# Chapter 5 – Groundwater Sources

## Purpose

This chapter discusses *highly vulnerable aquifers* (HVAs), *significant groundwater recharge areas* (SGRAs) and *wellhead protection areas* (WHPAs) as part of a description of the *geology* and groundwater sources of the Cataraqui Source Protection Area (CSPA). All of these findings have been completed in accordance with the Technical Rules: Assessment Report (MOE, 2009a)(see **Appendix 'L-1'**) using the methods that are described in Chapter 4.

The findings in this chapter build on the two provincially-funded regional groundwater studies that were completed prior to the Ontario Clean Water Act, 2006 and that cover the CSPA: the United Counties of Leeds and Grenville Groundwater Management Study (Dillon Consulting Ltd., 2001) and the Western Cataraqui Region Groundwater Study (Trow Associates Inc., 2007). The findings also build on the Frontenac Islands Aquifer Characterization and Groundwater Study (CRCA, 2007) that was prepared as a background report on the *hydrogeology* of the islands in that municipality. A copy of the latter study is included in **Appendix 'L-7'**.

## 5.1 Area-Wide Groundwater Sources

### 5.1.1 Overview

Groundwater sources in the CSPA are generally characterized by the *geology*. Within the CSPA, most people draw their water from wells completed in either younger *Paleozoic limestones* and *sandstones* or the ancient *Precambrian* Shield. Water generally flows through small cracks in the rock (less than one millimetre) that are known as fractures. The fractures transmit the water from higher to lower levels through a network of cracks that is known as the rock *aquifer*.

These rock *aquifers* are generally covered with a thin layer of sand and/or clay (soil or *overburden*), but most wells are drilled through to the rock. Some parts of the Source Protection Area have thicker soil cover, which can act as a protective barrier to our valuable groundwater sources when the soil mainly consists of clay. Areas with less soil cover tend to be highly vulnerable to surface *contamination* as random rock fractures can act as a direct conduit for *contamination* to reach the *drinking water* source.

Once groundwater is contaminated, it can be very difficult and expensive to clean up, and sometimes it can no longer be used as a source of potable water. For these reasons, the vulnerability of the groundwater in eastern Ontario is an important challenge that requires careful attention. We need to ensure that our groundwater resources can be used in the future.

#### 5.1.1.1 Geology and Hydrogeology

*Precambrian* aged rocks of *igneous* and *metamorphic* origin underlie the entire CSPA, and form a region commonly known as the *Precambrian* Shield. The shield forms the core of the North American continent. Because of the complexity of the rock types, geologists have subdivided the region into belts and *terranes* based on differing rock types and age of development.

The *Precambrian* rock in the CSPA is part of the Frontenac *terrane*, which is a subunit of the Central Metasedimentary Belt. The *Precambrian* rock is comprised of a combination of metamorphosed *igneous* and *sedimentary rocks*. The *Precambrian* rock is exposed along a northwest – southeast trending ridge, referred to as the *Frontenac Axis*. Along the east and west flanks of this ridge, *Paleozoic* age *sediments* were deposited. These *sediments* hardened and are expressed today as *limestone*, *dolostone* and *sandstone*.

Groundwater flow within the *Precambrian* rock is mainly through fractures that have developed as a result of volcanic and mountain building processes (Ostry and Singer, 1981). In general, *igneous* rocks are not very porous. Groundwater is less able to flow through the pore spaces in the rock itself, as opposed to a sand *aquifer* (Freeze and Cherry, 1979).

The distribution and density of fractures commonly decreases with depth. More fractures exist near the surface because *glaciations* between 100,000 and 10,000 years ago placed extreme pressure on the northern land surface. With the retreat of the glaciers, the release of this pressure created horizontal fractures. These shallow fractures, when filled with water, can be of sufficient density to provide an adequate volume for a potable water source.

Vertical fractures, formed during mountain building episodes, are also present. These fractures connect the horizontal fractures, and can allow vertical migration of water. Estimates of bulk *hydraulic conductivity* of fractured *igneous* and *metamorphic rocks* typically range from $10^{-6}$ to $10^{-2}$ centimetres per second (Freeze and Cherry, 1979).

The depth of active groundwater flow will vary spatially; however, previous studies (Ostry and Singer, 1981) have suggested that in the vicinity of the CSPA, most flow is within the top 30 metres.

Regional groundwater flow patterns in *Precambrian* rock are mainly controlled by both *topography* and the density/connectivity of horizontal and vertical fractures. Because of the complexity of groundwater flow patterns in *Precambrian* rock, local *scale* groundwater movement is difficult to describe and predict. At the regional *scale*, patterns will be similar to that observed for porous materials, in that groundwater flow generally moves from areas of high elevation to low elevation. As with all areas dominated by exposed or shallow fractured *bedrock*, *recharge* at the regional level is expected to occur over most of the area.

However, at the local *scale*, there will be a tremendous variability in local *recharge*. Local *recharge* conditions may exist where *surface water* features are located in local topographical depressions.

Overlying the *igneous* and *metamorphic rocks* of the *Precambrian* shield are *sedimentary rocks* of *Paleozoic* (Cambrian to Ordovician) age. Deposition of these *sediments* began approximately 500 million years ago when a shallow ocean inundated the eastern portion of the ancestral North American continent known as "Laurentia".

During the development of marine conditions, *erosion* of the *Precambrian* land mass resulted in the deposition of sands and gravels along its continental shores. East of the *Frontenac Axis*, these Cambrian aged *sediments* are referred to as the Covey Hill and *Nepean Formations*, which together are often referred to as the Potsdam Group (Williams, 1991) or *Nepean Formation* (Wilson, 1946). For purposes of this report, the Wilson (1946) description will be used.

As sea levels increased, and quieter, deeper water environments prevailed, carbonate rich *sediments* were deposited on top of the sandy *sediments* of the Potsdam Group. East of the *Frontenac Axis*, these deposits formed the Oxford and *March Formations*. While these carbonate *sediments* were being deposited, the landmass west of the Axis was exposed. It was later inundated by an ocean, resulting in the deposition of carbonate deposits (Gull River, *Bobcaygeon* and *Verulam Formations*) as seas became deeper.

The *Shadow Lake Formation* is presently generally west of the arch, and underlies the Gull River Foundation. It consists of *arkosic* siltstones, *sandstone* and *shale* and represents the last stages of sedimentary inputs of the reworked materials from the *Frontenac Axis*. Descriptions of the formations, and their *geology* and *hydrogeology* properties for the eastern and western *Paleozoic* Formations, are summarized in **Tables 5-1** and **5-2**, respectively.

**Table 5-1: Paleozoic Formations East of the Frontenac Arch**

| Formation | Description | Hydrological Properties |
|---|---|---|
| Oxford | • Dolostone and shale interbeds<br>• Exposure is limited to far eastern portion of the Source Protection Area, east and north of the City of Brockville | • Reported to be moderately permeable |
| March | • Interbedded sandstone and dolostone<br>• Thicknesses range from zero to 20 metres in Source Protection Area<br>• Exposed along eastern extremes of the Source Protection Area | • Relatively permeable when sandstone interbeds are present |
| Nepean | • Well sorted quartz sandstone deposited on top of Precambrian rock<br>• Thickness ranges from zero to 50 metres. | • Groundwater flow through pore spaces as well as rock fractures<br>• Known to be a high yielding *aquifer*. |

**Table 5-2: Paleozoic Formations West of the Frontenac Arch**

| Formation | Description | Hydrological Properties |
|---|---|---|
| *Verulam* | • Layered limestone and shale beds Many fossils are found in the limestone layer<br>• It is exposed mainly in the southwestern extremity of the Source Protection Area, as well as on Amherst Island and the southern portion of Wolfe Island | • *Well yields* are often poor, indicating relatively low bulk permeability (ability to transmit water through the rock) as compared to other *Paleozoic* rocks in the study area |
| Bobcaygeon | • Limestone with some shale content (exposed on Wolfe Island and east of Loyalist Township | • *Well yield* adequate to acceptable for domestic consumption (10-13 litres per minute) |
| Gull River | • Thickly bedded dolomitic limestones (slightly different chemical structure than regular limestone) and shaley limestone<br>• Exposed in areas west of Gananoque | • *Well yield* adequate to acceptable for domestic consumption (10-13 litres per minute)<br>• Formation can be *karstic* (cavernous limestone that forms due to solution *weathering* by water flow through fractures) |
| Shadow Lake | • Sandstones, siltstone and shale<br>• It is rarely exposed in the Source Protection Area. Thickness ranges from zero to five metres. | • Data unavailable. |

#### Groundwater / Surface Water Interaction

Waterbodies in the area that are identified as potentially having a substantial groundwater baseflow component include:

- The Cataraqui River, Colonel By Lake, Little Cranberry Lake and portions of Loughborough Lake (based on the cold water fishery) in the Cataraqui River *watershed*

- Charleston Lake, Fosters Creek, Willy's Brook, Upper Beverly Lake and Wiltse Lake in the Gananoque River *watershed*
- Jones, Plum Hollow, Cooligan's, Golden and Butlers Creeks in the smaller *watersheds* draining to the St. Lawrence River
- Little, Spring, Thorpe, Wilton, Millhaven and Glenvale Creeks in the smaller *watersheds* draining to Lake Ontario.

This is based on field work over 2007 to 2009, including water temperature *monitoring*, and measurements for radon concentrations (which are generally higher in groundwater). Mapping of *groundwater recharges* is not yet available for the Cataraqui area, such that this has been listed as a *data gap* in **Appendix 'K-1'**.

#### Groundwater Flow in the Nepean Aquifer

The most permeable *bedrock* material in the CSPA is the *sandstone* of the *Nepean Formation*. The *March Formation* is also relatively permeable because of the *sandstone* layers. These formations have a higher *permeability* largely because of the presence of both primary and secondary (fracture) *porosity*.

The significance of these formations from both a *recharge* and vulnerability perspective is difficult to quantify. It is possible that these formations are *recharged* where they are exposed at the surface. Where these deposits are buried beneath carbonate rocks, it is speculated that they may act as preferential groundwater flow pathways between the lower *permeability* underlying *Precambrian* shield and overlying *Paleozoic* carbonate rocks. Therefore, it is possible that regional groundwater flow is affected by the fractures in these higher *permeability* formations.

Also, the groundwater flow, especially at depth, may not coincide with surface *drainage* patterns. For example, deep groundwater flow in the neighbouring Rideau River *watershed* may be partially *recharged* in the CSPA *watershed* where the *Nepean* and *March Formations* are exposed. Unfortunately, insufficient water level data are available to adequately test this assumption at this time.

#### Cross-boundary Groundwater Flow

It is assumed that a component of groundwater flow may be directed northwest from the CSPA into the Mississippi-Rideau Source Protection Region ground *watersheds* through the *Nepean Formation*. The likelihood of this occurrence will depend upon the contrast in *permeability* of the *Nepean aquifer* and the surrounding rock (*Precambrian* below and carbonate rock above). A higher contrast translates into a greater potential for cross-boundary flow. The contrast will largely be a result of the density and connectivity of the fractures within the rock unit. If fracture characteristics are the same for all rock formations then the entire groundwater flow system may act as one *aquifer* and the potential for flows across *surface water*shed boundaries is reduced.

Cross-boundary flow may also occur at depth, where groundwater flow patterns will reflect larger *scale topography* trends rather than the smaller *scale watershed drainage* patterns. For example, the boundary between the CSPA (Little Creek, Wilton Creek) and Quinte Source Protection Region (Napanee River) *watersheds* may reflect a groundwater flow divide for shallow groundwater flow, but at depth, groundwater may flow beneath the Napanee River and *discharge* to Lake Ontario. Also, groundwater from the Cataraqui Source Protection Area is located within the 25 year *time of travel* for the Westport WHPA (see Section 5.2.5 below).

#### Groundwater Flow and Contaminant Transport in Fractured Rock Aquifers

Groundwater flow and *contaminant* transport is controlled by the structure of the *aquifer* and water pressure in a given area. Water always flows from high to low areas, following the law of gravity. However, the structure and *geology* of the *aquifer* can complicate this simple law. The *geology* of the *Precambrian* shield in Canada, including the *Frontenac Axis* in eastern Ontario, has a complex history of sedimentation, mountain building, plutonic intrusions, and metamorphism that is usually combined as one *aquifer* system despite this intricate history. The *Frontenac Axis* is flanked by *Paleozoic sedimentary* rocks that were laid down in warm, shallow seas.

Groundwater flow in fractured rock *aquifers* is governed by fracture flow, or secondary *porosity*. Primary *porosity* is defined as the pore spaces between the grains within the rock while secondary *porosity* are the fractures or cracks in the rock (NRC, 1996). In fractured rocks in Canada, the most dominant water-bearing fractures were created by unloading during glacier retreats. When the weight of two kilometres of ice released pressure on the rock and the land rebounded, horizontal fracture features opened up and allowed *meteoric water* to flow through the cracks. Vertical fractures can be formed by faulting, jointing or during rock formation (Lapcevic et al, 1999).

*Aquifer* properties can be considered from different perspectives including, *recharge*, response, and *discharge* (Knustsson, 2008). *Recharge* values will be highest where *precipitation* is high and there is very permeable ground. Response in wells, as water level changes, may be a result of low groundwater storage, response to rain events, connectivity to surface flow, and diurnal fluctuations. *Discharge* to *surface water* bodies depends on areas of high groundwater levels that are geologically connected to lower *surface water* levels. In fractured rock *aquifers*, *recharge* amounts can be very low while response to *precipitation* events is extremely high (Milloy, 2007).

*Contaminant* transport in any *aquifer* can be considered in terms of the source, pathway, and receptor, as follows:

- **Source**. Potential sources of *contamination* include agricultural *nutrients* and *pathogens*, industrial *solvents* and/or *DNAPLs*, oil and gas (*LNAPL*s), cemeteries, and septic tanks.
- **Pathway**. The pathway is governed by the groundwater flow path and geological structure of the *aquifer*.
- **Receptor**. The receptor is the water body or drinking water well where *contaminants* are *discharged* and potentially consumed.

Though *recharge* to fractured *bedrock aquifers* can be limited, any open vertical fracture creates a high velocity conduit for *contamination* to reach the drinking water *aquifer*. Thus rapid *recharge* to fractured rock *aquifers* is particularly important, since even small quantities of water are capable of transporting potentially detrimental *contaminants* to the *drinking water* source (Gleeson et al., 2009).

Local fracture variability and limited techniques for locating vertical fractures make it very difficult to quantify groundwater *infiltration* to fractured rock *aquifers*. Horizontal fractures can be more easily located in a drilled well using a down-hole camera, straddle packers or the FLUTe system, which is comprised of a plastic liner inserted into the *bedrock* well while changes in water levels are measured. Hydraulic properties of the horizontal fractures can be quantified using slug tests, constant head testing, and the FLUTe system. Vertical fractures can be located using similar techniques in angled or horizontally drilled wells (Lapcevic et al., 1999). To determine fracture connectivity between wells, pumping tests and pulse interference testing can be used (Stephenson et al, 2006). Locating vertical and horizontal fractures (or both) can be fiscally prohibitive.

At a regional *scale*, the cost and time constraints make it impossible to delineate fracture locations. Considering that any vertical fracture potentially creates a direct, high velocity conduit to the *aquifer*, a conservative approach to delineating HVAs is recommended where insufficient protective *overburden* exists.

## 5.1.2 Highly Vulnerable Aquifers

### 5.1.2.1 What is a Highly Vulnerable Aquifer (HVA)?

Sources of groundwater (*aquifers*) are considered *highly vulnerable aquifers* when an insufficient protective layer exists above the *aquifer*. Since rocks and *sediments* are generally found in layers, it is ideal to find a layer of clay above the *aquifer*.

