functions on the landscape and include wetlands, woodlands and riparian areas. For the purpose of the DWSP characterization, wetlands, woodlands and ANSIs have been addressed separately, although in reality they overlap somewhat or are often one in the same feature.

1.4.1 Wetlands

From a DWSP standpoint, wetlands and their surrounding area are known to be important for the control and storage of surface water and the recharge and discharge of groundwater; for maintaining and improving water quality, aiding in flood control and protecting shorelines from erosion; for trapping sediments that would otherwise enter watercourses; for immobilizing some contaminants and nutrients; for reducing other contaminants to less damaging compounds and for assisting in maintaining water quality in adjacent lakes and streams that support fish populations (Brownell, 2006).

A recent wetlands policy paper from the Muskokas (2002) states that wetlands are essential ecosystems. In conjunction with the surrounding land, wetlands create regional hydrological systems that help control surface water flow, purify the water and maintain soil moisture levels. Ninety percent (90%) of wildlife that rely on the wetland also live in the upland area for a portion of their life. Forty percent (40%) of endangered species rely on both the wetland and the surrounding land for all or a portion of their life cycle. Therefore, in order to ensure the continued functioning of wetland environments, consideration must be given to the wetland and the surrounding land as changes are proposed.

The Ontario Wetland Evaluation System (OWES) Southern Manual (1993) notes that there has been, and still is, much debate over the hydrological functions of wetlands (Carter et al., 1978). However, much of the debate is a result of trying to attribute hydrological generalities across all wetlands. It has long been recognized that different wetland types have very different hydrologies. For example, bogs receive all input of water from the atmosphere (Bay, 1969); while fens (Siegel and Glasser, 1987) and some swamps (Roulet, 1990) receive considerable groundwater inputs. Evapotranspiration from swamps and treed bogs is controlled by the conduction of water through the tree canopy, while evapotranspiration from fens and marshes is controlled by graminoid plants (Carter, 1986). Evaporation from treeless bogs dominated by Sphagnum mosses is limited by the non-vascular canopy (Price, 1991).

Bogs, fens, swamps, and marshes have very different combinations of peat and mineral soils which affect the water table/storage-capacity relationships differently (Verry, 1988). With large hydrological differences among wetland types, one cannot assume all wetlands serve the same hydrological function. To assess the hydrological function of a wetland, it must be evaluated relative to its role in the drainage basin where it occurs and the hydrological setting in that drainage basin.

Wetland coverage in the MRSPR is shown in Figure 1.4-1 and detailed in Table 1.4-1. The wetlands figure details the type of wetland (bog, fen, marsh, swamp, open water and other). In addition, the significance of the wetlands (provincial or local) is presented on the figure.

The MVC contains thousands of wetlands and of these, 52 have been assessed using the Ontario Wetland Evaluation System (MNR, 1993, 1994, 2002). The number of assessed wetlands as provincially and locally significant in the MVC is 36 and 16, respectively. The number of unevaluated wetlands in the MVC is 14,931.

The RVCA also contains thousands wetlands, of which 89 have been assessed using the Ontario Wetland Evaluation System (MNR, 1993, 1994, 2002). Of these, 19 have been assessed as locally significant and 70 as provincially significant. The number of unevaluated wetlands in the RVCA is 13,810.

Using provincial Natural Resources Values Information System (NRVIS) data, it has been determined that there are a total of 623.4 km^2 of provincially significant wetland and 51.4 km^2 of locally significant wetland within the MRSPR. This means that evaluated wetlands cover 8% of the geographic area of the MRSPR, while unevaluated wetlands are estimated to cover an additional 5% of the MRSPR. It should be noted that the total percentage of wetlands based on the NRVIS data does not coincide with the land cover dataset for wetland coverage. This is likely due to a number of the smaller unevaluated wetlands not being captured within the land cover dataset.

Wetlands evaluated under the OWES have been assessed and grouped according to four principal components: biological, social, hydrological and special features. The hydrological component of the evaluation system assesses the role a wetland plays in the maintenance, control, and/or modification of the quantity and quality of water passing through a drainage basin. The hydrological component is designed to determine the net hydrological benefit provided by the wetland to the portion of the basin downstream of the wetland.

The evaluated wetland data and scoring records for evaluated wetlands in the RVCA has a section on hydrology that addresses the functional role of a wetland in:

- flood attenuation;
- the retention and modification of nutrients and other elements in surface water and via groundwater discharge (i.e., water quality improvements);
- the long-term storage of atmospheric carbon;
- shoreline erosion control; and
- groundwater recharge.

The rationale for the inclusion of each function is discussed in the corresponding subcomponent section of the OWES Southern Manual. This information should be perused to attempt to better understand the hydrological contribution of wetlands to the protection of water resources.

For example, using the hydrological information contained within each wetland data record, the dominant site type of an evaluated wetland can be extracted. From it, one can assess the hydrological contribution of palustrine or isolated wetlands, both of which are generally considered to be more hydrologicaly important than riverine or lacustrine wetlands.

Two other wetland projects completed recently in Eastern Ontario: the Eastern Ontario Wetland Valuation System (Burns and Wilson, 2003), and the RVCA Wetlands Prioritization System (Brownell, 2006). These also address wetland hydrology and should be examined through the DWSP watershed characterization project to determine their applicability.

The spatial distribution of wetlands is uneven, with few wetland features of any note remaining in the Lower Rideau or Eastern Mississippi regions. However, the limited numbers of wetland features remaining in the Lower Rideau and Eastern Mississippi regions are extremely significant to the landscape. The substantive wetland coverage is found in the Middle and Upper Rideau and Western and Central Mississippi regions, most of which has never been evaluated using the OWES.

1.4.2 Woodlands and Riparian Areas

Woodlands

The Rideau Valley Watershed is located within the Upper St. Lawrence Forest District (L.2) of the Great Lakes - St. Lawrence Forest Region according to Rowe (1972). This forest region is characterized by forests of a predominantly deciduous nature. Poorly-drained depressions frequently carry a hardwood swamp type in which Black Ash is prominent. Wet sites may bear Black Spruce or Eastern White Cedar. The latter species is also found on dry, rocky or stony sites. Extensive settlement and clearing has taken place over much of the area.

Rowe (1972) describes uplands in the District as being dominated by deciduous forests of Sugar Maple and Beech, with Red Maple, Yellow Birch, Basswood, White Ash, Large-toothed Aspen, Ironwood, Bur Oak and Red Oak, with local occurrences of more southern hardwoods like Black Maple, White Oak, Bitternut Hickory and Rock Elm. Wetland vegetation includes deciduous swamps in which Black Ash and Silver Maple are predominant. Conifers such as White and Red Pine are confined to coarser, well-drained soils. White Cedar is common and occurs in upland and lowland situations. White Elm is also common in the lowlands. The general character of the forest cover is broadleaved on deep calcareous soils, while on shallow, acidic, or eroding materials a representation of conifers is usual, particularly the Eastern Hemlock, Eastern White Pine, White Spruce, and Balsam Fir.

The final shaping of the landscape by marine deposits over glacial till is considered a defining characteristic here. Rowe's (1972) forest district encompasses an area extending well beyond the limits of the site district and treats vegetation in broad, forest-dominant terms. Hills (1959) evaluation scheme delineates landform-vegetation relationships in Ontario in a more detailed manner (site regions and site districts) and is based on how the constitution of vegetation associations (forest and otherwise) reflects varying biophysical site conditions.

Using the land cover dataset, described above in Section 1.2, 41% of the MRSPR is estimated to be wooded area. However, the spatial distribution of that coverage is uneven when one takes a closer look at the map. Similar to the wetland distribution, much of the Lower Rideau and Eastern Mississippi regions are devoid of woodland, whereas much of the Middle Rideau region and most of the Upper Rideau and Eastern and Central Mississippi regions are covered with more extensive woody natural vegetation (trees and shrubs).

What this means in terms of drinking water source protection (i.e., the hydrological relationship between forests and surface/groundwater resources) must be further investigated. It should be noted that the Eastern Ontario Model Forest did attempt to assess this hydrological relationship (and many other bio-ecophysical associations) when it developed the Eastern Ontario Woodland Valuation System, whereby woodland features within eastern Ontario would be given a relative value of significance or importance with respect to several criteria, including proximity to water.

Vegetated Riparian Areas

The shorelines of individual properties on the Rideau River from Smiths Falls to Ottawa have been classified for ecological integrity using a standard protocol by the RVCA. Three reports based on field work and analysis conducted between 2002 and 2004 have been produced that identify four predominant shoreline conditions along the river: natural, regenerating, ornamental and degraded (Guertin and Schelenz 2002; Stephens 2004, 2005).

From a DWSP perspective, it is important to know the general extent of each one of these riparian conditions because of the documented role of naturalized shorelines in watershed protection. The benefits of a healthy buffer of riparian and littoral zone vegetation are extensive. In a natural state, shorelines provide diverse terrestrial and aquatic habitat and perform many hydrologic functions, significantly contributing to the overall health of a water body or watercourse. For example, Belsky et al. (1999) and Johnson et al. (2001) observe that riparian zone vegetation benefits river ecology in many ways. Vegetation improves water quality and temperature, nutrient and sediment content in runoff, bank stability, terrestrial and aquatic habitat, biodiversity and species richness. These factors are each extremely important in contributing to the health of a watercourse.

Areas of Natural and Scientific Interest

Areas of Natural and Scientific Interest (ANSI) have been surveyed by the Ontario Ministry of Natural Resources to address the protection objective of the Ontario Provincial Parks Policy (MNR, 1978 as referenced in White, 1992) which is “to protect provincially significant elements of the natural and cultural landscape of Ontario”. To meet this objective, natural areas surveys (using site districts boundaries) have been performed throughout the province to identify a series of ecological areas that comprises the spectrum of natural landscapes, environments, and biotic communities in Ontario.

The ANSI program is based on the geographical and ecological framework of the site region and site district system that was largely developed by Hills. This system divides the province into seven broad zones called site regions, in which “the response of vegetation to the features of landform follows a consistent pattern”. A site district is a subdivision of a site region “based on a characteristic pattern of physiographic features that set apart fairly large areas from one another” (Hills, 1959). The Ecological Site Districts for the MRSPR are presented on Figure 1.4-3.

Site Region 6 is a very broad zone that extends from the extreme eastern end of Ontario to the Lake Huron shores of the Bruce Peninsula. This site region consists of a midhumid climate and a gently undulating to rolling terrain of deeply covered Paleozoic bedrock (Hills, 1959). The RVCA is located in five Site Districts: 6-11 covers 50% of the watershed, while 6-12 covers 29%, 5-11 covers 21%, and 6-10 and 6-16 have less than 1%. The MVC is located in four Site Districts: 5-11 contains 71%, 6-11 contains 15%, 6-12 contains 12% and 6-16 contains 1%. The MVC numbers for Site Districts do not add up to 100% due to rounding of the percentages.

Some of the more significant wetlands, woodlands and riparian areas have been formally recognized as regionally or provincially significant wetlands or ANSIs, as are shown in Figures 1.4-1 and 1.4-2. This is potentially important from a DWSP perspective, where an ANSI has been identified as hydrologicaly valuable, because they have some protective status under the *Planning Act* of Ontario.

Site District 5-11

Site District 5-11 is located at the southern edge of the Canadian Shield. It is the largest site district in southern Ontario and comprises parts of Renfrew, Lanark, Lennox & Addington, Hastings, Frontenac, Peterborough and Haliburton Counties. Fragments of the site district are also located Victoria County and Nipissing District.

Site District 5-11 shares its western boundary with Site Districts 5-8 and 5-9, northern boundary with Site Districts 5-10 and 5-12. To the east, the site district abuts Site District 6-11 and to the south Site Districts 6-9 and 6-10.

There are four subdistricts located within Site District 5-11 which are the Kawartha, Mazinaw, Madawaska and Bonnechere subdistricts. The site district is characterized by the rolling landscape consisting of thin glacial soil over Precambrian bedrock of the Canadian Shield.

Twenty-three sites were considered to offer the best representation of the landform-vegetation features of the site district (provincially significant). In addition, another 14 sites were considered to be regionally significant sites. The most significant natural characteristic of Site District 5-11 is the large area of thinly buried and exposed marble bedrock (Brunton, 1990).

Site District 6-10

Site District 6-10 comprises parts of Leeds & Grenville and Frontenac Counties. Smaller portions of the site district are also located Lanark, Hastings, and Lennox & Addington Counties. A very small portion of Site District 6-10 is located within the MRSPR.

Site District 6-10 shares its northern boundary with Site Districts 5-11 and 6-11. The western boundary is also shared between Site District 5-11 and 6-9. The southern boundary is shared between Site District 6-9 and Lake Ontario / St. Lawrence River. The eastern boundary is also shared between Site District 6-11 and the St. Lawrence River.

There are three subdistricts located within Site District 6-10 which are the Kaladar, Frontenac and Leeds subdistricts. The site district generally coincides with the southern extension of the Canadian Shield (Frontenac Axis) that connects the Algonquin Highlands to the Adirondack Mountains of New York State.

Twenty-two sites were considered to offer the best representation of the landform-vegetation features of the site district (provincially significant). In addition, another 14 sites were considered to be regionally significant sites. The most significant natural characteristics of Site District 6-10 are the isolated exposed rock ridges, extensive rock barrens, the expansive ridge and valley topography and its associated forest, the numerous small and diverse wetlands, the extensive shorelines associated with the lakes, and the ‘knobs and flats’ landform (White, 1993).

Site District 6-11

Site District 6-11, as defined by Hills (1959), coincides essentially with the Smiths Falls Limestone Plain that is “the largest and most continuous tract of shallow soil over limestone in Southern Ontario” (Chapman & Putnam, 1984). This site district extends from Westport in the west almost to Kemptville and Prescott in the east, and from Pakenham in the north to the St. Lawrence River in the south. The site district occurs wholly within Ontario Ministry of Natural Resources Kemptville District.

Site District 6-11 shares its western boundary with Site District 5-11 in the north and Site District 6-10 in the south. To the east, the site district abuts Site District 6-12. Site Districts 5-11 and 6-10 exhibit the more acidic substrates of the igneous and metamorphic rocks of the Canadian Shield. Site District 5-11 exhibits a more boreal climate than Site District 6-11. Site District 6-12 to the east supports deeper soils associated with extensive clay, sand, and till plains.

Glacial activity has had an important effect on the landscape of Site District 6-11, as in many other parts of Southern Ontario. Upland areas have been scoured of most of the surface material and much of the eastern half of the site district was inundated by the Champlain Sea. This glacial and post-glacial activity has left a variety of inland deposits including clay plains, sand plains, marine beaches, and occasional drumlins and eskers.

The site district is a relatively flat limestone plain with thin, impoverished, drought-prone soil, frequent blocked drainage, numerous wetlands and small lakes, frequent bedrock exposures and rock barrens, and only occasional cliffs and escarpments. The frequent shallow basins and limited drainage gradient across much of the site district have fostered the conditions for the development of organic (peat and muck) deposits. Small isolated pockets as well as broad extensive deposits are common and are also an important and distinctive feature.

Site District 6-11 is comprised of three major landforms: limestone plain (74%), organic (muck & peat) (12%), and clay plain (9%); and three minor landforms: till plain (2%), sand plain (2%), and kame moraine (less than 1%) (Chapman & Putnam, 1984). These landforms support a wide range of upland and wetland communities. Due to extensive landscape modification from farming, logging, and development, the uplands of the site district have been much disturbed. Few little-disturbed examples of upland forest remain. The wetlands have been far less disturbed and many examples remain in good condition.

Seventeen provincially significant and 9 regionally significant ANSI have been identified to represent the landscape diversity of the site district. These sites provide very good representation of wetlands; however, upland features, especially of the minor landforms, are poorly represented. In order to complete the representation of these minor features it may be necessary either to look in adjacent site districts, or to reconsider more disturbed areas than would normally be accepted as provincially or regionally significant ANSI (White, 1992).

Site District 6-12

Site District 6-12 is an area of approximately 970,000 ha extending from the Ottawa River on the north to the St. Lawrence River to the south. The Quebec border delimits northern, eastern and southern boundaries, with Site District 6-11 forming the western limit along a line running approximately from Arnprior to Prescott.

Site District 6-12 comprises all of Prescott & Russell and Stormont, Dundas and Glengarry Counties and parts of Leeds & Grenville County and the City of Ottawa. There are five subdistricts located within Site District 6-12 which are the Carp-Mississippi, Rideau, South Nation, St. Lawrence and Rigaud subdistricts. The site district is generally a relatively level area of till and marine deposits over deep buried sedimentary bedrock with the exception of the Carp Ridge.

The site district is a relatively level area of post-glacial till, outwash and marine deposits over relatively deeply buried sedimentary bedrock (limestone, shale and sandstone) which rarely outcrops. Marine clay deposited by the post-glacial Atlantic embayment known as the Champlain Sea (Ca. 12,000 - 10,000 year B. P.) dominate the substrate, with lacustrine-deposited sand plains associated with it. Glacial till is common only in the southern portion of the site district where the sea inundation was shallow. Organic deposits have developed in drainage channels left by these post-glacial phenomena, some constituting the largest peat lands known in southern Ontario. Rock flats and exposures are confined largely to sedimentary flats along the Ottawa River and the granite outcrops associated with the Carp Ridge.

Organically based landforms are well represented in Site District 6-12. The less dominant Rock Outcrop landform is also proportionately well represented. Both of these landforms have presented serious barriers for most intensive development and agricultural activities, at least until recently. Conversely, the poor level of representation of wide spread Clay Plain, Sand Plain and (less common) Ground Moraine complexes reflects the economically advantageous condition of these landforms for many intensive development and agricultural activities. Similar land-use history in the adjacent Site District 6-11 suggests that compensation for these deficits will not likely be possible in that area.

The site district has been severely affected by two centuries of subsistence and industrial agriculture as well as the development of several major urban centers, most particularly those in the City of Ottawa. Only between 15% and 20% of the site district remains forested; the natural value of most of this have been severely compromised by intensive firewood and saw log cutting, cattle grazing, sugar bush development and estate residential development.

Existing representation is provided by Natural Environment zoning in the Carillon and Fitzroy Provincial Parks, other provincial conservation areas, and by NCC Conservation Areas. The 20,350 ha NCC Greenbelt surrounding Ottawa constitutes the ecologically most significant area in Site District 6-12, despite its location within the major urban development area. It not only contains a number of the most significant natural environment areas in the site district but it surrounds these sites in a more or less protected, largely continuous area of open space and natural habitat.

For the purposes of this study, the system of existing ANSI proposed in January 1988 is also considered to provide protection zoning areas, although in reality, ANSI designation only identifies and describes significant sites. Total existing representation is 21,637 ha, 2.2% of the land base of Site District 6-12.

A total of 40 Candidate ANSIs are proposed in Site District 6-12 to supplement the 14 existing reserve areas. This includes a number representing modified, existing ANSI sites. These proposals would add an additional 8,895 ha, for a total of 30,522 ha - 3.3% of Site District 6-12. Clearly, as a result of centuries of human activity, this site district has relatively little natural land remaining and is a deficit in terms of the MNR Protection Objective commitment to the designation and protection of 12% of the provincial land-base (Brunton, 1992).

Site District 6-16

The Carp – Mississippi Rivers subdistrict from Site District 6-12 was reclassified as its own Site District 6-16. The most significant feature of Site District 6-16 is the Precambrian bedrock outcrop of the Carp Ridge. Additional details regarding Site

District 6-16 can be found within the Brunton (1992) review of Life Science Areas in Site District 6-12.

Ecological Land Classification

The Ecological Land Classification (ELC) looks at the distribution and groupings of plant species. These groupings are then evaluated to establish patterns with respect to vegetation, soils, geology, physiography and climate. These patterns are evaluated on various ELC scales ranging 10,000 km^2 to 100 m^2. The ELC classification from largest to smallest are described as Site Region, System, Community Class, Community Series, Ecosite and Vegetation (Lee, H.T. et al., 1998). Utilizing the ELC field guide prepared by Lee et al., (1998) and the Provincial Landcover, 28 Class, the ELC Community Class and Community Series were prepared for the MRSPR and are presented in Figures 1.4-4 and 1.4-5.

1.5 Aquatic Ecology

The work of the MVC and the RVCA, and their role in fisheries management, has mainly dealt with examining aspects of water quality, monitoring overall health of various water bodies, and protecting aquatic habitat from harmful impacts. These parameters, and specifically information on the status of fish populations and habitat, have been collected through such studies as the Ontario Stream Assessment Protocol, City Stream Watch, Macro Stream Assessment, Beaver Dam Monitoring, and Municipal Drain Classification. In addition to the parameters listed above, these studies have been useful to monitor any changes that may occur, highlight areas where improvements can be made, characterize the existing conditions of the watershed and identify opportunities for enhancement.

1.5.1 Fisheries

Temperature profiles

Fish habitat is commonly described in terms of the species present and the associated temperature regimes that exist for various lakes and watercourses. Habitat can be described as being a warm, cool, or cold water fishery. Warm water fisheries have water temperatures above 25 degrees and consist of species such as largemouth bass, rock bass, pumpkinseed and bluegill. Cool water fisheries are found in the 19 to 25 degree range and some species which prefer these temperatures include smallmouth bass, walleye, muskellunge and northern pike. Cold water is below 19 degrees and many salmonids like brook trout, lake trout and Atlantic salmon prefer these colder waters.

The MVC watershed contains cold, cool and warm-water fish species. In the western portion of the watershed most lakes support populations of walleye, although lakes such as Mazinaw contain lake trout and support both warm and cold water populations. The central and eastern portions of the Mississippi River system contain primarily cool and warm-water fish species such as northern pike, walleye, smallmouth bass, bluegill, pumpkinseed, rock bass and yellow perch. More detailed analysis of fish communities can be found in such reports as the Carp River Watershed / Subwatershed Plan, Upper Poole Creek Subwatershed Plan and the Shirley's Brook / Watts Creek Subwatershed Plan.

The RVCA mainly consists of warm water fish habitat with some cool water reaches. Portions of the watershed (Eagle Lake, Bobs Lake, and portions of the Tay River for example) also exhibit cold water characteristics and species (Esseltine, 2002). This classification is made based on the species of fish found throughout the watershed and sub-watershed reaches. More detailed analysis of fish communities can be found in such reports as the Rideau River Fisheries Assessment Report, Jock River Watershed Plan, Kemptville Creek Watershed Plan, Lower Rideau Watershed Plan and Fish Habitat of the Tay River Watershed.

Temperature studies in the watershed are conducted on various lakes to show profiles at different locations. Profiles for temperature in streams are conducted using data loggers left at a site for a number of days to show changes in temperatures as well as averages used in classifying the water type.

Habitat can also be considered sensitive when it is used for specific life processes of fish. Areas that are considered to be nursery or spawning grounds are extremely important to the well being of a particular species and health of the system. As data is collected it becomes clearer where nursery or spawning habitat exists in our watershed.

The Mississippi River system has a diversity of aquatic habitats (spawning, nursery, rearing, food supply and migration areas) upon which fish depend directly or indirectly to carry out their life processes. Many of the important fish spawning areas are located below the sections of rapids and dams and along shorelines of lakes and the river proper. Water levels and flows are important to fish species during the spawning and incubation periods of the eggs which can last from ice break-up to early summer for most species. Walleye spawn in spring on rocky areas in white water below dams or rapids in the river. Lake trout spawning occurs mainly in October on rocky shoals found in lakes.

There are three identified lake trout spawning shoals in Mazinaw Lake; the primary shoal is in Campbell Bay. The other known lake trout spawning sites are located at the Narrows and on the east shore of the south basin. Deep water spawning activity is suspected in Mazinaw Lake, however, no sites have been confirmed. Walleye spawn throughout the south basin, as well as in Campbell Bay, German Bay and at the extreme north end of the lake.

Lake trout have been documented spawning at several locations throughout Shabomeka Lake. However, the shoals are susceptible to fall drawdowns.

Walleye have been historically documented spawning throughout Mississagagon Lake, however, spawning assessments completed in 1987 and 2003 showed that walleye spawn in small numbers at a small number of sites located on the north shore and small islands in the western portion of the lake. The lake struggles to support a self-sustaining population and has received rehabilitative stocking of walleye for many years. Spawning sites of other species have not been assessed.

Kashwakamak Lake has an abundant walleye population which is known to spawn near the main inlet at Whitefish Rapids and at several locations along the north shore of the lake. Bass reproduction has been assessed in the lake; bass nesting activities have been documented throughout Kashwakamak Lake, though higher nest densities occur in shallow bays on the north and east ends of the lake. Northern pike reproductive activities have been recorded at two shallow sites in the extreme eastern end of the lake.

Walleye are known to spawn throughout Big Gull Lake. The lake has limited walleye spawning substrate. Numerous enhancement projects have been undertaken in recent years by local cottage associations, to supplement the existing walleye spawning habitat. Spawning sites of other species have not been assessed.

Walleye are documented as spawning in large numbers at several locations in Crotch Lake. The primary spawning shoal and staging area is located at Sidedam Rapids. Another important spawning site for walleye has been documented at Kings Falls, both above and below the dam. Walleye spawning has also been documented around islands in the north basin, as well as at two inlets to Fawn Lake and on Gull Creek, upstream from Crotch Lake. Spawning sites of other species have not been assessed.

1.5.2 Aquatic Macroinvertibrates

The RVCA has been partnered with the OBBN since 2003. The scope of the sampling program has grown so that 15 lake sites and 33 stream sites have been sampled twice a year since 2003 for invertebrates as indicators of water quality. The MVC has been involved with the OBBN since 2005 and a total of 9 sites have been sampled. The locations of the OBBN sampling sites are presented on Figure 1.5-1. Sites are sampled using a dip net, collections are preserved on site, and invertebrates are identified to the family level back at a laboratory.

In addition to the OBBN monitoring program, the City of Ottawa has sampled for benthic macroinvertibrates since 2000 at many of the urban streams and tributaries in the MRSPR. A total of 131 invertebrate sampling locations within the MRSPR have been sampled by the City of Ottawa and are presented on Figure 1.5-1. The sampling locations coincide with the stream water quality sampling stations that the City of Ottawa operates. The City of Ottawa surface water quality monitoring stations are discussed in further detail in Section 2.2.

A number of indices can be gathered from invertebrate composition that can be used as indicators of water quality (percent diptera or percent midges for example). The main index used in comparisons of water quality is known as the Family Biotic Index (FBI). Each family of invertebrate is given a tolerance value between zero and ten (zero being very intolerant to contaminants and ten being very tolerant). When an abundance of organisms are found which are considered to be intolerant to pollution, then it may be said that the water quality is good. When the proportion of animals considered to be tolerant to pollution is greater, it can be an indication that water quality is poor. The following chart shows how the numbers calculated in the FBI equate to water quality.

THE HILSENHOFF INDEX

Hilsenhoff Index Water quality Degree of Organic Pollution

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00–3.75	excellent	organic pollution unlikely
3.76–4.25	very good	possible slight organic pollution
4.26–5.00	good	some organic pollution probable
5.01–5.75	fair	fairly substantial pollution likely
5.76–6.50	fairly poor	substantial pollution likely
6.51–7.25	poor	very substantial pollution likely
7.26–10.00	very poor	severe organic pollution likely

Hilsenhoff, 1982

The conditions of the RVCA with regards to the FBI can be said to be generally good. Conclusions regarding the water quality due to the presence of benthic species should be viewed with caution due to the limited timeframe that the data has been collected (since 2003 in the RVCA). The Tay River, Jock River and Kemptville Creek all exhibit numbers considered to be good water quality. Sites within the Lower Rideau region have a decreased quality of water. Areas like Cranberry Creek and Sawmill Creek have low abundance and show numbers indicating fairly poor to very poor conditions. This decrease can be a reflection of location (Sawmill Creek is an urban watercourse) or reduced habitat quality (Cranberry had fairly stagnant water with poor substrate conditions). Conditions within the MVC have not been assessed as only two years of monitoring has been collected.

There are factors involved which influence benthic populations and may or may not have a direct influence on water quality. One should take into account substrate composition, flow characteristics, riparian land use and buffer condition, and basic chemical parameters (dissolved oxygen, pH, and temperatures) when analyzing water quality. Species of invertebrates will react to changes in habitat type as well as to chemical impacts.

1.5.3 Species and Habitats at Risk

Certain species of fish are considered to be more sensitive than others and can therefore be used as indicators of watershed health. For example, the brook silverside (*Labidesthes sicculus*) is considered to be a sensitive species and is found in most parts of the Rideau River. As a result, the health of the river can be said to be in a healthy condition (Poulin, 2001). The health of the river as a result of the presence or absence of a sensitive species should be viewed with caution as this only forms a portion of the total health of the river.

There are currently no recordings of any species at risk (SAR) fish species in the Rideau River watershed. The classification 'special concern' is used to describe species with characteristics that make it particularly sensitive to human activities or natural events, but does not include an extirpated, endangered or threatened species (Natural Heritage Information Center website).

There are species found in RVCA that are considered to be either threatened or of special concern. Species of concern in the RVCA include lake sturgeon (*Acipenser fulvescens*) and northern brook lamprey (*Ichthyomyzon fossor*) and threatened species include the channel darter (*Percina copelandi*). Species of concern in the MVC include the river redhorse sucker (*Maxostoma carinatum*) and freshwater mussels (various species). The American eel (*Anguilla rostrata*) is also a species of concern within the tributaries of the Ottawa River.

Other species in the watershed which are worthy of note include the musk turtle (*Sternotherus odoratus*), map turtle (*Graptemys geographica*), Blanding's turtle (*Emydoidea blandingii*), spotted turtle (*Clemmys guttata*), black rat snake (*Elaphe obsoleta*), milk snake (*Lampropeltis triangulum*) and loggerhead shrike (*Lanius ludovicianus*). The information collected on these species and the monitoring of their status is not actively done by the RVCA or MVC. Such information is available from the MNR, DFO and the Natural Heritage Information Center (NHIC).

In 2005, butternut was identified as an endangered species. The decline in butternut tree population is due to butternut canker disease. Within the MRSPR, there is a very high canker infection rate within the butternut trees. The RVCA and the Ferguson Forest Centre are partnered in a butternut tree planting and recovery program.

1.5.4 Invasive Species

Species that have been introduced to an ecosystem illegally, intentionally, or accidentally, can often cause great ecological and socio-economic damage to the area. Several invasive species of concern have colonized the Rideau Watershed and numerous others have been sighted within adjoining watersheds. These invasive plants and animals often thrive because there are no predators in the new habitat and they have well developed survival methods such as prolific reproduction and high tolerance to poor water quality and degraded conditions.

One of the highest profile animal invaders of the RVCA is the zebra mussel (*Dreissena polymorpha*) which was transported from Europe to North America in ballast water of ships. These mussels have the ability to lay up to a million eggs during a breeding season and due to the lack of natural predators in the RVCA, they have managed to colonize very quickly. Zebra mussels cannot swim, so are only able to disperse downstream during their free-floating larval, or veliger, stage. However, they are easily transported into upstream lakes and streams in boat live wells and bait buckets and attached to boats, trailers and fishing equipment.

Currently both the MVC and RVCA are participating in a monitoring program, in conjunction with the Ontario Federation of Anglers and Hunters (OFAH), with sampling for zebra mussels at their microscopic veliger stage in the lakes of the watershed. This sampling is conducted as part of the Watershed Watch programs in both the MVC and the RVCA. Further detail regarding these programs is discussed below in Section 2.2.

Veligers have been found in 16 of the 39 lakes sampled in the RVCA and 12 of the 42 lakes sampled in the MVC. Along with the mussels, this program is designed to detect spiny water flea (*Bythotrephes longimanus*) which have not been identified in any of the lakes within the RVCA but have been found in three lakes of the neighbouring MVC. It should be noted that the presence of spiny water flea and / or zebra mussels within these lakes may or may not be indicative of the current conditions. Previous sampling events have indicated the presence of invasive species, whereas the current sampling events were negative. The presence or absence of these invasive species in specific lakes within the MRSPR should be viewed with caution.

Other animal species that are known to have colonized the Rideau but are not currently being monitored by the RVCA include the rusty crayfish (*Orconectes rusticus*) and the common carp (*Cyprinus carpio*). Several other fish species threaten to invade the Rideau System, including the round goby (*Neogobius melonostomus*), the rudd (*Scardinius erythropthalumus*) and ruffe (*Gymnocephalus cernuus*).