The speed that groundwater travels depends on the type of materials that the water is flowing through (sand, clay, rock), the number and size of the fractures and holes in that material and the action of gravity. Since water moves much more slowly through clay than sand or rock fractures (over years versus minutes or days), clay is considered a protective material while the sand or rock fractures are considered the *aquifer*. A *highly vulnerable aquifer* has little or no protective layer.

In defining *highly vulnerable aquifers*, the most commonly used *aquifer* is considered. In most cases, this is the first *aquifer* encountered during well drilling, which in the CSPA is typically (but not always) the *bedrock aquifer*. *Aquifer* vulnerability is assessed for all locations, whether or not they are serviced by a *drinking water system*.

Considering the complexity of the *geology* in the CSPA, precise mapping of *HVA*s is difficult. Vulnerability scores, which are largely dependent upon the presence and thickness of overlying silt/clay, will vary over very short distances. In order to assess *aquifer* vulnerability at a property *scale*, additional site-specific information will likely be required.

### 5.1.2.2 Delineation and Scoring of Highly Vulnerable Aquifers

#### Method: Overview

The most recent definition of *HVA*s in the CSPA was completed by Dillon Consulting Ltd. in 2008 (see **Appendix 'L-8'**) and later refined in 2010 by the Cataraqui Region Conservation Authority (in consultation with Dillon Consulting Ltd.) for this report.

Several methods to delineate *high vulnerable aquifers* are prescribed by the Technical Rules: Assessment Report (MOE, 2009a). An August 26, 2002 amendment to the MOE Intrinsic Susceptibility Index (ISI) protocol was used as the preferred method for the CSPA. It was also used in the adjacent *source protection regions*, which have similar a *geology* and *hydrogeology*.

The method used to prepare the HVAs in the Cataraqui area included the following steps:

1. The ISI protocol (2002 Amendment) was completed at each of wells (see **Map 5-1a**)
2. These results were interpolated (smoothed out using a technique called kriging) to define areas of high, medium, and low vulnerability (see **Map 5-1b).** This map was filtered to remove situations in which one or two wells were influencing the result.
3. The *surficial geology* was assessed to also define areas of high, medium, and low vulnerability (see **Map 5-1c**)
4. The ISI and *surficial geology* maps were overlain to finalize the areas of high, medium, and low vulnerability (see **Map 5-1d)**.
5. The areas of high vulnerability were then transferred to **Map 5-1e**.

The execution of each of these steps and the associated maps are described below.

#### Method: Amended MOE Intrinsic Susceptibility Index Protocol

The ISI protocol was developed by the MOE in 2002 to create a consistent approach to *aquifer* vulnerability mapping in Ontario. The method is applied to all provincial groundwater studies. Inputs into the protocol calculations included depth to *water table*, *aquifer* depth, and thickness/material type of *overburden* overlying the *aquifer*. The *permeability* of the *overburden* is a factor of material type and thickness. An August 26, 2002 amendment to the protocol was prepared to account for areas with limited *overburden* and fractured *bedrock*, such as those found in eastern Ontario.

*Aquifer* vulnerability is relatively higher in areas where materials overlaying the *aquifer* are more permeable or thinner and in areas where the *water table* is shallow. In general, the ISI protocol is used to describe the vulnerability of the first *aquifer* encountered below ground surface. The protocol is most suited to assessing the vulnerability of an *aquifer* to *contamination* from surface or near surface sources.

A summary of the MOE ISI protocol follows:

- Task 1: Data Preparation
  - Improve quality of MOE Water Well Records and remove suspect records
- Task 2: Water table Mapping
  - Determine depth to groundwater near each well
- Task 3: Classification of Aquifers and Calculation of ISI value
  - Identify *aquifers* in each well, and determine *aquifer* type
    (confined, unconfined, semi-confined)

  - Calculate ISI value at each well.
- Task 4: Categorize vulnerability of wells based on ISI value
  - ISI less than 30: High Vulnerability
  - ISI 30 – 80: Moderate Vulnerability
  - ISI greater than 80: Low Vulnerability
- Task 5: Mapping of ISI values map study area based on calculated ISI values to identify regions of similar vulnerability.

The principal source of information for the ISI protocol is the Ontario water well records. Information on the observed soil conditions, well construction details and depth of water for each well drilled in Ontario is compiled in the MOE Water Well Information System (WWIS). The WWIS is created from information provided by the driller at the time of well construction.

Added to this information is an MOE estimated ground elevation and geographic position for each well. Uncertainty in the elevation and geographic location is reflected through the assignment of accuracy codes. Information in the well records was enhanced using protocols set up by the Geological Survey of Canada, which enhances the accuracy of the original well record by simplifying the number of rock and *sediment* layers reported.

There are limitations to the amended ISI protocol, such as:

- the accuracy, completeness and representativeness of the provincial Water Well Information System, which is the principal data source, which depends of the records of well drillers, and which does not always account for wells that have been abandoned/decommissioned, and
- its lack of consideration for the patterns of groundwater flow.

It should be noted that hydraulic data from the WWIS was not considered with respect to confined or semi-confined *aquifers* as part of the amended ISI method. All of the limitations are discussed in greater detail by Dillon Consulting Ltd. (2008).

To reduce error in the Water Well Information System records, the data were processed prior to interpretation to remove erroneous and suspicious entries, where practical. A total of 15,469 wells were studied as part of the groundwater vulnerability assessment, out of the approximately 25,000 water well records that exist for the Cataraqui area (see **Table 3-2**). Specific wells were chosen depending on the quality of the well location information and the application.

The combination of these limitations will result in variable degrees of uncertainty associated with the results of the analysis. In general, the ISI protocol will produce low uncertainty in geologically similar areas where wells are closely spaced and tap into the same *aquifer*. Unfortunately, many of these assumptions are not applicable in the CSPA because of the complex *geology* and low density of wells in many areas. Nevertheless, the interpolated ISI results, when used in combination with *surficial geology* information, can be used to assess general trends.

#### Method: Assessment of Surficial Geology

Information from *surficial geology* maps can be used to qualitatively assess the vulnerability of *aquifers* within the CSPA. These maps are prepared by geologists who specialize in geological descriptions of each rock formation. Therefore these maps provide better information about shallow geological conditions than using only the water well records. Application of this method is especially useful in areas where few wells are present such as on the *Precambrian* Shield and in between settlement.

Seamless *surficial geology* maps created by the Ontario Geological Survey were used to identify large areas that may have a high vulnerability. The *surficial geology* mapping was created by harmonizing *geology* maps that were originally created at the 1:50,000 and 1:63,360 scales.

Areas mapped as predominantly bare rock, shallow *overburden* (generally less than 1.5 metres thick) or sand and gravel were considered to be highly vulnerable because of the lack of low *permeability* deposits, such as clay, that would impede vertical *contaminant* migration to the *aquifer* below. Classification of vulnerability based on *surficial geology* is shown in **Table 5-5.**

**Table 5-3: Vulnerability Ranking by Surficial Geology**

| Geological Unit | Vulnerability |
|---|---|
| *Precambrian* bedrock | High |
| *Precambrian* bedrock-shallow overburden | High |
| *Paleozoic* bedrock | High |
| *Paleozoic* bedrock-shallow overburden | Moderate |
| Shield-derived silty to sandy till | Moderate |
| Stone-poor silty to sandy till | Moderate |
| Ice-contact stratified deposits | High |
| Moraines, kames and eskers | High |
| Glaciofluvial deposits | High |
| Fine grained glaciolacustrine deposits | Low |
| Coarse glaciolacustrine deposits | High |
| Offshore glaciomarine deposits | Low |
| Near-shore glaciomarine deposits | High |
| Littoral-foreshore deposits | Moderate |
| Eolian Deposits | High |
| Modern Alluvium | Moderate |
| Organic Deposits | Moderate |

The *surficial geology* method complements the ISI method by providing excellent regional *scale* data for the top one to 1.5 metres of *sediment* and *bedrock*, while the WWIS provides geological information to the depth of the well. In addition, the *surficial geology* assessment provides a general identification of *overburden* type and therefore, the general capacity for the *overburden* to provide a protective cover.

#### Assumptions

As part of the work, all *bedrock* was considered as one unconfined *aquifer*. Furthermore, it was assumed that *aquifer* protection is provided solely by *overburden* materials. No attempts were made to differentiate *aquifer* vulnerability based on overlying lower permeable *bedrock* zones or vertical groundwater *hydraulic gradients*; however, at the local *scale*, these conditions would influence vulnerability.

All *bedrock aquifers* with less than 1.5 or two metres of *overburden* or with *overburden* that is relatively highly permeable were assumed to be unconfined *aquifers*. All areas with less than two metres of *overburden* or with *overburden* that is relatively highly permeable were assumed to be *highly vulnerable aquifers*.

#### Rationale for Method and Assumptions

The amended ISI method and its assumptions were selected to reflect the complex geologic setting of eastern Ontario. The extensive delineation of *HVA*s for eastern Ontario is appropriate from a scientific perspective, since:

- In most locations there is a limited cover of *overburden* to prevent *contaminants* from entering into the groundwater
- Although our knowledge is incomplete, fracturing has been observed in the shallow and deep *bedrock* of eastern Ontario, including the *Canadian Shield* and shallow *limestone* areas, and it is reasonable to assume as part of groundwater vulnerability assessments that fractures may exist under any location across the *source protection areas* and that the *bedrock* is an unconfined *aquifer*, and
- Research to-date in eastern Ontario has demonstrated that the presence of vertical fractures creates a direct, high velocity conduit to the *drinking water aquifer*.

For example, in the CSPA two municipal water systems show evidence of *contamination* due to the vulnerability of fractured rock *aquifers*:

- At Lansdowne, there is significant evidence that suggests a direct connection from ground surface to the supply wells. Geofirma Engineering Ltd. (2011) has classified the wells as potentially *GUDI*, even though there are no adjacent water bodies, because of continued positive bacteriological results in the supply wells. Cascading water has also been reported in the supply wells at a depth of six metres below ground surface at a rate of 45 litres per minute (Malroz Engineering Inc., 2003). It is suspected that this fracture represents a direct pathway from ground surface to the well.
- At Sydenham, individual private homeowners' wells have been plagued with nitrate and bacteriological *contamination* for many years due to connections between septic tanks

and drinking water wells. Of the 210 private wells in Sydenham, 25 wells are drilled directly on *bedrock*, while 185 contain an average of three metres of *overburden*. Lot sizes are on average 0.1 hectares. Water quality surveys were completed in 1966, 1970, 1972, 1981, 1983, and 1997; the 1983 and 1997 studies found exceedances the Ontario Drinking Water Standards (ODWS) in up to 50 per cent of wells sampled. Through these studies, TSH Associates (2001) concluded that that a drinking water treatment plant with an intake from Sydenham Lake would solve the *drinking water contamination issues*. The drinking water treatment plant has been online since 2006, however septic tanks remain in use, suggesting that nitrate and bacterial loading is still occurring in the fractured rock *aquifer*.

#### Execution of Combined ISI and Surficial Geology Method

The following section details the methods and results of the combined ISI and *surficial geology* method that was used to produce the *HVA* map (**Map 5-1e**).

#### Execution of Steps 1 and 2: Intrinsic Susceptibility at the Wells

Mapping of *aquifer* vulnerability at individual public and private wells using the ISI protocol is shown in **Map 5-1a**. The map shows that the majority of wells are deemed to have high *aquifer* vulnerability. A breakdown of the number of wells assessed and the overall percentage of low, moderate and high vulnerability wells is shown in the table below.

Overall, the majority (84 per cent) of the 15,469 wells studied received a high vulnerability ranking. Moderate to low vulnerability conditions were detected in some wells, but the occurrence of these conditions were generally isolated and discontinuous.

**Map 5-1b** shows the use of an interpolation technique (called kriging) to smooth out the values between individual wells. The results of this step point to the majority of the CSPA being considered a *highly vulnerable aquifer*.

#### Execution of Step 3: Surficial Geology Assessment

*Aquifer* vulnerability assessment results based on the *surficial geology* is shown in **Map 5-1c**, with 61 per cent of the CSPA considered high vulnerability, 23 per cent moderate, and 16 per cent as low vulnerability over a total area of 3,751 square kilometres.

Areas of high vulnerability correspond with shallow *bedrock* that is either exposed or thinly covered with *glacial drift*. Moderate vulnerability was mapped in areas where the *bedrock* is buried beneath *glacial till*. Areas that are overlain by *glaciolacustrine* silts and clays are deemed to have low vulnerability. Low vulnerability conditions exist in portions of mainland Loyalist Township, Amherst and Wolfe Islands, the City of Kingston and the Township of Leeds and the Thousand Islands. In general, many of the areas of low to moderate vulnerability are isolated and discontinuous, reflecting the complex *surficial geology* of the area.

The *surficial geology* method does not take into account the thickness of the overlying material, but rather its spatial extent only. As a result, many of the areas that are mapped as moderate to low vulnerability will likely have a low accuracy because low *permeability* materials may only be thin and not provide adequate protection of the underlying *aquifers* from *contamination*.

#### Execution of Step 4: Overlay of the ISI Protocol and Surficial Geology Assessment

In accordance with the 2002 amendment to the ISI protocol, the interpolated Intrinsic Susceptibility Index map (**Map 5-1b**) was overlain with the *surficial geology* assessment (**Map 5-1c**) to produce **Map 5-1d**.

#### Execution of Step 5: Extent of Highly Vulnerable Aquifers

The extent and vulnerability scoring of *highly vulnerable aquifers* is shown in yellow on **Map 5-1e.** It is based on the understanding that:

- This map has a high uncertainty, such that portions of the remainder of the CSPA may also be highly vulnerable to *contamination*,
- Conversely, some wells may have been determined to have low or moderate *aquifer* vulnerability under the original ISI methodology may be designated as *highly vulnerable aquifers* under the method used in the Cataraqui area, and
- The vulnerability of any given location should be confirmed through site-specific investigation.

Under the Technical Rules: Assessment Report (MOE, 2009a), all areas that are considered to be *HVA*s are automatically assigned a vulnerability score of six out of ten.

### 5.1.2.3 Drinking Water Issue Evaluation for Highly Vulnerable Aquifers (HVAs)

While recent groundwater quality data for the Cataraqui area are sparse, an evaluation of available data revealed region-wide *drinking water issues* with microbiological *contamination* and elevated chloride, sodium, and nitrate. These findings are described in detail in the Cataraqui Source Protection Area Watershed Characterization Report (CRCA, 2008) and are summarized below.

#### Sodium and Chloride

The Ontario Drinking Water Standard (ODWS) for sodium in drinking water is 200 milligrams per litre (aesthetic objective where a salty taste can be detected); however the ODWS health objective is 20 milligrams per litre (**Appendix 'C-2', Table 2** and within the Cataraqui Source Protection Area Watershed Characterization Report (CRCA, 2008)). Levels of sodium in the CSPA *watershed* are well below the upper limit of 200 milligrams per litre yet concentrations commonly exceed 20 milligrams per litre (the health-related warning level) throughout the Western Cataraqui Region Groundwater Study area (Trow Associates Inc., 2007) and in Provincial Groundwater Monitoring Network (PGMN) wells located in Loyalist Township and at the Mac Johnson Wildlife Area near Brockville. The United Counties of Leeds and Grenville Groundwater Management Study (Dillon Consulting Ltd., 2001) also revealed areas with sodium concentrations exceeding 20 milligrams per litre in 70 per cent of wells sampled and 200 milligrams per litre in ten per cent of wells sampled in the *local area* between Mallorytown and Brockville.

Chloride concentrations exceeding 250 milligrams per litre (the ODWS aesthetic objective) have been found in private wells throughout the Cataraqui area. This includes wells in the vicinity of Odessa, Westbrook, Elginburg, Sydenham and Harrowsmith (Trow Associates Inc., 2007)**,** the area between Mallorytown and Brockville (Dillon Consulting Ltd., 2001) and the PGMN well in Loyalist.

Sources of sodium and chloride in groundwater may be both natural and human-related. The *weathering* of rocks may cause naturally high concentrations of sodium and/or chloride in groundwater; whereas, human sources include sewage, road salt, de-icing compounds, and the *discharge* of conditioning salts from water softeners.

#### Nitrate

The ODWS maximum acceptable concentration of nitrates in drinking water is ten milligrams per litre (**Appendix 'C-2', Table 2** and within the Cataraqui Source Protection Area Watershed Characterization Report (CRCA, 2008)). Nitrate concentrations of over ten milligrams per litre have been sampled in private wells in Verona (KFL&A, 1994), Sydenham (Malroz Engineering Inc., 2002), six per cent of wells tested in the Western Cataraqui Region Groundwater Study area (Trow Associates Inc., 2007), and 15 per cent of wells sampled on farms in the jurisdiction of the Kingston, Frontenac, Lennox & Addington Health Unit (KFL&A, 1994).

Sources of nitrate may be natural or human sourced and include the *weathering* of nitrate-containing mineral formations, decay of plant and animal material, agricultural fertilizers, and effluent from septic systems and sewage treatment plants.

#### Microbiological

Areas of microbiological *contamination* have been identified in Harrowsmith, Sydenham (KFL&A, 1994) and other areas throughout the Western Cataraqui Region Groundwater Study area (Trow Associates Inc., 2007). Historically, microbiological *contamination* has also been found on Amherst Island (MOE, 1985), other areas in Loyalist Township (OMM, 2001), and throughout the jurisdiction of the Leeds and Grenville District Health Unit (Dillon Consulting Ltd., 1993).

The presence of total coliform, fecal coliform or *Escherichia coli* in groundwater is an indication of the presence of human and animal waste; however, total coliform bacteria may also be naturally occurring in soil and water.

### 5.1.2.4 Threat Assessment

Initial *watershed* surveys were completed for the entire Cataraqui area in advance of the Technical Rules: Assessment Report (MOE, 2009a). All of the 21 prescribed *drinking water threats* could be associated with the *activities* observed within the *HVAs* and *SGRAs* within the Cataraqui area.

Since the vulnerability score for a *HVA* is a six out of ten, according to the Technical Rules, it is not numerically possible to have a significant *drinking water threats* in these areas. Areas where moderate and low *threats* related to *chemicals*, *pathogens* and *DNAPLs* can occur are shown in **Maps 5-2**, **5-3**, and **5-4**. Areas where conditions may be moderate or low *threats* are shown in **Map 5-5**. As the assessment of significant drinking water threats is the primary focus of this report, further investigation into the specific locations of moderate and low *threats* for *HVAs* did not occur at this time.

## 5.1.3 Significant Groundwater Recharge Areas (SGRAs)

### 5.1.3.1 What is a Significant Groundwater Recharge Area?

An *aquifer* is an area of soil or rock under the ground that has many cracks and spaces and has the ability to store water. Water that seeps into an *aquifer* is called *recharge*. Much of the natural *recharge* of an *aquifer* comes from rain and melting snow. The land area where the rain or snow seeps down into an *aquifer* is called a *recharge area*. *Recharge areas* often have loose or permeable soil, such as sand or gravel, which allows the water to seep easily into the ground. Areas with shallow fractured *bedrock* are also often *recharge areas*.

A *recharge area* is considered significant when it provides high volumes of water to an *aquifer* that supplies *drinking water*. Identification of *SGRAs* in the CSPA is challenging. *Bedrock* comprises the main *aquifer* in the region, and it has a relatively low *permeability*. Flow within this *aquifer* is through fractures that have complex spatial distributions. *Groundwater recharge* is expected to occur at a low rate, but to be widespread and diffused across a large area. Furthermore, the irregular *topography* in the *Precambrian* Shield appears to produce locally controlled flow systems rather than *watershed scale recharge* and *discharge areas*.

Some initial field verification of the soil components of potential *SGRAs* was conducted during the 2009 field season. Soil conditions at more than 300 sites in the eastern area of the CSPA were examined, and almost all were confirmed to have the soil as noted in the *surficial geology* mapping. This built upon the preliminary estimates of potential *significant groundwater recharge areas* prepared by Dillon Consulting Ltd. (2008). Further work will be required to confirm these initial findings.

### 5.1.3.2 Delineation and Scoring of Significant Groundwater Recharge Areas

The delineation and scoring of SGRAs is based on methods that are prescribed by the Ontario government in the <u>Technical Rules: Assessment Report</u> (MOE, 2009a). According to the Rules, each SGRA must be tied to either a *drinking water system*, or a *surface water* body or *aquifer* that is the source for a *drinking water system*.

There are several methods that investigators can consider for mapping *SGRAs*. Where high quality borehole and water level data are available, *SGRAs* can be produced using groundwater flow *modeling*. For areas such as the Cataraqui, where groundwater data are sparse and of lower quality, and where no regional groundwater flow *model* exists, other methods may be used. The two methods prescribed by the Ontario government for use in this report are:

- Technical Rule 44(1): use by-products of the regional *water budget* process to map areas where the *recharge* rate is greater than 1.15 times the average annual *recharge*
- Technical Rule 44(2): use by-products of the regional *water budget* process to map areas where the calculated *recharge* is greater than 55 per cent of the annual water surplus.

These methods are based mainly on surficial *permeability*, *slope*, and *land cover*. The predominant influence is the distribution of permeable soils. Applying these methods relies on estimates from the *Conceptual Water Budget* that introduce uncertainty.

#### Technical Rule 44(1): Recharge Rate

This method is based on the outputs of the *conceptual water budget* undertaken by the Cataraqui Region Conservation Authority (CRCA) in 2007 (CRCA, 2009). Other aspects of the study are described in Chapter 3. The method was developed for areas where the *recharge* rates within the source protection areas are similar. This method can assist in distinguishing between high versus low *recharge* even when narrow ranges in *recharge* rates exist across an area.

Mapped *SGRAs* are produced through manipulation of the *recharge* information that was developed for the *watershed water budget* analysis in a GIS environment. Areas that have an *infiltration* value greater than 1.15 times the annual *recharge* rate over the entire CSPA are identified as a potential *SGRA*. Each area on this map is tied to either a *drinking water system*, or a *surface water* body or *aquifer* that is the source for a *drinking water system*.

#### Technical Rule 44(2): Recharge Volume

This method is also based on the outputs of the *conceptual water budget* undertaken by the CRCA in 2007 (CRCA, 2009). The method corresponds with earlier provincial guidance (MOEE, 1995), which calculates a percentage of the available water as *infiltration*. It was recommended by the MOE where detailed groundwater *models* are not present and where there are only subtle changes in estimated *recharge* rates. Considering the latter assumption and the complex *physiography* of the *watershed*, this method may not be reflective of the study area.

Mapped SGRAs are produced through manipulation of the *infiltration* and surplus water map and the surplus information that was developed for the *watershed water budget* analysis in a GIS environment. Areas that have an *infiltration* value greater than 55 per cent of the annual average water surplus over the same area are identified as a potential *SGRA*. Each area on this map is tied to either a *drinking water system*, or a *surface water* body or *aquifer* that is the source for a *drinking water system*. The reader is referred to the Drinking Water Source Protection Water Budget Conceptual Report (CRCA, 2009) report for supporting information.

#### Conclusion: Extent of Significant Groundwater Recharge Areas

**Map 5-6** depicts the results of applying the Technical Rule 44(1) method to the CSPA, and **Map 5-7** illustrates the resulting *SGRAs*.

The *SGRAs* delineated through this method cover a slightly larger area than those resulting from Technical Rule 44(2). A more conservative approach was deemed appropriate given the uncertainty in our understanding of the regional *hydrogeology*, and the importance of local *recharge* in the CSPA. The uncertainty, as per Technical Rules 13 and 14, with respect to the delineation of the *SGRAs* is considered high.

Under the Technical Rules: Assessment Report (MOE, 2009a), areas that are considered to be *SGRAs* are assigned vulnerability scores of six, four or two out of ten, depending on the vulnerability of the area (see **Map 5-7**). The uncertainty as per Technical Rules 13 and 14, with respect to the vulnerability scoring of the *SGRAs* is considered high. This reflects the high uncertainty of the *aquifer* vulnerability assessment in Section 5.1.2.

#### Other Considerations for Significant Groundwater Recharge Areas

Areas that have the greatest potential for *recharge* are thought to be topographically elevated locations where coarse-grained geological materials are present at surface. In the CSPA, this includes locations where the *Nepean Formation* and permeable horizons of the *March Formation* are either exposed or are covered by permeable materials, in northeastern part of the area. This topic was explored by Dillon Consulting Ltd. in their 2008 report, which includes a map of such locations in the CSPA.

The role of *recharge* in the large areas of shallow to exposed *bedrock* is uncertain. In many cases, these lands are characterized by small and poorly connected lakes, *rivers*, *swamps* and local surface depressions. While high rates of *recharge* may not occur in any particular location, significant volumes of *recharge* likely occur at the *watershed* and local *scale*. Where these surface depressions are connected to fracture networks in the *bedrock*, groundwater contribution from these features would be enhanced.

*Recharge* that is thought to support *ecological* features was identified in two locations; cool-water *streams* near South Lake and Wilton Creek. Cold-water lakes are present in several locations, but their sensitivity to groundwater input is unclear. Four *wetlands* were identified; Butternut Creek, Eel Bay/Sydenham Lake, Kingston Mills and Loon Lake *wetland*, as being reliant on groundwater inputs. Numerous other *surface water* bodies were identified as potential *groundwater discharge areas* based on *water table gradient* information, water temperature information, and isotope concentration in *surface water*; however, the sensitivity of these features to groundwater is not yet understood.

### 5.1.3.3 Drinking Water Issue Evaluation

While recent groundwater quality data for the Cataraqui area are sparse, an evaluation of available data revealed region-wide *drinking water issues* with microbiological *contamination* and elevated chloride, sodium, and nitrate. These findings are described in detail in the Cataraqui Source Protection Area Watershed Characterization Report (CRCA, 2008) and are summarized in Section 5.1.3.2 above.

### 5.1.3.4 Threat Assessment

Initial *watershed* surveys were completed for the entire Cataraqui area in advance of the Technical Rules: Assessment Report (MOE, 2009a). All of the prescribed and local *drinking water threats* could be associated with the existing *activities* observed within the identified *SGRAs* in the Cataraqui area.

Since the highest vulnerability score possible in a SGRA is a six out of ten, it is not numerically possible to have a significant *drinking water threats* in these areas (see **Map 5-7**). Areas where *chemicals, pathogens* and *DNAPLs* may be moderate and low *threats* are shown in **Maps 5-8**, **5-9** and **5-10**. Areas where *conditions* may be moderate or low *threats* are shown on **Map 5-11**, respectively.

As assessment of significant *drinking water threats* is the primary focus of this report, further investigation into the specific locations of moderate and low *threats* within *SGRAs* did not occur at this time.

### 5.1.4 Conclusions and Next Steps

The complex *geology* of the CSPA, comprised largely of shallow *glacial* soils over vulnerable *bedrock aquifers*, creates an environment where *aquifers* are generally highly vulnerable to surface *contamination* and *SGRAs* are difficult to quantify. The work outlined above represents a first attempt at delineating *highly vulnerable aquifers* and *SGRAs*.

Base estimates from the *Conceptual Water Budget* used in the application of Technical Rules 44(1) and 44(2) have uncertainties in the ten per cent and greater range, and bring those uncertainties to the *SGRA* identification. Uncertainty analyses within the Groundwater Vulnerability Analysis Report (Dillon Consulting Ltd., 2008) indicate that a high level of uncertainty is associated with the mapping of low to moderate vulnerability areas using the *surficial geology* and a general lack of high quality water level data within the MOE water well database. Due to the assigned high uncertainty, *HVAs* and *SGRAs* should be subject to site-specific hydrogeological assessment and *risk assessment* before proceeding with any development that may *impact* the groundwater.

Peer review of this work was completed by members of the *water budget* peer review team in 2008. Comments were integrated into the final report. Generally, peer review indicated that limitations exist in methodologies used and uncertainty must be acknowledged.

Understanding *recharge* in fractured rock *aquifers* is a challenge, since *recharge* is isolated to open fractures that must be connected to the surface or the overlying soil. The open fractures provide a conduit for *recharge*, but also for surface *contamination*. Due to the complex flow characteristics in the *watershed*, the mapped *SGRAs* will require confirmation through further investigation and ground-truthing over time. To further understand *recharge* in these complex geologic environments, hydrogeological *modeling* at the regional *scale* may be warranted.

Groundwater *modeling* could be used to examine regional flow in the *Nepean Formation* by *modeling* various scenarios of *recharge, gradient* and *permeability* contrasts. Isotopic groundwater analysis could also be used to map groundwater flow pathways, since groundwater has a different isotopic signature than *surface water*.

Groundwater *modeling* largely depends on accurate, useful data collection, including water quality data and water level elevations. To create a high quality, useful groundwater *model*, effort will be required to collect water level elevations on a regional *scale*, at static conditions, during a short window of time.

## 5.2 Wellhead Protection Areas

### 5.2.1 Overview

#### 5.2.1.1 What is a Wellhead Protection Area?

A wellhead is the physical structure of a well above ground. A *wellhead protection area* (WHPA) is the area around the wellhead where the land use *activities* have the potential to affect the quality of water that flows into the well.

Municipalities often rely on wells to supply *drinking water* to their residents. To protect the health of the people in a community, it is important to protect groundwater from becoming polluted. That job starts with protecting the land around the well. Pollutants spilled or dumped on the surface can seep into the ground and eventually make their way into the well, sometimes over a period of many years. Once that happens, the well may have to be closed down, or the water may have to undergo additional treatment in order to be used. It can be costly and time consuming to clean up polluted groundwater or find new sources of clean water.

A WHPA is delineated by mapping the *geology* and groundwater levels surrounding the wellhead and using this information to create a mathematical *model*. The mathematical *model* is used to predict the speed at which the groundwater is flowing toward the well and from which direction, depending on the pumping rate at the municipal well supply.

When water is pumped continuously from a well, the water level in the well decreases and creates a downward *gradient* towards the well, which continuously draws water from further afield. The speed that water travels towards the well depends on the type of materials that the water is flowing through (sand, clay, and rock), the number and size of the fractures and holes in that material and the action of gravity.

Using the mathematical *model*, a series of zones are delineated based on the time it would take groundwater and a *contaminant* to travel to the wellhead. The zones are as follows:

- WHPA 'A' is the surface and subsurface area centred on the well with an outer boundary of 100 metre radius around the wellhead
- WHPA 'B' is the surface and subsurface areas within which the *time of travel* to the well is less than or equal to two years, but excluding WHPA 'A'
- WHPA 'C' is the surface and subsurface areas within which the *time of travel* to the well is less than or equal to five years, but greater than two years
- WHPA 'D' is the surface and subsurface areas within which the *time of travel* to the well is less than or equal to twenty-five years, but greater than five years
- WHPA 'E' is delineated in a similar manner to *intake protection zone* 2 (as if the intake were located at the point of interaction between the *surface water* and groundwater; or, if the point of interaction is not known, as if the intake were located at the closest point in the waterbody to the well of the *surface water* body that is influencing the well designated as "groundwater under the direct influence of *surface water* (*GUDI*)")
- WHPA 'F' is delineated according to *intake protection zone* 3. It is based as if an intake for the system were located in the *surface water* body influencing the well at the point closest in proximity to the well to account for wells supplies designated as "groundwater under the direct influence of *surface water* (*GUDI*)". It is intended to capture additional areas that contain the source of a *drinking water issue* in the untreated water.

#### 5.2.1.2 Vulnerability Scoring

The vulnerability of the *aquifer* to *contamination* can be assessed within the delineated zones of the WHPA. If *contaminants* can infiltrate through the ground and into the *aquifer*, then wells that use that *aquifer* could become polluted. Studying *aquifer* vulnerability within mapped WHPAs can identify areas where extra care is needed to protect the water supply. If an *aquifer* allows water to enter and move through it quickly, like through sand, gravel or a rock fracture, then it is said to be highly vulnerable. However, if it repels water, such as when there is a lot of clay present then it would be assigned a lower vulnerability score.