Several invasive plant species threaten the biodiversity of the RVCA. Purple loosestrife is an attractive plant with purple flowers that reduces biodiversity by crowding out native plants along shorelines and wetland areas. This reduces nesting areas and food sources for waterfowl. Also in association with OFAH, the RVCA has been working to control loosestrife using the *Galerucella* species beetles which feed on the plants eventually killing them. Although it is still early in the project, promising results have been observed.

Other invasive wetland plants that are present within the watershed include flowering rush (*Butomus umbellatus*), European frogbit (*Hydrocharis morus-ranae*) and eurasian milfoil (*Myriophyllum spicatum*). Eurasian milfoil has caused a great deal of concern among recreational users of the watershed waterways because it tends to grow in thick mats that displace native plants and can impede boat passage and make swimming very difficult. Because milfoil can reproduce from plant fragments, it can be spread to other water bodies as simply as from pieces caught in boat propellers.

1.6 Human Characterization

1.6.1 Population Distribution and Density

The total population of the MRSPR is approximately 865,000. The detailed breakdown of the estimated population by municipality is presented in the Table 1.6-1. Population data was obtained from the Statistics Canada 2006 Census. The 2006 census data was distributed to the MRSPR by dissemination area. In areas, where the dissemination areas cross the MRSPR boundary, the estimated population was derived based on the percentage of the dissemination area falling within the MRSPR. The population data in Table 1.6-1 is presented on a lower tier or single tier basis (i.e., Township of Beckwith, Town of Carleton Place, Separated Town of Smiths Falls, etc.). Figure 1.6-1 also presents the population distribution by dissemination area. It should be noted that the dissemination areas, do not necessarily coincide with the boundaries of some of the smaller hamlets and villages.

Population density by dissemination area is presented in Figure 1.6-2. Population densities greater than 1,000 people per square kilometer are found within the urban areas of the City of Ottawa (Barrhaven / Riverside South, Kanata / Stittsville, Orleans, and Ottawa), several of the villages within the amalgamated City of Ottawa (Constance Bay, Manotick, Munster, Osgoode, and Richmond), and several other urban areas outside of the City of Ottawa (Almonte – Mississippi Mills, Carleton Place, Kemptville – North Grenville, Perth and Smiths Falls). The majority of the western portion of the MRSPR generally has a population density of less than 10 people per square km.

Projected populations data was collected from the Ministry of Finance for 2011, 2021, and 2031. The population data is presented on an upper tier or county basis. The projected population for the MRSPR is presented in Table 1.6-2. Population growth for the MRSPR, referenced to 2001 as the baseline population, is expected to range from 6 – 17% by 2011, 12 – 31% by 2021, and 16 – 44% by 2031. The area projected to have the slowest growth is within Renfrew County and the area with the largest is the City of Ottawa.

In addition to the permanent residents within the MRSPR, there is a significant seasonal population increase associated with the cottage and camp development within the MRSPR. Detailed records as to the population associated with these seasonal residents was not available from any of the population census data. From discussions with several municipalities with significant cottage and camp development, the overall population in these municipalities may increase by two to three times from the permanent population during the summer.

1.6.2 Land Use

Approved municipal Official Plans (OPs) within the MRSPR were collected for each municipal unit. The OPs were reviewed for policies regarding agriculture, brownfields / contaminated sites, landfills, natural hazards, natural environment, natural resources, settlement areas, transportation and water and wastewater services. Brief summaries of these OP policies and their respective subsections are presented in Appendix 4, Table A-4. Trends in commercial / industrial have not been completed, however commercial / industrial land use policies were reviewed and are presented in Appendix 4, Table A-4. OPs were reviewed for the City of Ottawa, Municipality of North Grenville, Towns of Carleton Place, Mississippi Mills, Perth and Smiths Falls, Townships of Addington Highlands, Augusta, Beckwith, Central Frontenac, Drummond/North Elmsley, Elizabethtown – Kitley, Lanark Highlands, Montague, North Frontenac, Rideau Lakes, South Frontenac and Tay Valley and Villages of Merrickville – Wolford and Westport.

Individual municipalities were contacted to obtain digital copies of their OP mapping. Digital copies of the OP mapping were found to be available for the City of Ottawa, Central Frontenac, and all municipalities within the Counties of Lanark and Leeds & Grenville. The OP mapping for the MRSPR is presented in Figure 1.6-3.

1.6.2.1 Settlement Areas

All settlement areas (Villages, Hamlets, Towns, etc.) within the OPs for the MRSPR were identified and mapped. The OP designated settlement areas were then compared to the Census data from 2001 and 2006. The purpose of this comparison was to identify settlement areas with populations greater than 500 persons. Data for the rural villages in the City of Ottawa was also provided by the City. Table 1.6-3 and Figure 1.6-4 present the settlement areas and their population within the MRSPR. Outside of the urban portion of the City of Ottawa, which includes Kanata / Stittsville, Barrhaven / Riverside South, Orleans and Ottawa, there are 20 settlement areas with populations greater than 500 persons.

Land use within the development areas is typically a mixture of residential, commercial, industrial and other land uses. Summaries of the OP designations for residential and commercial / industrial land uses within these urban settlements and their respective OP subsections are presented in Appendix 4, Table A-4.

Many of the employment opportunities within the MRSPR are related to the federal, provincial and municipal governments. In addition to the government sector, retail trade is one of the core areas of employment in the MRSPR. Small-scale manufacturing is also an important secondary source of employment (Snyder, 1980).

Historically in the 19th century much of the Rideau was used for timber production, mineral extraction or agricultural land use. In addition, manufacturing industries such as grist and saw mills, cheese factories and woolen mills were also present. By the late 19th century many of these resources were depleted and many of these primary and secondary industries were no longer viable (Snyder, 1980). However, it should be noted that within several areas of the MRSPR agriculture and timber production, still represent significant primary land uses. Agricultural land use is discussed in more detail in Section 1.6.2.12.

Within the urban and rural hamlet / village development areas, commercial development is generally permitted within most land use types. However, some restrictions may occur based on the size of the commercial development. Specific policies regarding the type of development area presented in the individual OP and summarized in Appendix 4, Table A-4.

Industrial development typically occurs within the larger urban development areas in industrial specific land use areas. However, some industrial land use is also conducted in the general rural area and specific zoning amendments are typically required for this type of development. Heavy industrial land use is generally not permitted within rural hamlet / village development areas. Specific policies regarding the type of development area presented in the individual OP and summarized in Appendix 4, Table A-4.

With the hundreds of lakes and rivers within the MRSPR, many significant regions of waterfront development exist. Typically in areas closer to the development areas, much of the waterfront development is permanent homes. In the more remote areas, significant seasonal cottage development exists. In all areas of the MRSPR there is an ongoing shift to redevelop and convert seasonal cottages into permanent year round homes. Some municipalities have distinct waterfront development land uses identified. Summaries of the OP designations for seasonal / waterfront lands and their respective OP subsections are presented in Appendix 4, Table A-4.

1.6.2.2 Brownfields

Brownfields are generally former commercial or industrial lands where previous land uses may have resulted in contamination of the soil or groundwater. As a result of these former land uses and associated potential presence of hazardous substances, pollutants or contaminants, rehabilitation or remediation activities are generally required prior to expansion, redevelopment or reuse. The locations of the brownfields from the MOE brownfields database is presented on Figure 1.6-5.

Most municipalities have policies regarding the redevelopment of known, suspected or potentially contaminated sites. In addition, some municipalities have inventories of the properties in which former land uses may have resulted in contamination. Known contaminated sites have been identified by Central Frontenac and Lanark Highlands

Townships and potentially contaminated sites have been identified by North Frontenac Township and are also presented on OP mapping. Brief summaries of the OP policies regarding brownfields and contaminated sites and their respective OP subsections are presented within Appendix 4, Table A-4. These known, suspected and potentially contaminated sites will be discussed in further detail in Section 4.0 – Existing Threats Inventories.

1.6.2.3 Landfills

Most municipalities have lands designated for waste management uses. Brief summaries of the OP policies regarding landfills / solid waste disposal activities and their respective OP subsections are presented in Appendix 4, Table A-4. The locations of the landfills within the MRSPR are presented on Figure 1.6-6. These former and existing landfills will be discussed in further detail in Section 4.0 – Existing Threats Inventories.

1.6.2.4 Mining and Aggregate Extraction

Aggregate and mineral resource designations have been identified within most municipalities as displayed on the OP mapping. Land uses associated with these natural resource designations are typically related to aggregate / mineral extraction or other land uses such as agriculture, conservation, forestry or outdoor recreation which will not preclude extraction at a further date. Brief summaries of the OP policies regarding mining and aggregate resources and their respective OP subsections are presented in the natural resources within Appendix 4, Table A-4. The locations of active extraction areas including existing pits and quarries are presented on Figure 1.6-7.

In addition, many municipalities have identified abandoned mine hazards which will be discussed in further detail in Section 4.0 – Existing Threats Inventories. The locations of abandoned mines and quarries are also presented on Figure 1.6-7.

1.6.2.5 Oil and Gas

No oil and gas reserves were identified within the MRSPR based on provincial mapping or OPs.

1.6.2.6 Forestry

Forestry or conservation activities are identified as one of the forms of agricultural land use practiced. Most rural lands within the municipalities of the MRSPR contain land used for agriculture. In addition, agriculture, conservation and forestry uses are also permitted within the aggregate and mineral resource designations that will not preclude extraction at a further date. Rural, agricultural and mineral resource land use designations are identified on the individual municipal OP maps. Brief summaries of the

OP policies regarding forestry and their respective OP subsections are presented in the natural resources within Appendix 4, Table A-4. In addition to the forestry or rural land uses identified on the OP mapping, wooded areas and rural land use is presented on Figure 1.2-24.

1.6.2.7 Transportation

The transportation network within the MRSPR is a mixture of airports, railways, roads, trails and waterways. The transportation networks are identified on the individual municipal OP maps. Brief summaries of the OP policies regarding transportation and their respective OP subsections are presented in the natural resources within Appendix 4, Table A-4.

1.6.2.8 Wastewater Treatment

There are nine municipal sewage treatment facilities in the MRSPR. Two of these facilities discharge to the Mississippi River (Carleton Place and Mississippi Mills – Almonte), four to the Rideau River (Merrickville-Wolford – Merrickville, North Grenville – Kemptville, Ottawa – Manotick Village Walk and Smiths Falls), one to the Tay River (Perth) and one to the Ottawa River (Ottawa). The sewage treatment facility in Westport does not discharge to a surface water body as the sewage is spray irrigated as snow in the winter (snow-fluent). The locations, receiving water body and type of facility are presented on Figure 1.6-8 and Table 1.6-4.

It should also be noted that in addition to the urban portions of the City of Ottawa, the sewage treatment plant in Ottawa, the Robert O. Pickard Environmental Centre (ROPEC), treats the sewage from several of the smaller rural villages including Carp, Munster and Richmond. Richmond and Munster formerly had lagoons for sewage treatment but are now connected to the Ottawa sewers.

1.6.2.9 Drinking Water Serviced vs. Non-Serviced Areas

Municipal Drinking Water Service Areas

Twelve municipal water supply systems exist within the MRSPR. Seven of these supplies are sourced from groundwater and five from surface water. The locations of the municipal water supplies are detailed in Table 1.6-5. The locations of these municipal water systems as well as their service boundaries are presented in Figures 1.6-9 and 1.6-10. More description as to the locations of the water takings and water use is described in Section 1.7.

Estimated populations of municipally and non-municipally supplied development areas are provided in Table 1.6-6. Table 1.6-6 identifies that the estimated municipally serviced population is 731,000. It should be noted that the estimated 731,000 people that are municipally serviced includes some people within the urban area of the City of Ottawa that live within the SNC watershed (Finlay Creek and Orleans). This population was included as the drinking water treatment plants are located within the MRSPR.

Private Drinking Water Wells

Outside of these twelve municipal water supplies, drinking water supply is provided by private wells. Within the MRSPR the MOE Water Wells database lists approximately 44,000 private wells. This version of the MOE Water Wells database is dated from 2001 and was used in the Renfrew-Mississippi-Rideau GW Study. The locations of these wells are presented on Figure 1.6-11.

OP policies were also reviewed to determine the municipal strategies for water supply. Outside of the municipal supply areas identified above, municipalities indicate that existing and future development is to be conducted on private water. Brief summaries of the OP policies regarding water supplies for both public and private sources and their respective OP subsections are presented in the water and wastewater section within Appendix 4, Table A-4.

As stated above in Section 1.6.1, the estimated population of the entire MRSPR is 865,000. Table 1.6-6 indicates that within the MRSPR approximately 135,000 people live on private services. From the development areas presented on Table 1.6-3 and Figure 1.6-4, it can be seen that approximately 20,000 people in the MRSPR live on private wells in these dense settlement areas.

It should be noted that the above mentioned tables only represent these development areas with populations greater than 500 persons. All other residential development in the MRSPR is serviced by private drinking water wells. The total population in the MRSPR on private wells is approximately 135,000.

Mixed Service Areas

It should be noted that in many cases where a municipality has a water supply system, not all of the municipality is supplied with water. Areas of many municipalities were originally supplied by private wells, prior to municipal servicing being extended to that location. Usually with existing properties, connection to the municipal supply is to be paid for by the individual property owner. As a result, some existing properties within the municipal supply area do not connect to the public service when the services are extended.

Several of these private service areas are located within the City of Ottawa and are presented on Figure 1.6-9. The majority of these private service areas are located on the edge of the greenbelt (i.e. Pineglen, Grenfell Glen, etc.) or in areas where serviced development has occurred subsequent to the initial development on private services (i.e. Heart's Desire, Honey Gables, etc.). These private service enclaves within the City of Ottawa were derived based upon the urban wells study (Dillon, 2007).

It should also be noted that two of the Villages within the City of Ottawa also contain areas of mixed services. The core of the Village of Manotick and the former Hillside Gardens communal well system are supplied by municipal water from the City of Ottawa water purification plants. However, the majority of the Village of Manotick is on private wells (approximately 4,000 people). Similarly, one subdivision within the Village of Richmond (King's Park) is supplied with municipal drinking water from two groundwater wells. The remainder of the Village of Richmond (approximately 4,000 people) is supplied via private drinking water wells.

1.6.2.10 Septic Systems and Wastewater Treatment Facilities

Municipal Sewage Service Areas

Most areas supplied with municipal water are also supplied with sanitary sewers. The locations of the municipal wastewater service areas are presented on Figures 1.6-12 and 1.6-13. The locations of the wastewater treatment plants are discussed above in Section 1.6.2.8 and presented on Figure 1.6-8.

One exception to the municipal service with both water and wastewater servicing occurs within the Village of Richmond. The majority of the Village of Richmond contains municipal sewers but not municipal water. The King's Park subdivision within Richmond has both municipal water and sewers (approximately 450 people).

Private Septic Systems

Outside of these municipal sanitary sewer service areas, the sanitary disposal of wastewater for all development is by private septic system. Assuming that for most properties the private services will consist of both a well and septic system, this would result in approximately 44,000 septic systems in the MRSPR. The locations of the private wells and inferred septic systems are presented on Figure 1.6-11, with the exception of the former Village of Richmond as detailed above.

Similar to the above noted private water service areas within the urban areas, there are also several areas within the defined urban areas that exist on private septic systems. These private service areas within the municipal wastewater service areas are also presented on Figure 1.6-12.

Within the Village of Manotick there are also several areas that are serviced by municipal water but remain on private septic systems. These two areas within the Village of Manotick that are on private septic systems include the core of the Village which was serviced by water as a result of the water contamination, discussed below in Section 5.1.3 and the former communal well location in Hillside Gardens.

In addition to portions of the Village of Manotick, there are also several other pockets of development that have municipal water only. These areas with municipal water and private septic systems are generally found within the greenbelt (i.e. Hwy 417 between March Rd. and Moodie Dr.) or on the edges of the fully serviced development (i.e. Cedarview, Navan Rd., Bank St., etc.).

OP policies were also reviewed to determine the municipal strategies for sanitary sewers. Outside of the municipal supply areas identified above, municipalities indicate that existing and future development is to be conducted on private septic systems. Brief summaries of the OP policies regarding sanitary sewage disposal for both public (sanitary sewers) and private (septic systems) and their respective OP subsections are presented in the water and wastewater section within Appendix 4, Table A-4.

1.6.2.11 Stormwater Management

Traditionally stormwater management has been involved in controlling the flow of water from peak flow events. Stormwater management has evolved into a more integrated approach that includes development policies, environmental goals, water quality and other aspects. Stormwater management is related to watershed and subwatershed planning which investigate the natural functions and features of the watershed. Watershed or subwatershed studies within the MRSPR have been completed for the following areas:

- Interim Watershed Plan – MVC (1983)
- Interim Watershed Plan – RVCA (1983)
- Rideau Valley Watershed Strategy (1992)
- Mississippi Valley Watershed Strategy (1993)
- Kemptville Creek Watershed Plan (1999)
- Shirley’s Brook / Watts Creek Subwatershed Study (1999)
- Upper Poole Creek Subwatershed Study (2000)
- Jock River Watershed Management Plan (2001)
- Kanata North Environmental / Stormwater Management Plan (2001)
- Tay River Watershed Management Plan (2002)
- Sawmill Creek Subwatershed Study Update (2003)
- Carp River Watershed / Subwatershed Plan (2004)
- Jock River Reach 2 and Mud Creek Existing Conditions Report (2005)
- Lower Rideau Watershed Strategy (2006)

Summaries of these reports are presented in Appendix 1. Where watershed or subwatershed plans have been completed, municipal stormwater management planning will have regard for these larger scale plans.

As indicated in the above sections, municipal systems for both water and sanitary sewers have been identified. In addition to the water and sanitary sewers, these areas generally have storm sewers. Brief summaries of the OP policies regarding stormwater management and their respective OP subsections are presented in the water and wastewater section within Appendix 4, Table A-4.

1.6.2.12 Agricultural Resources

Rural land use within the MRSPR is predominantly agricultural with commercial, industrial and other land uses. Summaries of the OP designations for rural lands and their respective OP subsections are presented in Appendix 4, Table A-4.

Most rural lands within the municipalities of the MRSPR contain land used for agriculture. Agricultural land use designations are identified in most municipalities. For these lands to be designated as agricultural, they generally have Class 1 to 3 soils as identified by the Canada Land Inventory or have been traditionally used for agricultural purposes. Some municipalities only have rural designations and not agricultural designations. In addition, agriculture uses are also permitted within the aggregate and mineral resource designations on the condition that will not preclude extraction at a further date.

Rural, agricultural and mineral resource land use designations are identified on the individual municipal OP maps. Brief summaries of the OP policies regarding agriculture and their respective OP subsections are presented in Appendix 4, Table A-4.

The distribution of the agricultural sector obtained from the 2001 Census of Agriculture is presented in Table 1.6-7. The data is presented on an upper / single tier basis for the Counties of Frontenac, Lanark, Leeds & Grenville and Lennox & Addington and the City of Ottawa. Further details as to the land cover and crop types are discussed in the agricultural water use section.

Land cover as presented on Figure 1.2-24 details the agricultural, rural land use and wooded area land cover types within the MRSPR. In addition, the lands designated as agricultural and rural from Official Plan mapping within the MRSPR are represented on Figure 1.6-3.

In the Renfrew-Mississippi-Rideau Groundwater Study (Golder et al., 2003) a comparison of agriculture from the 1996 Census of Agriculture to 2001 was undertaken for Renfrew and Lanark Counties and the City of Ottawa. From 1996 to 2001 agricultural land use indicated the following changes with respect to crops grown:

- Silage corn area remained unchanged;
- Grain corn area increased by 40%;
- Soybean area increased by 150%;

- Cereal grain area decreased by 10%; and
- Hay area decreased by about 5%.

The overall area used for the production of crops increased by approximately 10% indicating that a combination of pasture land and hay to crops occurred. However, the total farm land decreased by approximately 5%. Decreases in the number of livestock for beef cattle, dairy cattle and pigs also occurred from 1996 to 2001. The number of sheep increased from 1996 to 2001.

1.6.2.13 Recreation

Recreation lands are often identified as parkland and/or open space designations. In addition to the land based recreational activities, significant water-based recreational opportunities exist due to the abundance of lakes and rivers within the MRSPR. Parkland and open space designations are identified on the individual municipal OP maps. Brief summaries of the OP policies regarding recreation and their respective OP subsections are presented within the natural environment section in Appendix 4, Table A-4.

1.6.2.14 Protected Areas

Protected areas include crown lands, natural hazard areas, such as flood plains, organic soils, and unstable soils / slopes, and natural heritage features including areas of natural or scientific interest (ANSI), aquatic habitat, habitat for endangered or threatened species, valley lands, wetlands, wildlife habitat and woodlands. Provincial mapping of protected areas (ANSI and wetlands) and flood plains is presented on Figures 1.4-1 and 1.4-2. Environmental protection and natural hazard features are identified on the individual municipal OP maps. Brief summaries of the OP policies regarding protected areas and their respective OP subsections are presented within the natural environment section in Appendix 4, Table A-4.

1.7 Water Uses and Values

Water use within the MRSPR is a mixture of drinking water, recreational, ecological, agricultural and industrial uses. Within Ontario, any use of more than 50,000 L/day requires a permit to take water (PTTW). The PTTW program is operated and enforced by the MOE. The MOE maintains a PTTW database which lists all large water users and permitted water takings. It should be noted that the current PTTW database is only the maximum daily permitted water withdrawal amount and not the actually daily usage. Permit holders are now required to document their actual water takings (from 2005 onwards) and future iterations of the PTTW database will improve the knowledge of the actual usage of water.

As of February 2008, there are 193 active permits within the MRSPR. From these permitted locations, the total volume of water permitted to be withdrawn is greater than 23 million cubic m per day. The water use categories defined within the PTTW database include: agricultural, communal, industrial/commercial, miscellaneous, municipal and recreational uses. Further detail regarding the PTTW database is presented below in Section 1.7.5. The locations and classifications for the PTTW database are presented on Figure 1.7-1. Further detail regarding water use can be found within the MRSPR Conceptual Water Budget report (Proposed MRSPR, 2007).

1.7.1 Drinking Water Sources

1.7.1.1 Municipal Drinking Water Facilities under O. Reg. 170/03

Large Municipal Drinking Water Facilities

Twelve large municipal drinking water facilities exist within the MRSPR. Seven are sourced from groundwater while five are sourced from surface water. These large municipal water supplies are located in the municipalities detailed in Table 1.6-5. The locations of these large municipal water systems as well as their service boundaries are presented in Figures 1.6-9 and 1.6-10.

Table 1.7-1 presents details as to the PTTW, permitted water taking volumes, drinking water system number and actual water usage for the large municipal drinking water systems in the MRSPR. The actual water usage was determined from data collected from municipalities for the above noted facilities. A five-year average water use has been calculated for each facility and is compared with their respective total permitted water taking volumes.

Detailed descriptions of the large municipal drinking water systems are discussed below. The systems are discussed by municipality. In addition, a summary of the compliance inspection reports for the various drinking water systems has been compiled and is presented in Appendix 5.

Previous groundwater studies have been conducted in municipalities with municipally supplied groundwater treatment systems from 2000 to 2004. Details regarding the data gaps and plans to address them associated with these previous groundwater studies are presented below in Section 3.2.

Carleton Place

Municipally supplied drinking water in Carleton Place is provided via surface water from the Mississippi River. The Water Treatment Plant is located at 199 John Street in Carleton Place and was first constructed in 1914. The treatment process includes screening, Actiflo treatment trains consisting of flocculation, clarification and settling, dual media filtration, disinfection with chlorine gas and fluoridation (Wooding, 2007A). Details regarding the specific components of the Carleton Place Water Treatment Plant can be found in the Engineer's Reports (J.L. Richards, 2000).

The Municipal Water Use Database (MUD) indicates that in 2001 some 8,992 people were supplied with drinking water from this facility (EC, 2005). The locations of the surface water intake and Water Treatment Plant for Carleton Place are presented on Figure 1.7-2.

Merrickville – Wolford

Merrickville's municipally supplied drinking water is sourced from groundwater. Originally there were four drinking water supply wells, drilled between 1961 and 1973. Well No. 3 was decommissioned in 1992. The locations of the active groundwater supply wells are as follows:

- Well No. 1 is located on the north side of Main Street East approximately 60 m east of St. Lawrence Street;
- Well No. 2 is located on the north side of Main Street East approximately 60 m east of St. Lawrence Street; and
- Well No. 4 is located on the north side of Main Street East approximately 85 m east of St. Lawrence Street.

Each groundwater well pumps water to the pumping station. The pumping station contains an in-ground reservoir, associated distribution pumps and disinfection system. Disinfection occurs by injection of sodium hypochlorite solution (White, 2007A). Water is then distributed from this pumping station. The MUD database indicates that in 2001, 1,101 people were supplied with drinking water from these groundwater supply wells (EC, 2005). The locations of the groundwater supply wells for Merrickville are presented on Figure 1.7-2.

Mississippi Mills

Almonte municipal drinking water is sourced from groundwater. The groundwater supply wells were established between 1948 and 1991. The locations of the active groundwater supply wells are as follows:

- Well No. 3 is located in the eastern portion of the town, approximately 60 m north of Ottawa Street and Harold Street;

- Well No. 5 is located along Almonte Street (County Road 17) near the southwest end of the town;
- Well No. 6 is located in the south end of the town immediately east of Highway 29; and
- Well No. 7 and 8 are located near the northeast edge of the town along the north side of Patterson Street.

Each groundwater well location consists of a drilled groundwater well located within a pump house and a chlorine contact chamber. Disinfection occurs by injection of sodium hypochlorite solution (White, 2007B). Two drilled wells (Wells 7 and 8) are located within the same pump house. Water from Wells 7 and 8 is then pumped to an elevated water storage tank for later distribution. Water from the remaining groundwater supply wells is distributed from these pumping stations. The municipally supplied population in Almonte in 2001 was 4,659 people (EC, 2005). The locations of the groundwater supply wells for Almonte are presented on Figure 1.7-2.

North Grenville

Kemptville municipal drinking water supply is sourced from groundwater. The groundwater supply wells were established between 1948 and 1979. The locations of the active groundwater supply wells and associated pumping stations are as follows:

- Van Buren Street Pumping Station is located at 2 Van Buren Street;
- Kernahan Street Pumping Station is located at 508 Kernahan Street; and
- Alfred Street Pumping Station is located at 1 Alfred Street.

Each pumping station consists of a drilled groundwater well located within a pump house, a reinforced concrete storage reservoir and chlorine contact chamber. Disinfection occurs by injection of sodium hypochlorite solution (Millar, 2006). Water is then distributed from these pumping stations. The Kemptville municipal drinking water system supplied 3,395 people in 2001 (EC, 2005). The locations of the groundwater supply wells for Kemptville are presented on Figure 1.7-2.

Ottawa

The City of Ottawa has two drinking water treatment plants supplied from surface water and five municipal groundwater well supply systems. Both drinking water treatment plants and three of the municipal groundwater supply systems (Carp, King's Park – Richmond and Munster Hamlet) are found within the MRSPR. Two of the groundwater supply systems (Shadow Ridge and Vars) are located in SNC and are subsequently outside of the MRSPR. All municipal drinking water supply systems within the MRSPR are discussed below.

Britannia & Lemieux Island

Municipally supplied drinking water in the urban portion of the City of Ottawa is provided by surface water from the Ottawa River. The two drinking water purification plants, Britannia and Lemieux Island, supply the west and east sides of the urban area.

The Britannia Water Purification Plant is located at 2713 Cassels Road and was constructed in 1961. The Britannia treatment process includes screening, coagulation, flocculation, settling, dual media filtration, disinfection and fluoridation. Disinfection of the water is conducted by sodium hypochlorite, ammonia and sodium hydroxide (or carbon dioxide) (Villeneuve, 2007A).

The Lemieux Island Water Purification Plant is located at 1 River Street and was constructed in 1932. The Lemieux Island treatment process includes screening, coagulation, flocculation, settling, dual media filtration, disinfection and fluoridation. Disinfection of the water is conducted by sodium hypochlorite, ammonia and sodium hydroxide (or carbon dioxide) (Villeneuve, 2007B). Details regarding the specific components of the Britannia and Lemieux Island Water Purification Plants can be found in the Engineer's Reports (Stantec, 2001A and 2001B).

In 2001, 692,341 people were supplied with drinking water from the City of Ottawa Drinking Water Purification Plants. The locations of the surface water intakes and Water Purification Plants for the City of Ottawa are presented on Figure 1.7-2.

Carp

Carp municipal drinking water supply is sourced from groundwater. The groundwater supply wells were established between 1986 and 1994. The locations of the active groundwater supply wells are as follows:

- Well No. 1 is found at 135 Salisbury Street; and
- Well No. 2 is approximately 10 m north of Well No. 1.

Each groundwater well pumps water to the pumping station. The pumping station contains an in-ground reservoir, associated distribution pumps and disinfection system. Disinfection occurs by injection of sodium hypochlorite solution (Villeneuve, 2007A). Water is then distributed from this pumping station. The Carp municipal drinking water system supplied 1,500 people in 2001 (EC, 2005). The locations of the groundwater supply wells for Carp are presented on Figure 1.7-2.

King's Park – Richmond

The King's Park subdivision in the Village of Richmond has municipally supplied drinking water that is sourced from groundwater. The wells were established in 1970 and 1971 and are located as follows:

- Well No. 1 is located at 2 Chanonhouse Drive, Richmond; and
- Well No. 2 is located 300 m northeast of Well No. 1.

Each pumping station consists of a drilled groundwater well located within a pump house and chlorine contact chamber. The treatment process includes disinfection by injection of sodium hypochlorite solution (Sterling, 2007). Water is then distributed from these pump houses. The MUD database indicates that in 2001, approximately 450 people were supplied with drinking water from these groundwater supply wells (EC, 2005). The locations of the groundwater supply wells for King's Park – Richmond are presented on Figure 1.7-2.

Munster Hamlet

Munster Hamlet municipal drinking water supply is sourced from groundwater. The groundwater supply wells were established between 1969 and 1973. The locations of the groundwater supply wells are as follows:

- Well No. 1 is located on Cold Stream Drive, approximately 200 m east of the Munster Side Road; and
- Well No. 2 is located 290 m south of Well No. 1l along the north side of the Munster Side Road, approximately 570 m south of Sixth Line Road.

Each groundwater well pumps water to the pumping station. The pumping station contains an in-ground reservoir, associated distribution pumps and disinfection system. Disinfection occurs by injection of sodium hypochlorite solution (Villeneuve, 2007C). Water is then distributed from this pumping station. The Munster Hamlet municipal drinking water system supplies approximately 1,350 people (Golder et al., 2003). The locations of the groundwater supply wells for Munster are presented on Figure 1.7-2.

Perth

Municipally supplied drinking water in Perth is provided from surface water out of the Tay River. The Water Treatment Plant is located at 15 Sunset Boulevard in Perth and was constructed in 1964. The treatment process includes screening, coagulation, flocculation, settling, dual media filtration, disinfection and fluoridation. Disinfection of the water is conducted by chlorine dioxide and sodium hypochlorite for pretreatment of the raw water and secondary disinfection by sodium hypochlorite (Lynds, 2007). Details regarding the specific components of the Perth Water Treatment Plant can be found in the Engineer's Reports (Xie et al., 2001).

The MUD database indicates that in 2001 some 5,973 people were supplied with drinking water from this facility (EC, 2005). The locations of the surface water intake and Water Treatment Plant for Perth are presented on Figure 1.7-2.

Smiths Falls

Municipally supplied drinking water in Smiths Falls and a portion of Montague Township is provided from surface water out of the Rideau River. The Water Treatment Plant is located at 25 Old Mill Road in Smiths Falls and was first constructed in 1924. The treatment process includes a coagulant mixing tank, disinfection by chlorine gas application, two sedimentation tanks, five dual media filters (granular activated carbon and sand) and a series of three clear wells (White, 2006). Details regarding the specific components of the Smiths Falls Water Treatment Plant can be found in the Engineer's Reports (MacViro, 2001).

The MUD database indicates that in 2001, 9,700 people were supplied with drinking water from this facility which includes 9,140 people in Smiths Falls and 560 people in Montague Township (EC, 2005). The locations of the surface water intake and Water Treatment Plant for Smiths Falls are presented on Figure 1.7-2.

Westport

The Village of Westport municipal drinking water supply is sourced from groundwater. The groundwater supply wells were established between 1969 and 2003. The locations of the groundwater supply wells are as follows:

- Well No. 2 is situated east of Highway 42 between George and Spring Streets; and
- Well No. 3 is situated approximately 100 m northeast of Well No. 3.

Well No. 2 is located within a pump house. Well No. 3 is located within a concrete chamber. The treatment process includes disinfection by injection of sodium hypochlorite solution and iron sequestering using sodium hexametaphosphate (Wooding, 2007B). Water from both wells is disinfected within the pump house and then pumped to an elevated water storage tank for later distribution. The Westport municipal drinking water system supplies approximately 670 people (Golder et al., 2003). The locations of the groundwater supply wells for Westport are presented on Figure 1.7-2.

1.7.1.2 Communal Wells & Designated Facilities

The locations of communal wells and designated facilities (nursing homes, schools, day care facilities, etc.) that supply drinking water to the public within the MRSPR are presented on Figure 1.7-3. In addition to the communal wells and designated facilities, all non-municipal water supply wells from the MOE PTTW database are also presented on Figure 1.7-3.

It should be noted that the locations of many of the communal wells were not able to be plotted on Figure 1.7-3 due to incomplete addresses. However, Table 1.7-2 presents a summary of the different types of communal wells and designated facilities within the

MRSPR (including those sites that did not have complete geographic locations and could not be included on Figure 1.7-3). Due to the incomplete addresses for many of the communal wells, the summary presented in Table 1.7-2 includes all communal wells based on the entire municipal boundaries and may include some locations that are outside of the MRSPR.

Within the MRSPR there are 47 communal water supplies that supply residential water on a seasonal basis and are referred to as non-municipal seasonal residential supplies (NMSRS) in Table 1.7-2. These NMSRS are typically trailer parks, campgrounds or other water supplies.

In addition, within the MRSPR there are also 39 communal water supplies that supply residential water on a year round basis and are referred to as non-municipal year-round residential supplies (NMYRRS) in Table 1.7-2. These NMYRRS are permanent mobile home parks, condominiums or other communal water supplies.

There are also several other types of non-residential water supply types presented in Table 1.7-2. The non-municipal non-residential water supply facilities include churches, motels, resorts, etc. The municipal non-residential water supply facilities include places such as community halls, township offices, sports complexes, etc. Within the MRSPR there are 371 non-municipal and 135 municipal non-residential water supplies.

Private Groundwater Supplies

The locations of the private groundwater wells as identified by the MOE well records database is presented on Figure 1.6-11. Within the MRSPR there are approximately 44,000 private wells. Estimated domestic water use within the MRSPR is presented in Table 1.7-3.

The estimated total amount of water used by private residents was found to range from approximately 16,500 - 22,100 m^3/day. The largest estimated population existing on private wells is found within the City of Ottawa with an estimated water use ranging from 8,000 - 10,700 m^3/day.

1.7.2 Recreational Water Use

Within the MRSPR, there are many lakes and rivers that provide for various types of recreational uses. Numerous communities along these rivers and around these lakes rely on the water for economic prosperity by providing goods and services to those who come to use the lakes and rivers for recreational purposes. Recreational uses made available by the lakes and rivers include boating, canoeing/kayaking, fishing, swimming, etc.

One of the key features of the MRSPR is that the Precambrian Bedrock formation in the western portion of the region has resulted in the formation of hundreds of lakes (over 250 and 100 in the MVC and RVCA, respectively). As indicated in the Mississippi River Water Management Plan (French et al., 2005), Bon Echo Provincial Park, located in the western portion of the MRSPR, attracts more than 175,000 visitors annually. As a result of this abundance of surface water resources in the western portion of the region, a significant seasonal population exists. This results in large amounts of water being used for recreational purposes within the MRSPR.

Several of the subwatershed studies completed have identified the importance of healthy waters as they related to the economic prosperity of the region. Especially within the western portion of the MRSPR, the seasonal population is relied upon to support the tourist economy. From the Tay River Watershed Management Plan (RVCA and Tay River Roundtable, 2002), municipalities within the central portion of the MRSPR were contacted to determine the proportion of tourism that was related to the natural resources. The municipalities (Central Frontenac, Drummond/North Elmsley, Rideau Lakes, South Frontenac, Tay Valley), many of which are located within both the MVC and RVCA, responded that approximately 80 to 100% of the tourism was related to their natural resources.

Within the RVCA, significant recreational use of the Rideau Canal has been documented in the Lower Rideau Watershed Strategy – Phase 1 (Robinson Consultants, 2003). The total annual lockages (number of vessels passing through the locks) of the locks downstream of Smith's Falls on the Rideau Canal is approximately 40,000 boats/year. Significant water usage is associated with these recreational lockages. In addition to the recreational use of the water within the MRSPR, many residents use the riverside environment for such uses as hiking, biking, and sun bathing in addition to the in-water recreational uses. This indicates that significant non-consumptive recreational water use occurs throughout the MRSPR and not just within the western portion of the region.

1.7.3 Ecological Water Use

Ecological water use is the amount of water required for an ecosystem to survive. An ecosystem is a community of organisms (plant, animal and other living organisms) living and interacting with its physical environment. It can take on many shapes and forms. Examples of ecosystems include an estuarine reach of a river, a spring fed by groundwater, or an urban creek. The proper functioning of the ecosystem is critical to sustaining human life. The more diverse the system, the more benefits and services it can provide. Water, like the air we breathe, is one of the key elements needed for ecosystems to function and provide services. Water is required at certain depths and velocities, degree of oxygenation, and with an adequate amount of groundwater recharge for the ecosystem to survive and diversify. Water needs to be present or absent at certain times of the year for spawning and breeding and to signal the start of migration. Some organisms even need water to dry up while others cannot survive without it. The naturally vegetated areas and aquatic habitat of the MRSPR are discussed in more detail in the previous Sections 1.4 and 1.5, respectively.

How much water is needed to keep ecosystems in balance? How is this determined? How much water can be removed from the system before causing negative impacts to the ecosystem? There are many users competing for water in the watershed. Water takings and diversions that are not properly evaluated for impacts to the environment can adversely affect the balance in aquatic ecosystems such as wetlands and marshes. There are many rapid and comprehensive methods for determining water allocations. The methodology should be consistent with integrated environmental management principles. It should be legally and scientifically defensible, adhere to information and database format requirements, be conservative and precautionary, be applicable to where the ecosystem is situated, and be evaluated based on the ecosystem factors and not just based on the hydrologic factors. Once a water allocation is determined for an ecosystem, the water must be provided at the times and rates specified. Flows released from a dam are always required for ecosystem needs downstream. A flow gauging station at the dam can be used to check that the correct flows are being released and that the timing is appropriate.

For example, in the Rideau River watershed, concern has been raised with regards to water takings by OMYA, the calcite producing plant, located on the Tay River. This issue was reviewed recently in the Tay River Subwatershed Plan (RVCA and Tay River Roundtable, 2002). One of the recommendations was to determine water requirements for the ecosystem that would be affected by takings from the OMYA plant. In response to the concerns regarding the ecological health of the Tay River with respect to the water withdrawals from the OMYA plant, the PTTW from the MOE was issued after consultation with the DFO. The conditions identified by the DFO have the plant apply a range of variability based on the amount of water removed with respect to the overall flow in the Tay River. As a result of this complex situation, protocols for evaluating adverse ecological impacts are evolving.

1.7.4 Agricultural Water Use

Within the MRSPR, approximately 35% (3,034 km^2) of the land is identified as agricultural or rural land use. This percentage indicates that agriculture is a significant factor in the MRSPR. Agricultural land use, however, is not evenly distributed throughout the region. Figure 1.2-24 presents the land cover within the MRSPR.

As presented on Figure 1.2-24, the majority of agricultural land is found in the Counties of Lanark and Leeds & Grenville and the City of Ottawa. The remaining two Counties, Frontenac and Lennox & Addington, are covered predominantly with dense deciduous forest and dense coniferous forest. As a result, most of the water use for agricultural purposes is concentrated in Lanark, Leeds & Grenville, and Ottawa.

The MNR agricultural water use by watershed database was consulted to determine the type of agriculture that the water was being used for (de Loe, 2002). The water use is detailed as being utilized for livestock, irrigation, and other uses. The information is presented for the Mississippi and Rideau watersheds and the Ottawa subwatersheds. The Ottawa subwatersheds are an amalgamation of smaller subwatersheds such as the Carp River, Greens Creek, etc. This information is summarized in the Table 1.7-4.

In addition, the MOE PTTW database identifies nine permits for agricultural uses in the MRSPR. These permits, along with the water source, their purpose and total amount of water they are permitted and summarized in Table 1.7-5. The locations of the agricultural PTTW are also presented on Figure 1.7-1.

In general, farm irrigation systems have not been developed in a large scale way within the MRSPR. In the low water events that have occurred since inception of the Ontario Low Water Response program, there have been impacts on agriculture, but during the event, water allocation amongst competing irrigation systems did not present itself as an issue. However, with climate change this may become a bigger issue in the future.

1.7.5 Industrial - Commercial Water Use

The MOE PTTW database indicates six general purpose classifications for permits in the industrial/commercial sector. All permits including general classifications and identified purpose within the MRSPR from the PTTW database are detailed in Table 1.7-6 is presented by subwatershed. Table 1.7-6a presents the number of permits by subwatershed. The permitted daily water use by subwatershed is shown in Table 1.7-6b (permitted volume) and Table 1.7-6c (percentage of permitted volume). The permitted yearly water use by subwatershed is shown in Table 1.7-6d (permitted volume) and Table 1.7-6e (percentage of permitted volume). In addition, Figure 1.7-4 presents pie charts of the yearly water use by subwatershed.

Commercial water use in the MRSPR accounts for a relatively small percentage of the total permitted water use (0.27% of the yearly permitted water use). However, in some subwatersheds, commercial water use represents a significant portion of the water use. In the Ottawa River MVC subwatershed 73% of the water used is for commercial golf course irrigation. In the Buckshot Creek and Fall River subwatersheds all of the PTTW is used for commercial aquaculture.

Industrial water use in the MRSPR represents a larger percentage of the total permitted water use (33% of the yearly permitted water use). The locations with industrial water use is the Lower Mississippi subwatershed (99% of the water use in this subwatershed is for industrial power generation).

It should be noted that the largest water use in the MRSPR is for miscellaneous classification with the purpose of wildlife conservation. Wildlife conservation represents 61% of the yearly permitted water use in the MRSPR. It is also the largest water use (>80% of the yearly permitted water use) in most of the subwatersheds in the MRSPR including the Clyde River, CP Dam, Indian River, Jock River, Kemptville Creek, Lower Rideau, Middle Rideau, Rideau Lakes and Tay River subwatersheds.

1.8 Data and Knowledge Gaps for Watershed Description

The following data gaps were identified for Section 1.0 – Watershed Description within the MRSPR. Additional details as to the data gaps are provided in Appendix 2.

<u>Section 1.2.4 Surficial Geology</u>

Surficial geology for a portion of Frontenac and Lennox & Addington Counties has not been completed.

Digital soils mapping for the City of Ottawa and Lanark County does not exist.

<u>Section 1.3.1 Surface Water Hydrology</u>

The surface water hydrology section mainly refers to description of where the rivers flow. Details regarding stream density (% of watercourse length in various stream orders (km of stream per km^2 of drainage area) and in stream storage (natural depressions, wetlands and lakes) should be added to this section, which do not currently exist.

The largest data gap is the lack of stream flow gauges representing the lower Mississippi River. There are no stream flow gauges on or near the outlet of the Mississippi River. The most downstream gauge is at Appleton, which is approximately 1/4 of the way up the River. Flows in the downstream reach are a major data gap and will have to be estimated by some other method for water budgeting purposes.

Within the Rideau watershed, gauges are lacking on the un-regulated portions of the watershed, specifically on many tributaries.

<u>Section 1.3.2 Groundwater and Hydrogeology</u>

Several limitations were identified with the MOE water wells database which was used for the generation of the potentiometric groundwater surfaces:

- Static water levels in “open” boreholes completed in bedrock represent a hydraulically diluted (average) water elevation (blended head) due to intersecting multiple fractures over the depth of the well.
- Errors associated with static water level measurements in MOE records – each water level was recorded immediately following drilling and therefore may not have equilibrated. In addition, each reading was collected at various dates spanning decades.

- Regional groundwater elevations are being interpolated over large areas where the data is sparse (i.e., western area in Addington Highlands).
- Location errors associated with MOE wells (UTM coordinates) – most UTM coordinates were selected from an Ontario Base Map and therefore are not overly accurate.

Limitations were also identified with the groundwater recharge / discharge calculated. Similarly, the source of error associated with determining groundwater elevations for both shallow and deep aquifers using these methods is carried through into the delineation of potential recharge and discharge features. These maps should only be used as a general regional interpretation and should not be relied on for local conditions.

The large depth to water associated with the highest topographic regions is a function of the sparse dataset in this area and therefore the depths presented are not considered to be realistic. Hydrogeologic information from wells drilled in this area is a significant data gap, therefore further site specific information is needed to increase the confidence in this data.

Base-flow monitoring is the component of surface water attributed to groundwater discharge. No long-term base-flow monitoring exists for the MRSPR.

Section 1.3.4 Climate

There are no active climate stations located at the north end of the Mississippi Watershed. There is very little data in this area. Other stations such as in Quebec (Luskville) or the Ottawa station will have to be considered to represent the north end. This same issue applies to the Rideau. There are no active climate stations in the south end of the Rideau Region. The next active stations in the south end are Godfrey and Brockville; however Brockville is not representative of the Region as it is affected by Lake Ontario. There is also a lack of long-term climate data in the west. The Ompah and Ompah-Seitz stations, although active, only have 10 years of record.

There is also a lack of evaporation data in the west. The only stations with evaporation data are in the east. They are Ottawa and Kemptville. The next western station is in Peterborough, which is at least 100 km beyond the boundary of the MRSPR.

Section 1.4.1 Wetlands

The spatial distribution of wetlands is uneven, with few significant wetland features of any note remaining in the Lower Rideau or Eastern Mississippi regions. The substantive wetland coverage is found in the Middle and Upper Rideau and Western and Central Mississippi regions, many of which have never been evaluated using the OWES.

Section 1.4.2 Riparian Areas

The shorelines of individual properties of the Rideau River from Smiths Falls to Ottawa have been classified for ecological integrity using a standardized protocol by the RVCA. However, this is the only area in the MRSPR for which riparian classification has been conducted.

Section 1.6.1 Population Distribution and Density

The following limitations were identified with the population statistics:

- Known populations of development areas (Stats Canada reports by dissemination area).
- Known populations on private services (water and septic).
- Known populations of seasonal residents.

Section 1.6.2 Land Use

Digital OP mapping has not been obtained for Addington Highlands, North Frontenac & South Frontenac.

Section 1.7.1 Private Groundwater Supplies

Population that relies upon private wells / septic is estimated.

Section 1.7.5 Industrial / Commercial Water Use

Several limitations within the PTTW database were identified:

- The permits that are noted above include all that are current. Permits that have expired have been excluded from analysis.
- Volumes of actual takings from PTTW.

2.0 Water Quality

2.1 Selecting Indicator Parameters

2.1.1 Surface Water Quality Indicator Parameters

The following eight general chemistry, three metals and one biological parameters were selected as indicator parameters for surface water:

- ammonia (un-ionized), chloride, nitrate (NO_3), nitrite (NO_2), pH, total Kjeldahl nitrogen (TKN), total phosphorus (TP), and total suspended solids (TSS);
- copper, lead, and zinc; and
- *Escherichia coli* (*E. coli*).

A list of indicator parameters and their general classification are presented in Table 2.1-1. The locations of the surface water quality monitoring stations are presented on Figure 2.1-1. Table 2.1-2 details the relevant provincial and federal criteria for the indicator parameters selected. For surface water, the Provincial Water Quality Objectives (PWQO) were selected as the generic criteria. Where a PWQO was not available for the indicator parameter the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG), Ontario Drinking Water Quality Standards (ODWQS), Ontario Drinking Water Standards, Objectives and Guidelines (ODWSOG) or other relevant criteria were selected.

2.1.2 Groundwater Quality Indicator Parameters

The groundwater quality indicator parameters that are deemed most informative for the characterization of natural groundwater conditions throughout the MRSPR include:

- major cations - calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na);
- major anions - chloride (Cl), and sulphate (SO_4);
- aesthetic parameters that affect taste, smell and appearance of potable water - hardness (as calcium carbonate ($CaCO_3$)), hydrogen sulphide (H_2S), iron (Fe), TDS and turbidity; and
- environmental parameters that help characterize the health of the groundwater system - alkalinity, ammonia (NH_3), conductivity, dissolved organic carbon (DOC), *E. coli*, fluoride (F), NO_3, pH, total coliforms, and TKN.

A list of indicator parameters and their general classification are presented in Table 2.1-1. The locations of the groundwater quality monitoring stations are presented on Figure 2.1-2. Table 2.1-2 details the relevant provincial and federal criteria for the indicator parameters selected. For groundwater the ODWQS and ODWSOG were selected as the generic criteria. Where the ODWQS or ODWSOG were not available for the indicator parameters other relevant criteria were selected.

2.2 Surface Water Quality Data Analysis and Reporting

Surface water consists of a combination of water from either precipitation (including run-off) and baseflow (groundwater). Both of these sources of water can be found at differing percentages within surface water (due to precipitation vs. non-precipitation events as compared to the baseflow component) and as a result the associated chemical composition will vary. Typically the chemical composition of precipitation is dependent upon the equilibrium with the natural gases within the atmosphere. The chemical composition of groundwater is much more dependent upon the soil or rock formation from which the groundwater is sourced. As a result, there are much higher percentages of dissolved solids found within groundwater as compared to precipitation. The chemical composition of groundwater is discussed in more detail in Section 2.3.

In addition to the mixture of baseflow and precipitation in surface water, there are many natural factors that influence the chemical composition of the water. Some of these include increased flow during precipitation events and potentially increased erosion, the reactions of the surface water with the mineral solids in the riverbed and in suspension, water losses due to evaporation or transpiration of plants and effects of organic matter. Lastly, human influence can have a significant impact on the surface water quality from such things as stream pollution and waste disposal (Hem, 1985).

2.2.1 Background Studies

The following background studies with significant sections related to surface water quality have been conducted within the MRSPR.

- Rideau Valley Conservation Report (1968)
- Mississippi Valley Conservation Report (1970)
- Interim Report on the Functions and Status of Kemptville Creek – Kemptville Creek Watershed Plan – Volumes 1 and 2 (1996)
- Jock River Watershed Plan – Interim Report (1996)
- Kemptville Creek Watershed Plan (1999)
- Shirley’s Brook and Watts Creek Subwatershed Study (1999)
- Existing Conditions and Trends in the Tay River Watershed (2000)
- Jock River Watershed Management Plan (2001)
- Rideau River – State of the River Report (2001)
- Tay River Watershed Management Plan (2002)
- Lower Rideau Watershed Strategy – Phase I (2003)
- Baseline Surface Water Quality Program – Technical Report Five-Year Analysis 1998 through 2002 (2004)
- Carp River Watershed / Subwatershed Study (2004)

- Jock River Reach 2 & Mud Creek Subwatersheds – Draft Existing Conditions Report (2005)
- Sawmill Creek Subwatershed Study Update (2005)
- Kemptville Creek Watershed Plan Update (2006)
- Lower Rideau Watershed Strategy (2006)

Summaries of these reports are presented in Appendix 1. In addition, a detailed list of recommendations associated with the various reports is also presented in Appendix 1.

2.2.2 Surface Water Quality Monitoring Programs

The following surface water quality monitoring programs are currently in operation within the MRSPR and are described in more detail below. A list of all physical, chemical and biological parameters monitored is provided in Table 2.2-1. A list of all active surface water quality stations, as of 2006, is presented in Table 2.2-2. The locations of all active surface water monitoring stations are presented on Figure 2.1-1.

<u>City of Ottawa Baseline Surface Water Quality Monitoring Program</u>

In 2006, there were 70 surface water quality stations monitored by the City of Ottawa within the MRSPR. Several sites within SNC are also monitored as part of the City of Ottawa Baseline Surface Water Quality (OBSWQ) monitoring program. Each monitoring location is sampled monthly, when possible, for 45 physical, chemical, and biological parameters. A list of these parameters is provided in Table 2.2-1 and a list of the OBSWQ monitoring stations is provided in Table 2.2-2. A detailed summary of the program and results are presented in the Technical Report, Five-Year Analysis 1998 through 2002 composed by the Water Environment Protection Program of the City of Ottawa.

<u>MVC Watershed Watch Lake Monitoring Program</u>

The MVC Watershed Watch program was initiated in 1998 and involves the sampling of 42 lakes. Approximately 8 lakes are sampled each year with all 42 lakes being sampled every five years. At each lake, during the sampling year a number of locations at various depths throughout the lake are sampled three times a year unless the lake is adopted and then it is sampled eight times a year. Chemical parameters monitored during the program include TP and chlorophyll. In addition, physical parameters such as Secchi Disk (water clarity), pH, temperature and dissolved oxygen are also monitored. A list of the MVC Watershed Watch surface water monitoring stations is provided in Table 2.2-2. After each sampling year, a report is put together with any historical sampling results and presented for each lake.

Provincial Water Quality Monitoring Network (PWQMN)

As of 2006, there are 21 active PWQMN stations within the MRSPR. Each monitoring location is sampled monthly, when possible, for 36 physical, chemical, and biological parameters. A list of these parameters is provided in Table 2.2-1 and a list of the PWQMN monitoring stations is provided in Table 2.2-2.

RVCA Surface Water Quality Monitoring Program

In 2005, the RVCA maintained and samples 54 surface water quality monitoring stations. Each monitoring location is sampled monthly, when possible, for 41 physical, chemical, and biological parameters. A list of these parameters is provided in Table 2.2-1 and a list of the RVCA surface water monitoring stations is provided in Table 2.2-2.

RVCA Watershed Watch Lake Monitoring Program

The RVCA Watershed Watch program was initiated in 2002 and as of 2005 involves the sampling of 41 lake sites. Historically, approximately 15 lake sites were sampled each year. At each lake, during the sampling year a number of locations at various depths throughout the lake are sampled monthly from late spring until early fall (approximately four to six times a year). Bacteriological and chemical parameters monitored during the program include *E. coli*, DOC, TKN and TP. In addition, physical parameters such as Secchi Disk (water clarity), temperature and dissolved oxygen are also monitored. After each sampling year, a report is put together with any historical sampling results and presented for each lake. The program has been expanded in 2006 in terms of the number of sites sampled per year.

2.2.3 Exploratory Analysis

Data for the selected indicator parameters from the surface water monitoring locations is presented in Appendix 6. Scatter-plots were compiled for the OBSWQ, PWQMN and RVCA surface water monitoring stations. These plots were prepared for the 12 indicator parameters identified above over the 2001 to 2005 (2000 to 2006 for OBSWQ) period and are presented in Appendix 7. Detailed listing of the indicator parameters exceeding the surface water objectives is presented in Appendix 8. A brief summary of the exploratory analysis is presented below.

General Chemistry

Ammonia (un-ionized)

There were 6,250 samples analyzed for un-ionized ammonia from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. Nine samples were found in excess of the

PWQO criterion of 0.02 milligrams per liter (mg/L), which represents less than 1% of the total number of samples analyzed for un-ionized ammonia.

Chloride

There were 7,081 samples analyzed for chloride from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 669 samples were found in excess of the ODWSOG criterion of 250 mg/L, which represents 9% of the total number of samples analyzed for chloride.

Nitrate

There were 3,633 samples analyzed for nitrate from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR and all samples were found to be below the ODWQS criterion of 10 mg/L.

Nitrite

There were 2,794 samples analyzed for nitrite from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 827 samples were found in excess of the CWQG criterion of 0.06 mg/L, which represents 30% of the total number of samples analyzed for nitrite.

pH

There were 7,254 samples analyzed for pH from 2001 to 2005 (1998 to 2005 for the MVC watershed watch program and 2000 to 2006 for OBSWQ) within the MRSPR. A total of 153 samples were found outside of the PWQO range for pH (6.5 to 8.5), which represents 2% of the total number of samples analyzed for pH.

Total Kjeldahl Nitrogen

There were 10,167 samples analyzed for TKN from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 5,583 samples were found in excess of the EC guideline (0.5 mg/L) for TKN, which represents 55% of the total number of samples analyzed for TKN.

Total Phosphorus

There were 10,440 samples analyzed for total phosphorus from 2001 to 2005 (1998 to 2005 for the MVC watershed watch program and 2000 to 2006 for OBSWQ) within the MRSPR. A total of 3,691 samples were found in excess of the PWQO criterion for total phosphorus (0.03 mg/L), which represents 35% of the total number of samples analyzed for total phosphorus.

Total Suspended Solids

There were 7,116 samples analyzed for total suspended solids from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 1,419 samples were found in excess of the Saskatchewan Surface Water Quality Objectives (SSWQO) of 10 mg/L for total suspended solids, which represents 20% of the total number of samples analyzed for total suspended solids.

Metals

Copper

There were 6,971 samples analyzed for copper from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 1,035 samples were found in excess of the PWQO criterion for copper (0.005 mg/L), which represents 15% of the total number of samples analyzed for copper.

Lead

There were 6,748 samples analyzed for lead from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. The lead PWQO criterion varies from 0.005 to 0.025 mg/L depending upon the alkalinity concentration of the water. Six samples were found in excess of the PWQO criterion for lead, which represents less than 1% of the total number of samples analyzed for lead.

Zinc

There were 6,749 samples analyzed for zinc from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 146 samples were found in excess of the PWQO criterion for zinc (0.03 mg/L), which represents 2% of the total number of samples analyzed for zinc.

Biological

E. coli

In total, there were 9,309 samples analyzed for *E. coli* from 2001 to 2005 (2000 to 2006 for OBSWQ) within the MRSPR. A total of 2,842 samples were found in excess of the PWQO criterion for *E. coli* (100 colony forming units (cfu) / 100 mL of water), which represents 31% of the total number of samples analyzed for *E. coli*.

2.2.4 Statistical Analysis

Basic statistical analyses including calculation of minimum, maximum, number of samples exceeding the criteria, average, average concentration exceeding the criteria, geometric mean, geometric mean concentration exceeding the criteria and total number of samples was prepared for all of the above noted surface water monitoring programs. These statistics were prepared for the 12 indicator parameters identified above over the 1998 to 2005 period and are presented in Appendix 9, Table A-9.

Appendix 9 presents a summary of the surface water quality monitoring programs discussed on a subwatershed basis. Data presented is from 2000 to 2005 with the exception of the MVC watershed watch program (1998-2005) and the OBSWQ monitoring program (2000-2006). Each of the indicator parameters will be discussed for the sampling locations within the individual subwatersheds.

Box and whisker plots were compiled for all surface water monitoring programs. These plots were prepared for the 12 indicator parameters identified above over the 2001 to 2005 period (1998 to 2005 for the MVC watershed watch program and 2000 to 2006 for the OBSWQ monitoring program) and are presented in Appendix 10.

The PWQMN represents the best historical water quality data set. Surface water monitoring has been conducted as part of this program for decades. As a result, geometric means were prepared for the PWQMN indicator parameters in five year intervals (i.e., 1981-1985, 1986-1990, etc.) from 1981 to 2005 and are presented graphically in Appendix 11. Increasing concentrations of chlorides were noted for the Carp River and Kinburn PWQMN stations from 1981 – 2005. Decreasing concentrations were generally noted for TKN, TP and TSS for all PWQMN stations from 1981 – 2005. Decreasing concentrations were also noted for copper and zinc, however this may be a result of improved detection levels and not an actual decrease in concentrations.

In addition, the average values for the indicator parameters are presented in Figures 2.2-1 to 2.2-11. Figure 2.2-12 presents the geometric mean values for *E. coli*. Data presented is from 2000 to 2005 with the exception of the MVC watershed watch program (1998-2005) and the City of Ottawa Baseline Surface Water Quality monitoring program (2000-2006).

2.2.5 Results

The following is a presentation of the results of the surface water quality monitoring programs discussed on a subwatershed basis. Data presented is from 2000 to 2005 with the exception of the MVC watershed watch program (1998-2005) and the OBSWQ monitoring program (2000-2006). Detailed listing of the surface water quality monitoring sites is presented in Table 2.2-2.

CCME developed a scoring system based on the level of impairment of the water. For example, excellent water quality was identified if 95-100 % of the samples showed no evidence of impairment / compliance with the relevant objectives. The following classifications were identified through the CCME work:

- Excellent water quality (WQ) – 95-100%;
- Good WQ – 80-94%;
- Fair WQ – 65-79%;
- Marginal WQ – 45-64%; and
- Poor WQ – 0-44%.

Appendix 12 and Table 2.2-3 lists the CCME scoring for each individual water quality station for the indicator parameters selected above. Appendix 13 presents the surface water summary graphs and CCME scoring for the various subwatersheds.

In general, the regional surface water within the MRSPR is of good to excellent quality. Water quality within the larger rivers is better than in smaller tributaries. Data is relatively sparse in the western portions of the MRSPR and most dense within the City of Ottawa limits. In some instances, local conditions such as the mineral composition of the surficial geology or impact due to human activities may deteriorate the quality of the surface water.

Figures 2.2-2 (chloride), 2.2-6 (TKN), and 2.2-7 (TP) show that elevated concentrations of parameters associated with likely impact from human activities such as nitrogen compounds and chloride (associated with human waste / water softeners) and sodium chloride (common road salt) are highest in the areas of higher density developments. In addition, Figure 2.2-7 (TP) indicates that increasing concentrations are detected further downstream within the surface water systems.

2.3 Groundwater Quality Data Analysis and Reporting

Groundwater obtains its natural geochemical signature based on the lithology of, and the residence time within the groundwater flow system. For example, younger groundwater will exhibit similar chemical characteristics to its source (i.e., rainfall or surface water) while groundwater that has resided in the subsurface for a long period of time will exhibit chemical characteristics of the dissolved minerals along the groundwater flow path and under certain circumstances can eventually evolve to exhibit a similar composition to seawater. This process is called the Chebotarev sequence and is described in greater detail by Freeze and Cherry (1979).

Generally, groundwater is older with depth. Therefore the natural composition of shallow groundwater is typically dominated with bicarbonate (highest anion concentration) and is low in TDS; intermediate aged (depth) groundwater exhibits a higher TDS concentration and sulphate will dominate as the highest anion concentration, and; the older groundwater (assumed as deepest) exhibits high TDS with chloride dominating the anions.

2.3.1 Groundwater Quality Data Sources and Organization

The following data sources were made available for inclusion in this report:

- Renfrew County - Mississippi - Rideau Regional Groundwater Study (Golder et al., 2003), which included:
    - Groundwater chemistry from selected bedrock wells (Belanger, 2001) [41 locations];
    - Groundwater chemistry from selected overburden wells (Belanger, 2001) [13 locations];
    - Review of paper copy reports from MOE Regional office in Kingston [115 locations];
    - Leeds and Grenville Regional Groundwater Study (Dillon, 2001) [129 locations];
    - 2002 groundwater sampling program (Golder et al., 2003) [35 locations];
    - subdivision and quarry reports filed with RVCA - current to 2000 [176 locations];
- Provincial Groundwater Monitoring Network (PGMN) - current to 2003 [18 locations];
- 2005 groundwater sampling program as part of Carp Road Groundwater Study (Dillon, 2006) [58 locations];
- 2005 groundwater sampling program as part of North Gower Groundwater Study (Dillon, 2006) [63 locations];
- 2005 groundwater sampling program as part of Constance Bay Groundwater Study (Dillon, 2006) [74 locations];
- City of Ottawa Municipal Well Data - 2001 through 2005 [7 locations]; and
- MVC 2007 groundwater sampling program near Crotch Lake [15 locations].

All of the groundwater quality data has been manipulated to be stored in the MRSPR database using the EarthFX software called SiteFX. As such, this database template relates each groundwater sampling result with a Universal Transverse Mercator (UTM) location that can link to information about well design, aquifer penetrated, previous results, etc. and can be sorted by date, location, geology, etc. This database format will optimize the task data management and allow for detailed interpretation of groundwater quality information in the future.

2.3.2 Individual Groundwater Wells

Table 2.3-1 summarizes all of the groundwater quality results from individual monitoring wells and domestic wells that were made available for this report. There are a total of

729 locations included in this table, the sources of which are summarized in Section 2.3.1. Where multiple sample results were available for any one location, the average value is presented in Table 2.3-1.