The Technical Rules: Assessment Report (MOE, 2009a) under the Ontario Clean Water Act, 2006 set out a process for scoring vulnerability within a WHPA. It is based on the combination of *aquifer* vulnerability and overlapping WHPAs. Simply put, the more vulnerable the *aquifer* and the closer proximity to the well, the higher the vulnerability score.

To produce a vulnerability scoring, the first step is to determine how easily *contaminants* can infiltrate into the *aquifer*. Vulnerability values can be assigned as low, medium or high for specific locations.

The next step is to determine if human *activity* in the WHPA has altered the landscape making it easier for *contaminants* to reach the *aquifer*. These alterations are called *transport pathways*. As outlined in the Technical Rules: Assessment Report (MOE, 2009a), the presence of *transport pathways* within a WHPA can increase the vulnerability. An area with low vulnerability can increase to medium, and an area with medium vulnerability can increase to high. Areas that are already high cannot increase any more. Once the vulnerability of the *aquifer* has been finalized, the last step is to combine it with the WHPAs to determine final vulnerability scores for the WHPA. **Table 5-4,** below, shows the scoring system laid out in the provincial Technical Rules. Possible vulnerability scores are two, four, six, eight, and ten. A score of ten is highest, indicating an area where *drinking water* is most vulnerable to *contamination*.

**Table 5-4: Wellhead Protection Area Vulnerability Scores**

| Vulnerability | Wellhead Protection Area | | | |
|---|---|---|---|---|
| | WHPA 'A' (100 metres) | WHPA 'B' (2 year) | WHPA 'C' (5 year) | WHPA 'D' (25 year) |
| **HIGH** | 10 | 10 | 8 | 6 |
| **MEDIUM** | 10 | 8 | 6 | 4 |
| **LOW** | 10 | 6 | 4 | 2 |

#### 5.2.1.3 Well Supplies in the Cataraqui Source Protection Area

There are four well supplies for which WHPAs have been delineated in the CSPA. The Cana, Lansdowne and Miller Manor Apartments wells and WHPAs are located entirely within our area; whereas, the Westport wells are located in the neighbouring Mississippi-Rideau Source Protection Region, with only a small portion of WHPA 'D' extending into this area. The classification, number of residents served and locations of the municipal residential well supplies in our area are given in **Table 5-5**.

**Table 5-5: Groundwater Supply Well Summary Information**

| Drinking Water System | DWS Information |
|---|---|
| **Cana Well Supply (DWS# 2200060538001)** | |
| Location | Kingston Mills, City of Kingston |
| Population Served | 32 subdivision homes (1) |
| Area Served | 0.1 $km^2$ |
| Classification (O.Reg. 170/03) | Small municipal residential system (2) |
| Supply Well Location | Northern part Lot 40, Concession IV, Kingston Twp |
| Average Annual Volume ($m^3$) | 8,410 (3) |
| Average Monthly Volume | 701 (3) |
| Monitoring Well Locations | None designated |
| **Lansdowne Well Supply (2 wells) (DWS# 210001022)** | |
| Location | Lansdowne, Leeds and Thousand Islands Township |
| Population Served | 735 people served in the village of Lansdowne (4) |
| Area Served | 1.44 $km^2$ |
| Classification (O.Reg. 170/03) | Large municipal residential (5) |
| Supply Well Location | Southern part of Lot 18, Concession III, Lansdowne |
| Average Annual Volume ($m^3$) | 71,363 (6) |
| Average Monthly Volume | 5,947 (6) |
| Monitoring Well Locations | MW1: 419286 mE, 4917737 mN<br>MW2: 419287 mE, 4917737 mN<br>MW3: 419328 mE, 4918047 mN<br>MW4: 419328 mE, 4918049 mN<br>MW5: 419003 mE, 4917895 mN<br>Potential future wells shown in Fig. 2 of Malroz (2008) |
| **Miller Manor Apartments Well Supply (DWS# 260006958)** | |
| Location | Mallorytown, Leeds and Thousand Islands Township |
| Population Served | 17 unit residential apartment building in Mallorytown |
| Area Served | 0.0076 $km^2$ |
| Classification (O.Reg. 170/03) | Small municipal residential (7) |
| Supply Well Location | Northern part Lot 22 Broken Front, Yonge Township |
| Average Annual Volume ($m^3$) | 26.6 $m^3$/day (8) |
| Average Monthly Volume | n/a |
| Monitoring Well Locations | None designated |

1. Cana Well Supply – Drinking Water System Inspection Report, Ontario Ministry of the Environment, November 24, 2009
2. Utilities Kingston 2009 Annual Report – Cana Water Treatment System, Utilities Kingston, December 31, 2009
3. Utilities Kingston website or file provided by Utilities Kingston
4. Lansdowne Well Supply – Drinking Water System Inspection Report, Ontario Ministry of the Environment, November 2009
5. Lansdowne Annual Report, Leeds and the Thousand Islands, December 31, 2008
6. Ontario Clean Water Agency
7. Miller Manor Apartments Well Supply – Drinking Water System Inspection Report, Ontario Ministry of the Environment, September 15, 2009
8. Miller Manor Apartments Wellhead Protection Area Study, Golder Associates Ltd., July 2009

#### 5.2.1.4 Transport Pathways within Wellhead Protection Areas

As discussed in Section 5.2.1.2, vulnerability scoring is determined based on how easily *contaminants* can infiltrate into an *aquifer* as well as the presence of human-produced alterations. These anthropogenic alterations are termed *transport pathways* and can include ditches, pipelines, utility trenches, tile drains, sewer networks and other human-made features where water and other substances can potentially flow. The presence of a *transport pathway* can potentially increase the vulnerability scoring by producing additional conduits that could infiltrate to our drinking water supply.

The presence of a *transport pathway* alone does not increase the vulnerability rating automatically, but rather has to be determined significant enough to warrant an increase. The determination and assignment of vulnerability ratings and the specific locations of the *transport pathway* for each of the WHPAs are described in the subsequent sections below.

The following table indicates the presence of *transport pathways* (as well as watercourses) for each WHPA within the CSPA.

**Table 5-6: Transport Pathways & Watercourses in WHPAs**

| Well Supply | Transport Pathways | | | | Watercourses |
|---|---|---|---|---|---|
| | Ditches | Sewers | Utility Trenches | Wells | Streams |
| Cana* | ✓ | ✓ | ✓ | ✓ | ✓ |
| Lansdowne | ✓ | ✓ | ✓ | ✓ | |
| Miller Manor | ✓ | | ✓ | ✓ | |

* The watercourse in Cana represents a drainage swale

### 5.2.2 Cana Well Supply, City of Kingston

#### 5.2.2.1 The Drinking Water System and Its Context

Located in the northeastern part of Kingston, the Cana subdivision is a small residential community that was established as a cooperative development in the early 1950s (Trow Associates Inc., 2007). It is situated in the triangular area west of Highway 15, south and east of the Rideau Canal and north of Kingston Mills Road. Utilities Kingston operates a groundwater well, a water treatment plant (WTP) and a sewage treatment plant (located less than 100 metres west of the well) at this location. These facilities provide service to approximately 32 households in the community. The *drinking water system* is owned by the City of Kingston.

*Drinking water* for the Cana subdivision was formerly treated only with primary disinfection. Since late 2008, potable water has been supplied from a new well and a new WTP that includes both primary and secondary disinfection and polishing filters for iron removal. There is no water softening treatment method present at this time.

A Phase 1 WHPA study, which was completed as part of the Western Cataraqui Region Groundwater Study (Trow Associates Inc., 2007), provides general information about potential *threats* to the water supply in the area. A Phase 2 WHPA study was conducted by Golder Associates Ltd. (2009a) to delineate the *well capture zones* and to provide detailed information about *aquifer* vulnerability. The Cana Subdivision Wellhead Area Protection Study by Golder Associates Ltd. is included in **Appendix 'L-9'**.

The Cana supply well (18.6 metres deep) was drilled in November 2001 as a test well and was commissioned for use as a supply well in late 2008. According to the MOE well record, the well has 6.6 metres of steel casing. In order of increasing depth, the deposition of geologic materials include 2.4 metres of clay, 1.1 metres of sand, 3.8 metres of *sandstone*, and 11.3 metres of *granite*. At the time of drilling, the *static water level* was measured to be 2.2 metres below the top of the well casing, and water-bearing zones were encountered at 13.4 metres and 14.3 metres below the surface of the ground (Trow Associates Inc., 2004).

The *surficial geology*, *bedrock geology*, *hydrogeology* and *physiography* of the area surrounding the Cana *drinking water system* are described by Golder Associates Ltd. (2009a).

#### 5.2.2.2 Delineation of the Wellhead Protection Area

Golder Associates Ltd. (2009a) completed the Cana Subdivision Wellhead Protection Area Study using the following methods:

- a field component included a private well survey and *transport pathway* mapping
- a conceptual *model* describing the geological and hydrogeological system was developed through synthesis of existing data
- the *well capture zones* were delineated using calibrated three-dimensional numerical *models* with reverse particle tracking. The *models* were developed using MODFLOW (McDonald and Harbaugh, 1988)
- WHPA 'A', 'B', 'C' and 'D' were delineated using a weighted scenario approach
- WHPA 'E' was delineated to account for a "groundwater under the direct influence of *surface water* (*GUDI*)" designation
- groundwater vulnerability mapping was performed using the Intrinsic Susceptibility Index (ISI) protocol
- vulnerability scores were calculated.

The results of the WHPA delineation are summarized herein. The vulnerability mapping and scoring, *drinking water issue* evaluation and *threat* assessment are described below.

During the conceptual *model* development, hydrogeological and geological information from the WWIS was used to create northeast-southwest and northwest-southeast cross-sections (Golder Associates Ltd., 2009a). Six hydrogeological units were represented:

- clay (at the ground surface)
- sand

- *limestone*
- *sandstone*
- weathered *Precambrian bedrock*
- un-weathered *Precambrian bedrock*.

Contours of groundwater elevation were also inferred from the WWIS dataset. *Groundwater recharge* and *discharge* were assumed to occur at local uplands and lowlands (*wetlands* and *streams*), respectively (Golder Associates Ltd., 2009a).

A *calibrated* base case numerical *model* (a foundation *model*) was developed to simulate the observed groundwater elevations, inferred from the WWIS. Two additional scenarios were used to account for the uncertainty of some variables; the *groundwater recharge* rates and the *hydraulic conductivity* of the *Precambrian bedrock* (Golder Associates Ltd., 2009a). The *models* were run with the supply well pumping at 20 per cent greater than historical rates, to account for any future increased water usage in the Cana subdivision (although there is presently no plan for increased usage). Reverse-particle tracking (particles released in the supply well and their locations traced backwards through time) was conducted to determine the *well capture zones* (zero to two years, two to five years and five to 25 years) for each of the *modeled* scenarios.

WHPA 'A' was delineated at a radius of 100 metres from the supply well. WHPAs 'B', 'C' and 'D' were then mapped by drawing smooth polygons around the appropriate delineated *capture zones*. Professional judgment was used to determine the weighting of the *capture zones* from each of the three simulated scenarios to the final delineation of the WHPAs.

A limited *GUDI* assessment of the supply well was conducted, which resulted in a designation of potentially *GUDI* (Golder Associates Ltd., 2009a). The assessment was based on a review of existing data and previous research on the supply well, with reference to the *GUDI* criteria defined in Ontario Regulation 170/03 and the Terms of Reference for the Hydrogeological Study to Examine Groundwater Sources Potentially Under the Direct Influence of Surface Water (MOE, 2001).

The GUDI designation for the Cana Well Supply was based on the following factors:

- the detection of total coliforms in the *raw water*
- the shallow depth of the well and;
- the proximity of a watercourse (drainage swale) to the well.

For the delineation of WHPA 'E' it was assumed that the point of interaction between *surface water* and groundwater was the point at which WHPA 'A' intersected with the watercourse 30 metres to the south of the well (Golder Associates Ltd., 2009a). Please refer to the inset maps within **Maps 5-14** to **5-18** for the delineation of WHPA 'E'. If deemed necessary in future work, a WHPA 'F' will be delineated in conjunction with the delineation of an *issue contributing area*, as discussed in Section 5.2.2.4 below.

The final delineated WHPA for the Cana Well Supply is shown in **Map 5-12.** The total length of the WHPA is approximately 1.2 kilometres, and is oriented from the well towards the southeast.

The shape of the WHPA is based on the groundwater flow direction, water velocities, *gradient*, and hydraulic properties of the soil and rock. According to Golder Associates Ltd. (2009a), the Cana sewage treatment plant, private residences, industrial areas, natural areas and transportation corridors are all within the delineated WHPA. Golder Associates Ltd. assigned a low uncertainty rating to all of the zones.

#### 5.2.2.3 Vulnerability Scoring

A local assessment of groundwater vulnerability was completed for the Cana area, supplementing the Cataraqui-wide assessment that is discussed above. Golder Associates Ltd. (2009a) used two steps to assign vulnerability scoring for the Cana WHPA. First, the ISI protocol was used to conduct vulnerability mapping in WHPAs ‘A’ through ‘D’ (see **Map 5-13**). The ISI was calculated on the basis of the thickness of the clay layer and a K-Factor of six, which resulted in zones of medium and high vulnerability. This approach assumes that the weathered *Precambrian* is directly connected to the sand *overburden* (Golder Associates Ltd., 2009a). It is consistent with the Cataraqui-wide assessment of *aquifer* vulnerability that is described in Section 5.1.2.

Second, Golder Associates Ltd. considered the affect of *transport pathways* on the ISI results. The results of the private well survey and an additional *transport pathways* survey were used to identify potential *transport pathways* in the vicinity of the Cana well supply. Golder Associates Ltd. (2009a) observed four groundwater supply wells located at houses and buildings throughout the WHPA. It is estimated that there are up to six additional wells southeast of the subdivision, within the WHPA. In addition, there are also buried utility trenches, water mains and sewers located within the Cana subdivision, as well as a ditch (1.5 metres in depth) that runs along the east side of Canal Drive. These potential *transport pathways* were not considered significant enough to warrant the adjustment of the vulnerability ratings. Golder assigned a low uncertainty rating to the vulnerability mapping.

*Bedrock* outcrops are not recognized *transport pathways* and therefore, are not accounted for when determining vulnerability. However, rock outcrops are still important to consider as a component of the intrinsic groundwater vulnerability, similar to the presence of thin soils. In the Cana WHPA, *bedrock* outcrops are present on the north side of Rochdale Drive.

Using the results of the vulnerability mapping, the vulnerability scores were calculated for WHPAs ‘A’, ‘B’, ‘C’, and ‘D’ (see **Map 5-14**). The scores range from six to ten (Golder Associates Ltd., 2009a). The highest score (ten) is located within the 100 metre radius of the wellhead and in the vicinity of Highway 15 and the Canadian National Railway, and the lowest score (six), furthest away approximately one to 1.2 kilometres from the wellhead including Highway 401.

Similar to the above WHPA vulnerability calculations, the vulnerability of WHPA ‘E’ was calculated based on the Technical Rules: Assessment Report (MOE, 2009a) and represents a vulnerability score of seven. The area vulnerability factors that contribute to a more conservative vulnerability score in WHPA ‘E’ are based on the following (Golder Associates Ltd., 2009a):

- the amount of land (nearly 100 per cent)

- the presence of clay at the surface
- no identified *transport pathways* (within WHPA 'E').

### 5.2.2.4 Drinking Water Issue Evaluation

#### Water Quality in the Supply Well

According to a report by Trow Associates Inc. (2004), the water from the current supply well (the 2001-vintage test well in the referenced document) is of a better quality than the older 1950s-vintage supply well, but some substances exceed the benchmark used for *drinking water issue* evaluation. These include sodium, manganese and chloride. The concentrations of these substances decreased over the 72 hours of continuous pumping, leading the authors to expect that water quality will continue to improve with respect to these substances with continued use of the new well.

#### Water Quality in Monitoring Wells

Although no longer in use, data from the old supply wells may provide insight into overall groundwater quality in the area, especially in the *overburden* near the surface. This well was tested on a weekly basis for *Escherichia coli* and total coliform under the Drinking Water Information System. Data from this program spanning from 2003 to 2008 show events where *Escherichia coli* and total coliform exceeded acceptable levels. The majority of *Escherichia coli* exceedances appear to have occurred in the earliest sampling dates, but there is a continued presence of bacterial *contamination*. Treated (disinfected) water from the old supply well exceeded several aesthetic and operational guidelines, but did not surpass the health-related *chemical* guidelines.

Higher than acceptable concentrations of iron, *hardness* and manganese reported from the *raw water* in the old well are suspected to be from natural sources, while chloride, organic nitrogen and sodium may be the result of land uses in the surrounding area. It is important to note however, that some problems with the old well can be attributed to well integrity and not to *aquifer contamination*, therefore, these data should be interpreted with caution.

The Cana subdivision falls partially within WHPAs 'B', 'C' and 'D' of the Cana WHPA. Well water from the three test wells and two local wells in the Cana subdivision was tested for a variety of *chemical* and biological parameters in 1990. High levels of chloride, sodium, manganese and fluoride were found in some wells. All of the wells sampled had *hardness* above desirable levels, but no total coliform bacteria were detected.

One-time water quality sampling was also carried out at three neighbouring wells in July 2003 as part of a 72-Hour Pump Test (Trow Associates Inc., 2004). High levels of *hardness* were common at these wells. Iron, manganese, sodium and total dissolved solids also occurred at high concentrations at some wells and one well also exceeded the *drinking water issue* benchmark for chloride.

#### Drinking Water Issues

Based on all of the information sources discussed above, the protocol outlined in **Appendix 'E-1'** and the tests in rule 114 of the Technical Rules: Assessment Report (MOE, 2009a) the following parameters are considered as *drinking water issues* with potential human sources in the raw, untreated water for this *drinking water system*:

- *Escherichia coli*
- total coliform
- chloride
- sodium.

Iron, manganese, *hardness* and fluoride are likely naturally elevated, the result of local *geology* and not human *impacts* in the area.

For more detailed information about natural and human-source *drinking water issues*, please see **Appendix 'E-2', Table 2**. *Drinking water issues* for all municipal residential *drinking water systems* are summarized in **Appendix 'E-2', Table 1**.

#### Delineation of Issue Contributing Areas

There is not enough information to delineate the *issue contributing area* at this time. A detailed work plan for gathering this information is included in **Appendix 'E-3'.**

### 5.2.2.5 Threat Assessment

Two of the approaches that are outlined in Chapter 4 for the identification of *drinking water threats* are applicable to this location: the *issues* approach and the *threats* approach. Only the *threats* approach has been applied at this time.

#### Vulnerability Scoring and Threat Locations

Significant threats can occur in a WHPA with a vulnerability score of eight or higher with the exception of the handling, storage or transportation of *DNAPLs*; where a vulnerability score of two or higher can produce a significant *threat*. Therefore, a significant *threat* pertaining to *DNAPLs* can occur in all WHPA zones.

However, it is important to note that the predominant significant *threat* locations for the Cana subdivision occur within WHPAs 'A' and 'B' and portions of 'C'. It is in these zones where the vulnerability scores of eight or higher could numerically produce a significantly scored *threat* (see **Map 5-14**). Please refer to **Table 4-1** in Chapter 4 for a more detailed list of the *activities* that could produce a significant *threat*.

The areas where significant, moderate and low *drinking water threats* related to *chemicals, pathogens* and *DNAPLs* are shown on **Maps 5-15**, **5-16** and **5-17**, respectively. Similarly, areas where *conditions* may result in significant, moderate or low *threats* are shown in **Map 5-18**.

#### Historical and Existing Activities

The Cana subdivision is a hamlet that was historically an agricultural area. For this report, the Cana WHPA was surveyed for existing *activities* using the *threats* approach. Further research will be required to confirm whether or not any *conditions* exist.

Existing *activities* that are found within the WHPA include a water pumping facility, a sewage treatment plant, a gas station, a roads management work yard, industrial facilities and private residences. These are situated over 45 parcels of land.

Prescribed types of *drinking water threats* that are associated with these existing *activities* could include:

- the establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Ontario Environmental Protection Act
- the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
- the application of road salt
- the handling and storage of road salt
- the handling and storage of fuel
- the handling and storage of a dense non-aqueous phase liquid (*DNAPL*)
- the handling and storage of an organic solvent
- the use of a water softener
- the transportation of specified substances along corridors.

#### Transportation Corridors

Transportation corridors for the Cana WHPA are shown on **Map 5-19** and include local roadways, provincial highways and railways. Please refer to **Appendix 'I'** for a detailed list of transportation corridors within the Cana WHPA.

The main corridors within the Cana WHPA along which specified substances (*chemicals*) are or could be transported include:

- the Canadian National Railway
- Highway 15, Highway 401
- Kingston Mills Road, John F. Scott Road.

#### Investigation of Drinking Water Threat Activities

Investigation of the *drinking water threat activities* within the *vulnerable areas* of WHPAs 'A' through 'D' was conducted through research and landowner contact. Site visits to the Cana subdivision confirmed a total of 13 significant, 24 moderate and two low *threats*, respectively.

The prescribed *threats* associated with the 13 significant parcels include the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage (one parcel), and the handling and storage of fuel (seven parcels, with three parcels having both *activities*). The remaining two parcels with significant *threats* represent one land *activity* spanning both parcels. The *threats* occurring on the two parcels (in addition to the *threats* listed above) include the handling and storage of a *DNAPL* and the handling and storage of an *organic solvent*.

Of the twenty-four parcels with moderate *threats*, the *threat activities* associated with the land parcels include the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage (three land parcels, the handling and storage of fuel (14 parcels). An additional seven parcels include both of the above *threats*.

Low *threat activities* were found to occur on two parcels of land (one parcel associated with the handling and storage of fuel, and another parcel with land *activities* that include the storage of road salt, the handling and storage of fuel, the handling and storage of a *DNAPL* and the storage of an *organic solvent*).

#### Threat Activities along Transportation Corridors

In addition to the *threats* associated with individual parcels of land, *activities* along transportation corridors and sanitary sewer networks also contribute to the number of *threats* in the *vulnerable area*. The application of road salt on local and provincial roads contributes to six moderate and four low *threats* (dependant on the location of each road within the WHPA).

The transportation of specified substances along corridors contributes to nine significant, 14 moderate and three low *threats*, respectively. The transportation of specified substances includes fuel (ten moderate and one low *threat), pesticides* (two significant, two moderate and one low *threat*), *DNAPLs* (five significant *threats*) and *organic solvents* (two significant, two moderate and one low *threat*).

The sewer network also contributes one additional significant *threat*.

**Table 5-7** below provides an enumeration summary of *drinking water threats* present for the Cana Well Supply.  The table provides the total number of assessed parcels, total *threats* present and the ranking for each *threat* circumstance: significant (S), moderate (M) or low (L). **Table 5-8**, provides an expanded list of the threat *activities* and their occurrence within the Cana WHPA. For a more detailed outline of the *threats* and circumstances occurring within the Cana WHPA, please refer to **Table 1** of **Appendix 'H'.**

**Table 5-7: Cana Well Supply Drinking Water Threats Summary***

| Summary of Parcels with Identified Drinking Water Threats | | | | | Total Number of Parcels | | | Total Number of Threats within Parcels | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Threat Classification** | **WHPA "A"** | **WHPA "B"** | **WHPA "C"** | **WHPA "D"** | **S** | **M** | **L** | **S** | **M** | **L** |
| **Significant (S)** | 8 | 14 | 0 | 1 | 23 | | | 30 | | |
| **Moderate (M)** | 8 | 35 | 1 | 0 | | 44 | | | 52 | |
| **Low (L)** | 0 | 3 | 0 | 6 | | | 9 | | | 13 |
| **Total Number of Parcels** | 16 | 52 | 1 | 7 | 76 | | | | | |
| **Total Number of Threats Present**** | 17 | 66 | 2 | 10 | | | | 95 | | |

*The local *drinking water threat* of the use of water softeners is not included in the above summary table. It is assumed that each private well owner is using a water softener.
**Note: A parcel can have multiple *threats*. The transportation of *chemicals* along corridors, the application of salt on roads and sewer main line *threats* are enumerated within the total *threat* count.

**Table 5-8: Threat Type and Occurrence in Cana WHPA**

| DWT No | Drinking Water Threat | Total | Total Ranked Significant |
|---|---|---|---|
| 2 | Septic system, holding tank or other treatment | 14 | 3 |
| | Wastewater collection facility (sewer mainline & connections; does not include storage tanks or bypasses) | 1 | 1 |
| | Wastewater treatment facility (sewage treatment) | 1 | 1 |
| 12 | The application of road salt | 2 | - |
| 15 | The handling and storage of fuel | 35 | 12 |
| 16 | The handling and storage of DNAPLs | 3 | 2 |
| 17 | The handling and storage of an organic solvent | 3 | 2 |
| **Corridor Related Threats** | | | |
| 12 | Application of road salt on roads | 10 | - |
| local | Transportation of fuel | 11 | - |
| local | Transportation of pesticides | 5 | 2 |
| local | The transportation of a DNAPL | 5 | 5 |
| local | Transportation of an organic solvent | 5 | 2 |
| **Total** | | **95** | **30** |

#### Future Activities

As explained in Section 4.3, an *activity* that emerges in the future would be ranked as a *threat* to the *source water* if the underlying vulnerability score is high enough for it to be listed in the Tables of Drinking Water Threats (MOE, 2009d) as a significant, moderate, or low *threat*.

Land uses associated with *activities* that would be *threats* may or may not be permitted in the current municipal official plan and zoning by-law. An initial review of the relevant planning documents has been completed to assess which land uses are currently permitted in the *vulnerable area*; partial findings are provided below for the information of the reader.

The Cana WHPA is located in the City of Kingston. WHPA ‘A’ is characterized by residential uses (City of Kingston, 2009; Township of Pittsburgh, 2008). WHPAs ‘B’, ‘C’ and ‘D’ contain residential, commercial, institutional, industrial and other rural permitted uses that are associated with prescribed *drinking water threats*. All of the non-residential designations and zones that permit these uses are associated with prescribed *drinking water threats* will need to be reviewed. A review will help determine if changes to the permitted uses in general or to specific properties should be recommended as part of the *source protection plan*.

The City of Kingston is in the process of preparing a zoning by-law to implement the recently adopted official plan. This process will provide an opportunity to flag certain zones and/or permitted land uses for further analysis prior to the completion of the *source protection plan*.

#### 5.2.2.6 Conclusions and Next Steps

Golder Associates Ltd. (2009a) completed a study of the Cana *drinking water system* to delineate a WHPA around the supply well. A corresponding *drinking water issues* evaluation and a *threats* assessment were conducted by the CRCA. These efforts have investigated the areas from where the groundwater potentially travels to reach the supply well, and have also evaluated potential *activities* and *conditions* which can affect the groundwater quality.

From the WHPA delineation exercise, Golder Associates Ltd. (2009a) indicated where additional information would improve the findings. In particular, the certainty of the groundwater flow direction in the vicinity of the Cana Well Supply would be improved through the installation of at least three *monitoring* wells (and may result in the delineation of a smaller WHPA). The proposed *monitoring* wells may be useful for the delineation of an *issue contributing area* (as discussed above). Golder Associates Ltd. also recommends that future bacteriological results from the supply well should be monitored. If total coliform counts are persistent then a *GUDI* designation might be recommended (Golder Associates Ltd., 2009a).

Peer review of the study by Golder Associates Ltd. (2009a) was completed by XCG Consultants Ltd. Comments were integrated into the final report. Generally, peer review indicated that limitations exist in methodologies used and uncertainty must be acknowledged, however the work was well done and insightful within the confines of the data.

An uncertainty analysis was completed on the *hydrogeological model* to account for limited knowledge of *recharge* and *hydraulic conductivity* values. These scenarios were integrated into the final delineation of the WHPA. The uncertainty, as per Technical Rules 13 and 14, with respect to these WHPAs is considered to be low. The details of the uncertainty analyses are provided in the <u>Cana Subdivision Wellhead Area Protection Study</u> by Golder Associates Ltd. (**Appendix 'L-9'**).

### 5.2.3 Lansdowne Well Supply

#### 5.2.3.1 The Drinking Water System and Its Context

The community of Lansdowne is situated on the *Frontenac Arch* of the *Canadian Shield* and is located in the Township of Leeds and the Thousand Islands between Gananoque and Mallorytown, north of Highway 401 and County Road 2. Within Lansdowne, County Road 3 (Prince Street/Outlet Road) runs north-south and County Road 34 runs east-west with the Canadian National Railway intercepting the south portion of the village. The municipal groundwater system supplies drinking water and sanitary services to approximately 735 people within the village of Lansdowne.

Raw groundwater is collected from two supply wells that were drilled in 1974, located in the northern part of the village. The first well is 50 metres deep. It was drilled through 2.5 metres of clay, 16 metres of *sandstone*, and 31.5 metres of granitic *gneiss*. Both well casings extend to a 3.5 metre depth. The second well is also 50 metres deep. It was drilled through two metres of clay, 15 metres of *sandstone*, and 33 metres of granitic *gneiss*.

The raw groundwater is treated using an on-site treatment system operated by the Ontario Clean Water Agency (OCWA). Treatment upgrades were completed in 2010. Prior to the upgrades, the

*raw water* coming into the Lansdowne well supply was disinfected only by sodium hypochlorite injection (chlorination) using the appropriate contact time. Following the upgrades, a three filter (coarse, medium, fine) system and an ultraviolet light disinfectant system were added to treat the *raw water* prior to the chlorination process (MOE, 2010).
There is no water softening treatment methods present at this time.

A regional groundwater study was conducted for the United Counties of Leeds and Grenville area in 2001; it provides general information about the vulnerability of *aquifers* in the area to *contamination* (Dillon Consulting Ltd., 2001).

Two preliminary WHPA studies were conducted by Malroz Engineering Inc. (2004, 2008) for the CRCA to delineate *well capture zones* around the Lansdowne well supply and to provide detailed information about *aquifer* vulnerability in those zones. Malroz Engineering Inc. (2008) describes the surface *geology*, *bedrock geology*, *hydrogeology* and *physiography* of the area surrounding the community of Lansdowne.

A peer review evaluation by Golder Associates (2008) indicated that further evaluation of the WHPA would be required to more accurately delineate the WHPA. A third WHPA study completed by Geofirma Engineering Ltd. (2011) (formerly Intera Engineering Ltd.) provides the basis for the *wellhead protection areas* in this *Assessment Report* (see **Appendix 'L-6'**).

#### 5.2.3.2 Delineation of the Wellhead Protection Area

Geofirma Engineering Ltd. (2011) completed the Lansdowne Wellhead Protection Area Study using the following methods:

- a field component included six to eight hour pumping tests on two *monitoring* wells, straddle packer testing on one *monitoring* well to establish *hydraulic conductivity* values for the geological *model*, groundwater sampling and *chemical* analysis, a private well survey and *transport pathway* mapping
- a *conceptual model* describing the geological and hydrogeological system was developed through synthesis of existing data
- the *well capture zones* were delineated using calibrated three-dimensional numerical *models* with reverse particle tracking. The *models* were developed using MODFLOW (McDonald and Harbaugh, 1988)
- WHPA 'A', 'B', 'C' and 'D' were delineated using a weighted scenario approach
- WHPA 'E' was delineated to account for a "potentially groundwater under the direct influence of *surface water* (*GUDI*)" designation
- groundwater vulnerability mapping was performed using the ISI method
- vulnerability scores were calculated.