Figures 2.3-1 through 2.3-12 show the spatial distribution of the following parameters of interest throughout the MRSPR: ammonia, calcium, chloride, hardness, iron, magnesium, nitrate, pH, potassium, sodium, sulphate, and TDS, respectively. The remaining indicator parameters did not have sufficient data to warrant a figure.

In general, the regional groundwater supplies within the MRSPR are of good quality. Data is relatively sparse in the western and southern rural portions of the MRSPR and most dense within the City of Ottawa limits, especially within the larger rural population communities serviced by domestic wells and septic (Constance Bay, Carp Road Corridor, North Gower) due to the focused studies recently completed in these areas.

In some instances, local conditions such as the mineral composition of aquifer material or impact due to human activities may deteriorate the quality of a groundwater supply aquifer. Table 2.3-2 lists each parameter that has an aesthetic objectives or operational guidelines (ODWSOG) or health related criteria in the ODWQS the percentage of samples exceeding these standards and the locations of these samples within the MRSPR.

Figures 2.3-1 (ammonia), 2.3-3 (chloride), 2.3-7 (nitrate), and 2.3-10 (sodium) show that elevated concentrations of parameters associated with likely impact from human activities such as nitrogen compounds and chloride (associated with human waste) and sodium chloride (common road salt) are highest in the higher density developments of Constance Bay, Carp Road Corridor and North Gower and to the east of Ottawa near Rockland. Figure 1.3-8 also indicates that although some of these areas (Carp Road Corridor, North Gower, Rockland) primarily use bedrock wells, the shallow overburden aquifers also support overburden wells, where impact from human activities is more common. Figures 2.3-2 (calcium), 2.3-4 (hardness), and 2.3-6 (magnesium) show that groundwater obtained from bedrock aquifers throughout the entire region is generally considered to be hard and are therefore susceptible to scaling and poor taste. Figures 2.3-5 (iron), 2.3-8 (pH), 2.3-9 (potassium), 2.3-11 (sulphate), and 2.3-12 (total dissolved solids) show no clear pattern of iron, pH, potassium, sulphate or TDS distribution.

2.3.3 Aquifer Characteristics

Golder et al. (2003) contains a detailed summary of the natural groundwater chemistry at a regional scale in water supply aquifers for their MRSPR, which includes the MRSPR as well as Renfrew County. The range in concentration and median concentration, expressed as percent milliequivalents per liter (meq/L), were presented for both major anions (bicarbonate [HCO_3], sulphate, chloride) and major cations (calcium, magnesium, sodium, potassium) grouped into six regional bedrock aquifers (Upper Ordovician, Mid-Upper Ordovician, Lower Ordovician, Cambro-Ordovician, and two categories of

Precambrian). The bedrock aquifer grouping relates to the identified major aquifers as outlined in Section 1.3.2.1 as:

- Upper Ordovician + Mid-Upper Ordovician = Limestone/Shale Aquifer (Rockcliffe / Shadow Lake / Gull River / Bobcaygeon / Verulam / Lindsay / Eastview / Billings / Carlsbad Formations);
- Lower Ordovician = Dolostone Aquifer (Oxford / March Formations);
- Cambro-Ordovician = Sandstone Aquifer (Nepean Formation); and
- Precambrian (carbonate metasedimentary, igneous and metamorphic) = Upper Precambrian Aquifer.

Assigning groundwater concentrations to an aquifer type was completed using the following steps:

- UTM coordinates for each well was projected onto Figure 1.2-4 (Generalized Bedrock Geology);
- the uppermost aquifer unit at that particular location was assigned to the well;
- all wells associated with similar aquifer units were analyzed together.

A total of 347 wells were included in this analysis and the general conclusions, which are applicable for the MRSPR, are as follows:

- natural groundwater within the uppermost aquifer within the MRSPR is relatively young in age, based on:
  - bicarbonate (assumed equal to alkalinity) was the dominant anion in all groundwater aquifers (median greater than70%);
  - sulphate and chloride were typically less than 20 % of all anion concentrations for all groundwater aquifers;
- Limestone/Shale Aquifers exhibited cation concentrations dominated by sodium (greater than 50% of all cations), with minor concentrations of calcium and magnesium (less than 20%). The exception was when significant limestone layers were present and therefore calcium also dominated occasionally;
- Dolostone Aquifer exhibited cation concentrations dominated by calcium (approximately 50%), followed by magnesium (approximately 35%), with minor concentrations of sodium (median less than 15%);
- Sandstone and Upper Precambrian Aquifers exhibited cation concentrations dominated by calcium (approximately 60%), followed by magnesium (less than 30%), with minor concentrations of sodium (less than 10%). The exception is when significant igneous and metamorphic Precambrian bedrock exists, sodium concentrations are higher (approximately 15%) and magnesium concentrations are lower (approximately 20%);
- Sandstone Aquifer exhibited a slightly lower relative abundance of bicarbonate, corresponding with a higher concentration of TDS, which suggests slightly longer groundwater residence times; and,
- Golder et al. (2003) also completed environmental isotope analyses using oxygen-18 (^{18}O), deuterium (^{2}H), and tritium (^{3}H) that support these conclusions.

Piper plot analyses were completed for all 220 of the 729 well locations listed in Table 2.3-1 that contained concentrations of all four major cations (Ca, Mg, Na, K) and three major anions ($CaCO_3$, SO_4, Cl). For this analysis $CaCO_3$ was assumed to be equal to the hardness concentration. Similar to the calculations completed by Golder et al. (2003), this analysis identified the percentage of each ion (expressed as meq/L) for a particular groundwater sample and projected the results onto a Piper plot. Appendix 14 shows the results of this analysis, where all of the sample locations exhibiting similar characteristics (i.e., dominant cation = calcium, dominant anion = carbonate) were grouped together and displayed on the same plot. There are eleven plots in total, one for each combination of dominant cation-anion pairs. The total number of sampling locations within each dominant cation category is: sodium/potassium (79), calcium (63), magnesium (3), and 91 samples did not have a dominant cation (i.e., all less than 50% meq/L). Similarly, the breakdown of dominant anion categories includes: carbonate (156), chloride (57), sulphate (1), and 23 locations did not have a dominant anion.

Figure 2.3-13 displays the results of this analysis by projecting the dominant cation/anion pair of each sampling location on top of the generalized bedrock geology (Figure 1.2-4). This figure shows that although the data is scarce in the western, central and southern portions of the MRSPR, the dominant anion throughout the MRSPR is carbonate. This is attributed to the limestone and dolostone aquifers that are made up of $CaCO_3$ and magnesium carbonate ($MgCO_3$), and provide potable water to the majority of the central, eastern and parts of the northern portions of the MRSPR. Appendix 14 also shows that there are 47 locations that are dominated by sodium/potassium and chloride, which is a common chemical used for road salting purposes and therefore it is a possibility that locations with this groundwater signature may be impacted by human activities. Figure 2.3-13 shows that these sampling locations are grouped in the northern and eastern portions of the MRSPR (Carp, North Gower and south of Cumberland) in areas where overburden groundwater aquifers are sometimes used for groundwater supply.

2.3.4 Temporal Variations in Groundwater Quality

The only groundwater wells that contain a substantial period of record for groundwater sampling over time are the municipal groundwater supply wells located within the MRSPR (Almonte, Carp, Kemptville, King's Park (Richmond), Merrickville, Munster, and Westport). The PGMN wells were installed in 2003 and have only a limited number of water quality sampling events. Generally, the remaining groundwater quality information is from domestic or monitoring wells that were only sampled on one occasion, therefore temporal data was not available for review and groundwater quality trends cannot be commented on.

Scatter-plots were compiled for the municipal drinking water wells. These plots were prepared for the 21 groundwater indicator parameters identified above over the 2001 to

2006 period and are presented in Appendix 7. Box and whisker plots were compiled for the same data set and are presented in Appendix 10.

Carp Overburden Aquifer

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the Carp municipal supply wells (Wells 1 & 2) was available for alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3.

All samples for hardness were found to exceed the ODWSOG Operational Guideline (OG) of 80 – 100 mg/L. All samples for hydrogen sulphide were found to exceed the ODWSOG Aesthetic Objective (AO) of 0.05 mg/L. Iron concentrations in excess of the ODWSOG AO of 0.3 mg/L were found at two sampling events for each of the Carp wells during this period. Concentrations of pH in excess of the ODWSOG OG of 6.5 – 8.5 were found at four and one sampling events for Wells 1 and 2, respectively. Detectable total coliform concentrations were found at 11 and five sampling events for Wells 1 and 2, respectively. It should be noted that coliform bacteria concentrations in the raw groundwater are not indicative of the treated water concentrations in the Carp municipal water supply. TKN concentrations in excess of the EC guideline of 0.5 mg/L were found at 42% and 1% of the sampling events at Wells 1 and 2, respectively.

All samples for alkalinity, chloride *E. coli*, fluoride, nitrate, sulphate, TDS, and turbidity were found to be in compliance with the ODWQS or ODWSOG for the Carp municipal supply wells. There are no ODWQS or ODWSOG criteria for ammonia and conductivity.

The data shows that the natural groundwater quality of the Carp municipal well water supply aquifer (sand and gravel esker deposit) has demonstrated consistent quality since January 2001. Most of the parameters show a seasonal influence as concentrations increase during the summer months when lower water levels and a decrease in recharge rates result in less dilution occurring, and decrease during the spring and fall months when groundwater recharge is occurring and therefore the effects of dilution are most evident.

Nepean Aquifer

Merrickville-Wolford (Merrickville)

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the Merrickville municipal supply wells (Wells 1, 2 & 4) was available for *E. coli* and total coliforms from 2003 to 2006.

E. coli was only detected once at Well 1 during the sampling events. Total coliforms have been sporadically detected at low concentrations in all three municipal supply wells during this period. The most frequent detection of total coliforms in the raw groundwater quality occurred in the spring of 2005. It should be noted that these detectable bacteriological concentrations in the raw groundwater are not indicative of the treated water concentrations in the Village of Merrickville-Wolford.

Mississippi Mills (Almonte)

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the Almonte municipal supply wells (Wells 3, 5, 6, 7 & 8) was available for alkalinity, calcium, DOC, *E. coli*, hardness, magnesium, nitrate, pH, total coliforms and turbidity from 2000 to 2007. Summaries of the indicator parameters are presented in Table 2.3-3.

One sample at Well 8 for alkalinity was found to be outside of the ODWSOG OG of 30 – 500 mg/L. All samples for hardness were found to exceed the ODWSOG OG of 80 – 100 mg/L. One sample at Well 3 for nitrate was found to exceed the ODWQS Maximum Acceptable Concentration (MAC) of 10 mg/L. Total coliforms were detected at the following locations: Well 3 (three samples); Well 6 (three samples); Well 7 (two samples); and Well 8 (one sample).

All samples for DOC, *E. coli*, pH and turbidity were found to be in compliance with the ODWQS or ODWSOG for the Almonte municipal supply wells. There are no criteria for the major ions calcium and magnesium. It should be noted that these detectable bacteriological concentrations in the raw groundwater are not indicative of the treated water concentrations in the Almonte municipal water supply.

The data shows that the natural groundwater quality of the Almonte municipal well water supply aquifer (Nepean aquifer) has demonstrated consistent quality since January 2000. Most of the parameters show a seasonal influence as concentrations increase during the summer months when lower water levels and a decrease in recharge rates result in less dilution occurring, and decrease during the spring and fall months when groundwater recharge is occurring and therefore the effects of dilution are most evident.

North Grenville (Kemptville)

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the Kemptville municipal supply wells (Alfred, Kernahan and Van Buren Wells) was available for *E. coli* and total coliforms from 2003 to 2006. Summaries of the indicator parameters are presented in Table 2.3-3.

E. coli was detected at the Van Buren Well during three sampling events. Total coliforms were detected once at the Kernahan Well. Total coliforms were detected at 25% of the sampling events for the Van Buren well during this period. It should be noted that these detectable bacteriological concentrations in the raw groundwater are not indicative of the treated water concentrations in the Kemptville municipal water supply system.

Ottawa

King's Park Subdivision (Richmond)

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the King's Park Subdivision municipal supply wells (Wells 1 & 2) in Richmond was available for alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3.

All samples for hardness were found to exceed the ODWSOG OG of 80 – 100 mg/L. Iron concentrations in excess of the ODWSOG AO of 0.3 mg/L were found at 92% and 90% of the sampling events at Wells 1 and 2, respectively. Detectable total coliform concentrations were found at two sampling events for Well 1. It should be noted that these coliform bacteria concentrations in the raw groundwater are not indicative of the treated water concentrations in the King's Park municipal water supply. TDS concentrations in excess of the ODWSOG AO of 500 mg/L were found at 44% and 71% of the sampling events at Wells 1 and 2, respectively.

All samples for alkalinity, chloride, *E. coli*, fluoride, hydrogen sulphide, nitrate, pH, sulphate, TKN, and turbidity were found to be in compliance with the ODWQS or ODSWOG for the King's Park municipal supply wells. There are no ODWQS or ODWSOG criteria for ammonia and conductivity.

The data shows that the natural groundwater quality of the King's Park municipal well water supply aquifer (Nepean aquifer) has demonstrated consistent quality since January 2001. The groundwater quality at the King's Park wells does not have much seasonal variation as compared to some of the other groundwater supply wells. This lack of seasonal variation may be a result of the thick overlying aquitard which limits the direct recharge to the Nepean aquifer in this area.

Munster

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the Munster municipal supply wells (Wells 1 & 2) was available for alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3.

One sample at Well 1 for alkalinity was found to be outside of the ODWSOG OG of 30 – 500 mg/L. All samples for hardness were found to exceed the ODWSOG OG of 80 – 100 mg/L. Iron concentrations in excess of the ODWSOG AO of 0.3 mg/L were found at 4% and 48% of the sampling events at Wells 1 and 2, respectively. Concentrations of pH in excess of the ODWSOG OG of 6.5 – 8.5 were found at two sampling events for Well 1.

All samples for chloride, *E. coli*, fluoride, hydrogen sulphide, nitrate, sulphate, total coliforms, TDS, TKN, and turbidity were found to be in compliance with the ODWQS or ODWSOG for the Munster municipal supply wells. There are no ODWQS or ODWSOG criteria for ammonia and conductivity.

The data shows that the natural groundwater quality of the Munster municipal well water supply aquifer (Nepean aquifer) has demonstrated consistent quality since January 2001. Similar to the King's Park wells, the groundwater quality at the Munster wells does not have much seasonal variation as compared to some of the other groundwater supply wells. This lack of seasonal variation may be a result of the thick overlying aquitard which limits the direct recharge to the Nepean aquifer in this area.

Westport

For the groundwater indicator parameters identified above, raw groundwater quality data (pre-treatment) with multiple sampling events for the Westport municipal supply well (Wells 2) was available for *E. coli*, nitrate, sodium and total coliforms from 2003 to 2006.

E. coli was only detected once at Well 2 during the sampling events. Total coliforms were detected at 23% of the sampling events for Well 2 during this period.

All samples for nitrate and sodium were found to be in compliance with the ODWQS and ODWSOG, respectively for the Westport municipal supply well. The sodium concentrations in the groundwater were found in excess of the level for notification of the local Medical Officer of Health regarding patients on sodium restricted diets (20 mg/L). It should be noted that these detectable bacteriological concentrations in the raw groundwater are not indicative of the treated water concentrations in the Village of Westport.

2.3.5 Limitation with Groundwater Quality Data

Variability in sample results at any one location is expected to some extent due to:

- seasonal variations of groundwater levels, and recharge rates;

- changing local groundwater flow patterns with seasonal variability; and
- sampling and lab analysis error.

Therefore, sample results within 10 to 20% of each other are, for the purpose of this study, considered to be similar.

In addition, most of the groundwater quality data were obtained from domestic water wells that are completed as open bedrock wells. These wells are likely accessing more than one water-producing zone, and may be accessing more than one aquifer and/or formation; therefore the potential for error when characterizing the groundwater quality associated with a particular aquifer needs to be recognized.

The data included in this report represents all data that was made available in electronic format at this time, and it is expected that as more data becomes available this new data will be incorporated into the same analyses and assist with interpretation.

2.4 Raw Water Characterization for Drinking Water Intakes

2.4.1 Surface Water Drinking Water Intakes

Raw water sampling from the drinking water systems are conducted as part of the compliance protocol for the operation of the drinking water plants. Data for the surface water drinking water intakes has been collected from various databases and the respective municipalities. Water quality summary results for the indicator parameters from surface water plants are presented in Table 2.4-1.

Carleton Place

The Engineer's Report identified several raw water quality parameters (turbidity, colour, DOC and pH) that were found to exceed the ODWSOG (J.L. Richards, 2000). Turbidity causes interference with the disinfection of the water. The high natural DOC content, when combined with chlorine, can form disinfection by-products such as trihalomethanes (THMs). As a result of these disinfection by-products major upgrades to the plant have been recommended and are intended to be implemented in 2001.

Raw water was sampled weekly for total coliforms and E. coli in 1999 and 2000. Based on 1999 data, total coliforms were found to range from non-detect to less than 5,000 cfu per 100 mL, with six of 51 samples being reported as greater than 100 cfu per 100 mL. In 2000 (partial results with only 43 weeks available), total coliforms was found to range from non-detect to less than 5,000 cfu per 100 mL, with two of 43 samples being reported as greater than 100 cfu per 100 mL. Based on 1999 data, *E. coli* was found to range from non-detect to less than 10 cfu per 100 mL. In 2000 (partial results with only 43 weeks available), *E. coli* was found to range from non-detect to less than 500 cfu per 100 mL, with two of 43 samples being reported as greater than 10 cfu per 100 mL (J.L. Richards, 2000).

Raw water quality from the Carleton Place drinking water plant was available for the following indicator parameters: pH and *E. coli*. Summaries of the indicator parameters are presented in Table 2.4-1.

The Carleton Place drinking water treatment plant resides within the CP dam subwatershed within the MVC. In addition to the raw drinking water quality monitoring that is conducted at the drinking water plant, surface water monitoring conducted as part of the PWQMN and MVC watershed watch programs occurs upstream of the Carleton Place drinking water treatment plant. The results of these surface water monitoring programs are presented above in Section 2.2.

<u>Ottawa</u>

The Engineer's Report for Britannia and Lemieux Island Water Purification Plants (Stantec, 2001A and 2001B) identified several raw water quality parameters (aluminum, *E. coli*, total coliforms, turbidity, alkalinity, colour, DOC, organic nitrogen and temperature) that were found to exceed the ODWQS or ODWSOG. Turbidity causes interference with the disinfection of the water. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. It should be noted that not all parameters in the ODWQS or ODWSOG were tested for before the completion of the report and were to be included as an addendum to the report. No comments regarding changes to the treatment were recommended until the additional raw water quality testing was completed.

The Engineers Report identified that extensive sampling of the raw water from the Ottawa River has been conducted for Giardia and Cryptosporidium cysts from 1994 to 2000. Based on the survey the occurrence of Giardia cysts in the raw water was determined to be 1 to 10 cysts per 100 L of water 95% of the time and Cryptosporidium cysts to be 1 to 16.5 cysts per 100 L of water 95% of the time. Sampling results of the raw water quality for Heterotrophic Plate Counts (HPC) or background colonies was not included within the report. In 2000, concentrations of total coliforms in the raw water ranged from 34 to greater than 20,000 cfu per 100 mL, with the average concentration being 1,372 cfu per 100 mL. In 2000, concentrations of *E. coli* in the raw water ranged from not detectable to greater than 5,000 cfu per 100 mL, with the average concentration being 103 cfu per 100 mL (Stantec, 2001A and 2001B).

Raw water quality from the Ottawa drinking water plants (Britannia and Lemieux Island) from 2001 to 2006 was available for the following indicator parameters: *E. coli*, lead, nitrate, nitrite, pH, TKN, TP, TSS and zinc. Summaries of the indicator parameters are presented in Table 2.4-1.

Both drinking water plants for the City of Ottawa (Britannia and Lemieux Island) reside on the Ottawa River. Surface water monitoring is conducted on the Ottawa River by the OBSWQ monitoring program and the PWQMN Chats Falls station. The results of these surface water monitoring programs are presented above in Section 2.2.

Perth

The Engineer's Report indicated that not all parameters in the ODWQS and ODWSOG were tested for before the completion of the report and were to be included as an addendum to the report (Xie, 2001).

Sampling results of the raw water quality for HPC or background colonies was not included within the report. In 2000, concentrations of total coliforms in the raw water ranged from non-detect to greater than 5,000 cfu per 100 mL, with nine of 52 samples being reported as greater than 5,000 cfu per 100 mL. In 2000, concentrations of *E. coli* in the raw water ranged from non-detect to greater than 5,000 cfu per 100 mL, with one of 52 samples reported as greater than 5,000 cfu per 100 mL (Xie, 2001).

Raw water quality from the Perth drinking water plant was available for the following indicator parameters: *E. coli*, lead, nitrate, nitrite, pH, TKN, TP, TSS and zinc. Summaries of the indicator parameters are presented in Table 2.4-1.

The Perth drinking water treatment plant resides within the Tay River subwatershed within the RVCA. In addition to the raw drinking water quality monitoring that is conducted at the drinking water plant, surface water monitoring conducted as part of the PWQMN, RVCA surface water and RVCA watershed watch programs occurs upstream of the Perth drinking water treatment plant. The results of these surface water monitoring programs are presented above in Section 2.2.

Smiths Falls

Raw water quality was assessed from 1998 to 2000 (MacViro, 2001). Several raw water quality parameters (turbidity, aluminum, sodium, manganese, colour, DOC and temperature) were found to exceed the ODWSOG. Turbidity causes interference with the disinfection of the water. The sodium concentrations only exceeded the concentrations for the notification of the local Medical Officer of Health regarding patients on sodium restricted diets. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. Recommendations regarding the optimization of the coagulation / flocculation / sedimentation / filtration process to comply with the ODWQS and ODWSOG.

Raw water was sampled weekly for total coliforms and *E. coli* in 1999 and 2000. In 1999, concentrations of total coliforms in the raw water ranged from non-detect to less than 5,000 cfu per 100 mL, with four of 51 samples being reported as greater than

100 cfu per 100 mL. In 2000, concentrations of total coliforms in the raw water ranged from non-detect to greater than 5,000 cfu per 100 mL, with seven of 52 samples being reported as greater than 5,000 cfu per 100 mL. In 1999, concentrations of *E. coli* in the raw water ranged from non-detect to less than 5,000 cfu per 100 mL, with three of 51 samples reported as greater than 100 cfu per 100 mL. In 2000, concentrations of *E. coli* in the raw water ranged from non-detect to less than 5,000 cfu per 100 mL, with ten of 52 samples reported as greater than 100 cfu per 100 mL (MacViro, 2001).

Raw water quality from the Smiths Falls drinking water plant was available for the following indicator parameters: *E. coli*, lead nitrate, nitrite, pH, TKN, TP, TSS and zinc. Summaries of the indicator parameters are presented in Table 2.4-1.

The Smiths Falls drinking water treatment plant resides within the Middle Rideau subwatershed within the RVCA. No surface water monitoring within the Middle Rideau subwatershed occurs upstream of the plant. However, surface water monitoring occurs as part of the PWQMN, RVCA surface water and RVCA watershed watch programs in both upstream subwatersheds to the Middle Rideau subwatershed (Tay River and Rideau Lakes subwatersheds). The results of these surface water monitoring programs are presented above in Sections 2.2.

2.4.2 Groundwater Drinking Water Wells

Raw water sampling from the drinking water systems are conducted as part of the compliance protocol for the operation of the various municipal supply wells. Data for the municipal groundwater wells has been collected from various databases and the respective municipalities and is discussed above in the temporal groundwater quality section. Water quality summary results for the indicator parameters from groundwater wells are presented in Table 2.3-3.

Merrickville-Wolford

Raw water quality was reviewed in 2000 (Totten Sims Hubicki (TSH), 2001A). Several raw water quality parameters (sodium, hardness, colour and turbidity) were found to exceed the ODWSOG. Turbidity causes interference with the disinfection of the water. The sodium concentrations only exceeded the concentrations for the notification of the local Medical Officer of Health regarding patients on sodium restricted diets. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. Several upgrades were recommended for the facility.

Raw water test results in 1999 did not indicate any adverse microbiological results. Raw water quality test results in 2000 indicated elevated concentrations of total coliforms and background colonies at several sampling events. *E. coli* was not encountered in the raw water quality from 2000 (TSH, 2001A).

Raw water quality for the Merrickville wells was available for the following indicator parameters: *E. coli* and total coliforms from 2003 to 2006. The results of the groundwater monitoring programs for Merrickville are presented above in Section 2.3.

Mississippi Mills

Raw water was sampled in February 2001 (Oliver, Mangione, McCalla & Associates (OMMA), 2001A). The Engineer's Report for Almonte identified several raw water quality parameters (hardness, sodium, organic nitrogen, TDS, turbidity and aluminum) that were found to exceed the ODWSOG. Historic elevated turbidity during high pumping rates has been documented at one of the wells. Turbidity causes interference with the disinfection of the water. Nitrate concentrations have been documented at one of the wells but not at concentrations exceeding the ODWQS. The sodium concentrations only exceeded the concentrations for the notification of the local Medical Officer of Health regarding patients on sodium restricted diets. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. There were no immediate additional treatment requirements for the facility.

Raw water test results did not indicate any adverse microbiological results (OMMA, 2001A).

Raw water quality for the Almonte wells was available for the following indicator parameters: alkalinity, calcium, DOC, *E. coli*, hardness, magnesium, nitrate, pH, total coliforms and turbidity from 2000 to 2007. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for Mississippi Mills are presented above in Section 2.3.

North Grenville

Raw water quality was reviewed from 1991 to 2001 (OMMA, 2001B). The Engineer's Report for Kemptville identified several raw water quality parameters (hardness, sodium and colour) that were found to exceed the ODWSOG. The sodium concentrations only exceeded the concentrations for the notification of the local Medical Officer of Health regarding patients on sodium restricted diets. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. There were no immediate additional treatment requirements for the facility. It should be noted that not all parameters in the ODWQS and ODWSOG were tested for before the completion of the report and were to be included as an addendum to the report.

Microbiological raw water quality for each of the municipal supply wells from 1996 to 2000 was reviewed for total coliforms, *E. coli* and background colonies (OMMA, 2001B). Several raw water test results indicated the presence of background colonies and total coliforms. Re-testing of the raw water quality indicated that the contamination was not source related. *E. coli* was not detected in any of the raw water quality tests.

Raw water quality for the Kemptville wells was available for the following indicator parameters: *E. coli* and total coliforms from 2003 to 2006. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for North Grenville are presented above in Section 2.3.

<u>Ottawa</u>

Carp

Raw water quality was reviewed from 1996 to 2000 (R.V. Anderson, 2001). The Engineer's Report for the Village of Carp identified several raw water quality parameters (colour, hardness, HPC, organic nitrogen, sulphide and TDS) that were found to exceed the ODWQS or ODWSOG. However, these parameters are mostly aesthetic or parameters that affect the operation of the plant. No treatment changes with respect to water quality were recommended.

During the investigations for the construction of the communal well system in Carp water quality obtained from the test well and other sources indicated acceptable quality. Minor elevated sodium and hydrogen sulphide concentrations were also documented (Water & Earth Science Associates (WESA), 1987). During the construction of the second pumping well for Carp water quality was found to meet all MOE drinking water objectives with the exception of hardness and hydrogen sulphide. The treatment plant design includes treatment for hydrogen sulphide in terms of chloride oxidation only. It was noted that hardness treatment for aesthetic purposes may be conducted by the end users (WESA, 1994).

Raw microbiological water quality was reviewed from 1999 and 2000. Raw water quality test results did not indicate any adverse microbiological results (R.V. Anderson, 2001).

Raw water quality for the Carp wells was available for the following indicator parameters: alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for Carp are presented above in Section 2.3.

King's Park Subdivision - Richmond

Raw water quality was reviewed from 1994 to 2001 (Conestoga-Rovers & Associates (CRA), 2001). The Engineer's Report for the King's Park Subdivision identified several raw water quality parameters (iron, hardness, conductivity and TDS) that were found to exceed the ODWSOG. Iron is a non-health related parameter. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. There were no immediate additional treatment requirements for the facility; however buildup of scaling and/or sediments will normally occur with water supplies such as this. It should be noted that not all parameters in the ODWQS and ODWSOG were tested for before the completion of the report and were to be included as an addendum to the report.

Raw microbiological water quality was reviewed from 1998 to December 2000. Raw water test results did not indicate any adverse microbiological results (CRA, 2001).

Raw water quality for the King's Park (Richmond) wells was available for the following indicator parameters: alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for King's Park (Richmond) are presented above in Section 2.3.

Munster Hamlet

Raw water quality was reviewed for 1999 (Stantec, 2001C). One raw water quality parameter (hardness) was found to exceed the ODWSOG. Hardness is an aesthetic parameter potentially that affects plant operations and customer scaling problems. It should be noted that not all parameters in the ODWQS and ODWSOG were tested for before the completion of the report and were to be included as an addendum to the report. No comments regarding changes to the treatment were recommended until the additional raw water quality testing was completed.

Instances of elevated turbidity levels within Well 2 were documented during the Engineers Report. As a result a hydrogeological assessment and remedial activities were undertaken at the Munster Hamlet communal well supply to assess the cause and origin of the noted elevated turbidity levels encountered in Well 2 (Sauriol, 2002). After the remedial activities, the water quality analysis indicated relatively good water quality, with a few parameters exceeding the ODWSOG which included iron and turbidity. It was hypothesized that the elevated turbidity levels were occurring as a result of removal of rust particles as a result of shock chlorination or cascading water within the upper water bearing zones of the production well.

Microbial water quality was reviewed from 1998 and 1999 (Stantec, 2001C). Nine samples from 1998 and 1999 indicated detectable levels of HPC within the raw water. Raw water test results did not indicate any detectable concentrations of *E. coli*.

Raw water quality for the Munster wells was available for the following indicator parameters: alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3.

The results of the groundwater monitoring programs for Munster are presented above in Section 2.3.

Westport

The Engineer's Report for Westport identified several raw water quality parameters (arsenic, iron, sodium, hardness and turbidity) that were found to exceed the ODWQS or ODWSOG (TSH, 2001B). Elevated iron concentrations were documented during a MOE inspection report in 2000 (concentration of iron was not specified). Arsenic is a health related ODWQS parameter and was only detected at levels in excess of the ODWQS once. Confirmatory sampling of the raw water quality did not indicate the presence of arsenic in December 2000. Turbidity causes interference with the disinfection of the water. The elevated turbidity concentrations were only encountered in Well 1. The sodium concentrations only exceeded the concentrations for the notification of the local Medical Officer of Health regarding patients on sodium restricted diets. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. Investigations into the source of bacteria and turbidity in Well 1 were recommended. Several upgrades were recommended for the facility.

One of the report appendices includes a Hydrogeological Assessment of the Westport Water System conducted by Malroz Engineering Inc. which focused on the raw water characteristics and potential for groundwater contamination. Raw water test results in 1999 and 2000 indicated elevated concentrations of total coliforms and *E. coli* at several sampling events. It was noted that Well 2 had fewer samples exceeding the criteria for microbial contamination as compared to Well 1. It was also documented that the poor raw microbial water quality was noted in late summer / early fall. Elevated concentrations of HPC were not encountered in the raw water quality.

Water quality monitoring was conducted in 2005 by Malroz (2006) and the results of the water quality monitoring program indicated that the water quality in Well 2, with respect to the bacteriological parameters, improved following the decommissioning of Well 1.

Raw water quality for the Westport wells was available for the following indicator parameters: *E. coli*, nitrate, sodium and total coliforms from 2003 to 2006. The results of the groundwater monitoring programs for Westport are presented above in Section 2.3.

2.5 Raw Water Characterization for Rural Hamlets / Villages

2.5.1 Private Groundwater Supplies

The raw water quality from several villages and hamlets within the MRSPR has been characterized (Constance Bay, Cumberland, Heart's Desire, Lanark, North Gower). Summaries of these studies are presented in Appendix 1.

In addition, areas of known groundwater impairment are discussed in further detail in Section 5.1.3. Summaries of these villages and hamlets with known issues are also presented in Appendix 1.