The results of the WHPA delineation are summarized herein. The vulnerability mapping and scoring, *drinking water issue* evaluation and *threat* assessment are described below.

Three hydrogeological units were represented in the MODFLOW *model* to differentiate between the *sandstone* weathered and non-weathered *Precambrian aquifers*.

A calibrated base case numerical *model* (foundation *model*) was developed to simulate the observed groundwater elevations, inferred from the WWIS. Two additional scenarios were used to account for the uncertainty of some variables; the *groundwater recharge* rates and the *hydraulic conductivity* of the *sandstone* (vertical and horizontal) *Precambrian bedrock aquifers* (Geofirma Engineering Ltd., 2011). Reverse-particle tracking (particles released in the supply well and their locations traced backwards through time) was conducted to determine the *well capture zones* (zero to two years, two to five years and five to 25 years) for each of the *modeled* scenarios.

WHPA 'A' was delineated at a radius of 100 metres from the supply well. WHPAs 'B', 'C' and 'D' were then mapped by drawing smooth polygons around the appropriate delineated *capture zones*. Professional judgment was used to determine the weighting of the *capture zones* from each of the three simulated scenarios to the final delineation of the WHPAs.

A limited *GUDI* assessment of the supply well was conducted, which resulted in a designation of potentially *GUDI* (Geofirma Engineering Ltd., 2011). The assessment was based on a review of existing data and previous research on the supply well, with reference to the *GUDI* criteria defined in Ontario Regulation 170/03 and the Terms of Reference for the Hydrogeological Study to Examine Groundwater Sources Potentially Under the Direct Influence of Surface Water (MOE, 2001).

The *GUDI* designation for the Lansdowne municipal wells was based on the following factors:

- continued positive detection of total coliforms in the *raw water*
- the shallow depth of the wells and;
- the reported ponding of water on the surface near the wells.

As discussed earlier in this chapter, cascading water has also been reported in the supply wells at a depth of six metres below ground surface at a rate of 45 litres per minute (Malroz Engineering Inc., 2003). It is suspected that this fracture represents a direct pathway from ground surface to the well.

As the Lansdowne municipal wells are considered to be "potentially *GUDI*", a WHPA 'E' was subsequently required. The delineation of WHPA 'E' was determined by (Geofirma Engineering Ltd., (2011). According to the Technical Rules: Assessment Report (MOE, 2009a), WHPA 'E' is delineated based on the "point of interaction" between the municipal groundwater *capture zone* and the *surface water* influencing this groundwater supply. In the case of Lansdowne, no *surface water* body exists; therefore, for the purpose of delineating WHPA 'E', the "point of interaction" is defined as the municipal well location (where the municipal well intersects the *surface water*).

According to the Technical Rules: Assessment Report (MOE, 2009a), a WHPA 'E' comprises two parts:

- The area within the *surface water* body where the time of travel is equal or less than the time that is sufficient to allow the operator of the system to respond to an adverse condition in the quality of the *surface water* (minimum of two hours)
- A maximum 120 metre setback onto land if the area within the *surface water* body abuts land.

For the Lansdowne municipal wells where there is no surface water body identified. Part 1 of WHPA 'E' was not delineated and therefore, the WHPA 'E' was defined entirely as a 120 metre radius around each well.

If deemed necessary in future work, a WHPA 'F' will be delineated in conjunction with the delineation of an *issue contributing area*, as discussed in Section 5.2.3.4 below.

The *capture zones* for the WHPA are shown on **Map 5-20.** The area is based on the combination of the *capture zones* for both supply wells. The total area of WHPA'D' is 60.8 hectares (approximately 150 acres) 4.5 kilometres, the total width is approximately 1.1 kilometres, and is oriented to the northeast to southwest of the pumping wells. The shape of the WHPAs is based on the groundwater flow direction, water velocities, *gradient*, and hydraulic properties of the soil and rock.

#### 5.2.3.3 Vulnerability Scoring

A local assessment of groundwater vulnerability was completed for the Lansdowne area, supplementing the Cataraqui-wide assessment that is discussed above. Geofirma Engineering Ltd. (2011) used two steps to assign vulnerability scoring for the Lansdowne WHPA.

First, the ISI protocol was used to conduct vulnerability mapping in WHPAs 'A' through 'D'. This method uses the thickness and type of soil overlaying the *aquifer* to determine the degree of protection the soil provides. To conduct the ISI calculation, Geofirma Engineering Ltd. considered the total thickness of the *overburden* and *bedrock* above the *water table*. The *overburden* was assigned a K-Factor of three for weathered clay while the *bedrock* was assigned a K-Factor of one. In supplementing the Cataraqui-wide assessment of groundwater vulnerability, Geofirma Engineering Ltd. determined that it was appropriate to assume that water moves relatively slowly through the *bedrock* underneath Lansdowne. The results of these calculations are shown on **Maps 5-21**.

Second, Geofirma Engineering Ltd. considered the effect of *transport pathways* on the ISI results. Although several types of *transport pathway* were identified in the WHPAs, their presence did not warrant the adjustment of the vulnerability ratings. The rationale for not adjusting the vulnerability ratings was because the entire area was already deemed to be highly vulnerable to *contamination* from the surface.

Using the results of the vulnerability mapping, the vulnerability scores were calculated for WHPA 'A', 'B', 'C', and 'D' (see **Map 5-22**) in accordance to the Technical Rules: Assessment Report (MOE, 2009a). The vulnerability scores range from six to ten (Geofirma Engineering Ltd., 2011), with the highest score (ten) located within a 100 metre radius of the wellhead and the two year *time of travel* and the lowest score (six) in the area furthest away in WHPA 'D'.

WHPA 'A' is assigned a high vulnerability score despite the depth of the wells. As noted above, the wells at Lansdowne are 50 metres in depth and extend through both *Paleozoic* and *Precambrian* rock. The wells are cased to 3.5 metres below ground surface. Despite the overall depth of the wells, there is evidence to suggest that a direct connection exists from the ground surface to the supply.

Similar to the vulnerability calculations for WHPAs 'A' through 'D', WHPA 'E' was calculated based on the Technical Rules: Assessment Report (MOE, 2009a). The WHPA 'E' vulnerability score for Lansdowne is nine (the highest score possible for WHPA 'E'). Geofirma Engineering Ltd. (2011) has classified the wells as potentially *GUDI*, even though there are no adjacent water bodies. The factors for the vulnerability score and the potential *GUDI* classification relate to:

- continued positive bacteriological results in the supply wells
- cascading water in both supply wells observed by Geofirma Engineering Ltd. 2009, as well as being earlier reported by Malroz Engineering Inc., 2003 (at a depth of six metres below the ground surface at a rate of 45 litres per minute)
- potential poor well seals around the wells and/or fractures in the rock may create direct pathways from the ground surface to the well.

### 5.2.3.4 Drinking Water Issue Evaluation

#### Water Quality in the Supply Wells

*Raw water* was characterized in the January 2001 Engineer's Report, referenced in Lansdowne Well Supply Drinking Water System Inspection Reports by the Ontario Ministry of the Environment (2004 - 2007). In samples collected between 1999 and 2000, low levels of total coliform were detected. The groundwater also had high *hardness*, sodium and total colour. Both samples collected from Lansdowne as part of the United Counties of Leeds and Grenville Groundwater Management Study (Dillon Consulting Ltd., 2001) had elevated sodium and *hardness*.

Between 2003 and 2008, well # 1 was sampled more frequently and for more water quality parameters than well # 2 under the provincial Drinking Water Information System. Results show that both total coliform and *Escherichia coli* occurred at low concentrations in both wells during that period. Lansdowne Water Treatment Plant Annual Reports from 2007 and 2008 also show low concentration bacterial events in *raw water* and a single event where sodium concentrations exceeded 20 milligrams per litre (the benchmark for *drinking water issue* evaluation).

A Lansdowne Well Supply Drinking Water System Inspection Report produced by the Ontario Ministry of the Environment for the 2008-2009 sampling period indicates that Well # 2 had been taken off line in September 2008 and was to remain offline until bacterial *drinking water issues* are addressed. With the upgrades to the drinking water system complete, both wells were in regular use by December 2010 (Ontario Clean Water Agency, 2011).

There is no evidence of radiological or health-related parameters in excess of the Ontario Drinking Water Quality Standards in the treated water. *Raw water* data are not available for this well source. Because of this well's location, there is no information available for *monitoring* sites.

#### Drinking Water Issues

Based on the above information, the protocol outlined in **Appendix 'E-1'** and the tests in rule 114 of the Technical Rules: Assessment Report (MOE, 2009a), the following parameters are considered as *drinking water issues* with potential human sources in the raw, untreated water for this *drinking water system*:

- *Escherichia coli*
- total coliform.

The remainder of the *drinking water issues* discussed above are considered to be natural characteristics of the *source water* for this system.

For more detailed information about natural and human source *drinking water issues*, please see **Appendix 'E-2', Table 3**. *Drinking water issues* for all municipal residential *drinking water systems* are summarized in **Appendix 'E-2', Table 1**.

#### Delineation of Issue Contributing Areas

There is not enough information to delineate the *issue contributing area* (and *wellhead protection area* 'F') at this time. A detailed work plan for gathering this information is included in **Appendix 'E-3'.**

### 5.2.3.5 Threat Assessment

Two of the approaches that are outlined in Chapter 4 for the identification of *drinking water threats* are applicable to this location: the *issues* approach and the *threats* approach. Only the *threats* approach has been applied at this time.

#### Vulnerability Scoring and Threat Locations

Significant threats can occur in a WHPA with a vulnerability score of eight or higher with the exception of the handling, storage or transportation of *DNAPLs*; where a vulnerability score of two or higher can produce a significant *threat*. Therefore, a significant *threat* pertaining to *DNAPLs* can occur in all WHPA zones.

However, it is important to note that the predominant significant *threat* locations for Lansdowne occur within WHPAs 'A', 'B' and 'C'. It is in these zones where the vulnerability scores of eight or higher could numerically produce a significantly scored *threat* (see **Map 5-22**). Please refer to **Table 4-1** in Chapter 4 for a more detailed list of the *activities* that could produce a significant *threat*.

The areas where significant, moderate and low drinking water *threats* related to *chemicals, pathogens*, *DNAPLs* could occur are shown **Maps 5-23**, **5-24** and **5-25**, respectively. Similarly, areas where *conditions* may result in significant, moderate or low *threats* are shown in **Map 5-26**.

#### Historical and Existing Activities

Lansdowne is a village that historically serviced the surrounding agricultural community. For this report, Lansdowne WHPA was surveyed for only for existing *activities* using the *threats* approach. Further research will be required to confirm whether or not any *conditions* exist.

Existing *activities* that are found within the WHPA include wells, sewage treatment (lagoons), private residences, a public works garage (road salt building) and municipal office, retail, grocery and hardware stores, restaurants, an elementary school, community hall and library, storage facilities, agricultural and livestock related *activities*, and are situated over a total of approximately 245 parcels of land.

Prescribed types of *drinking water threats* that are associated with these existing *activities* could include:

- the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
- the application of *agricultural source material* to land
- the storage of *agricultural source material*
- the handling and storage of *non-agricultural source material*
- the application of commercial fertilizer to land
- the handling and storage of commercial fertilizer
- the application of *pesticide* to land
- the handling and storage of *pesticide*
- the application of road salt
- the handling and storage of road salt
- the handling and storage of fuel
- the handling and storage of a dense non-aqueous phase liquid (*DNAPL*)
- the handling and storage of an *organic solvent*
- the use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard
- the use of a water softener
- the transportation of specified substances along corridors.

#### Transportation Corridors

Transportation corridors for the Lansdowne WHPA are shown on **Map 5-27** and include county roads and several local roadways. The Canadian National Railway runs southeast through Lansdowne and is just outside of the Lansdowne WHPA. Please refer to **Appendix 'I'** for a detailed list of transportation corridors within the Lansdowne WHPA.

The main corridors within the Lansdowne WHPA along which specified substances (*chemicals*) are or could be transported include:

- County Road 3 (Prince Street/Outlet Road)
- Eden Grove Road.

#### Investigation of Drinking Water Threat Activities

Investigation of the *drinking water threats* through research and landowner contact confirmed that there are 64 significant, 106 moderate and 41 low *threat activities* associated with land parcels within the Lansdowne WHPA.

Of the 64 parcels with significant *threats*, 58 relate to significant *activities* on individual parcels of land. Seven parcels have two or more significant *threats* (with five parcels with four to nine significant *threats*). The main significant *threats* in Lansdowne include the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage, the application and storage of *agricultural source material* to land, the handling and storage of commercial fertilizer, the application of *pesticide* to land, the handling and storage of fuel (49 parcels) and the handling and storage of a *DNAPL*.

As well as the significant *threats*, there are also 86 parcels with moderate *drinking water threats* and 27 with low *drinking water threats*, respectively. Similar to the significant *threats*, the majority of moderate and low *threats* relate to the use of a septic system, the handling and storage of fuel and agricultural related *activities*.

#### Threat Activities along Transportation Corridors

In addition to the *threats* associated with individual parcels of land, *activities* along transportation corridors and sanitary sewer networks also contribute to the number of *threats* in the *vulnerable area*. The application of road salt contributes to five moderate and eleven low (dependant on the location of each road within the WHPA).

The transportation of specified substances along corridors contributes to six significant, 15 moderate and three low threats, respectively. The transportation of specified substances includes fuel (15 moderate and three low *threats*); *pesticides* (two significant *threats*); *DNAPLs* (two significant *threats*); and of *organic solvents* (two significant *threats*).

The sewer network also contributes one additional significant *threat*.

**Table 5-9** below provides an enumeration summary of *drinking water threats* present for the Lansdowne Well Supply. The table provides the total number of assessed parcels, total *threats* present and the ranking for each *threat* circumstance: significant (S), moderate (M) or low (L). **Table 5-10**, provides an expanded list of the threat *activities* and their occurrence within the Lansdowne WHPA. For a more detailed outline of the *threats* and circumstances occurring within the Lansdowne WHPA, please refer to **Table 2** of **Appendix 'H'.**

### Table 5-9: Lansdowne Well Supply Drinking Water Threats Summary*

| Summary of Parcels with Identified Drinking Water Threats | | | | | Total Number of Parcels | | | Total Number of Threats within Parcel | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Threat Classification** | **WHPA "A"** | **WHPA "B"** | **WHPA "C"** | **WHPA "D"** | **S** | **M** | **L** | **S** | **M** | **L** |
| **Significant (S)** | 4 | 60 | 0 | 0 | 64 | | | 77 | | |
| **Moderate (M)** | 0 | 26 | 80 | 0 | | 106 | | | 127 | |
| **Low (L)** | 0 | 8 | 2 | 31 | | | 41 | | | 52 |
| **Total Number of Parcels** | 4 | 94 | 82 | 31 | 211 | | | | | |
| **Total Number of Threats Present**** | 11 | 106 | 100 | 39 | | | | 256 | | |

*The local *drinking water threat* of the use of water softeners is not included in the above summary table. It is assumed that each private well owner is using a water softener.
**Note: A parcel can have multiple *threats*. The transportation of *chemicals* along corridors, the application of salt on roads and sewer main line threats are enumerated within the total *threat* count.