2.6 Microbial Source Water Characterization

2.6.1 Surface Water

Surface water quality monitoring for microbial parameters (*E. coli* only) is conducted by the City of Ottawa Baseline Surface Water Quality, RVCA surface water quality and RVCA watershed watch monitoring programs. Results of these programs are discussed above in Section 2.2. Additional surface water quality monitoring for microbial parameters is conducted by the drinking water treatment plants (Carleton Place, Ottawa, Perth and Smiths Falls) and is discussed above in Section 2.4.

<u>Carleton Place</u>

Several potential sources of microbial contamination were identified (J.L. Richards, 2000). These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water. It was also noted that the Mississippi River and Mississippi Lake are popular recreational water bodies and are also surrounded by agricultural land uses.

<u>Ottawa</u>

The Engineer's Report for the Britannia and Lemieux Island Water Purification Plants (Stantec, 2001A and 2001B) identified several potential sources of microbial contamination to the Ottawa River. These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water.

Perth

The Engineer's Report identified several potential sources of microbial contamination (Xie, 2001). These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water.

Smiths Falls

Several potential sources of microbial contamination were identified from the Engineer's Report (MacViro, 2001). These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water. In addition as a result of the building being located within the flood plain and the clear well location below the grade of sanitary sewers, it was recommended that the treatment plant be relocated.

2.6.2 Groundwater

Groundwater quality monitoring for microbial parameters (*E. coli* and total coliforms) are conducted by the municipalities as part of the operation of the groundwater supply wells and is discussed above in Sections 2.3 and 2.4.

Merrickville-Wolford

Several potential sources of microbial contamination to the municipal wells were identified during the Engineer's Report (TSH, 2001A). These included site grading allowing surface water entry, access openings to untreated & treated water reservoirs, abandoned or improperly decommissioned wells within the Village.

Mississippi Mills

The Engineer's Report for Almonte (OMMA, 2001A) identified several potential sources of microbial contamination to the municipal wells. Several potential sources of microbial contamination to the municipal wells were identified and these included the Town's sewage lagoons, sewage force mains, treated sewage outfall, pasture & crop lands.

North Grenville

The Engineer's Report for Kemptville (OMMA, 2001B) identified several potential sources of microbial contamination to the municipal wells. These included the access openings to untreated & treated water reservoirs, and location of one well within the reservoir. One area of known bacteria and nitrate contamination is known within the Municipality of North Grenville and is described below in Section 5.1.3.

<u>Ottawa</u>

Carp

The Engineer's Report for the Village of Carp did not identify any potential sources of microbial contamination at the municipal wells (R.V. Anderson, 2001).

King's Park Subdivision

The Engineer's Report for the King's Park Subdivision located in the Village of Richmond (CRA, 2001) identified several potential sources of microbial contamination to the municipal wells. These included the former Richmond sewage lagoons, potential for water to accumulate on the ground in surface depressions at Well 1 near the underground chlorine contact chambers, the close proximity of the Jock River and the Richmond sewage pumping station.

Munster

The Engineer's Report for Munster identified several potential sources of microbial contamination to the municipal wells (Stantec, 2001C). These include well head and aquifer contamination through surface water entry, access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water.

<u>Westport</u>

Several potential sources of microbial contamination to the municipal wells were identified during the Engineer's Report for Westport (TSH, 2001B). These included a small stream originating in agricultural land west of the site is directed to a culvert less than 10 m from one of the wells, the Village's sewage lagoons, sanitary sewers, sewage "Snowfluent" facility, pasture & crop lands, site grading allowing surface water entry and cracks and distortions in the elevated tank.

A study was undertaken by Malroz (2006) to establish whether or not the groundwater sources from the municipal supply well (Well 2) in the Village of Westport are under the direct influence of surface water (GUDI) following the abandonment of the former supply well (Well 1). The results of the water quality monitoring program indicated that the water quality in Well 2, with respect to the bacteriological parameters, improved following the decommissioning of Well 1. However, as the suggested trend was only observed over one year of data, it was recommended that additional data be collected and that a subsequent evaluation should be conducted in two years.

2.7 Data and Knowledge Gaps for Water Quality

The following data gaps were identified for Section 2.0 – Water Quality within the MRSPR. Additional details as to the data gaps are provided in Appendix 2.

Section 2.2 Surface Water Quality

The following data gaps were identified in the surface water quality monitoring programs:

- Lack of monitoring program for streams and tributaries in the MVC west and south of the City of Ottawa;
- Surface water monitoring stations upstream of drinking water intakes (Britannia, Lemieux Island, Smiths Falls & Carleton Place);
- Additional PWQMN stations on the Ottawa River;
- Lack of bacteriological quality testing in PWQMN program;
- Bacterial sampling is not conducted upstream of Carleton Place in MVC – significant data gap;
- Additional microbial parameters should be sampled and tested as part of the various water quality programs (cryptosporidium, giardia, microcystins, etc.); and
- Inconsistent suites of parameters monitored at various locations.

Section 2.3 Groundwater Quality

The following data and knowledge gaps are associated with groundwater quality information:

- lack of data within western, central and southern portions of MRSPR;
- much of the groundwater quality data is in paper format, therefore it was not included in this initial interpretation;
- many groundwater sampling locations are described by lot and concession or by municipal address and do not have UTM coordinates;
- lack of geological information into which the well is completed makes it difficult to characterize aquifers;
- lack of temporal groundwater quality; and
- inconsistent suites of parameters at various locations.

3.0 Description of Vulnerable Areas

3.1 Identification of Drinking Water Source Protection Areas

This section describes the areas within the MRSPR that may be vulnerable in terms of both water quality and/or quantity. The water quantity vulnerability issues are discussed in more detail in the water budget guidance module.

The water vulnerability studies are defined as applying to one of the following areas:

- Groundwater - WHPA;
- Surface Water – IPZ;
- Highly Vulnerable Aquifers;
- Significant Groundwater Recharge Areas; and
- Potential Future Drinking Water Areas

These vulnerability studies are generally presented on two scales, consisting of the entire MRSPR or site specific areas within the MVC or RVCA. Many of these studies have been discussed above but have relevant sections relating to vulnerability. A list of these studies is presented below:

- Municipal Well Head Protection Study, Town of Kemptville, Township of North Grenville (2000)
- Village of Merrickville-Wolford Municipal Groundwater Management Study (2000)
- Preliminary Evaluation of Relative Aquifer Vulnerability: City of Ottawa (2001)
- United Counties of Leeds & Grenville Groundwater Management Study (2001)
- Renfrew County – Mississippi – Rideau Groundwater Study (2003)
- Wellhead Protection Area Study, Almonte, Ontario (2003)
- Wellhead Protection Study, Carp Communal Wells, City of Ottawa (2003)
- Wellhead Protection Study, Munster Hamlet and Kings Park Communal Wells, City of Ottawa (2003)
- Village of Westport, Preliminary Wellhead Protection Area Study (2004)
- Hydrogeological Evaluation of Municipal Water Supply – Village of Lanark Water Supply Study, Township of Lanark Highlands, Ontario (2005)
- North Grenville Water and Wastewater Servicing Master Plan (2005)
- Vulnerability Pilot Study, Almonte Municipal Water Supply Wells (2005)
- Additional Vulnerability Analysis for Almonte WHPA Model (2007)
- Carp, Munster Hamlet and Kings Park Wellhead Protection Area Maps (2007)

Summaries of these reports are presented in Appendix 1.

3.2 Groundwater: Wellhead Protection Areas (WHPA)

Within the MRSPR, there are seven municipal drinking water systems that are sourced from groundwater. The locations of these systems are presented in Table 1.6-6 and on Figure 3.2-1. Details as to the locations of these municipal drinking water supply systems are presented above in Section 1.7.1.1. Relevant information including population and location and number of wells is also detailed above.

Groundwater WHPA have been established for four of the municipal supply systems (Mississippi Mills – Almonte, Ottawa – Carp, King's Park & Richmond). Preliminary groundwater WHPA were also developed for the other municipally supplied systems (Merrickville-Wolford - Merrickville, North Grenville – Kemptville & Westport); however, the studies were either incomplete or conducted prior to the current terms of reference. As a result, refinement of the WHPA for Kemptville, Merrickville and Westport are to be established as part of the MOE Technical Studies. The WHPA for each specific area are discussed in more detail below.

<u>Mississippi Mills</u>

Five communal wells serving approximately 4,700 persons in Almonte, which is now incorporated within the Town of Mississippi Mills, are operated as a municipally supplied water system sourced from groundwater. As summarized above, groundwater WHPA for Almonte was established by Intera (2003A). Numerical modeling in MODFLOW was conducted to define the WHPA.

In 2007, Intera updated the WHPA for Almonte to the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report. The updates included the delineation of a 5 year TOT capture zone, vulnerability mapping for the entire capture zone, aquifer vulnerability scoring and uncertainty analysis (Intera, 2007).

The following TOT for Almonte were conducted in MODFLOW for these intervals and are also presented on Figure 3.2-2:

- 100 m;
- 100 m to 2 years TOT;
- 2 to 5 years TOT; and
- 5 to 25 years TOT.

The groundwater supplied to the residents of Almonte is sourced from the Nepean sandstone aquifers. Three of the wells (Wells 3, 7 and 8) are located on the east side of the Mississippi River and the corresponding capture zones extend to approximately 4 km to the northeast. The remaining two wells (Wells 5 and 6) are located on the west side of the Mississippi River and the capture zones extend approximately 2 km to the south. The capture zones from the wells on the east side of the Mississippi River terminate within the Nepean aquifer. The capture zones from the wells on the west side of the Mississippi River terminate within the Nepean aquifer and the Precambrian bedrock outcrop.

It should be noted that the TOT established through the numerical modeling were based upon groundwater travel within the Nepean aquifer in which the wells are established. Travel from the surface through the unsaturated zone is not considered when establishing the TOT for these wells.

The MOE initiated a pilot study to map the WHPA for municipal supply wells using actual travel times from ground surface to the well, which incorporates unsaturated travel time plus saturated travel time. The previous WHPA studies utilize reverse particle tracking methods in MODFLOW and only take into account the travel time in the saturated zone. This analysis method is termed Water table to Well Advection Time (WWAT).

The Surface to Well Advection Time (SWAT) pilot study was completed by Intera (2005) and incorporated the existing MODFLOW model that was previously created. The results of this study indicate that the actual travel times from ground surface to the municipal wells are in the order of 2 to 25 years for wells 5 and 6 (southwest of Mississippi River) and greater than 25 years for wells 3, 7 and 8 (northeast of Mississippi River). Sensitivity analyses were completed on various parameters including residual moisture content of unsaturated zone, hydraulic conductivity of bedrock units, and porosity of bedrock units.

A generalized conceptual geological cross section for the Almonte area is presented on Figure 1.2-8 and is discussed in Section 1.3. In addition to establishing the WHPA for the municipal supply wells, aquifer vulnerability of the Nepean was calculated by ISI. The results of the ISI calculations indicated a range in aquifer vulnerability from low to high. Highly vulnerable areas were documented when the overlying stratigraphic material was noted to be present for the semi-confined conditions (thin cover of the Oxford-March formation above the Nepean aquifer) documented on the west side of the Mississippi River. Moderate vulnerability was noted for Well 6 which is found within this area; however this well is a flowing well, indicating artesian conditions. Outside of the immediate vicinity of Well 6, high vulnerability is expected to occur. Low aquifer vulnerability is documented on the east side of the Mississippi River where a significant thickness of the Oxford-March formation is noted overlying the Nepean aquifer (source of water for Wells 3, 7 and 8).

It should be noted that the general aquifer vulnerability of the overlying bedrock units (Oxford and March formations) differs from the aquifer vulnerability of the Nepean formation east of the Mississippi River. The general aquifer vulnerability in this area is defined as highly vulnerable. This is a result of the thickness of the overlying Oxford-March formation on the east side of the Mississippi River. A conceptual geological cross section is presented in Figure 1.2-8. As a result of the thickness of this formation, the majority of the residents east of the Mississippi River near Almonte rely upon the upper Oxford and March formations for their source of groundwater. The residents west of the Mississippi River near Almonte rely upon the Nepean aquifer or Precambrian bedrock for their source of water. In Section 3.4, the general aquifer vulnerability for the entire MRSPR is discussed in more detail.

Ottawa

Carp

Two communal wells serving approximately 1,500 persons in the former village of Carp, which is now incorporated within the City of Ottawa, are operated as a municipally supplied water system sourced from groundwater. As summarized above, groundwater WHPA for Carp was established by Golder (2003). Numerical modeling in MODFLOW was conducted to define the WHPA.

In 2004, Golder updated the capture zones for Carp with increased pumping rates (Golder, 2004B). In 2007, Golder updated the Carp WHPA to the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report. These updates included delineation of a 5 year TOT capture zone, aquifer vulnerability scoring and uncertainty analysis (Golder, 2007).

The following TOT for Carp were conducted in MODFLOW for these intervals and are also presented on Figure 3.2-3:

- 100 m;
- 100 m to 2 years TOT;
- 2 to 5 years TOT; and
- 5 to 25 years TOT.

The groundwater supplied to the residents of Carp is sourced from an overburden sand and gravel aquifer. The capture zone extends to the northeast and south (approximately 1.5 km) of the supply wells. The northeast capture zone terminates along the Carp Ridge Precambrian bedrock outcrop. The south capture zone is terminated in the sand and gravel aquifer.

It should be noted that the TOT established through the numerical modeling were based upon groundwater travel within the saturated sand and gravel aquifer in which the wells are established. Travel from the surface through the unsaturated zone is not considered when establishing the TOT for these wells.

A generalized conceptual geological cross section for the Carp area is presented on Figure 1.2-7 and discussed in Section 1.3. In addition to establishing the WHPA for the communal supply wells, aquifer vulnerability of the sand and gravel aquifer was calculated for this area. The general aquifer vulnerability was conducted by ISI and the results indicated a range in aquifer vulnerability from low to high. Highly vulnerable areas were documented when the overlying stratigraphic material was noted to be fine sand at surface and the water table is near surface. These highly vulnerable areas are noted in close vicinity to the communal wells. Moderate vulnerability is documented for areas where fine sands are at surface but the water table is at significant depth (southwest of the Carp Hills) and where a thin layer of weathered clay is overlying the fine sand deposit. Low aquifer vulnerability is documented where a significant thickness of silty clay overlies the fine sand or sand and gravel deposits. As the groundwater supply for the Carp communal wells is sourced from the first significant aquifer, the general aquifer vulnerability is similar to the aquifer vulnerability mapping calculated for the entire MRSPR. The general aquifer vulnerability for the entire MRSPR is discussed in more detail in Section 3.4.

King's Park (Richmond)

Two communal wells serving approximately 450 persons in the King's Park subdivision within the Village of Richmond, now incorporated within the City of Ottawa, are operated as a municipally supplied water system sourced from groundwater. It should be noted that the remainder of the residents within the Village of Richmond, approximately 4,000 persons, rely upon private wells and not upon the communal system in the King's Park subdivision.

As summarized above, groundwater WHPA for the King's Park subdivision was established by Golder (2003). Numerical modeling in MODFLOW was conducted to define the WHPA.

In 2007, Golder updated the King's Park (Richmond) WHPA to the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report. These updates included delineation of a 5 year TOT capture zone, aquifer vulnerability scoring and uncertainty analysis (Golder, 2007).

The following TOT for the King's Park subdivision were conducted in MODFLOW for these intervals and are also presented on Figure 3.2-4:

- 100 m;
- 100 m to 2 years TOT;
- 2 to 5 years TOT; and
- 5 to 25 years TOT.

The groundwater supplied to the residents of King's Park subdivision is sourced from the Nepean sandstone aquifer. The proximity of the Jock River to the King's Park subdivision communal wells influences the groundwater flow pattern. As a result, the predicted groundwater flow direction was bifurcated. The first capture zone passes beneath the Jock River and extends approximately 14 km to the west-northwest. The capture zone terminates in a Provincially Significant wetland (Huntley) indicating the likely source of the water to the wells. The second capture zone does not intercept the Jock River and extends approximately 9 km to the south. The second capture zone also terminates in another Provincially Significant wetland (Richmond Fen). The extents of these wetlands are also depicted on Figure 3.2-4.

It should be noted that the TOT established through the numerical modeling were based upon groundwater travel within the saturated bedrock unit in which the wells are established. Travel from the surface through the unsaturated zone is not considered when establishing the TOT for these wells.

A generalized conceptual geological cross section for the King's Park area is presented on Figure 1.2-9 and discussed in further detail in Section 1.3. In addition to establishing the WHPA for the communal supply wells, aquifer vulnerability of the Nepean sandstone bedrock was calculated for this area. The general aquifer vulnerability was conducted by ISI for a confined bedrock unit. The results of the ISI calculations indicated low aquifer vulnerability for the Nepean sandstone bedrock due to the presence of a relatively large depth to the top of the Nepean formation.

It should be noted that the general aquifer vulnerability of the overlying bedrock units (Oxford and March formations) differ from the Nepean formation. The majority of the residents within the model boundary domain for the King's Park subdivision rely upon the upper Oxford and March formations for their source of groundwater. The general aquifer vulnerability in this area is defined as high to medium vulnerability for the Oxford and March formations. In Section 3.4, the general aquifer vulnerability for the entire MRSPR is discussed in more detail.

Munster

Two communal wells serving approximately 1,300 persons in Munster Hamlet, which is now incorporated within the City of Ottawa, are operated as a municipally supplied water system sourced from groundwater. As summarized above, groundwater WHPA for Munster was established by Golder (2003). The WHPA for both Munster and King's Park subdivision were established as part of the same study. Numerical modeling in MODFLOW was conducted to define the WHPA.

In 2007, Golder updated the Munster WHPA to the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report. These updates included delineation of a 5 year TOT capture zone, aquifer vulnerability scoring and uncertainty analysis (Golder, 2007).

The following TOT for Munster were conducted in MODFLOW for these intervals and are also presented on Figure 3.2-4:

- 100 m;
- 100 m to 2 years TOT;

- 2 to 5 years TOT; and
- 5 to 25 years TOT.

The groundwater supplied to the residents of Munster is also sourced from the Nepean sandstone aquifer. The capture zone extends approximately 9 km to the northwest. The capture zone terminates in the same Provincially Significant wetland (Huntley) as the western capture zone from the King's Park subdivision. The extent of this wetland is depicted on Figure 3.2-4.

It should be noted that the TOT established through the numerical modeling were based upon groundwater travel within the saturated bedrock unit in which the wells are established. Travel from the surface through the unsaturated zone is not considered when establishing the TOT for these wells.

A generalized conceptual geological cross section for the Munster area is presented on Figure 1.2-9 and is discussed in Section 1.3. In addition to establishing the WHPA for the communal supply wells, aquifer vulnerability of the Nepean sandstone bedrock was calculated for this area. The general aquifer vulnerability was conducted by ISI for a confined bedrock unit and the results of the ISI calculations indicated low aquifer vulnerability for the Nepean sandstone bedrock due to the presence of a relatively large depth to the top of the Nepean formation.

It should be noted that the general aquifer vulnerability of the overlying bedrock units (Oxford and March formations) differ from the Nepean formation. The majority of the residents within the model boundary domain and outside of Munster rely upon the upper Oxford and March formations for their source of groundwater. The general aquifer vulnerability in this area is defined as high to medium vulnerability for the Oxford and March formations. In Section 3.4, the general aquifer vulnerability for the entire MRSPR is discussed in more detail.

Westport

Two communal wells serving approximately 670 persons in the Village of Westport are operated as a municipally supplied water system sourced from groundwater. Well 3 (drilled 2003) replaced Well 1 (decommissioned 2005) as a supply well in February 2005. The current communal wells supplying Westport are designated as Wells 2 and 3. As summarized above, preliminary groundwater WHPA for Westport was established by Malroz in 2004. Numerical modeling in MODFLOW was conducted to define the WHPA.

The following TOT for Westport were conducted in MODFLOW for these intervals and are also presented on Figures 3.2-5a and 3.2-5b:

- 100 m;
- 100 m to 2 years TOT;

- 2 to 5 years TOT; and
- 5 to 25 years TOT.

The groundwater supplied to the residents of Westport is also sourced from the Nepean sandstone aquifer. The capture zone extends approximately 1.5 km to the west-southwest. It should be noted that the TOT established through the numerical modeling were based upon groundwater travel within the saturated bedrock unit in which the wells are established. Travel from the surface through the unsaturated zone is not considered when establishing the TOT for these wells.

A generalized conceptual geological cross section for the Westport area is presented on Figure 1.2-10. Hydrogeologic cross sections are discussed in detail in Section 1.3. Aquifer vulnerability of the Nepean sandstone bedrock was not calculated for the specific WHPA area.

MOE Technical Grant funding was provided to the Village of Westport to refine the conceptual hydrogeological understanding and finalize the WHPA. In completing the WHPA, the ISI vulnerability for the specific WHPA will also be conducted. The establishment of the final WHPA for Westport will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR.

It should be noted that the general aquifer vulnerability of the overlying bedrock units (Oxford and March formations) will likely differ from the underlying Nepean formation. The general aquifer vulnerability in this area is defined as high vulnerability for the Oxford and March or Precambrian bedrock formations. In Section 3.4, the general aquifer vulnerability for the entire MRSPR is discussed in more detail.

Merrickville-Wolford

Three communal wells serving approximately 1,100 persons in the Village of Merrickville are operated as a municipally supplied water system sourced from groundwater. The locations of the Merrickville Municipal Wells are presented on Figure 3.2-6.

A groundwater study was conducted for Merrickville in 2000 by Golder. A fixed radius WHPA was established during this study which included a 330 m exclusion zone and a 4.2 km restricted zone. The study and WHPA were conducted prior to the MOE Terms of Reference for groundwater studies in 2001. The groundwater supplied to the residents of Merrickville is sourced from the Nepean sandstone aquifer.

MOE Technical Grant funding was provided to the MRSPR on behalf of the Village of Merrickville-Wolford to develop the conceptual hydrogeological understanding and establish a WHPA based upon numeric modeling (modular finite-difference groundwater flow model (MODFLOW) time of travel (TOT)). In completing the WHPA, the Intrinsic Susceptibility Index (ISI) vulnerability for the specific WHPA will also be conducted. The establishment of the WHPA for Merrickville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR.

It should be noted that the general aquifer vulnerability of the overlying bedrock units (Oxford and March formations) will likely differ from the underlying Nepean formation. The general aquifer vulnerability in this area is defined as high vulnerability for the Oxford and March formations. A generalized conceptual hydrogeological cross section for Merrickville is presented on Figure 1.2-11 and is discussed in more detail in Section 1.3. In Section 3.4, the general aquifer vulnerability for the entire MRSPR is discussed in more detail.

<u>North Grenville</u>

Three communal wells (Alfred, Kernahan and Van Buren Wells) serving approximately 3,500 persons in the former Town of Kemptville, which has been incorporated within the Municipality of North Grenville, are operated as a municipally supplied water system sourced from groundwater. The locations of the municipal groundwater supply wells in Kemptville are presented on Figure 3.2-7.

A Municipal Well Head Protection Study was conducted for Kemptville (OMMA, 2000). WHPA were established using the two dimensional numeric modeling program, Flowpath. Five and ten year capture zones were developed for the three municipal supply wells. The study and WHPA were conducted prior to the MOE Terms of Reference for groundwater studies in 2001. The groundwater supplied to the residents of Kemptville is sourced from the Nepean sandstone aquifer.

MOE Technical Grant funding was provided to the MRSPR on behalf of the Municipality of North Grenville to develop the conceptual hydrogeological understanding and establish a WHPA based upon numeric modeling (MODFLOW TOT). In completing the WHPA, the ISI vulnerability for the specific WHPA will also be conducted. The establishment of the WHPA for Kemptville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR.

It should be noted that the general aquifer vulnerability of the overlying bedrock units (Oxford and March formations) will likely differ from the underlying Nepean formation. The general aquifer vulnerability in this area is defined as high vulnerability for the Oxford and March formations. A generalized conceptual hydrogeological cross section for Kemptville is presented on Figure 1.2-11 and is discussed in more detail in Section 1.3. In Section 3.4, the general aquifer vulnerability for the entire MRSPR is discussed in more detail.

3.3 Surface Water: Intake Protection Zones (IPZ)

Within the MRSPR, there are five municipal drinking water supply systems which are sourced via surface water. The locations of these systems are presented in Table 1.6-5 and on Figures 3.2-1 and 3.3-1 to 3.3-5. Details as to the locations of these municipal drinking water supply systems are presented above in Section 1.7.1.1. Relevant information including population and location of the surface water intake and the treatment facilities are also detailed above.

Surface water IPZ have not been established for any of the surface water sourced municipal drinking water supply systems. Several of the IPZ are to be established as part of the MOE Technical Studies and are discussed in more detail below.

3.3.1 Inland River Systems

MOE Technical Grant funding was provided to the MRSPR on behalf of the Towns of Carleton Place, Perth and Smiths Falls to develop topographic mapping and Digital Terrain Models (DTM). This refined data will be used to establish the IPZ based upon numerical modeling (Flood Plain modeling for IPZ TOT and Geographical Information System (GIS) for Total Contributing Area). MOE Technical Grant funding was also provided to complete the IPZ for Carleton Place, Perth and Smiths Falls. The second study will involve the following components: intake characterization, preferential pathways assessment, modification of the IPZ and vulnerability scoring. The establishment of the IPZ for Carleton Place, Perth and Smiths Falls will be discussed in further detail in the Surface Water Vulnerability Component Module (5) of the Technical Assessment Report for the MRSPR. The locations of the surface water intakes for Carleton Place, Perth and Smiths Falls are presented on Figures 3.3-1, 3.3-2 and 3.3-5, respectively.

3.3.2 Modified Inland River Systems

MOE Technical Grant funding was provided to the City of Ottawa to establish the IPZ for the Britannia and Lemieux Island Water Purification Plants. The establishment of the IPZ for Ottawa (Britannia and Lemieux Island) will be discussed in further detail in the Surface Water Vulnerability Component Module (5) of the Technical Assessment Report for the MRSPR. The locations of the surface water intakes for Britannia and Lemieux Island are presented on Figures 3.3-3 and 3.3-4, respectively.

3.4 Other Vulnerable Areas: Aquifer Vulnerability

3.4.1 Aquifer Vulnerability

Aquifer vulnerability for the MRSPR was conducted by Golder during the regional Renfrew County – Mississippi – Rideau Groundwater Study (Golder et al., 2003). The vulnerability was calculated using the MOE ISI methodology as prescribed in the MOE groundwater studies terms of reference (MOE, 2001). The MOE ISI protocol involved the following steps:

- Application of the GSC protocol for harmonizing the subsurface stratigraphy into common units;
- Determination of the depth to the water table;
- Classification of the aquifers into confined, unconfined and semi-confined conditions;
- Calculation of the ISI value at each well;
- Class the wells based on ISI values;
- High vulnerability – ISI less than 30;
- Moderate vulnerability – ISI 30 to 80;
- Low vulnerability – ISI greater than 80; and
- Interpolate the results of the individual ISI values and produce regions of high, moderate and low vulnerability.

In addition, the surficial geology mapping was also incorporated into the process for determining the vulnerability in the MRSPR. This modification to the ISI methodology was completed to adapt the ISI methodology from overburden aquifers to shallow bedrock, and was done in consultation with the MOE and the Technical Advisory Group for the Renfrew County – Mississippi – Rideau Groundwater Study. This inclusion of the surficial geology involved representing all areas that were mapped as having less than 1.5 m of overburden, exposed bedrock at surface or sand and gravel deposits as highly vulnerable.

A map presenting the aquifer vulnerability is presented on Figure 3.4-1. Within the MRSPR there are 7,666, 641 and 279 km^2 of high, moderate and low vulnerability, respectively. This represents 89%, 8% and 3% of high, moderate and low vulnerability, respectively. Areas of low to moderate vulnerability are located mainly within the City of Ottawa and are near the Ottawa River and within the southeastern portion of the City of Ottawa. A more detailed breakdown of the vulnerable regions by County is presented in the Renfrew County – Mississippi – Rideau Groundwater Study (Golder et al., 2003).

It should be noted that the general aquifer vulnerability calculated by ISI is for the first aquifer. Multiple aquifers found at depth are not incorporated within this ISI methodology.

Additionally, the uncertainty of the aquifer vulnerability mapping was addressed. This was produced to identify the accuracy of the aquifer vulnerability mapping. The uncertainty was based upon the possible errors in the reported thickness of the stratigraphic units and the error associated with the assigned hydraulic conductivity factor to the stratigraphic unit. The accuracy of the mapping is expressed as a confidence rating based on the aquifer vulnerability and included the following uncertainty classifications:

- High confidence of High Vulnerability;
- High confidence of Low to Moderate Vulnerability; and
- Low or Unknown confidence of High, Moderate or Low Vulnerability.

The uncertainty mapping is presented on Figure 3.4-2 and should be interpreted in concert with the general aquifer vulnerability mapping presented on Figure 3.4-1. The resulting confidence review map results in high confidence in the majority of the highly vulnerable areas and a reduction in the size of the low and moderate vulnerable areas. The vulnerability confidence review is a more conservative approach to the general vulnerability of the MRSPR.

Selected other regions, specifically the City of Ottawa and the United Counties of Leeds & Grenville have also conducted vulnerability studies. Approximately 76% of the City of Ottawa and 38% of Leeds & Grenville lie within the MRSPR.

The “relative” aquifer vulnerability of the City of Ottawa was conducted by Waterloo Hydrogeologic and CH2M Hill (2001). The relative aquifer vulnerability for the City of Ottawa was developed using the DRASTIC (Depth to water table, Recharge, Aquifer media, Soil type, Topography, Impact of vadose zone media & Conductivity) method and predates the MOE methodology in the groundwater study terms of reference. The majority of the City of Ottawa relative aquifer vulnerability was identified as being medium to high vulnerability.

Aquifer vulnerability was conducted during the Leeds & Grenville Groundwater Study (Dillon, 2001). The aquifer vulnerability generated during the Leeds & Grenville study was also conducted prior to the MOE methodology. The aquifer vulnerability was calculated using the AVI methodology. The majority of Leeds & Grenville was ranked as having high to extremely high susceptibility to surface contamination (high vulnerability).

Each of the vulnerability studies contains qualifiers as to the use of the vulnerability mapping produced. The purpose of the vulnerability mapping is for interpretation at regional or large scales at which the mapping was produced. Site specific variations in the general aquifer vulnerability will likely exist when the vulnerability is interpreted at local and smaller scales.

3.4.2 Significant Groundwater Recharge Areas

Areas of potential groundwater recharge are discussed above in Section 1.3.2.3. Areas of potential groundwater recharge, interpreted as vertical gradients, are presented on Figure 1.3-6. As detailed above, areas of significant groundwater recharge will be calculated during the Tier 1 Water Budget for the MRSPR.

3.5 Potential Future Drinking Water Sources

<u>Lanark</u>

Historic water quality issues regarding bacterial and nitrate impacts to private wells in the Village of Lanark have been identified since 1979. As a result of this water quality issue, a hydrogeologic evaluation for a future municipal groundwater supply for the Village of Lanark was conducted by Golder (2005B).

A potential location for the communal supply wells was identified approximately 2.2 km northwest of the Village of Lanark. Two test wells were drilled within the Precambrian marble bedrock and evaluated for their capacity to serve as municipal supply wells. Based on the available capacity, it was estimated that a total of four to six wells will be required to adequately supply the Village of Lanark. The locations of the potential future groundwater supply wells for the Village of Lanark are presented on Figure 3.5-1.

<u>North Grenville</u>

Growth of the former Town of Kemptville within the Municipality of North Grenville has resulted in the need for additional water supply. As a result, a Water and Wastewater Servicing Master Plan was conducted by Stantec and Golder (2005). Five potential new communal well sites were identified, three within the eastern development quadrant and two within the western development quadrant. The proposed communal wells are to be established in the same bedrock formation as the existing water supply wells (Nepean aquifer). Criteria for selection of these sites as potential locations included:

- Interpreted groundwater flow directions;
- Overburden geology;
- Existing and historical potential sources of contamination;
- Proximity to surface water; and
- Proximity to proposed water main infrastructure.

Based on the preliminary schedule included in the SMP, it is expected that four of these proposed locations will be developed by 2020. The locations of the proposed future municipal supply wells are presented on Figure 3.2-7.

3.6 Data and Knowledge Gaps for Vulnerable Areas

The following data gaps were identified for Section 3.0 – Vulnerable Areas within the MRSPR. Additional details as to the data gaps are provided in Appendix 2.

Section 3.2 Groundwater – WHPA

Final WHPA have not been established for Kemptville, Merrickville and Westport.

Section 3.3 Surface Water - IPZ

IPZ have yet to be established for Carleton Place, Ottawa, Perth and Smiths Falls.

4.0 Existing Specific Threats Inventories

This section describes the existing threats inventories that have been conducted within the MRSPR. The focus of the existing threats inventories are generally with respect to water quality. The water quantity threats are discussed in more detail in the water budget guidance module.

Within the various threats inventories conducted to date, specific focus on the associated vulnerable areas will also be regarded. These vulnerable areas include:

- Groundwater – WHPA;
- Surface Water – IPZ;
- Highly Vulnerable Aquifers;
- Significant Groundwater Recharge Areas; and
- Potential Future Drinking Water Areas

These existing threats inventories are generally presented on two scales, consisting of the entire MRSPR or site specific areas within the MVC or RVCA. Many of these studies have been discussed above but have relevant sections relating to threats inventories. A list of these studies is presented below:

- Mapping and Assessment of Former Industrial Sites, City of Ottawa (1988)
- Municipal Well Head Protection Study, Town of Kemptville, Township of North Grenville (2000)
- Village of Merrickville-Wolford Municipal Groundwater Management Study (2000)
- United Counties of Leeds & Grenville Groundwater Management Study (2001)
- Renfrew County – Mississippi – Rideau Groundwater Study (2003)
- Wellhead Protection Area Study, Almonte, Ontario (2003)
- Wellhead Protection Study, Carp Communal Wells, City of Ottawa (2003)
- Wellhead Protection Study, Munster Hamlet and Kings Park Communal Wells, City of Ottawa (2003)
- Old Landfill Management Strategy, Phase 1 – Identification of Sites, City of Ottawa (2004)
- Village of Westport, Preliminary Wellhead Protection Area Study (2004)
- Hydrogeological Evaluation of Municipal Water Supply – Village of Lanark Water Supply Study, Township of Lanark Highlands, Ontario (2005)
- North Grenville Water and Wastewater Servicing Master Plan (2005)
- Village of North Gower Groundwater Study (2005)
- Village of Constance Bay Groundwater Study (2006)

Summaries of these studies are presented in Appendix 1.

4.1 Threats of Provincial Concern

The drinking water threats inventory will focus primarily on land use activities. Both past and current land use activities will be assessed. These threats are defined as any contaminant (chemical or pathogen) currently or having the potential to negatively affect a drinking water source from a water quality perspective. The Threats of Provincial Concern (TPC), identified by the MOE, has been classified according to the following three designations: direct introduction, landscape activities and storage of potential contaminants. Specific activities associated with these three classes are presented in the list below:

- Direct Introduction
  - Water treatment plant waste water discharge;
  - Sewage treatment plant effluent;
  - Sewage treatment plant by-passes; and
  - Industrial effluent
- Landscape Activities
  - Road salt application;
  - De-icing activities;
  - Snow storage;
  - Stormwater management systems;
  - Cemeteries;
  - Landfills;
  - Organic soil-conditioning;
  - Septage application;
  - Hazardous waste disposal;
  - Liquid industrial waste;
  - Mine tailings;
  - Biosolids application;
  - Manure application;
  - Fertilizer application;
  - Pesticide / herbicide application; and
  - Historical activities – contaminated lands
- Storage of Potential Contaminants
  - Fuels / Hydrocarbons;
  - Dense Non-Aqueous Phase Liquids (DNAPLs);
  - Organic Solvents;
  - Pesticides;
  - Fertilizers; and
  - Manure

4.2 Threats to Groundwater Quality

4.2.1 Previous Threats Inventories

Additional details regarding the previous threats inventories listed above are found within Appendix 15. A listing of the database sources for the various threats inventory by municipality is presented in Table 4.2-1. Included within this table is the source of information for each category. The preliminary threats database for the MRSPR has been compiled and will be discussed below in Section 5.4. The sources of data for the MRSPR threats database are presented in Table 4.2-2.

4.2.2 Municipal WHPAs

Merrickville-Wolford

As the establishment of the WHPA for Merrickville is on-going, the threats inventory could not be compiled for Merrickville. The threats inventory will be discussed in more detail in the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR. Lists of the previous databases reviewed for previous Merrickville groundwater study are presented in Appendix 15.

Mississippi Mills

Listings of the potential contaminant sources identified in Mississippi Mills are presented in the Almonte WHPA (Intera, 2003A). Table 4.2-3 presents the potential contaminant sources for the Almonte WHPA, which was compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4.

North Grenville

As the establishment of the WHPA for Kemptville is on-going, the threats inventory could not be compiled for Kemptville. The threats inventory will be discussed in more detail in the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR. Lists of the previous databases reviewed for previous Kemptville groundwater study are presented in Appendix 15.

City of Ottawa

Carp WHPA

Potential contaminant sources were identified during the WHPA study for Carp (Golder, 2003C). Table 4.2-3 presents the potential contaminant sources for the Carp

WHPA, which was compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4.

King's Park Subdivision (Richmond) WHPA

Potential contaminant sources were identified during the WHPA study for King's Park Subdivision (Richmond) (Golder, 2003C). Table 4.2-3 presents the potential contaminant sources for the King's Park WHPA, which was compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4.

Munster Hamlet WHPA

Potential contaminant sources were identified during the WHPA study for Munster WHPA (Golder, 2003C). Table 4.2-3 presents the potential contaminant sources for the Munster WHPA, which was compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4.

<u>Westport</u>

Potential contaminant sources were identified during the preliminary WHPA study for Westport (Malroz, 2004). Table 4.2-3 presents the potential contaminant sources for the Westport WHPA, which was compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4. As the WHPA is preliminary for the Westport groundwater supply wells, the listing of contaminant sources may change depending on the shape of the final WHPA.

4.2.3 Other Vulnerable Areas

Other vulnerable areas, with respect to groundwater, within the MRSPR include general highly vulnerable aquifers, significant groundwater recharge areas and future drinking water supply areas. These vulnerable areas are discussed above in more detail in Section 3.0. Outside of the municipal supply areas, the MRSPR is generally considered highly vulnerable, with respect to the first potable aquifer.

The locations and type of potential threats within the MRSPR are presented on Figure 4.2-1. The potential threats represented on Figure 4.2-1 have been compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4.

4.3 Threats to Surface Water Quality

4.3.1 Surface Water IPZ

As the establishment of the IPZ for Carleton Place, Ottawa (Britannia & Lemieux Island), Perth and Smiths Falls are on-going, the threats inventory could not be compiled. The threats inventory will be discussed in more detail in the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

4.4 Data Gaps

The following data gaps were identified for Section 4.0 – Threats Inventories within the MRSPR. Additional details as to the data gaps are provided in Appendix 2.

<u>Section 4.2 Threats to Groundwater Quality</u>

The following data gaps were identified during the Renfrew –Mississippi – Rideau groundwater study.

- MOE spills database was only reviewed from 1999-2001
- MOE file review / interviews was not geo-referenced – not plotted on figures – not represented in tables
- Municipal clerk survey was not geo-referenced – not plotted on figures – not represented in tables
- Urban area of the City of Ottawa not included in many of the database searches

The following additional data gaps were identified with the other previous threats inventories conducted within the MRSPR:

- Inconsistencies in the various data sources used to generate the threats inventories. There is a need for a standard approach to generating the base threats inventories;
- Many of the databases contain references to the same properties that need to be cross referenced to remove duplicate entries (i.e., The Anderson's waste disposal inventory & the MOE waste disposal site inventory may list the same site. This does not necessarily mean that there are two landfills corresponding to the site but there will be a threat recorded for each database and they need to be cross referenced.)

The following threats inventories have been conducted but were not currently available to the MRSPR: City of Ottawa – Historic Land Use Inventory

5.0 Summary of Identified Issues & Concerns

5.1 Identified Issues

Issues are defined as the realization of a specific threat within a drinking water source. A map of known issues in the MRSPR was not compiled due to the potential for misinterpretation of this map. A description of the known issues within the MRSPR is presented below in the following subsections.

5.1.1 Municipal WHPA

Merrickville-Wolford

Several water quality parameters including colour, hardness, total coliforms, and turbidity were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Merrickville municipal water supply is discussed above in Sections 2.3 and 2.4. Turbidity causes interference with the disinfection of the water. Some of these parameters such as hardness are typically associated with the natural groundwater quality within the Nepean formation. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The establishment of the WHPA for Merrickville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Mississippi Mills (Almonte)

The WHPA study conducted in 2003 for the Almonte municipal supply wells identified one (1) issue within the WHPA. The respective municipal supply wells and associated land use of issue was encountered as a spill located at the Sewage Lagoons which are located within the 2 year TOT of Well 5.

Several water quality parameters including aluminum, hardness, organic nitrogen, TDS, and turbidity were found to exceed the ODWSOG. The groundwater quality for the Almonte municipal water supply is discussed above in Sections 2.3 and 2.4. Historic elevated turbidity during high pumping rates has been documented at one of the wells.

Turbidity causes interference with the disinfection of the water. Some of these parameters such as hardness and TDS are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

North Grenville

Several water quality parameters including colour, hardness and total coliforms (Van Buren well only) were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Kemptville municipal water supply is discussed above in Sections 2.3 and 2.4. Some of these parameters such as hardness are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The establishment of the WHPA for Kemptville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa

Carp

During the WHPA study conducted in 2003 for the Carp municipal supply wells, no issues were identified within the WHPA. However, several potential concerns were identified and are discussed below.

Several water quality parameters, including colour, hardness, HPC, hydrogen sulphide, iron, organic nitrogen, and TDS were found to be in excess of the ODWSOG. The groundwater quality for the Carp municipal water supply is discussed above in Sections 2.3 and 2.4. Some of these parameters such as hardness, hydrogen sulphide, and TDS are typically associated with the natural groundwater quality within the overburden sand formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

King's Park (Richmond)

During the WHPA study conducted in 2003 for the King's Park (Richmond) municipal supply wells, no issues were identified within the WHPA. However, several potential concerns were identified and are discussed below.

Several water quality parameters, including conductivity, hardness, iron and TDS were found to be in excess of the ODWSOG. The groundwater quality for the King's Park (Richmond) municipal water supply is discussed above in Sections 2.3 and 2.4. These parameters are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Munster Hamlet

During the WHPA study conducted in 2003 for the Munster municipal supply wells, no issues were identified within the WHPA. However, several potential concerns were identified and are discussed below.

Several water quality parameters, including hardness and iron were found to be in excess of the ODWSOG. Elevated turbidity levels have also been documented in one of the wells at Munster. The groundwater quality for the Munster municipal water supply is discussed above in Sections 2.3 and 2.4. These parameters are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Westport

Several water quality parameters, including hardness, iron, total coliforms and turbidity were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Westport municipal water supply is discussed above in Sections 2.3 and 2.4. Some of these parameters such as hardness, iron and turbidity are typically associated with the natural groundwater quality within the Nepean formation. Water quality in Well 2 has improved since the decommissioning of Well 1. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The establishment of the WHPA for Westport will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

5.1.2 Municipal IPZs

The establishment of the IPZs for Carleton Place, Ottawa (Britannia and Lemieux Island), Perth and Smiths Falls will be discussed in further detail in the Surface Water Vulnerability Component Module (5) of the Technical Assessment Report for the MRSPR. Upon completion of the IPZ work, the identification of issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Carleton Place

Several water quality parameters, including colour, DOC, and turbidity were found to be in excess of the ODWSOG. The water quality for the Carleton Place municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. These parameters are typically associated with the natural surface water quality within the Mississippi River. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

Ottawa

Several water quality parameters, including colour, DOC, and turbidity were found to be in excess of the ODWSOG. In addition, the alkalinity within the Ottawa River was found to be below the ODWSOG range. The water quality for the Ottawa municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. These parameters are typically associated with the natural surface water quality within the Ottawa River. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

Perth

The water quality for the Perth municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

Smiths Falls

Several water quality parameters, including colour, DOC, and turbidity were found to be in excess of the ODWSOG. The water quality for the Smiths Falls municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. These parameters are typically associated with the natural surface water quality within the Rideau River. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

In addition to the water quality, the current drinking water treatment plant within Smiths Falls is located within the flood plain. Smiths Falls is in the process of trying to relocate the water treatment plant.

5.1.3 Other Vulnerable Areas

Several areas of known groundwater quality impairment are located within the MRSPR. Many of these areas also have residents drawing water from individual monitoring wells in these areas. A brief description of some of these more significant areas of groundwater impairment are described below.

Constance Bay

A groundwater study for the Village of Constance Bay within the amalgamated City of Ottawa was completed during August 2005 by Dillon (2006). This study was performed to determine if there are any area-wide groundwater quality or quantity concerns that may affect future development on private services.

The Village of Constance Bay is characterized by shallow sands overlying clay and/or bedrock at depth. The average overburden thickness exceeds 40 m however in the northern portion of the peninsula bedrock is encountered at less than 5 m below ground surface. The majority of wells (98%) extract water from the shallow sand aquifer. Many of the wells are dug wells or sand points and range in depth from 5 to 15 m. Based on the assumption that the majority of the groundwater use is sourced from the overburden sand aquifer and discharged through septic beds back to the same aquifer the potential for area wide aquifer dewatering is deemed to be low.

A detailed water quality investigation included the sampling of 69 water wells at select residential and commercial properties with an attempt to obtain a valid cross section of data. Water quality from the overburden sand aquifer appears to be of good natural water quality. However, significant nitrate concentrations have been detected (average concentration of 5.2 mg/L with 19% of the samples exceeding the ODWQS). These nitrate concentrations appear to be a result of the septic loading within the Village of Constance Bay. Detection of bacteria was not widespread and was likely related to well construction and / or maintenance and not septic loading.

Cranberry Estates (North Grenville)

Historical groundwater contamination related to both nitrates and bacteriological parameters has been documented in the groundwater west of Kemptville in the Municipality of North Grenville since 1984-1985. The 1998 investigation by OMMA which involved an assessment of available information concluded that nitrate concentrations in private wells have consistently exceeded the health related drinking water criterion of 10 mg/L. A potential source of contamination for the Oxford Heights subdivision was identified as the former Valley Sanitation septage disposal location.

In 2001, the most significant water quality problem occurred in the Cranberry Hill subdivision in which 83% of homes had unacceptable bacteriological water quality and 10-20 % exceeded the nitrate criterion of 10 mg/L. In addition, 40-50 % of the homes had nitrate concentrations that were greater than 7 mg/L. These nitrate and bacteriological impacts have been detected in the groundwater since 1985 and the likely source of the impacts was implied to be private septic systems and not the Valley Sanitation site. Recommendations were made to provide an alternate water source for the residents of the Cranberry Hill Subdivision. A public consultation process to decide the appropriate course of action was also recommended (OMMA, 2001C).

Two sampling events of 44 and 41 private wells, respectively, were conducted in the vicinity of the Cranberry Hill subdivision in June 2005. Nitrate was not detected in excess of the 10 mg/L criterion; however, 50 % of the private wells had nitrate concentrations in excess of 5 mg/L. Nitrate concentrations in ten of 21 wells indicated decreasing concentrations as compared to the 2001 data. Eight of the wells indicated relatively stable concentrations between the 2001 and 2005 data. Fourteen (14) wells and 13 wells during the two sampling events indicated unacceptable bacteriological water quality with respect to total coliforms. The poor bacteriological water quality results with respect to total coliforms were similar to the 2001 data. Four houses displayed positive *E. coli* concentrations during the sampling events indicating bacteriological contamination. As a result of the continued bacteriological impacts to the water quality in the Cranberry Hill subdivision, it was recommended that an alternate water source be investigated (Trow, 2005).

County Road 18 in the vicinity of Sommerville Road also has impacted groundwater quality with respect to bacteriological water quality with 47% of the homes exceeding the drinking water standards for bacteria. None of the wells exceeded the nitrate criteria, however 16 % were found to be greater than 7 mg/L. Potential sources of contamination were indicated to be self contamination from private septic systems (bacteria and nitrates) or potential up-gradient sources (Valley Sanitation or Cranberry Hill subdivision likely only for nitrates due to the distance) (OMMA, 2001C).

Highway 43, Johnston and Muldoon Roads indicated generally good water quality with only 15% of the wells exceeding the bacteriological water quality standards. Nine percent of the wells had nitrate in excess of the 10 mg/L criterion (OMMA, 2001C).

Phase I of the Oxford Heights subdivision indicated that 100% of the wells met the drinking water criteria for nitrate and bacteriological parameters. Only 2 of the tested wells were found to have nitrate concentrations greater than 7 mg/L. The higher standards of well construction for the Oxford Heights subdivision are considered to be directly reflected in the better water quality. The proposed Phase II of the Oxford Heights subdivision is to be located between the existing Phase I development and the up-gradient source of groundwater contamination from the Valley Sanitation site. As such, it was recommended that the proposed Phase II development of the Oxford Heights subdivision not be supported at this time (OMMA, 2001C).

<u>Crotch Lake</u>

A groundwater sampling event was conducted in the Fall of 2007 east of Crotch Lake in North Frontenac Township and Lanark Highlands Township. There are active uranium mine prospecting claims in this area. Previous exploration work had been conducted in this area dating back to the 1950’s. The sampling program was conducted to determine the concentrations of uranium in groundwater prior to the current exploration program.

Groundwater samples were collected from private drinking water wells at 15 locations. In addition, one surface water sample was collecting during the program. The program revealed that uranium was detected in the groundwater at 12 sample locations, with two (2) of the samples exceeding the ODWQS of 0.02 mg/L for uranium.

<u>Cumberland</u>

A water and wastewater alternative servicing solutions study was conducted for the Village of Cumberland within the amalgamated City of Ottawa during 2001 and 2002 (Golder, 2003A). The study was undertaken to evaluate the future servicing needs of the Village. The MRSPR is a rural village designated within the City of Ottawa which is primarily residential with some commercial and institutional land uses. Fewer than 20 commercial and institutional properties exist within the Village. The estimated population of the Village is approximately 1,500. All current development is serviced by private individual wells and septic systems.

Three sources of groundwater were identified within the Village of Cumberland: surficial sand and gravel aquifer; till / upper weathered bedrock aquifer; and deep bedrock aquifer. Based on the MOE well records, approximately 25 % of the wells were completed within the till / upper weathered bedrock aquifer and approximately 73 % of the wells are completed within the deeper bedrock aquifer.

Historic groundwater quality issues related to elevated chloride, nitrate and bacteria. A database of historic sample results and a sampling event in 2000 was conducted by Stantec. Elevated concentrations of total coliforms, nitrate, sodium and chloride concentrations were detected during the 2000 sampling event. Elevated sodium and chloride concentrations within the Village area are suspected to be naturally occurring.

Based on these historical sampling results a detailed groundwater quality assessment was conducted which included the installation and sampling of 13 monitoring wells at four locations and sampling of 148 water wells at select residential and commercial properties with an attempt to obtain a valid cross section of data. Based on the results of the study the following samples were noted to exceed the ODWQS or ODWSOG:

- 61 of 148 samples (41%) for chloride (250 mg/L);
- 32 of 148 samples (22%) for sodium (200 mg/L);
- 40 of 195 samples (21%) for total coliforms (non-detect);
- 3 of 195 samples (2%) for *E. coli* (non-detect);

Elevated nitrate concentrations were detected in the water wells in the MRSPR but not a level in excess of the ODWQS. In addition, several of the non-health related parameters commonly found at concentrations above ODWSOG (hardness, iron, and TDS) were also detected at concentrations in excess of the criteria.

The surface water quality sampling program was conducted in spring (15 samples) and fall (52 samples) 2001. Surface water results indicated elevated concentrations bacteria, nitrate, ammonia and total phosphorus. These elevated concentrations in surface water were attributed to the discharge from septic systems, road de-icing, water softener backwash discharges and grey water discharges.

Former Beckwith Landfill

Chlorinated solvent groundwater contamination in the Township of Beckwith is associated with the former private landfill located near Blacks Corners. The private landfill was in operation from approximately 1968 until 1978; however a Certificate of Approval (C of A) was never obtained for the site. In 1999, Beckwith Township retained Golder to conduct an assessment of the former private landfill and the former Beckwith Township landfill. Vinyl chloride (VC) and benzene were encountered in the groundwater during this assessment. As a result of this assessment, the MOE recommended that the Township of Beckwith undertake a domestic well sampling program and complete a detailed hydrogeologic study of both former landfills. The domestic well sampling program in 2000 indicated chlorinated solvent impacts. Duke Engineering & Services (Canada) Inc. (Duke) conducted a hydrogeologic study of the private landfill in 2000 that confirmed that the private landfill was the likely source of groundwater contamination in the area.

The primary contaminants of concern identified were the chlorinated solvent tricholorethene (TCE) and its associated degradation products 1,1-dichloroethene (1,1-DCE); cis and trans 1,2-DCE and VC. The aerial extent of the chlorinated solvent plume was determined to be approximately 9 km by 4 km from the private landfill. Groundwater modeling was conducted to estimate the potential expansion of the plume. It was determined that plume will continue to expand downgradient for at least the next 20 years. Source removal or containment was recommended as it would have a beneficial impact on the plume (Aqua Terre, 2001).

Water quality results indicated that some wells have chlorinated solvent concentrations in excess of the ODWQS. Residences with impacted wells have been provided with bottled water and / or granular activated carbon (GAC) treatment systems.

Lanark

A study was undertaken in 1977 and 1978 to determine the nature and extent of water contamination in individual domestic water supply wells and water pollution in surface water in the Village of Lanark (Fenco, 1979). A total of 260 houses were investigated for bacteriological contamination. A random subset of samples (totaling 38 houses) was also selected for chemical characterization. Based on this chemical characterization iron and total nitrates were present above the MOE Drinking Water Objectives in 18% of the samples. Chloride was also detected in excess of the objectives in 13 % of the samples.

Water supplies for each house were classified as satisfactory, doubtful, contaminated or substandard. Based on the results of the water testing 63% of the samples were deemed satisfactory (164 of 260 samples). Thirty-one (31) homes contained contaminated water which represents 12% of the homes tested. Sewage systems for each house were also classified into similar categories which included satisfactory, deteriorating, substandard or unacceptable. Based on the results of the septic inspections 59% of the homes were deemed satisfactory. Seventeen (17) homes contained unacceptable sewage disposal facilities which represent 7% of the homes inspected.

Based on the results of the water surveys in the late 1970's in the Village of Lanark, various private well and sewage systems were identified as requiring upgrades or new installations. In response to the poor water quality in 1980 and 1981 various individual corrections to the private water and sewer services were conducted.

A survey in 1986 by the Leeds, Grenville and Lanark Health Unit identified that 31 of 88 wells sampled indicated water of unsatisfactory quality and 13 indicated doubtful quality. As a result of the 1986 survey, a follow-up survey was conducted by the MOE in 1987 and involved the sampling of 261 wells in the Village. The results of the 1987 survey indicated that 35% of the wells were unsatisfactory and 16% were doubtful with respect to bacteriological contamination. In addition, during the 1987 survey five of 38 wells sampled for nitrates indicated levels in excess of the provincial criterion of 10 mg/L.

A sampling program was conducted in 1990 which involved the sampling of 299 wells in the Village of Lanark, which represents greater than 99% of the wells within the Village. Bacterial sample results during the 1990 survey indicated 7% of the wells as unsatisfactory and 10% of the wells as doubtful. The differences in bacterial quality from the 1987 survey were attributed to the seasonality of the survey (1987 survey in July and 1990 survey in April). Nitrate impacts were identified in approximately 75% of the wells sampled with 25% approaching the provincial criterion and 17% exceeding the criterion. The results of the 1987 and 1990 survey indicated that the individual corrections to the private wells and sewage systems in the Village of Lanark have not resolved the bacterial and chemical contamination (TSH, 1990).

Another groundwater sampling program was conducted in 2000 and involved the collection of samples from 329 wells. Nitrate concentrations in the groundwater wells sampled was found to exceed the provincial criterion of 10 mg/L in 14% of the wells and was approaching the criterion in 27% of the wells. Evidence of nitrate impacts were found in 75% of the wells sampled. Bacteriological sampling indicated that 16% of the wells were unsafe and that 8% showed some level of bacteriological impacts. These results were similar to the previous chemical and bacteriological concentrations reported in the Village of Lanark groundwater (Stantec, 2002).

<u>Manotick</u>

In December 1991, the MOE collected water samples from private drinking water wells in the core of the Village of Manotick. The sampling was conducted in response to complaints of water quality deterioration. Subsequent sampling of private wells in Manotick revealed that 42 to 65 wells were impacted with benzene and /or perchloroethene (PCE) in excess of the drinking water standards. As a result of the contamination, the Regional Municipality of Ottawa-Carleton extended the municipal water to the core of the Village of Manotick in the summer of 1993. Any residential homes that were connected to municipal water were required to decommission their existing private drinking water wells.

The commercial dry cleaning operation in Manotick was in operation from the mid 1970's until approximately 1985. An underground concrete holding tank that was used to store liquid wastes from the dry cleaning operations. Upon removal of the tank in 1985, it was noted that the tank was in poor condition with evidence of leakage. It was also suspected that disposal of PCE waste to the building floor drains occurred. Contamination of drinking water wells in the area is known to have existed since 1984 as one well in the vicinity of the site was abandoned and re-drilled to a greater depth to find potable water. Soil impacts associated with the former dry cleaning operations were also defined as part of the study.

The sources of benzene were associated with several former and current fuel service stations within the core of Manotick. Two benzene plumes, which are smaller than the PCE plume, were identified in the Upper Oxford aquifer. One benzene plume was also found to be within the Lower March / Nepean aquifer. Soil impacts associated with the fuel service stations were also identified.

The main PCE plume in both aquifers (Upper and Lower) are approximately 300 m by 200 m. An additional smaller PCE plume was also identified in both aquifers. The front of the PCE plume has migrated to below the Rideau River. PCE was not detected in either the Lower or Upper aquifers on Long Island. Based on the movement of the plume, the potential exists for the plume to migrate to private wells on Long Island. Recommendations were made to continue monitoring the status of the groundwater plume (Raven Beck, 1994A and 1996).

Risk based pathways associated with exposure to indoor air quality from PCE contaminated soils and groundwater was also conducted. The results of the pathways assessment indicated that for the purposes of the protection of human health that the PCE impacted soil or groundwater does not require active remediation.

Other Areas

Additional areas of known contamination were identified in the regional Renfrew-Mississippi-Rideau groundwater study discussed above in Section 4. These issues will be addressed as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

5.2 Identified Concerns

Concerns are defined as a potential threat within a drinking water source. This potential threat is not supported by scientific information documenting the realization of the threat (i.e., different than known documented contamination which is identified as an issue).

5.2.1 Municipal WHPAs

Merrickville-Wolford

The establishment of the WHPA for Merrickville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Mississippi Mills (Almonte)

During the WHPA study conducted in 2003 for the Almonte municipal supply wells, five (5) areas of potential concern were identified within the WHPA (Intera, 2003A). Rankings were also developed for all land uses of potential concern. It should be noted that the WHPA capture zones have been updated since the 2003 study (Intera, 2007).

The preliminary threats database for the MRSPR was cross referenced with the revised WHPA for the Almonte municipal wells and the associated potential threats are presented in Table 4.2-3. The following potential threats for the respective municipal supply wells in Almonte and associated land uses of concern are described as follows:

- Wells 3, 7&8 – Two (2) sites with Fuel / Hydrocarbon Storage within the 2 year TOT;
- Wells 3, 7&8 – One (1) site with Pesticide Storage / Sales within the 2 year TOT; and
- Wells 5 & 6 – One (1) site with Sewage Lagoons within the 2 year TOT.

The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

North Grenville

The establishment of the WHPA for Kemptville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

<u>Ottawa</u>

Carp

During the WHPA study conducted in 2003 for the Carp municipal supply wells, five (5) areas of potential concern were identified within the WHPA (Golder, 2003B). Rankings were also developed for all land uses of potential concern. It should be noted that the WHPA capture zones have been updated since the 2003 study (Golder, 2007).

The preliminary threats database for the MRSPR was cross referenced with the revised WHPA for the Carp municipal wells and the associated potential threats are presented in Table 4.2-3. The following potential threats for the respective municipal supply wells in Carp and associated land uses of concern are described as follows:

- Four (4) sites with Pesticide Storage / Sales within the 2 year TOT;
- One (1) site with Fuel / Hydrocarbon Storage within the 2 year TOT;
- One (1) site with a Landfill / Junkyard within the 5 year TOT;
- One (1) site with DNAPL Storage within the 5 year TOT; and
- Two (2) sites with Pesticide Storage / Sales within the 25 year TOT.

The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

King's Park (Richmond)

During the WHPA study conducted in 2003 for the King's Park (Richmond) municipal supply wells, 43 areas of potential concern were identified within the WHPA (Golder, 2003C). Rankings were also developed for all land uses of potential concern. It should be noted that the WHPA capture zones have been updated since the 2003 study (Golder, 2007).

The preliminary threats database for the MRSPR was cross referenced with the revised WHPA for the King's Park (Richmond) municipal wells and the associated potential threats are presented in Table 4.2-3. The following potential threats for the respective municipal supply wells in King's Park (Richmond) and associated land uses of concern are described as follows:

- One (1) site with Fertilizer Storage / Sales within 100 m;
- One (1) site with DNAPL Storage within the 2 year TOT;
- Eight (8) sites with Fuel / Hydrocarbon Storage within the 2 year TOT;
- Two (2) sites with Historic Land Uses (Fuel Spills) within the 2 year TOT;

- Four (4) sites with Organic Solvents (PCB) Storage within the 2 year TOT;
- One (1) site with Pesticide Storage / Sales within the 2 year TOT;
- Three (3) sites with Sewage Lagoons within the 2 year TOT;
- One (1) site with a Landfill / Junkyard within the 5 year TOT;
- One (1) site with Historic Land Uses (Fuel Spill) within the 5 year TOT;
- One (1) site with Organic Solvent (PCB) Storage within the 5 year TOT;
- One (1) site with Historic Land Uses (Fuel Spill) within the 25 year TOT; and
- Two (2) sites with a Landfill / Junkyard within the 25 year TOT.

The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

<u>Munster Hamlet</u>

During the WHPA study conducted in 2003 for the Munster municipal supply wells, ten (10) areas of potential concern were identified within the WHPA (Golder, 2003C). Rankings were also developed for all land uses of potential concern. It should be noted that the WHPA capture zones have been updated since the 2003 study (Golder, 2007).

The preliminary threats database for the MRSPR was cross referenced with the revised WHPA for the Munster municipal wells and the associated potential threats are presented in Table 4.2-3. The following potential threats for the respective municipal supply wells in Munster and associated land uses of concern are described as follows:

- One (1) site with Historic Land Uses (Fuel Spill) within the 2 year TOT; and
- One (1) site with Sewage Lagoons within the 2 year TOT.

The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

<u>Westport</u>

During the preliminary WHPA study conducted in 2004 for the Westport municipal supply wells, areas of potential concern were identified within the WHPA (Malroz, 2004). It should be noted that the WHPA capture zones are currently under revision and are to be updated in 2007.

The preliminary threats database for the MRSPR was cross referenced with the preliminary WHPA for the Westport municipal wells and the associated potential threats are presented in Table 4.2-3. The following potential threats for the respective municipal supply wells in Westport and associated land uses of concern are described as follows:

- Well 3 – Two (2) sites with Fuel / Hydrocarbon Storage within the 2 year TOT; and
- Wells 2 & 3 – One (1) site with a Sewage Lagoon within the 5 year TOT.

It should also be noted that the two sites with fuel storage within the 2 year TOT for Well 3 are also found within the 5 year TOT for Well 2.

The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

5.2.2 Municipal IPZs

The establishment of the IPZs for Carleton Place, Ottawa (Britannia and Lemieux Island), Perth and Smiths Falls will be discussed in further detail in the Surface Water Vulnerability Component Module (5) of the Technical Assessment Report for the MRSPR. Upon completion of the IPZ work, the identification of concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

5.2.3 Other Vulnerable Areas

During the regional groundwater study, land uses of potential concern were identified. An update of these concerns will be conducted as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

5.3 Summary Sheets of Identified Issues & Concerns

Summary sheets of identified issues and concerns will be compiled as part of the Threats Inventory and Issues Evaluation Component Guidance Module (6) of the Technical Assessment Report for the MRSPR.