### Table 5-10: Threat Type and Occurrence in the Lansdowne WHPA

| DWT No | Drinking Water Threat | Total | Total Ranked Significant |
|---|---|---|---|
| 2 | Septic system, holding tank or other treatment | 5 | 3 |
| | Wastewater collection facility (sewer mainline & connections; does not include storage tanks or | 1 | 1 |
| | Wastewater treatment facility (lagoons) | 1 | - |
| 3 | Application of agricultural source material to | 12 | 4 |
| 4 | Storage of agricultural source material to land | 2 | 2 |
| 7 | Handling and storage of non-agricultural source | 1 | - |
| 8 | Application of commercial fertilizer to land | 12 | 4 |
| 9 | Handling and storage of commercial fertilizer | 1 | - |
| 10 | Application of pesticide to land | 12 | 4 |
| 13 | Storage of road salt | 1 | - |
| 15 | Handling and storage of fuel | 160 | 49 |
| 16 | Handling and storage of a DNAPL | 2 | 2 |
| 17 | Handling and storage of an organic solvent | 2 | - |
| 21 | Livestock grazing, pasturing and/or outdoor confinement, farm-animal yard | 4 | 2 |
| **Corridor Related Threats** | | | |
| 12 | Application of road salt on roads | 16 | - |
| local | Transportation of fuel | 18 | - |
| local | Transportation of pesticides | 2 | 2 |
| local | The transportation of a DNAPL | 2 | 2 |
| local | Transportation of an organic solvent | 2 | 2 |
| **Total** | | **256** | **77** |

#### Future Activities

As explained in Section 4.3, an *activity* that emerges in the future would be ranked as a *threat* to the *source water* if the underlying vulnerability score is high enough for it to be listed in the Tables of Drinking Water Threats (MOE, 2009d) as a significant, moderate, or low *threat*.

Land uses associated with *activities* that would be *threats* may or may not be permitted in the current municipal official plan and zoning by-law. An initial review of the relevant planning documents has been completed to assess which land uses are currently permitted in the *vulnerable area*; partial findings are provided below for the information of the reader.

The Lansdowne WHPA is located in the Township of Leeds and the Thousand Islands. The applicable designations and zones allow a variety of residential, commercial, institutional and agricultural uses that could be associated with prescribed *drinking water threats* (J.L. Richards & Associates Limited for Township of Leeds and the Thousand Islands, 2006 and 2007). The relevant designations and zones that permit these uses will need to be reviewed to determine if changes to the permitted uses in general or to specific properties should be recommended as part of the *source protection plan*.

### 5.2.3.6 Conclusions and Next Steps

Malroz Engineering Inc. (2004, 2008) completed two preliminary phase studies of the Lansdowne *drinking water system* to delineate a WHPA around the supply wells. A third phase WHPA study has been completed by Geofirma Engineering Ltd. (2011). A corresponding *drinking water issues* evaluation and a *threats* assessment were conducted by the CRCA. These efforts have investigated the areas from where the groundwater potentially travels to reach the supply well, and have also evaluated potential *activities* and *conditions* which can affect the groundwater quality.

Peer review of the study by was completed by Golder Associates Ltd. (2011). Comments were integrated into the final report.

An uncertainty analysis was completed on the *hydrogeological model* to account for limited knowledge of *recharge* and *hydraulic conductivity* values. These scenarios were integrated into the final delineation of the WHPA. The uncertainty, as per Technical Rules 13 and 14, with respect to the delineation and the vulnerability scoring of this WHPA is considered to be:

- Low for WHPA ‘A’ and ‘E’, since they have a specified radius around the wells
- Low for WHPA ‘D’, based on confidence in the direction of groundwater flow and *geology*
- High for WHPA ‘B’ and ‘C’, based on uncertainty in the *bedrock porosity* and resultant *hydraulic conductivity.*

The details of the uncertainty analyses are provided in the Geofirma Engineering Ltd. (2011) report (**Appendix ‘L-6’**).

## 5.2.4 Miller Manor Apartments Well Supply, Mallorytown

### 5.2.4.1 The Drinking Water System and its Context

The Miller Manor Apartments is located at 3 Miller Drive (north of County Road 2 and west of County Road 5) in the village of Mallorytown in the Township of Front of Yonge. It is a two-storey building with 17 one-bedroom units that is owned and operated by the United Counties of Leeds and Grenville.

*Drinking water* for the Miller Manor Apartments is obtained from a groundwater well on the property. The facility is also serviced by an on-site sewage (septic) treatment system. Because of its location where the vulnerability score is ten, the septic system has been enumerated as a significant drinking *water threat* to this *drinking water system*. At this time the United Counties of Leeds and Grenville are working to make substantial improvements to the septic system.

The Miller Manor Apartments supply well (36.3 metres deep) was drilled and commissioned for use in July 2007. According to the MOE well record, the well has 6.6 metres of steel casing. In order of increasing depth, the geologic materials above the *granite* include 4.8 metres of clay, 1.8 metres of *limestone,* and 29.7 metres of *granite*. At the time of drilling, the *static water level* was measured to be 5.9 metres below the surface of the ground, and a water-bearing zone was encountered at 33 metres below the surface of the ground. The previous supply well was decommissioned in July 2007.

The raw groundwater is treated for the *drinking water system* using an on-site treatment system for disinfection (formerly by chlorine, now by ultraviolet light) and water softening. The *drinking water system* is operated by A.J.'s Water Treatment (based in Mallorytown). The Miller Manor Apartments is classified by the MOE as having a municipal residential *drinking water system* due to its size and public ownership.

A regional groundwater study was conducted for the United Counties of Leeds and Grenville area in 2001; it provides general information about the vulnerability of *aquifers* in the area to *contamination* (Dillon Consulting Ltd., 2001). A more focused WHPA study was conducted by Golder Associates Ltd. for the CRCA (2009b) to delineate *well capture zones* around the Miller Manor Apartments well supply and to provide detailed information about *aquifer* vulnerability in those zones. The study report is included in **Appendix 'L-10'**.

Golder Associates Ltd. (2009b) describes the surface *geology*, *bedrock geology*, *hydrogeology* and *physiography* of the area surrounding the Miller Manor Apartments.

### 5.2.4.2 Delineation of the Wellhead Protection Area

Golder Associates Ltd. (2009b) completed the Miller Manor Apartments Wellhead Protection Area Study using the following methods:

- a field component included a private well survey and *transport pathway* mapping
- a pumping test (6.9 hours duration) was conducted to determine the *transmissivity* of the *aquifer* (how easily the water is transmitted below the surface of the ground) surrounding the supply well

- a conceptual *model* describing the geological and *hydrogeological* system was developed through synthesis of existing data
- the *well capture zones* were delineated using calibrated three-dimensional numerical *models* with reverse particle tracking. The *models* were developed using MODFLOW (McDonald and Harbaugh, 1988)
- WHPA 'A', 'B', 'C' and 'D' were delineated using a weighted scenario approach
- a limited *groundwater under the direct influence of surface water* (*GUDI)* assessment was conducted
- groundwater vulnerability mapping was performed using the Intrinsic Susceptibility Index protocol
- vulnerability scores were calculated.

The results of the WHPA delineation are summarized herein, and the vulnerability mapping and scoring, *drinking water issue* evaluation and *threat* assessment are outlined below.

During the *conceptual model* development, *hydrogeological* and geological information from the WWIS was used to create northeast-southwest and northwest-southeast cross-sections (Golder Associates Ltd., 2009b). Three hydrogeological units were represented:

- clay (at the ground surface)
- weathered *Precambrian bedrock* and
- un-weathered *Precambrian bedrock*.

Contours of groundwater elevation were also inferred from the WWIS dataset. *Groundwater recharge* and *discharge* were assumed to occur at local uplands and lowlands (*wetlands*, ditches and *streams*), respectively (Golder Associates Ltd., 2009b).

A calibrated base case numerical *model* was developed to simulate the observed groundwater elevations (inferred from the WWIS). Two additional scenarios were used to account for the uncertainty of some variables (the *hydraulic conductivity* of the weathered *Precambrian bedrock*, and the *recharge* rate applied to the exposed *bedrock* in close proximity to the Miller Manor Apartments Well Supply) (Golder Associates Ltd., 2009b).

The *models* were run with the supply well pumping at ten per cent greater than historical rates, to simulate any future increased water usage (there is no plan to add additional apartment units to the building). According to Golder Associates Ltd. (2009b), a pumping at a rate of 0.72 cubic metres per day was also incorporated into the *models* at each of the domestic wells (located in Mallorytown) to account for the possibility that their pumping could significantly influence the groundwater flow direction in the vicinity of the Miller Manor Apartments Well Supply. Reverse-particle tracking (particles released in the supply well and their locations traced backwards through time) was conducted to determine the *well capture zones* (zero to two years, two to five years and five to 25 years) for each of the *modeled* scenarios.

WHPA 'A' was delineated at a radius of 100 metres from the supply well. WHPAs 'B', 'C' and 'D' were then mapped by drawing smooth polygons around the appropriate delineated *capture* *zones*. The WHPA boundaries fully include all the simulated particle traces, and an equal weighting was given to the three different scenarios (Golder Associates Ltd., 2009b).

Based on a limited *GUDI* assessment, it was interpreted that the Miller Manor Apartments supply well may be considered as non *GUDI*. The assessment was based on a review of existing data and previous research on the supply well, with reference to the *GUDI* criteria defined in the Ontario Regulation 170/03 and the Terms of Reference for the Hydrological Study to Examine Groundwater Sources Potentially Under the Direct Influence of Surface Water (MOE, 2001). Golder Associates Ltd. (2009b) found that no apparent connectivity exists between the water-bearing zone and *surface water* features, and that the groundwater quality data does not indicate *surface water contamination*.

The final delineated WHPA for the Miller Manor Apartments supply well is shown on **Map 5-28**. The total length of the WHPA is approximately one kilometre, and is oriented from the well towards the north-northeast. According to Golder Associates Ltd. (2009b), private residences (with wells and septic tanks), commercial areas, a school, natural/undeveloped areas, transportation corridors, recreational areas and agricultural areas are within the delineated WHPA.

Golder Associates Ltd. (2009b) assigned a high uncertainty rating to WHPAs ‘A’ through ‘D’. This high uncertainty rating arises since the *hydraulic conductivity* (which strongly controls the size and shape of the WHPA) of the weathered *Precambrian bedrock aquifer* is not known with certainty.

#### 5.2.4.3 Vulnerability Scoring

A local assessment of groundwater vulnerability was completed for the vicinity of the Miller Manor Apartments Well Supply, supplementing the Cataraqui-wide assessment that is discussed above. Golder Associates Ltd. (2009b) used two steps to assign vulnerability scoring for the Miller Manor Apartments WHPA.

First, the ISI protocol was used to conduct vulnerability mapping in WHPAs ‘A’ through ‘D’ (see **Map 5-29**). The ISI was calculated on the basis of the thickness of the clay layer and a K-Factor of six, which resulted in zones of medium and high vulnerability (Golder Associates Ltd., 2009b). The method is consistent with the Cataraqui-wide assessment of *aquifer* vulnerability that is described in **Section 5.1.2**. Two areas of medium vulnerability were identified where the *overburden* thickness is between five and ten metres.

Second, Golder Associates Ltd. considered the effect of *transport pathways* on the ISI results. Potential *transport pathways* in the vicinity of the Miller Manor Apartments supply well were identified during the private well survey, during an additional *transport pathways* survey and during the pumping test. According to Golder Associates Ltd. (2009b), 34 groundwater supply wells are located at houses and buildings throughout the WHPA (with up to an estimated 35 additional wells that could not be observed from the road during the survey, based on the assumption that there is a well at each house or building).

To account for these potential *transport pathways* (specifically the wells and utility trenches), the ISI vulnerability mapping was adjusted from medium to high within parts of the WHPA, where supply wells and buried utility trenches exist. Storm sewers are also present in the area. These areas are enclosed with a dashed line on-**Map 5-29**. Golder Associates Ltd. (2009b) assigned a low uncertainty rating to the vulnerability mapping, as the thickness of the soil (clay layer) is reasonably well defined.

*Bedrock* outcrops are not recognized *transport pathways* and therefore, are not accounted for when determining vulnerability. However, rock outcrops are still important to consider as a component of the intrinsic groundwater vulnerability, similar to the presence of thin soils. In the Miller Manor WHPA, *bedrock* outcrops are present along the south side of County Road 2 near Miller Drive and east of Quabbin Road as well as along the north side of Quabbin Road.

Using the results of the modified vulnerability mapping, the vulnerability scores were calculated for WHPAs 'A' through 'D' (see **Map 5-30**). The scores range from four to ten (Golder Associates Ltd., 2009b) where the highest score (ten) is located within a 100 metre radius of the wellhead and the two year *time of travel* and the lowest score (four) is located within the 25 year *time of travel*.

### 5.2.4.4 Drinking Water Issue Evaluation

#### Water Quality in the Supply Well

There is limited water quality information available for Miller Manor due to the recent commissioning of the current *drinking water* well. The Drinking Water Information System does however reveal multiple positive results for total coliform. In the Annual Summary for Miller Manor submitted by AJ's Water Treatment (2007), elevated levels of uranium were detected. More *monitoring* carried out over the 2008 reporting period showed that uranium was present atup to 0.014 milligrams per litre, most likely owing to the *weathering* of natural deposits in the area and not from human sources.

The Miller Manor Apartments Engineer's Report for Water Works, reporting on the *drinking water* well that was decommissioned in 2007, shows that the source had multiple positive results for *Escherichia coli* and total coliform, and exceeded aesthetic objectives for chloride and sodium in 2003 *monitoring* results (Eastern Engineering Group Inc., 2004 in Miller Manor Apartments Well Supply Drinking Water System Inspection Report (MOE, 2007)). The source also had high *hardness* and elevated nitrate concentrations (detailed information in **Appendix 'E-2', Table 4**).

Similarly, bacterial occurrences were reported under the Drinking Water Information System (MOE, 2003-2007). The *monitoring* carried out has revealed regular bacterial events in the untreated water (total coliform and, to a lesser extent, *Escherichia coli*).

#### Water Quality at Monitoring Sites

Groundwater data from a grouping of five wells in Zone 'D' of the Miller Manor Apartments WHPA was compiled in the United Counties of Leeds and Grenville Groundwater Management Study (Dillon Consulting Ltd., 2001). At these *monitoring* sites, concentrations of chloride, *hardness*, sodium and nitrate exceeded benchmark values for *drinking water issue* evaluation when they were tested in 1989-1990.

#### Drinking Water Issues

Based on the above information, the protocol provided in **Appendix 'E-1'** and the tests in rule 114 of the Technical Rules: Assessment Report (MOE, 2009a), the following parameters are considered *drinking water issues* with potential human sources in the raw, untreated water for this system:

- *Escherichia coli*
- total coliform
- chloride
- sodium
- nitrate.

The remainder of the *drinking water issues* discussed above are considered to be natural characteristics of the *source water* for this system.

For more detailed information about natural and human source *drinking water issues,* please see **Appendix 'E-2', Table 4**. *Drinking water issues* for all municipal residential *drinking water systems* are summarized in **Appendix 'E-2', Table 1**.

#### Delineation of Issue Contributing Areas

There is not enough information to delineate the *issue contributing area* at this time. A detailed work plan for gathering this information is included in **Appendix 'E-3'.**

### 5.2.4.5 Threat Assessment

Two of the approaches that are outlined in Chapter 4 for the identification of *drinking water threats* are applicable to this location: the *issues* approach and the *threats* approach. Only the approach has been applied at this time.

#### Vulnerability Scoring and Threat Locations

Significant *threats* can occur in a WHPA with a vulnerability score of eight or higher with the exception of the handling, storage or transportation of *DNAPLs*; where a vulnerability score of two or higher can produce a significant *threat*. Therefore, a significant *threat* pertaining to *DNAPLs* can occur in all WHPA zones.

However, it is important to note that the predominant significant *threat* locations for Miller Manor occur within WHPAs 'A' and 'B'. It is in these zones where the vulnerability scores of eight or higher could numerically produce a significantly scored *threat* (see **Map 5-30**). Please refer to **Table 4-1** in Chapter 4 for a more detailed list of the *activities* that could produce a significant *threat*.