5.4 Inventory / Database of Identified Issues & Concerns

The preliminary compilation of the MRSPR Threats Database has been initiated. This threats database is based upon the provincial data standards. Information within the threats database has been compiled from the previous threats inventories and is presented in Appendix 16. This database will provide the starting point for the Threats Inventory and Issues Evaluation Component Guidance Module (6) of the Technical Assessment Report for the MRSPR.

5.5 Data Gaps

Data gaps were not identified for this section, however additional work as detailed above is required to be completed as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

6.0 Summary

6.1 Watershed Description

The watershed description is an assessment of the natural and man-made characteristics of the watershed region. The description will compile available background information regarding the natural characteristics, hydrology, hydraulics, geology, hydrogeology, population distribution, land uses, water quality and quantity, vulnerable areas, existing threats inventories and identified issues and concerns.

The MRSPR is one of 19 drinking water source protection watershed regions in Ontario proposed within the *Clean Water Act* which consists of all lands within the MVC and RVCA with a total area of approximately 8,600 km^2. Both the MVC and RVCA are established as partnerships of their respective municipalities under the *Conservation Authorities Act*. The MVC is the lead inter-municipal agency involved in river-related environmental issues within the Mississippi Valley watershed and was formed in 1968. Similarly, the RVCA is also the lead inter-municipal agency regarding river-related environmental issues within the Rideau Valley watershed and was formed in 1966. A map showing the extents of the MRSPR is presented on Figure 1.1-1.

Physical Description

The following sections summarize the topography, bedrock geology, overburden geology and physiography of the MRSPR. The boundaries of the MRSPR are defined by the drainage areas of the Rideau and Mississippi Rivers and some smaller surface water courses that drain directly to the Ottawa River within the City of Ottawa. As a result the boundaries are influenced by topography as opposed to geology.

The topography of the MRSPR is highly variable and generally slopes from the southwest to the northeast with a total relief of approximately 420 m. The region can be generally divided into two topographic regions. The first topographic region corresponds to the western half of the MRSPR and consists of Precambrian bedrock outcrops with the ground surface elevation generally greater than 175 masl. The second topographic region corresponds to the eastern half of the MRSPR and consists of sedimentary Paleozoic bedrock overlying the Precambrian bedrock with the ground surface elevation generally less than 175 masl. The Precambrian / Paleozoic divide roughly coincides with a north-south oriented line between Pakenham and Perth. A map showing the topography of the MRSPR is detailed on Figure 1.2-2.

The geologic environment within the MRSPR is part of a larger physiographic region known as the Ottawa-St. Lawrence Lowland. Generally, the geology within the Ottawa-

St. Lawrence Lowland basin consists of Precambrian bedrock overlain by flat-lying Paleozoic sedimentary rocks, which are in turn overlain by unconsolidated Quaternary deposits. The geology of the Precambrian igneous and metamorphic bedrock is extremely complex with many faults, folds and a mixture of rock types. The Paleozoic sedimentary bedrock consists of three bedrock groups: Potsdam, Beekmantown and Ottawa. The Potsdam Group generally overlies the Precambrian bedrock, is comprised of coarse grained sandstone and conglomerate bedrock and includes the Covey Hill and Nepean Formations. The Beekmantown Group generally overlies the Potsdam Group and is comprised of interbedded sandstone, dolostone, limestone and shale bedrock. Bedrock formations within the Beekmantown Group include the March, Oxford and Rockcliffe. The Ottawa Group generally overlies the Beekmantown Group and consists of dolostone, limestone, sandstone and shale bedrock. Bedrock formations within the Ottawa group found within the MRSPR primarily include Shadow Lake, Gull River, Bobcaygeon and Verulam with isolated occurrences of Lindsay, Billings and Carlsbad formations in the northeastern extremes of the watershed region. A map detailing the generalized bedrock geology of the MRSPR is presented on Figure 1.2-4.

With the exception of the northern and eastern portions of the MRSPR, bedrock generally outcrops throughout the region. Generally the overburden deposits in the MRSPR are less than one meter in thickness. Within bedrock valleys near the Ottawa and Rideau Rivers, overburden deposits of clays and sands with thicknesses ranging from 10-30 m are common. As a result, the overburden deposits within the MRSPR are very sparse and disconnected. The overburden geology found within the MRSPR includes alluvium (fine-grained sand, silt and clay), organic (muck), sand and gravel, sand, clay and till (silty sand to sandy silt, with gravel and clay) materials. Maps showing the surficial geology and overburden thickness of the MRSPR are presented on Figures 1.2-12 and 1.2-18, respectively.

Seven physiographic regions exist within the MRSPR and are listed in decreasing order of size. In addition, the percentage of the each physiographic region within the MRSPR is included. Algonquin Highlands (40%) physiographic region is densely forested with many lakes and consists of shallow to non-existent soils underlain by Precambrian bedrock. Smiths Falls Limestone Plain (26%) physiographic region contains dense forest, agricultural lands and bogs or wetlands and is characterized by shallow soils over limestone or dolostone bedrock. Ottawa Valley Clay Plains (17%) physiographic region contains agricultural lands, dense forests and developed lands and is characterized by thick deposits of silty clay with ridges of rock or sand. Georgian Bay Fringe (10%) physiographic region is densely forested with lakes and is characterized by very shallow soils and bare rock ridges. Edwardsburg Sand Plain (3%) physiographic region contains agricultural lands, dense forests and wetlands and consists of glaciofluvial sand deposits overlying bedrock, till or clay. North Gower Drumlin Field (3%) physiographic region contains agricultural lands and dense forest and is a drumlinized till plain with clay and silt between the drumlins. Russell and Prescott Sand Plains (1%) physiographic region contains agricultural lands, dense forest and developed lands and is characterized by thick sand deposit overlying clay. Many of these physiographic regions extend beyond the boundaries of the MRSPR. A map detailing the physiography of the MRSPR is presented on Figure 1.2-19.

Hydrology

Surface Water

The MRSPR features a complex network of lakes, rivers, wetlands and streams. The upper (western) portion of the region is underlain by Precambrian bedrock and contains deep glacial lake systems. The lower (eastern) portion of the region is dominated by large river systems. Water flows and levels on many of these systems are controlled by numerous hydraulic structures both natural and man-made.

The two major watersheds within the MRSPR correspond to the two CAs with the watersheds being the Mississippi and Rideau Rivers. In addition to these two large watersheds, there are several smaller water courses that drain directly to the Ottawa River within the City of Ottawa. The locations of the major watersheds, tributary subwatersheds and smaller water courses are represented on Figure 1.1-1.

The Mississippi River is divided into three regions (west, central and east). The western Mississippi region is underlain by Precambrian bedrock, and is dominated by lakes. The central Mississippi region is also underlain by Precambrian bedrock however this region is a transition zone with a combination of lakes and rivers. The eastern Mississippi region is underlain by Paleozoic bedrock and is dominated by riverine systems. The major tributary subwatersheds within the Mississippi River include Buckshot Creek, Clyde River, Fall River, Indian River and Indian Creek. Several of the major lakes within the Mississippi River watershed include Shabomeka, Mazinaw, Kashwakamak, Mississagagon, Big Gull (Clarendon) and Crotch (Cross) Lakes. In addition, there are 12 major water control structures that have a significant effect on flow in the Mississippi River watershed.

The Rideau River is also divided into three regions (upper, middle and lower). The upper Rideau region is underlain by Precambrian bedrock and as a result of glaciations has resulted in long narrow lakes and rivers. The middle Rideau region is underlain by Paleozoic bedrock and is primarily a riverine system. The lower Rideau region is predominantly underlain by overburden deposits, typically clay, and is also a riverine system. The major tributary subwatersheds of the Rideau River include Irish Creek, Kemptville Creek, Jock River and Tay River. Several of the major lakes within the Rideau River watershed include Big Rideau, Upper Rideau, Wolfe, Bob's and Christie Lakes. The Rideau River is the northern portion of the Rideau Canal. As a result, the Rideau River is maintained for recreational navigation by a series of dams and navigation locks.

Groundwater

Groundwater flows through the interconnected spaces within the overburden soil (pores) and bedrock units (fractures). Aquifers, which typically consist of gravel, sand or fractured rocks such as; sandstone, dolostone, limestone or granite are/can be highly permeable and water can move through the spaces. Conversely, aquitards typically consist of clay, silt and unfractured bedrock such as limestone, shale or granite. Groundwater flow direction within low permeability aquitard units is conceptualized as vertically downward, while water flow through permeable aquifer units conceptualized as horizontal in direction of groundwater flow.

The regional groundwater flow direction within the MRSPR is spatially variable within the region; water generally flows from the topographic high areas (Precambrian Highlands in the southwest portion of the MRSPR) to the low lying areas associated with larger surface water features (Ottawa River or St. Lawrence River). Figure 1.3-5 details the interpreted regional deep bedrock groundwater flow. From this regional flow map, regional groundwater flow is described as follows: groundwater in Addington Highlands is generally from north to south; in Frontenac County groundwater flow is from northwest to southeast; in the majority of the MRSPR (Lanark County, northern portion of the United Counties of Leeds & Grenville and the southern portion of the City of Ottawa) groundwater flow is to the east; and in the northern portion of the City of Ottawa near the Ottawa River, the groundwater flow is towards the Ottawa River.

Local variation in geology influences groundwater flow where groundwater connection is typically through the higher permeability units. The orientation and distribution of fractures and joints within lower permeable units will influence the groundwater flow direction on a local scale.

Near the ground surface the vertical direction groundwater flow becomes important in drinking water source protection planning because areas where the dominant direction of groundwater flow is downward can provide a pathway for contaminants that originate at the ground surface into the underlying aquifers. These areas are considered to be under “recharge” conditions and typically exist on topographic high elevations or where a porous surficial sand cover exists, which allows precipitation to infiltrate into the deeper groundwater aquifers. Although surface water features are typically associated with discharge features, surface water features can sometimes recharge the underlying groundwater flow systems where they are situated on top of higher permeability bedrock formations (i.e., Mississippi Lake on top of Nepean Sandstone).

Conversely, areas where the dominant vertical groundwater flow direction is upwards near ground surface provide a level of protection to the underlying aquifers. These areas are considered to be under “discharge” conditions and typically exist in low lying areas and are a significant source of water for wetlands and some lakes, rivers and streams.

As expected, the areas of potential recharge generally correspond with topographically high areas in the western and local topographic highs throughout the MRSPR. Similarly, the discharge areas typically correspond to low lying river valleys such as the Mississippi and Rideau Rivers as shown by the locations of flowing well conditions.

Five regional domestic bedrock aquifers were identified within the MRSPR as follows:

- Igneous / Metamorphic (Precambrian < 50 m below ground surface (mbgs));
- Sandstone (Nepean / Covey Hill);
- Dolostone / Sandstone (Oxford / March);
- Limestone / Shale / Sandstone (Rockcliffe, Gull River, Bobcaygeon, Verulam, Lindsay, Eastview, Billings or Carlsbad); and
- Upper Weathered Bedrock Units (varying bedrock formations, upper 10 m of bedrock).

Three regional domestic overburden aquifers were identified within the MRSPR as follows:

- Surficial sand units;
- Basal Sand and Gravel units; and
- Sand and Gravel Eskers

Figure 1.3-8 shows the general distribution of domestic water taking from each aquifer detailed above. Typically, domestic groundwater supply is obtained from the following aquifers:

- the western portion of the MRSPR uses the unconfined upper Precambrian bedrock aquifer;
- the central portion uses the unconfined Nepean sandstone, confined Nepean sandstone or the unconfined Oxford-March aquifers; and
- the north and east portions use a mixture of unconfined and confined overburden (sand and gravel) and bedrock (limestone and shale) aquifers.

The Nepean sandstone aquifer is the most desirable aquifer from a quantity and quality perspective within Eastern Ontario. It provides the highest sustainable yield of high quality potable groundwater and it is targeted by large commercial and municipal systems. The Nepean aquifer is targeted by six of the seven municipal groundwater systems (Almonte, King's Park (Richmond), Munster, Merrickville, Kemptville and Westport) within the MRSPR. Only Carp extracts groundwater from a different aquifer (overburden sand and gravel esker deposit) due to the sufficiently high volume and quality of groundwater found within this local deposit.

Climate

Climate data which includes precipitation (rain or snow), temperature and pan evaporation data has been collected in the MRSPR for over 100 years. The climate within the MRSPR consists of warm summers and cold winters. The topographic changes from the upstream areas of the Mississippi and Rideau to the downstream areas near the Ottawa River exert a significant influence over the observed temperature and precipitation.

The following observations with respect to climate in the MRSPR have been noted:

- Mean annual precipitation ranges between 800 and 1000 mm (Canadian Hydrological Atlas – 1978);
- Average precipitation for active AES climate stations is 918 mm (1994-2003);
- Mean annual snowfall is 200 cm (Canadian Hydrological Atlas – 1978);
- Mean annual evapotranspiration is between 500 and 600 mm (Canadian Hydrological Atlas – 1978);
- Mean annual runoff is between 200 and 350 mm (Canadian Hydrological Atlas – 1978);
- Average annual temperature is 6.3°C (AES climate stations 1994-2003);
- July is the wettest and hottest month of the year;
- February is the driest month;
- January is the coldest month; and
- April is the month with the highest peak stream flows as a result of the spring freshet.

The locations of the climate stations and snow course stations are presented on Figures 1.3-10 and 1.3-11, respectively.

Naturally Vegetated Areas

Naturally vegetated areas in the MRSPR refer to ecological features that perform various beneficial functions on the landscape and include wetlands, woodlands and riparian areas. Wetlands and their surrounding areas are known to be important for the control and storage of surface water and the recharge and discharge of groundwater, for maintaining and improving water quality, aiding in flood control and protecting shorelines from erosion, for trapping sediments that would otherwise fill watercourses, for immobilizing some contaminants and nutrients, for reducing other contaminants to less damaging compounds and for assisting in maintaining water quality in adjacent lakes and streams that support fish populations (Brownell, 2006).

It has long been recognized that different types of wetlands have very different hydrologies. Bogs, fens, swamps and marshes have very different combinations of peat and mineral soils which affect the water table / storage capacity. Wetland coverage within the MRSPR is detailed on Figure 1.4-1.

The spatial distribution of wetlands within the MRSPR is uneven. Few wetlands remain within the Lower Rideau or Eastern Mississippi regions, however those remaining are significant. The substantive wetland coverage is found in the Middle and Upper Rideau and Western and Central Mississippi regions, many of which have not been evaluated using the OWES.

The MRSPR is located within the Upper St. Lawrence Forest District of the Great Lakes – St. Lawrence Forest Region which is characterized by forests of a predominantly deciduous nature. Forest cover is presented on Figures 1.2-24 and 1.4-2. Similar to the wetland distribution, much of the Lower Rideau and Eastern Mississippi regions have less woodland cover than the remainder of the MRSPR.

Natural area surveys to identify a series of ecological areas consisting of natural landscapes, environments and biotic communities were conducted by the MNR and resulted in the identification of ANSIs within the MRSPR. The locations of the ANSIs are presented on Figure 1.4-2.

Aquatic Ecology

The MRSPR and its role in fisheries management has mainly dealt with examining aspects of water quality, monitoring overall health of various water bodies and protecting aquatic habitat from harmful impacts. These parameters and specific information regarding the status of fish population and habitat have been collected through the Ontario Stream Assessment Protocol, Macro Stream Assessment, Beaver Dam Monitoring and Municipal Drain Classification.

Both the MVC and RVCA are partnered with the OBBN for invertebrate sampling as indicators of water quality. The locations of the OBBN sampling sites are presented on Figure 1.5-1. Conditions regarding the water quality due to the presence of benthic species should be viewed with caution due to the limited timeframe that the data has been collected (2003 for RVCA and 2005 for MVC). Conditions of the RVCA with regards to the FBI can be said to be generally good. Sites within the Lower Rideau region have a decreased quality of water as compared to the remainder of the RVCA monitoring sites. Conditions within the MVC have not been assessed with regards to water quality due to the limited amount of data.

Human Characterization

Population

The total population of the MRSPR is approximately 865,000. The detailed breakdown of the estimated population by municipality is presented in the Table 1.6-1. Population data was obtained from the Statistics Canada 2006 Census. Figure 1.6-1 presents the population distribution by dissemination area. It should be noted that the dissemination areas, do not necessarily coincide with the boundaries of some of the smaller hamlets and villages.

Population density by dissemination area is presented in Figure 1.6-2. Population densities greater than 1,000 people per square kilometer are found within the urban areas of the City of Ottawa (Barrhaven / Riverside South, Kanata / Stittsville, Orleans, and Ottawa), several of the villages within the amalgamated City of Ottawa (Constance Bay, Manotick, Munster, Osgoode, and Richmond), and several other urban areas outside of the City of Ottawa (Almonte – Mississippi Mills, Carleton Place, Kemptville – North Grenville, Perth and Smiths Falls). The majority of the western portion of the MRSPR generally has a population density of less than 10 people per square km.

The population data referenced only includes permanent residents and not seasonal residents. Population growth estimates within the MRSPR was collected from the Ministry of Finance which predict that the City of Ottawa will have the largest growth while the County of Renfrew will have the smallest growth.

Land Use

Land use policies were reviewed from the municipal Official Plans (OPs) within the MRSPR for policies with regards to agriculture, brownfields, landfills, contaminated sites, natural environment, natural hazards, natural resources, settlement areas, transportation, storm water management, water services and wastewater services. Details regarding the various OP policies regarding the above mentioned land uses are presented in Appendix 4, Table A-4. In addition, the OP mapping for the municipalities, where available, is presented on Figure 1.6-3.

Within the settlement areas, the land use is generally a mixture of residential, commercial and industrial land uses. Outside of the settlement areas, the land use is predominantly agricultural with some commercial, industrial and other land uses. As a result of the hundreds of lakes and rivers within the MRSPR, many significant regions of waterfront development exist. Typically, in waterfront areas closer to the settlement areas the waterfront development is permanent homes. There is also an ongoing shift to redevelop and convert seasonal cottages into permanent homes.

Approximately 731,000 people within the MRSPR are supplied with municipal water and sewers. It should be noted that the estimated 731,000 people that are municipally serviced includes some people within the urban area of the City of Ottawa that live within the SNC watershed (Finlay Creek and Orleans). The following municipalities have municipally supplied water systems within the MRSPR:

- City of Ottawa:
    - Carp;
    - King's Park Subdivision (Richmond);
    - Munster Hamlet; and
    - Ottawa urban area, including Barrhaven / Riverside South, Kanata / Stittsville and Orleans;
- Municipality of North Grenville (Kemptville)

- Town of Carleton Place;
- Town of Mississippi Mills (Almonte);
- Town of Perth;
- Town of Smiths Falls;
- Village of Merrickville – Wolford (Merrickville); and
- Village of Westport.

The locations of the service areas for municipally supplied water and sewer are presented on Figures 1.6-9, 1.6-10, 1.6-12 and 1.6-13.

Approximately 135,000 people in the MRSPR rely upon private services for both water and wastewater. Based on the MOE water wells records database, there are approximately 44,000 private wells within the MRSPR. In addition to the 44,000 private wells, it is assumed that there are a similar number of septic systems (approximately 44,000). Of these residents on private wells, approximately 20,000 people live in relatively dense rural villages or hamlets. The locations of the private wells and inferred septic systems, with the exception of the former Village of Richmond, are presented on Figure 1.6-11.

Water Use and Values

Water use within the MRSPR is a mixture of drinking water, recreational, ecological, agricultural and industrial uses. Large water users comprised of the uses listed above with potential consumption of greater than 50,000 L/day are required to have a PTTW. The total volume of permitted water takings within the MRSPR is approximately 31 million cubic meters per day. It should be noted that the PPTW database is the total permitted volume of water and not necessarily the amount of actual water taken.

The following municipalities have municipal drinking water systems supplied by groundwater within the MRSPR:

- City of Ottawa:
    - Carp – water source, overburden sand aquifer
    - King's Park Subdivision (Richmond) – water source, Nepean sandstone aquifer; and
    - Munster Hamlet – water source, Nepean sandstone aquifer;
- Municipality of North Grenville – Kemptville – water source, Nepean sandstone aquifer;
- Town of Mississippi Mills – Almonte – water source, Nepean sandstone aquifer;
- Village of Merrickville-Wolford – Merrickville – water source, Nepean sandstone aquifer; and
- Village of Westport – Westport – water source, Nepean sandstone aquifer.

The following municipalities have municipal drinking water systems supplied by surface water within the MRSPR:

- City of Ottawa – Britannia and Lemieux Island Water Treatment Plants – water source, Ottawa River;
- Town of Carleton Place – Carleton Place Water Treatment Plant – water source, Mississippi River
- Town of Perth – Perth Water Treatment Plant – water source, Tay River; and
- Town of Smiths Falls – Smiths Falls Water Treatment Plant – water source, Rideau River.

As detailed above, the total population on private drinking water wells is approximately 135,000 persons. The locations of the private wells within the MRSPR are presented in Figure 1.6-11.

Data Gaps

A detailed listing of all data gaps within the watershed description is found within Section 1.8 and Appendix 2. Several of the more significant data gaps are listed below:

- Lack of stream flow gauges representing the lower Mississippi River;
- Lack of stream flow gauges on the various un-regulated tributaries;
- Limitations with the quality of data within the water well records database and inferred products (potentiometric surfaces, groundwater recharge, etc.);
- Lack of classification for many of the substantive wetland areas (western and central Mississippi and upper and middle Rideau regions);
- Many of the populations were estimated due to lack of information (settlement areas, private wells, septic systems, seasonal residents, etc.);
- Limitations with the PTTW database (permitted vs. actual takings, missing entries, expired permits, etc.).

6.2 Water Quality

Surface Water Quality

Indicator Parameters

The following eight general chemistry, three metals and one biological parameter were selected as indicator parameters for surface water quality: ammonia (un-ionized); chloride; copper; *E. coli*; lead; nitrate; nitrite; pH; TKN; TP; TSS; and zinc. For surface water, the PWQO was selected as the generic criteria.

Sampling Programs

The following surface water monitoring programs are currently in operation within the MRSPR:

- City of Ottawa Baseline Surface Water Quality Monitoring Program;
- MVC Watershed Watch Lake Monitoring Program;
- Provincial Water Quality Monitoring Network;
- RVCA Surface Water Quality Monitoring Program; and
- RVCA Watershed Watch Lake Monitoring Program.

The locations of all active surface water quality monitoring stations, as of 2006, are presented on Figure 2.1-1. A detailed listing of the sampling parameters monitored as part the various surface water monitoring programs is presented in Table 2.2-1.

The surface water quality indicator parameters data was analyzed from 2001-2005 for all of the programs detailed above with the exception of the OBSWQ Program (2000-2006) and MVC Watershed Watch Program (1998-2005). The average concentrations from 2001-2005 for the indicator parameters are presented on Figures 2.2-1 to 2.2-11. Geometric mean concentrations are presented on Figures 2.2-12.

Results

The Canadian Council of Ministers of the Environment (CCME) developed a scoring classification based on the level of impairment of the water. For example excellent water quality was identified if 95-100% of the samples showed no evidence of impairment or compliance with the relevant objectives. The CCME classifications are as follows:

- Excellent water quality – 95-100%;
- Good water quality – 80-94%;
- Fair water quality – 65-79%;
- Marginal water quality – 45-64%; and
- Poor water quality – 0-44%.

The following number of samples and number of samples exceeding the relevant criteria for the indicator parameters are presented below:

- Ammonia (un-ionized) – 6,250 samples analyzed for un-ionized ammonia from 2001 to 2005 (2000 to 2006 for OBSWQ) with nine sample exceeding the PWQO of 0.02 mg/L indicating excellent water quality with respect to un-ionized ammonia (>99% of the samples in compliance);
- Chloride – 7,081 samples analyzed for chloride from 2001 to 2005 (2000 to 2006 for OBSWQ) with 669 samples exceeding the ODWSOG of 250 mg/L indicating good water quality with respect to chloride (91% of the samples in compliance);
- Nitrate – 3,633 samples analyzed for nitrate from 2001 to 2005 (2000 to 2006 for OBSWQ) with no samples exceeding the ODWQS of 10 mg/L indicating excellent water quality with respect to nitrate (100% of the samples in compliance);

- Nitrite – 2,794 samples analyzed for nitrite from 2001 to 2005 (2000 to 2006 for OBSWQ) with 827 samples exceeding the CWQG of 0.06 mg/L indicating fair water quality with respect to nitrite (70% of the samples in compliance);
- pH – 7,254 samples analyzed for pH from 2001 to 2005 (1998 to 2005 for the MVC watershed watch program and 2000 to 2006 for OBSWQ) with 153 samples outside of the PWQO range of 6.5 to 8.5 indicating excellent water quality with respect to pH (98% of the samples in compliance);
- TKN – 10,167 samples analyzed for TKN from 2001 to 2005 (2000 to 2006 for OBSWQ) with 5,583 samples exceeding the EC guideline of 0.5 mg/L indicating marginal water quality with respect to TKN (45% of the samples in compliance);
- TP – 10,440 samples analyzed for total phosphorus from 2001 to 2005 (1998 to 2005 for the MVC watershed watch program and 2000 to 2006 for OBSWQ) with 3,691 samples exceeding the PWQO of 0.03 mg/L indicating fair water quality with respect to TP (65% of the samples in compliance);
- TSS – 7,116 samples analyzed for total suspended solids from 2001 to 2005 (2000 to 2006 for OBSWQ) with 1,419 samples exceeding the SSWQO of 10 mg/L indicating good water quality with respect to TSS (80% of the samples in compliance);
- Copper – 6,971 samples analyzed for copper from 2001 to 2005 (2000 to 2006 for OBSWQ) with 1,035 samples exceeding the PWQO of 0.005 mg/L indicating good water quality with respect to copper (85% of the samples in compliance);
- Lead – 6,748 samples analyzed for lead from 2001 to 2005 (2000 to 2006 for OBSWQ) with six samples exceeding the PWQO (0.005 to 0.025 mg/L depending upon alkalinity concentration) indicating excellent water quality with respect to lead (>99% of the samples in compliance);
- Zinc – 6,749 samples analyzed for zinc from 2001 to 2005 (2000 to 2006 for OBSWQ) with 146 samples exceeding the PWQO of 0.03 mg/L indicating excellent water quality with respect to zinc (98% of the samples in compliance); and
- *E. coli* – 9,309 samples analyzed for *E. coli* from 2001 to 2005 (2000 to 2006 for OBSWQ) with 2,842 samples exceeding the PWQO of 100 cfu / 100 mL of water indicating fair water quality with respect to E. coli (69% of the samples in compliance).

Detailed listing of the water quality indicators by subwatershed is provided in Sections 2.2-4 and 2.2-5.

In general, the regional surface water within the MRSPR is of good to excellent quality. Water quality within the larger rivers is better than in smaller tributaries. Data is relatively sparse in the western portions of the MRSPR and most dense within the City of Ottawa limits. In some instances, local conditions such as the mineral composition of the surficial geology or impact due to human activities may deteriorate the quality of the surface water.

Figures 2.2-2 (chloride), 2.2-6 (TKN), and 2.2-7 (TP) show that elevated concentrations of parameters associated with likely impact from human activities such as nitrogen compounds and chloride (associated with human waste / water softeners) and sodium chloride (common road salt) are highest in the areas of higher density developments. In addition, Figure 2.2-7 (TP) indicates that increasing concentrations are detected further downstream within the surface water systems.

<u>Groundwater Quality</u>

Indicator Parameters

The groundwater quality indicator parameters selected include the following:

- major cations – calcium, magnesium, sodium, potassium;
- major anions – sulphate and chloride;
- aesthetic parameters – hardness (as CaCO3), hydrogen sulphide, iron, TDS and turbidity; and
- environmental parameters - *E. coli*, total coliforms, nitrate, alkalinity (as CaCO3), DOC, fluoride, ammonia, TKN, conductivity, and pH.

For groundwater, the ODWQS or ODWSOG were selected as the generic criteria.

In general, the regional groundwater supplies within the MRSPR are of good quality. Data is relatively sparse in the western and southern rural portions of the MRSPR and most dense within the City of Ottawa limits, especially within the larger rural population communities serviced by domestic wells and septic (Constance Bay, Carp Road Corridor, North Gower) due to the focused studies recently completed in these areas.

In some instances, local conditions such as the mineral composition of aquifer material or impact due to human activities may deteriorate the quality of a groundwater supply aquifer. Table 2.3-2 lists each parameter that has an aesthetic objective, operational guideline (ODWSOG) or health related criterion (ODWQS), the percentage samples exceeding these standards and the locations of these samples exceeding the criteria within the MRSPR.

Figures 2.3-1 (ammonia), 2.3-3 (chloride), 2.3-7 (nitrate), and 2.3-10 (sodium) show that elevated concentrations of parameters associated with likely impact from human activities such as nitrogen compounds and chloride (associated with human waste) and sodium chloride (common road salt) are highest in the higher density developments of Constance Bay, Carp and North Gower and to the east of Ottawa near Rockland. Figure 1.3-8 also indicates that these areas commonly support shallow overburden aquifers, where impact from human activities is more common. Figures 2.3-2 (calcium), 2.3-4 (hardness), and 2.3-6 (magnesium) show that groundwater obtained from bedrock aquifers throughout the entire region is generally considered to be hard and are therefore susceptible to scaling and poor taste. Figures 2.3-5 (iron), 2.3-8 (pH), 2.3-9 (potassium), 2.3-11 (sulphate) show no clear pattern of iron, pH, potassium or sulphate distribution.

Raw Water Characterization

Drinking Water Intakes

Raw water sampling from the drinking water systems are conducted as part of the compliance protocol for the operation of the drinking water plants. Data for the surface water drinking water intakes has been collected from various databases and the respective municipalities. Water quality summary results for the indicator parameters from surface water plants are presented in Table 2.4-1.

Carleton Place

The Engineer's Report identified several raw water quality parameters (turbidity, colour, DOC and pH) that were found to exceed the ODWSOG (J.L. Richards, 2000). Raw water quality from the Carleton Place drinking water plant was available for the following indicator parameters: pH and *E. coli*. Summaries of the indicator parameters are presented in Table 2.4-1.

The Carleton Place drinking water treatment plant resides within the CP dam subwatershed within the MVC. In addition to the raw drinking water quality monitoring that is conducted at the drinking water plant, surface water monitoring conducted as part of the PWQMN and MVC watershed watch programs occurs upstream of the Carleton Place drinking water treatment plant. The results of these surface water monitoring programs are presented above in Section 2.2.

Ottawa

The Engineer's Report for Britannia and Lemieux Island Water Purification Plants (Stantec, 2001A and 2001B) identified several raw water quality parameters (turbidity, alkalinity, colour, DOC, organic nitrogen and temperature) that were found to exceed the ODWSOG. Raw water quality from the Ottawa drinking water plants (Britannia and Lemieux Island) was available for the following indicator parameters: *E. coli*, lead, nitrate, nitrite, pH, TKN, TP, TSS and zinc. Summaries of the indicator parameters are presented in Table 2.4-1.

Both drinking water plants for the City of Ottawa (Britannia and Lemieux Island) reside on the Ottawa River. Surface water monitoring is conducted on the Ottawa River by the OBSWQ monitoring program and the PWQMN Chats Falls station. The results of these surface water monitoring programs are presented above in Section 2.2.

Perth

Raw water quality from the Perth drinking water plant was available for the following indicator parameters: *E. coli*, lead, nitrate, nitrite, pH, TKN, TP, TSS and zinc. Summaries of the indicator parameters are presented in Table 2.4-1.

The Perth drinking water treatment plant resides within the Tay River subwatershed within the RVCA. In addition to the raw drinking water quality monitoring that is conducted at the drinking water plant, surface water monitoring conducted as part of the PWQMN, RVCA surface water and RVCA watershed watch programs occurs upstream of the Perth drinking water treatment plant. The results of these surface water monitoring programs are presented above in Section 2.2.

Smiths Falls

Raw water quality was assessed from 1998 to 2000 (MacViro, 2001). Several raw water quality parameters (turbidity, aluminum, sodium, manganese, colour, DOC and temperature) were found to exceed the ODWSOG. Raw water quality from the Smiths Falls drinking water plant was available for the following indicator parameters: *E. coli*, lead nitrate, nitrite, pH, TKN, TP, TSS and zinc. Summaries of the indicator parameters are presented in Table 2.4-1.

The Smiths Falls drinking water treatment plant resides within the Middle Rideau subwatershed within the RVCA. No surface water monitoring within the Middle Rideau subwatershed occurs upstream of the plant. However, surface water monitoring occurs as part of the PWQMN, RVCA surface water and RVCA watershed watch programs in both upstream subwatersheds to the Middle Rideau subwatershed (Tay River and Rideau Lakes subwatersheds). The results of these surface water monitoring programs are presented above in Sections 2.2.

Municipal Drinking Water Groundwater Supply Wells

Raw water sampling from the drinking water systems are conducted as part of the compliance protocol for the operation of the various municipal supply wells. Data for the municipal groundwater wells has been collected from various databases and the respective municipalities. Water quality summary results for the indicator parameters from groundwater wells are presented in Table 2.3-3.

Merrickville-Wolford

Raw water quality was reviewed in 2000 (Totten Sims Hubicki (TSH), 2001A). Several raw water quality parameters (sodium, hardness, colour and turbidity) were found to exceed the ODWSOG. Raw water test results in 1999 did not indicate any adverse microbiological results. Raw water quality test results in 2000 indicated elevated concentrations of total coliforms and background colonies at several sampling events. *E. coli* was not encountered in the raw water quality from 2000 (TSH, 2001A).

Raw water quality for the Merrickville wells was available for the following indicator parameters: *E. coli* and total coliforms from 2003 to 2006. The results of the groundwater monitoring programs for Merrickville are presented above in Section 2.3.

Mississippi Mills

Raw water was sampled in February 2001 (Oliver, Mangione, McCalla & Associates (OMMA), 2001A). The Engineer's Report for Almonte identified several raw water quality parameters (hardness, sodium, organic nitrogen, TDS, turbidity and aluminum) that were found to exceed the ODWSOG. Historic elevated turbidity during high pumping rates has been documented at one of the wells. Raw water test results did not indicate any adverse microbiological results (OMMA, 2001A).

Raw water quality for the Almonte wells was available for the following indicator parameters: alkalinity, calcium, DOC, *E. coli*, hardness, magnesium, nitrate, pH, total coliforms and turbidity from 2000 to 2007. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for Mississippi Mills are presented above in Section 2.3.

The data shows that the natural groundwater quality of the Almonte municipal well water supply aquifer (Nepean aquifer) has demonstrated consistent quality since January 2000. Most of the parameters show a seasonal influence as concentrations increase during the summer months when lower water levels and a decrease in recharge rates result in less dilution occurring, and decrease during the spring and fall months when groundwater recharge is occurring and therefore the effects of dilution are most evident.

North Grenville

Raw water quality was reviewed from 1991 to 2001 (OMMA, 2001B). The Engineer's Report for Kemptville identified several raw water quality parameters (hardness, sodium and colour) that were found to exceed the ODWSOG. Microbiological raw water quality for each of the municipal supply wells from 1996 to 2000 was reviewed for total coliforms, *E. coli* and background colonies (OMMA, 2001B). Several raw water test results indicated the presence of background colonies and total coliforms. Re-testing of the raw water quality indicated that the contamination was not source related. *E. coli* was not detected in any of the raw water quality tests.

Raw water quality for the Kemptville wells was available for the following indicator parameters: *E. coli* and total coliforms from 2003 to 2006. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for North Grenville are presented above in Section 2.3.

Ottawa – Carp

Raw water quality was reviewed from 1996 to 2000 (R.V. Anderson, 2001). The Engineer's Report for the Village of Carp identified several raw water quality parameters (colour, hardness, HPC, organic nitrogen, sulphide and TDS) that were found to exceed the ODWSOG. During the investigations for the construction of the communal well system in Carp water quality obtained from the test well and other sources indicated acceptable quality. Minor elevated sodium and hydrogen sulphide concentrations were also documented (WESA, 1987). Raw microbiological water quality was reviewed from 1999 and 2000. Raw water quality test results did not indicate any adverse microbiological results (R.V. Anderson, 2001).

Raw water quality for the Carp wells was available for the following indicator parameters: alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for Carp are presented above in Section 2.3.

The data shows that the natural groundwater quality of the Carp municipal well water supply aquifer (sand and gravel esker deposit) has demonstrated consistent quality since January 2001. Most of the parameters show a seasonal influence as concentrations increase during the summer months when lower water levels and a decrease in recharge rates result in less dilution occurring, and decrease during the spring and fall months when groundwater recharge is occurring and therefore the effects of dilution are most evident.

Ottawa – King's Park Subdivision (Richmond)

Raw water quality was reviewed from 1994 to 2001 (Conestoga-Rovers & Associates (CRA), 2001). The Engineer's Report for the King's Park Subdivision identified several raw water quality parameters (iron, hardness, conductivity and TDS) that were found to exceed the ODWSOG. Raw microbiological water quality was reviewed from 1998 to December 2000. Raw water test results did not indicate any adverse microbiological results (CRA, 2001).

Raw water quality for the King's Park (Richmond) wells was available for the following indicator parameters: alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for King's Park (Richmond) are presented above in Section 2.3.

The data shows that the natural groundwater quality of the King's Park municipal well water supply aquifer (Nepean aquifer) has demonstrated consistent quality since January 2001. The groundwater quality at the King's Park wells does not have much seasonal variation as compared to some of the other groundwater supply wells. This lack of seasonal variation may be a result of the thick overlying aquitard which limits the direct recharge to the Nepean aquifer in this area.

Ottawa – Munster Hamlet

Raw water quality was reviewed for 1999 (Stantec, 2001C). One raw water quality parameter (hardness) was found to exceed the ODWSOG. The hydrogeological assessment and remedial activities were undertaken at the Munster Hamlet communal well supply to assess the cause and origin of the noted elevated turbidity levels encountered in Well 2 (Sauriol, 2002). The water quality analysis indicated relatively good water quality, with a few parameters exceeding the ODWSOG which included iron and turbidity. Microbial water quality was reviewed from 1998 and 1999 (Stantec, 2001C). Nine samples from 1998 and 1999 indicated detectable levels of HPC within the raw water. Raw water test results did not indicate any detectable concentrations of *E. coli*.

Raw water quality for the Munster wells was available for the following indicator parameters: alkalinity, ammonia, chloride, conductivity, *E. coli*, fluoride, hardness, hydrogen sulphide, iron, nitrate, pH, sulphate, total coliforms, TDS, TKN and turbidity from 2001 to 2005. Summaries of the indicator parameters are presented in Table 2.3-3. The results of the groundwater monitoring programs for Munster are presented above in Section 2.3.

The data shows that the natural groundwater quality of the Munster municipal well water supply aquifer (Nepean aquifer) has demonstrated consistent quality since January 2001. Similar to the King's Park wells, the groundwater quality at the Munster wells does not have much seasonal variation as compared to some of the other groundwater supply wells. This lack of seasonal variation may be a result of the thick overlying aquitard which limits the direct recharge to the Nepean aquifer in this area.

Westport

The Engineer's Report for Westport identified several raw water quality parameters (arsenic, iron, sodium, hardness and turbidity) that were found to exceed the ODWQS or ODWSOG (TSH, 2001B). Elevated iron concentrations were documented during a MOE inspection report in 2000 (concentration of iron was not specified). One of the report appendices includes a Hydrogeological Assessment of the Westport Water System conducted by Malroz Engineering Inc. which focused on the raw water characteristics and potential for groundwater contamination. Water quality monitoring was conducted in 2005 by Malroz (2006) and the results of the water quality monitoring program indicated that the water quality in Well 2, with respect to the bacteriological parameters, improved following the decommissioning of Well 1.

Raw water quality for the Westport wells was available for the following indicator parameters: *E. coli*, nitrate, sodium and total coliforms from 2003 to 2006. The results of the groundwater monitoring programs for Westport are presented above in Section 2.3.

Microbial Source Water Characterization

Surface Water Systems

Surface water quality monitoring for microbial parameters (*E. coli* only) is conducted by the City of Ottawa Baseline Surface Water Quality, RVCA surface water quality and RVCA watershed watch monitoring programs. Results of these programs are discussed above in Section 2.2. Additional surface water quality monitoring for microbial parameters is conducted by the drinking water treatment plants (Carleton Place, Ottawa, Perth and Smiths Falls) and is discussed above in Section 2.4.

Carleton Place

Several potential sources of microbial contamination were identified (J.L. Richards, 2000). These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water. It was also noted that the Mississippi River and Mississippi Lake are popular recreational water bodies and are also surrounded by agricultural land uses.

Ottawa

The Engineer's Report for the Britannia and Lemieux Island Water Purification Plants (Stantec, 2001A and 2001B) identified several potential sources of microbial contamination to the Ottawa River. These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water.

Perth

The Engineer's Report identified several potential sources of microbial contamination (Xie, 2001). These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water.

Smiths Falls

Several potential sources of microbial contamination were identified from the Engineer's Report (MacViro, 2001). These include the inherent susceptibility of surface water to contamination from runoff, effluent, transmission of a disease or pathogen from one organism to another, etc., access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water. In addition as a result of the building being located within the flood plain and the clear well location below the grade of sanitary sewers, it was recommended that the treatment plant be relocated.

Groundwater Systems

Groundwater quality monitoring for microbial parameters (*E. coli* and total coliforms) are conducted by the municipalities as part of the operation of the groundwater supply wells and is discussed above in Sections 2.3 and 2.4.

Merrickville-Wolford

Several potential sources of microbial contamination to the municipal wells were identified during the Engineer's Report (TSH, 2001A). These included site grading allowing surface water entry, access openings to untreated & treated water reservoirs, abandoned or improperly decommissioned wells within the Village.

Mississippi Mills

The Engineer's Report for Almonte (OMMA, 2001A) identified several potential sources of microbial contamination to the municipal wells. Several potential sources of microbial contamination to the municipal wells were identified and these included the Town's sewage lagoons, sewage force mains, treated sewage outfall, pasture & crop lands.

North Grenville

The Engineer's Report for Kemptville (OMMA, 2001B) identified several potential sources of microbial contamination to the municipal wells. These included the access openings to untreated & treated water reservoirs, and location of one well within the reservoir. One area of known bacteria and nitrate contamination is known within the Municipality of North Grenville and is described below in Section 5.1.3.

Ottawa – Carp

The Engineer's Report for the Village of Carp did not identify any potential sources of microbial contamination at the municipal wells (R.V. Anderson, 2001).

Ottawa – King's Park Subdivision

The Engineer's Report for the King's Park Subdivision located in the Village of Richmond (CRA, 2001) identified several potential sources of microbial contamination to the municipal wells. These included the former Richmond sewage lagoons, site grading at Well 1 with regards to the underground chlorine contact chambers, the close proximity of the Jock River and the Richmond sewage pumping station.

Ottawa – Munster

The Engineer's Report for Munster identified several potential sources of microbial contamination to the municipal wells (Stantec, 2001C). These include well head and aquifer through surface water entry, access openings to treated water reservoirs and maintenance work on piping and equipment in contact with the treated water.

Westport

Several potential sources of microbial contamination to the municipal wells were identified during the Engineer's Report for Westport (TSH, 2001B). These included a small stream originating in agricultural land west of the site is directed to a culvert less than 10 m from one of the wells, the Village's sewage lagoons, sanitary sewers, sewage "Snowfluent" facility, pasture & crop lands, site grading allowing surface water entry and cracks and distortions in the elevated tank.

A study was undertaken by Malroz (2006) to establish whether or not the groundwater sources from the municipal supply well (Well 2) in the Village of Westport are under the direct influence of surface water (GUDI) following the abandonment of the former supply well (Well 1). The results of the water quality monitoring program indicated that the water quality in Well 2, with respect to the bacteriological parameters, improved following the decommissioning of Well 1. However, as the suggested trend was only observed over one year of data, it was recommended that additional data be collected and that a subsequent evaluation should be conducted in two years.

<u>Data Gaps</u>

A detailed listing of all data gaps within the watershed description is found within Section 1.8 and Appendix 2. Several of the more significant data gaps are listed below.

The following data gaps were identified in the surface water quality monitoring programs:

- Lack of monitoring program for streams and tributaries in the MVC west and south of the City of Ottawa;
- Surface water monitoring stations upstream of drinking water intakes (Britannia, Lemieux Island, Perth, Smiths Falls & Carleton Place);

- Additional PWQMN stations on the Ottawa River;
- Bacterial sampling is not conducted upstream of Carleton Place in MVC – significant data gap; and
- Additional microbial parameters should be sampled and tested as part of the various water quality programs (cryptosporidium, giardia, microcystins, etc.).

The following data and knowledge gaps are associated with groundwater quality information:

- Lack of data within western, central and southern portions of MRSPR;
- Much of the groundwater quality data is in paper format, therefore it was not included in this initial interpretation;
- Many groundwater sampling locations are described by lot and concession or by municipal address and do not have UTM coordinates;
- Lack of geological information into which the well is completed makes it difficult to characterize aquifers; and
- Lack of temporal groundwater quality.

6.3 Vulnerable Areas

<u>WHPA</u>

The WHPA for City of Ottawa and Mississippi Mills groundwater supply systems within the MRSPR were established in 2003 and updated in 2007. A preliminary WHPA for Westport was established in 2004. The WHPA were developed using numerical modeling in MODFLOW and establishing horizontal TOT within the representative aquifers. The map presenting the locations of all WHPAs for each of the systems is presented on Figure 3.2-1. The following figures show a more detailed depiction of the WHPAs showing the various calculated TOT:

- Figure 3.2-2 – Mississippi Mills – Almonte WHPA;
- Figure 3.2-3 – Ottawa – Carp WHPA;
- Figure 3.2-4 – Ottawa – King’s Park Subdivision (Richmond) & Munster Hamlet WHPAs; and
- Figure 3.2-5 – Westport – Westport WHPA.

Final groundwater WHPAs for Kemptville, Merrickville and Westport are being established as part of the forthcoming Groundwater Vulnerability Module. The locations of the groundwater wells for Merrickville and Kemptville are presented on Figures 3.2.6 and 3.2-7, respectively.

<u>IPZ</u>

The following municipalities have municipal drinking water systems supplied by surface water within the MRSPR:

- City of Ottawa – Britannia and Lemieux Island Water Purification Plants;
- Town of Carleton Place – Carleton Place Water Treatment Plant
- Town of Perth – Perth Water Treatment Plant; and
- Town of Smiths Falls – Smiths Falls Water Treatment Plant.

Surface water IPZ have not yet been established for any of the above systems, but will be determined as part of the forthcoming Surface Water Vulnerability Module. The locations of the surface water intakes in the MRSPR are presented on Figures 3.3.-1 to 3.3-5.

Other Vulnerable Areas

Aquifer vulnerability for the MRSPR was conducted by Golder during the regional Renfrew County – Mississippi – Rideau Groundwater Study (Golder et al., 2003). The vulnerability was calculated using the MOE ISI methodology as prescribed in the MOE groundwater studies terms of reference (MOE, 2001). In addition, the surficial geology mapping was also incorporated into the process for determining the vulnerability in the MRSPR. This inclusion of the surficial geology involved representing all areas that were mapped as having less than 1.5 m of overburden, exposed bedrock at surface or sand and gravel deposits as highly vulnerable.

A map presenting the aquifer vulnerability is presented on Figure 3.4-1. Within the MRSPR there are 7,666; 641 and 279 km^2 of high, moderate and low vulnerability, respectively. This represents 89%, 8% and 3% of high, moderate and low vulnerability, respectively. Areas of low to moderate vulnerability are located mainly within the City of Ottawa and are near the Ottawa River and within the southeastern portion of the City of Ottawa.

It should be noted that the general aquifer vulnerability calculated by ISI is for the first aquifer. Multiple aquifers found at depth are not incorporated within this ISI methodology.

Significant groundwater recharge areas will be identified during the Tier 1 Water Budget for the MRSPR.

Potential Future Drinking Water Sources

Lanark

Historic water quality issues regarding bacterial and nitrate impacts to private wells in the Village of Lanark have been identified since 1979. As a result of this water quality issue, a hydrogeologic evaluation for a future municipal groundwater supply for the Village of Lanark was conducted by Golder in 2005. A potential location for the communal supply wells was identified approximately 2.2 km northwest of the Village of Lanark. Two test wells were drilled within the Precambrian marble bedrock and evaluated for their capacity to serve as municipal supply wells. The locations of these test wells are presented on Figure 3.5-1.

North Grenville

Growth of the former Town of Kemptville within the Municipality of North Grenville has resulted in the need for additional water supply. As a result a Water and Wastewater Servicing Master Plan was conducted by Stantec and Golder in 2005. Five potential new communal well sites were identified, three within the eastern development quadrant and two within the western development quadrant. The proposed communal wells are to be established in the same bedrock formation as the existing water supply wells (Nepean sandstone aquifer). The locations of these potential future well sites for North Grenville are presented on Figure 3.2-7.

Data Gaps

A detailed listing of all data gaps within the vulnerable areas is found within Section 3.6 and Appendix 2. Several of the more significant data gaps are listed below:

- Final WHPA for Kemptville, Merrickville and Westport;
- IPZ for all surface water drinking water systems in the MRSPR (Carleton Place, Ottawa – Britannia and Lemieux Island, Perth and Smiths Falls); and
- Significant groundwater recharge areas have not been defined for the MRSPR.

6.4 Threats Inventories

WHPA

Threats inventories were conducted for the municipal groundwater supply wells that have had WHPA established. The locations of WHPA and corresponding threats inventories are listed below:

- Mississippi Mills – Almonte (Intera, 2003A);
- Ottawa
    - Carp (Golder, 2003B);
    - King's Park (Golder, 2003C); and
    - Muster Hamlet (Golder, 2003C); and
- Westport (Malroz, 2004) – preliminary only.

Table 4.2-3 presents the potential contaminant sources for the Almonte, Ottawa and preliminary Westport WHPA, which was compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4. As the WHPA is preliminary for the Westport groundwater supply wells, the listing of contaminants may change depending on the shape of the final WHPA.

WHPA have not been established for Merrickville and Kemptville. As the establishment of the WHPA for Merrickville and Kemptville are on-going, the threats inventory could not be compiled for either Merrickville or Kemptville. The threats inventory will be discussed in more detail in the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

IPZ

IPZ have not been established for any of the surface water supplies within the MRSPR. As a result, the threats inventory could not be compiled for Carleton Place, Ottawa (Britannia and Lemieux Island), Perth and Smiths Falls. The threats inventory will be discussed in more detail in the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Other Vulnerable Areas

Other vulnerable areas, with respect to groundwater, within the MRSPR include general highly vulnerable aquifers, groundwater recharge areas and future drinking water supply areas. These vulnerable areas are discussed in more detail in Section 3.0. Outside of the municipal supply areas, the MRSPR is generally considered highly vulnerable, with respect to the first potable aquifer.

The locations and type of potential threats within the MRSPR are presented on Figure 4.2-1. The potential threats represented on Figure 4.2-1 have been compiled from the preliminary MRSPR Threats Database. Details regarding the MRSPR Threats Database are discussed in Section 5.4.

Significant groundwater recharge areas within the MRSPR have not been defined. As a result, the potential threats with respect to these areas have not been defined.

Data Gaps

A detailed listing of all data gaps within the threats inventories is found within Section 4.4 and Appendix 2. Several of the more significant data gaps are listed below:

The following data gaps were identified during the Renfrew –Mississippi – Rideau groundwater study.

- MOE spills database was only reviewed from 1999-2001
- MOE file review / interviews was not geo-referenced – not plotted on figures – not represented in tables
- Municipal clerk survey was not geo-referenced – not plotted on figures – not represented in tables
- Urban area of the City of Ottawa not included in many of the database searches

The following additional data gaps were identified with the other previous threats inventories conducted within the MRSPR:

- Inconsistencies in the various data sources used to generate the threats inventories. There is a need for a standard approach to generating the base threats inventories;
- Many of the databases contain references to the same properties that need to be cross referenced to remove duplicate entries (i.e., The Anderson's waste disposal inventory & the MOE waste disposal site inventory may list the same site. This does not necessarily mean that there are two landfills corresponding to the site but there will be a threat recorded for each database and they need to be cross referenced.)

6.5 Issues and Concerns

Issues

Issues are defined as the realization of a specific threat within a drinking water source.

WHPA

Merrickville-Wolford

Several water quality parameters including colour, hardness, total coliforms, and turbidity were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Merrickville municipal water supply is discussed above in Sections 2.3 and 2.4. Turbidity causes interference with the disinfection of the water. Some of these parameters such as hardness are typically associated with the natural groundwater quality within the Nepean formation. The remaining parameters are mostly aesthetic or parameters that affect the operation of the plant. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The establishment of the WHPA for Merrickville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Mississippi Mills

The WHPA study conducted in 2003 for the Almonte municipal supply wells identified one (1) issue within the WHPA. The respective municipal supply wells and associated land use of issue was encountered as a spill located at the Sewage Lagoons which are located within the 2 year TOT of Well 5.

Several water quality parameters including aluminum, hardness, organic nitrogen, TDS, and turbidity were found to exceed the ODWSOG. The groundwater quality for the Almonte municipal water supply is discussed above in Sections 2.3 and 2.4. Historic elevated turbidity during high pumping rates has been documented at one of the wells. Turbidity causes interference with the disinfection of the water. Some of these parameters such as hardness and TDS are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

North Grenville

Several water quality parameters including colour, hardness and total coliforms (Van Buren well only) were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Kemptville municipal water supply is discussed above in Sections 2.3 and 2.4. Some of these parameters such as hardness are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The establishment of the WHPA for Kemptville will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa – Carp

During the WHPA study conducted in 2003 for the Carp municipal supply wells, no issues were identified within the WHPA. However, several potential concerns were identified and are discussed below.

Several water quality parameters, including colour, hardness, HPC, total coliforms, hydrogen sulphide, iron, organic nitrogen, and TDS were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Carp municipal water supply is discussed above in Sections 2.3 and 2.4. Some of these parameters such as hardness, hydrogen sulphide, and TDS are typically associated with the natural groundwater quality within the overburden sand formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa – King's Park (Richmond)

During the WHPA study conducted in 2003 for the King's Park (Richmond) municipal supply wells, no issues were identified within the WHPA. However, several potential concerns were identified and are discussed below.

Several water quality parameters, including conductivity, hardness, iron and TDS were found to be in excess of the ODWSOG. The groundwater quality for the King's Park (Richmond) municipal water supply is discussed above in Sections 2.3 and 2.4. These parameters are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa – Munster Hamlet

During the WHPA study conducted in 2003 for the Munster municipal supply wells, no issues were identified within the WHPA. However, several potential concerns were identified and are discussed below.

Several water quality parameters, including hardness and iron were found to be in excess of the ODWSOG. Elevated turbidity levels have also been documented in one of the wells at Munster. The groundwater quality for the Munster municipal water supply is discussed above in Sections 2.3 and 2.4. These parameters are typically associated with the natural groundwater quality within the Nepean formation. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system.

The identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Westport

Several water quality parameters, including hardness, iron, total coliforms and turbidity were found to be in excess of the ODWQS or ODWSOG. The groundwater quality for the Westport municipal water supply is discussed above in Sections 2.3 and 2.4. Some of these parameters such as hardness, iron and turbidity are typically associated with the natural groundwater quality within the Nepean formation. Water quality in Well 2 has improved since the decommissioning of Well 1. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that the raw bacteriological water quality is not indicative of the finished treated water.

The establishment of the WHPA for Westport will be discussed in further detail in the Groundwater Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of additional issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

IPZ

The establishment of the IPZs for Carleton Place, Ottawa (Britannia and Lemieux Island), Perth and Smiths Falls will be discussed in further detail in the Surface Water Vulnerability Component Module (5) of the Technical Assessment Report for the MRSPR. Upon completion of the IPZ work, the identification of issues will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Carleton Place

Several water quality parameters, including colour, DOC, and turbidity were found to be in excess of the ODWSOG. The water quality for the Carleton Place municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. These parameters are typically associated with the natural surface water quality within the Mississippi River. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

Ottawa

Several water quality parameters, including colour, DOC, and turbidity were found to be in excess of the ODWSOG. In addition, the alkalinity within the Ottawa River was found to be below the ODWSOG range. The water quality for the Ottawa municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. These parameters are typically associated with the natural surface water quality within the Ottawa River. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

Perth

The water quality for the Perth municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

Smiths Falls

Several water quality parameters, including colour, DOC, and turbidity were found to be in excess of the ODWSOG. The water quality for the Smiths Falls municipal surface water supply is discussed above in Sections 2.2, 2.4 and 2.6. These parameters are typically associated with the natural surface water quality within the Rideau River. However, it should be noted that the parameters exceeding the ODWSOG are generally aesthetic or related to the operation of the drinking water system. It should also be noted that surface water is intrinsically susceptible to bacteriological contamination and as such the raw bacteriological water quality is not indicative of the finished treated water.

In addition to the water quality, the current drinking water treatment plant within Smiths Falls is located within the flood plain. Smiths Falls is in the process of trying to relocate the water treatment plant.

Other Vulnerable Areas

Areas of known groundwater quality impairment with residents drawing water from individual monitoring wells:

- Constance Bay – Bacteria & nitrates;
- Cranberry Estates – Bacteria & nitrates;
- Cumberland – Bacteria & nitrates;
- Former Beckwith Landfill – TCE; and
- Lanark Village – Bacteria & nitrates

Additional areas of known contamination were identified in the regional groundwater study discussed in Section 4. These issues will be addressed as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Concerns

Concerns are defined as a potential threat within a drinking water source. This potential threat is not supported by scientific information documenting the realization of the threat (i.e., different than known documented contamination which is identified as an issue).

WHPA

Mississippi Mills

During the WHPA study conducted in 2003 for the Almonte municipal supply wells, five (5) areas of potential concern were identified within the WHPA. Where possible these potential concerns were mapped into the preliminary MRSPR Threats Database and are discussed above in Section 5.2. The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa – Carp

During the WHPA study conducted in 2003 for the Carp municipal supply wells, five (5) areas of potential concern were identified within the WHPA. Where possible these potential concerns were mapped into the preliminary MRSPR Threats Database and are discussed above in Section 5.2. The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa – King's Park (Richmond)

During the WHPA study conducted in 2003 for the King's Park (Richmond) municipal supply wells, 43 areas of potential concern were identified within the WHPA. Where possible these potential concerns were mapped into the preliminary MRSPR Threats Database and are discussed above in Section 5.2. The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Ottawa – Munster Hamlet

During the WHPA study conducted in 2003 for the Munster municipal supply wells, ten (10) areas of potential concern were identified within the WHPA. Where possible these potential concerns were mapped into the preliminary MRSPR Threats Database and are discussed above in Section 5.2. The identification of additional concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Merrickville, Kemptville and Westport

The establishment of the WHPAs for Merrickville, Kemptville and Westport (final WHPA) will be discussed in further detail in the Ground Water Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the WHPA work, the identification of concerns will be conducted for these vulnerable areas as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

IPZ

The establishment of the IPZs for Carleton Place, Ottawa (Britannia and Lemieux Island), Perth and Smiths Falls will be discussed in further detail in the Surface Water Vulnerability Component Module (4) of the Technical Assessment Report for the MRSPR. Upon completion of the IPZ work, the identification of concerns will be conducted for these regions as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

Data Gaps

Data gaps were not identified for this section, however additional work as detailed above is required to be completed as part of the Threats Inventory and Issues Evaluation Component Module (6) of the Technical Assessment Report for the MRSPR.

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NOTE: All references are not cited in this section. GIS Metadata is listed in a separate database

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8.0 Acronyms

AAFC – Agriculture and Agri-Food Canada

AES – Atmospheric Environment Survey

ANSI – Areas of Natural or Scientific Interest

AO – Aesthetic Objective

AVI – Aquifer Vulnerability Index

Ca – Calcium

CA – Conservation Authority

$CaCO_3$ – Calcium Carbonate

CFU – Colony forming units

CCME – Canadian Council of Ministers of the Environment

Cl – Chloride

cm – centimeter

CO – Conservation Ontario

C of A – Certificate of Approval

CPS – Canadian Parks Service

CRA – Conestoga-Rovers & Associates

CRCA – Cataraqui Region Conservation Authority

CURB – Clean Up Rural Beaches

CWQG – Canadian Water Quality Guidelines

DCE – Dichloroethene

DEM – Digital Elevation Model

DFO – Department of Fisheries and Oceans, Canada
DNAPL – Dense Non-Aqueous Phase Liquid

DOC – Dissolved Organic Carbon

DRASTIC – Depth to water table, Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone media and Conductivity

DTM – Digital Terrain Model

DWSP – Drinking Water Source Protection

EC – Environment Canada

E. coli – Escherichia coli

ELC – Ecological Land Classification

EOWRMS – Eastern Ontario Water Resources Management Study

ERIS – Environmental Risk Information Service

F – Fluoride

Fe – Iron

FBI – Family Biotic Index

FN – First Nations

GAC – Granular Activated Carbon

GIS – Geographic Information Systems

GMS – Groundwater Management Strategy

GSC – Geological Survey of Canada

GUDI – Groundwater Under the Direct Influence of Surface Water

ha – hectare

HADD – Harmful Alteration, Destruction or Disturbance

HCO_3 – Bicarbonate

HYDAT – Hydrometric Data

H_2S – Hydrogen Sulphide

IGPM – Imperial Gallons per Minute

IPZ – Intake Protection Zone

ISI – Intrinsic Susceptibility Index

K – Potassium

km – kilometer

L – Liter

m – meter

MAC – Maximum Acceptable Concentration

masl – meters above sea level

mbgs – meters below ground surface

meq – milliequivalent

meq/L – milliequivalent per liter

mg – milligram

Mg – Magnesium

$MgCO_3$ – Magnesium Carbonate

mg/L – milligram per liter

mL – milliliter

mm – millimeter

MMAH – Ontario Ministry of Municipal Affairs and Housing

MMM – Marshall Macklin Monahan Ltd.

MNDM – Ontario Ministry of Northern Development and Mines

MNR – Ontario Ministry of Natural Resources

MOA – Memorandum of Agreement

MODFLOW – Modular Finite-Difference Ground-Water Flow Model
MOE – Ontario Ministry of the Environment

MOHLTC – Ontario Ministry of Health & Long Term Care

MOU – Memorandum of Understanding

MRSPR – Mississippi-Rideau Source Protection Region

MUD – Municipal Water Use Database

MVC – Mississippi Valley Conservation

Na – Sodium

NCC – National Capital Commission

NCR – National Capital Region

NGO – Non-Governmental Organization

NHIC – National Heritage Information Center

NH_3 – Ammonia

NO_3 – Nitrate

NO_2 – Nitrite

NRC – National Resources Canada

NRVIS – Natural Resources Values Information System

OBBN – Ontario Benthos Biomonitoring Network

OBM – Ontario Base Mapping

OBSWQ – Ottawa Baseline Surface Water Quality

ODWQS – Ontario Drinking Water Quality Standards

ODWSOG – Ontario Drinking Water Standards, Objectives and Guidelines

OFAH – Ontario Federation of Anglers and Hunters

OG – Operational Guideline

OGS – Ontario Geological Survey

OMAFRA – Ontario Ministry of Agriculture, Food and Rural Affairs

OMMA – Oliver Mangione McCalla & Associates

OP – Official Plan

O. Reg. – Ontario Regulation

OWES – Ontario Wetland Evaluation System

PCB – Polychlorinated Biphenyl

PCE – Perchloroethene

PGMN – Provincial Groundwater Monitoring Network

PLC – Provincial Land Cover

PTTW – Permit to Take Water

PWQMN – Provincial Water Quality Monitoring Network

PWQO – Provincial Water Quality Objectives

ROPEC – Robert O. Pickard Environmental Centre

RRCA – Raisin Region Conservation Authority

RVCA – Rideau Valley Conservation Authority

RWDRT – Rideau Waterfront Development Review Team

SAR – Species At Risk

SIL – Southern Ontario Interim Landcover

SMP – Servicing Master Plan

SNC – South Nation Conservation

SO_4 – Sulphate

SSWQO – Saskatchewan Surface Water Quality Objectives

SWAT – Surface to Well Advection Time

SWE – Snow Water Equivalent

TCE – Trichloroethene

TDS – Total Dissolved Solids

THM – Trihalomethane

TKN – Total Kjeldahl Nitrogen

TOT – Time of Travel

TP – Total Phosphorus

TPC – Threats of Provincial Concern

TSH – Totten Sims Hubicki Associates

TSS – Total Suspended Solids

UTM – Universal Transverse Mercator

VC – Vinyl Chloride

WESA – Water and Earth Science Associates Ltd.

WHPA – Wellhead Protection Area

WSC – Water Survey of Canada

WQ – Water Quality

WWAT – Water Table to Well Advection Time