The areas where significant, moderate and low *drinking water threats* related to *chemicals, pathogens* and *DNAPLs* could occur are shown **Maps 5-31**, **5-32** and **5-33,** respectively. Similarly, areas where *conditions* may result in significant, moderate or low *threats* are shown in **Map 5-34**.

#### Historical and Existing Activities

Mallorytown is a village that has serviced the surrounding agricultural community for over 100 years. However, for this report, the Miller Manor Apartments WHPA was surveyed for existing *activities* only using the *threats* approach. Further research will be required to confirm whether or not any *conditions* exist.

Existing *activities* that are found within the WHPA include an apartment complex, a retail store, an elementary school, a restaurant, a municipal fire station, agricultural and livestock related *activities*, and private residences. These are situated over a total of approximately 110 parcels of land.

Prescribed types of *drinking water threats* that are associated with these existing *activities* could include:

- the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage
- the application of road salt
- the handling and storage of road salt
- the handling and storage of fuel
- the handling and storage of an *organic solvent*
- the use of land as livestock grazing or pasturing land, and outdoor confinement area or a farm-animal yard
- the use of a water softener
- the transportation of specified substances along corridors.

#### Transportation Corridors

Transportation corridors for the Miller Manor WHPA are shown on **Map 5-35** and include local roadways, provincial highways and railways. Please refer to **Appendix 'I'** for a detailed list of transportation corridors within the Miller WHPA.

The main corridors within the Miller Manor WHPA along which specified substances (*chemicals*) are or could be transported include:

- County Road 2
- Quabbin Road (County Road 4).

#### Investigation of Drinking Water Threat Activities

Investigation of the *drinking water threats* through research and landowner contact confirmed that there are 17 significant, 16 moderate and 71 low *threat activities* associated with land parcels within the Miller Manor WHPA.

Of the 17 parcels where significant *threats* were found, all parcels had significant *threats* classified as the establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage. Five of the parcels also had significant *threats* classified as the handling and storage of fuel with one parcel producing an additional significant *threat* for the use of land as livestock grazing or pasturing land and/or as an outdoor confinement area for one or more animals.

Similar to land *activities* that produce significant *drinking water threats*, the presence of sewage systems (septic systems and holding tanks), the handling and storage of fuel and agricultural related *activities* also produce 16 moderate and 71 low *threats* within the WHPA zones.

#### Threat Activities along Transportation Corridors

In addition to the *threats* associated with individual parcels of land, *activities* along transportation corridors also contribute to the number of *threats* in the *vulnerable area*. The application of road salt, results in two moderate and five low *threats* (dependant on the location of each road within the WHPA).

The transportation of specified substance along corridors contributes to three significant, five moderate and two low *threats*. The transportation of fuel contributes five moderate and two low *threats*; and the transportation of *pesticides*, *DNAPLs* and *organic solvents* each contribute one significant *threat*, respectively.

**Table 5-11** below provides an enumeration summary of *drinking water threats* present for the Miller Manor Apartments Well Supply. The table provides the total number of assessed parcels, total *threats* present and the ranking for each *threat* circumstance: significant (S), moderate (M) or low (L). **Table 5-12**, provides an expanded list of the threat *activities* and their occurrence within the Miller Manor WHPA. For a more detailed outline of the *threats* and circumstances occurring within the Miller Manor WHPA, please refer to **Table 3** of **Appendix 'H'.**

**Table 5-11: Miller Manor Well Supply Drinking Water Threats Summary***

| Summary of Parcels with Identified Drinking Water Threats | | | | | Total Number of Parcels | | | Total Number of Threats within Parcels | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Threat Classification** | **WHPA "A"** | **WHPA "B"** | **WHPA "C"** | **WHPA "D"** | **S** | **M** | **L** | **S** | **M** | **L** |
| **Significant (S)** | 17 | 3 | 0 | 0 | 20 | | | 26 | | |
| **Moderate (M)** | 4 | 0 | 18 | 0 | | 22 | | | 34 | |
| **Low (L)** | 0 | 0 | 2 | 77 | | | 79 | | | 125 |
| **Total Number of Parcels** | 21 | 3 | 20 | 77 | 121 | | | | | |
| **Total Number of Threats Present**** | 28 | 7 | 28 | 122 | | | | 185 | | |

*The local *drinking water threat* of the use of water softeners is not included in the above summary table. It is assumed that each private well owner is using a water softener.
**Note: A parcel can have multiple *threats*. The transportation of *chemicals* along corridors, the application of salt on roads and sewer main line *threats* are enumerated within the total *threat* count.

**Table 5-12: Threat Type and Occurrence in the Miller Manor WHPA**

| DWT No | Drinking Water Threat | Total | Total Ranked Significant |
|---|---|---|---|
| 2 | Septic system, holding tank or other treatment | 102 | 17 |
| 3 | Application of agricultural source material to land | 2 | - |
| 4 | Storage of agricultural source material to land | 1 | - |
| 8 | Application of commercial fertilizer to land | 2 | - |
| 10 | Application of pesticide to land | 2 | - |
| 13 | Storage of road salt | 1 | - |
| 15 | Handling and storage of fuel | 56 | 5 |
| 17 | Handling and storage of an organic solvent | 1 | - |
| 21 | Livestock pasturing, outdoor confinement, farm-animal yard | 1 | 1 |
| **Corridor Related Threats** | | | |
| 12 | Application of road salt on roads | 7 | - |
| local | Transportation of fuel | 7 | - |
| local | Transportation of pesticides | 1 | 1 |
| local | The transportation of a DNAPL | 1 | 1 |
| local | Transportation of an organic solvent | 1 | 1 |
| **Total** | | **185** | **26** |

#### Future Activities

As explained in Section 4.3, an *activity* that emerges in the future would be ranked as a *threat* to the *source water* if the underlying vulnerability score is high enough for it to be listed in the Tables of Drinking Water Threats (MOE, 2009d) as a significant, moderate, or low *threat*.

Land uses associated with *activities* that would be *threats* may or may not be permitted in the current municipal official plan and zoning by-law. An initial review of the relevant planning documents has been completed to assess which land uses are currently permitted in the *vulnerable area*; partial findings are provided below for the information of the reader.

The Miller Manor Apartments WHPA is located in the community of Mallorytown in the Township of Front of Yonge. The predominant permitted land uses are residential and commercial uses that could be associated with prescribed *drinking water threats* (Novatech Engineering Consultants Ltd. for Township of Front of Yonge, 2006 and 2008). All of the non-residential designations and zones that permit these uses are associated with prescribed *drinking water threats* will need to be reviewed. A review will determine if changes to the permitted uses in general, or to specific properties should be recommended as part of the *source protection plan*.

### 5.2.4.6 Conclusions and Next Steps

Golder Associates Ltd. (2009b) completed a study of the Miller Manor Apartments *drinking water system* to delineate a WHPA around the supply well. A corresponding *drinking water issues* evaluation and a *threats* assessment were conducted by the CRCA. These efforts have investigated the areas from where the groundwater potentially travels to reach the supply well, and have also evaluated *activities* and *conditions* which can affect the groundwater quality.

Golder Associates Ltd. (2009b) identified the following topics for which additional information would improve this WHPA study:

- In the area of the exposed *bedrock* south of the Miller Manor, the groundwater elevations are unknown (this could be remedied by the installation of *monitoring* wells in that specific area)
- The movement of water in the *bedrock aquifer* (outside the radius of influence of the pumping test) is uncertain (this could be determined with longer-duration pumping tests).

The additional information could perhaps result in a smaller WHPA (Golder Associates Ltd., 2009b).

Peer review of the study by Golder Associates Ltd. (2009b) was completed by XCG Consultants Ltd. Comments were integrated into the final report. Generally, peer review indicated that limitations exist in methodologies used and uncertainty must be acknowledged, however the work was well done and insightful within the confines of the data.

An uncertainty analysis was completed on the *hydrogeological model* to account for limited knowledge of *recharge* and *hydraulic conductivity* values. These scenarios were integrated into the final delineation of the WHPA. The uncertainty, as per Technical Rules 13 and 14, with respect to these WHPAs is considered to be high. The details of the uncertainty analyses are provided in the Golder Associates Ltd. report (**Appendix 'L-10'**).

## 5.2.5 Westport Well Supply

### 5.2.5.1 The Drinking Water System and Its Context

The Village of Westport is located 50 kilometres north of Kingston and lies within the Rideau Valley Conservation Authority (RVCA) jurisdiction. The reader is invited to review the *Assessment Report* for the Mississippi-Rideau Source Protection Region for more information about this *vulnerable area*.

Water is supplied to 650 people in the Village of Westport. The WHPA study, completed by Malroz Engineering Inc. (2009), provides delineated *well capture zones* and provides vulnerability mapping. A report on *transport pathways* was completed by Dillon Consulting Ltd. (2009) as a supplement to the WHPA report. The Village of Westport Wellhead Protection Area Study is included in this *Assessment Report* because Malroz Engineering Inc. (2009) determined that the WHPA extends into the CSPA.

The *drinking water* source for the Village of Westport consists of two wells that draw groundwater from a *sandstone aquifer*. There is also a *monitoring* well. The first supply well was constructed in 1969 and is 34 metres deep. It was drilled through ten metres of clay with sand and silt, one metre of *limestone* and 19 metres of *sandstone*. The well casing extends to ten metres depth. The second supply well was constructed in 2003 and is 40 metres deep. It was drilled through 20 metres of clay with sand and gravel, 16 metres of *sandstone* and four metres of quartz conglomerate. The well casing extends to 21 metres depth.

The wells are permitted to take 532 and 900 cubic metres per day; however the average collection rate in 2007/2008 was 327 and 46.9 cubic metres per day, respectively. Water from these two wells is disinfected and pumped to a water tower for distribution. A phosphate-based additive is used to prevent corrosion in the water tower and distribution system.

The *surficial geology*, *bedrock geology*, *hydrogeology* and *physiography* of the area surrounding the Westport *drinking water system* are described in Malroz Engineering Inc. (2009).

#### 5.2.5.2 Delineation of the Wellhead Protection Area

The Village of Westport Wellhead Protection Area Study was completed by Malroz Engineering Inc. (2009). The methods used for the delineation of the WHPA are described in the *Assessment Report* for the Mississippi-Rideau Source Protection Region (2010).

The results of the WHPA delineation are summarized herein. The vulnerability mapping and scoring, *drinking water issue* evaluation, and *threat* assessment are described below.

WHPA ‘A’ was delineated at a radius of 100 metres from the supply well. WHPAs ‘B’, ‘C’ and ‘D’ were then mapped by drawing smooth polygons around the appropriate delineated *capture zones*. Professional judgment was used to determine the weighting of the *capture zones* from each of the three simulated scenarios to the final delineation of the WHPAs.

A stable isotope study of groundwater and *surface water* samples indicated that the supply wells are not under the influence of *surface water*. The supply wells, therefore, do not require a WHPA ‘E’ or ‘F’.

The final delineation of the WHPA for the Village of Westport supply wells is shown on **Map 5-36.** The total length of the WHPA is approximately 3.2 kilometres, and is oriented from the well towards the southwest. Most of the WHPA is located within the Mississippi Rideau Source Protection Region, but approximately 0.5 kilometres of the total length (WHPA ‘D’) enters the CSPA.

#### 5.2.5.3 Vulnerability Scoring

A local assessment of groundwater vulnerability was completed for the vicinity of the Westport Well Supply, supplementing the area-wide assessments in the Cataraqui Source Protection Area and the Mississippi-Rideau Source Protection Region. Malroz Engineering Inc. (2009) used the ISI method to conduct vulnerability mapping in WHPAs ‘A’ through ‘D’ (see **Map 5-37**). This method uses the thickness and type of soil overlaying the *aquifer* (clay) to determine the degree of protection the soil provides. The ISI calculation resulted in areas of medium and high vulnerability (Malroz Engineering Inc., 2009).

*Transport pathways* were mapped by Dillon Consulting Ltd. (2009). *Transport pathways* considered present, or potentially present, within the WHPA consisted of wells, sewers, septic systems, sand/gravel pits and *bedrock* quarries.

Using the results of the vulnerability mapping, the vulnerability scores were calculated for WHPAs ‘A’ through ‘D’ (see **Map 5-38**). The scores range from two to ten (Malroz Engineering Inc., 2009).

#### 5.2.5.4 Drinking Water Issue Evaluation

##### Water Quality in the Supply Well

The evaluation of water quality at the Westport well supply was completed by Dillon Consulting Ltd.(2009) and focused on water quality from the supply wells. No water quality data from within the Cataraqui Source Protection Area was evaluated. For a review of the *source water* quality information available for the Westport well supply, please refer to the *Assessment Report* for the Mississippi-Rideau Source Protection Region (2010, forthcoming).

##### Drinking Water Issues

The Mississippi-Rideau Source Protection Committee has not identified any *drinking water issues* related to the Westport supply well.

For detailed information about *source water* quality for the Westport well supply, please see the *Assessment Report* for the Mississippi-Rideau Source Protection Region (2010, forthcoming).

#### 5.2.5.5 Threat Assessment

Two of the approaches that are outlined in Chapter 4 for the identification of *drinking water threats* are applicable to this location: the *issues* approach and the *threats* approach. Only the *threats* approach has been applied at this time; the *issues* approach may be applied in the future, pending the delineation of the *issue contributing area*.

##### Existing Activities

Only a portion of the Westport WHPA ‘D’ falls within the CSPA and was surveyed for existing *activities* using the *threats* approach. Further research will be required to confirm whether or not any *conditions* exist.

The highest vulnerability score in Westport WHPA ‘D’ is six out of ten; therefore, any *threats* found within this area cannot numerically be ranked as significant (see **Map 5-38**). For detailed list of the *activities* that could produce a significant *threat*, please see **Table 4-1** in Chapter 4.

The areas where significant, moderate and low *drinking water threats* related to *chemicals*, *pathogens*, *DNAPLs* and *conditions* could occur within the Westport WHPA are shown on **Maps 5-39**, **5-40** and **5-41**. Similarly, areas where *conditions* may result in significant, moderate and low *threats* are shown on **Map 5-42**.

The portion of WHPA ‘D’ that falls within the CSPA consists of only two parcels of land. Existing *activities* that are found on these parcels of land include agricultural related *activities*. Given the vulnerability scores of four and six, it is impossible for the above *threat* to be significant in the portion of WHPA ‘D’ that extends into the CSPA.

No transportation corridors exist within the portion of the WHPA ‘D’ that falls within the CSPA (see **Map 5-43**) and therefore, there is no corridors present for the transport of specified substances (*chemicals*).

Prescribed types of *drinking water threats* that are associated with these existing *activities* could include:

- the application of *agricultural source material* to land
- the application of commercial fertilizer to land
- the application of *pesticide* to land.

**Table 5-13** below provides a summary of *drinking water threats* present for the Westport drinking water system in WHPA "D". The table provides the total number of assessed parcels, total *threats* present and the ranking for each *threat* circumstance: significant (S), moderate (M) or low (L). Refer to **Table 4** of **Appendix 'H'** for a more detailed list of the *threats* and circumstances for each of the parcels occurring within both the Westport WHPA and the Cataraqui Source Protection Area.

**Table 5-13: Westport Well Supply Drinking Water Threats Summary**

| Summary of Parcels with Identified Drinking Water Threats | | Total Number of Parcels | | | Total Number of Threats |
|---|---|---|---|---|---|
| **Threat Classification** | **WHPA "D"** | **S** | **M** | **L** | |
| Significant (S) | 0 | 0 | | | 0 |
| Moderate (M) | 0 | | 0 | | 0 |
| Low (L) | 1 | | | 1 | 3 |
| Total Number of Parcels | 1 | 1 | | | |
| Total Number of Threats Present* | 3 | | | | 3 |

*Note: A parcel can have multiple *threats*

#### Future Activities

As explained in Section 4.3, an *activity* that emerges in the future would be ranked as a *threat* to the *source water* if the underlying vulnerability score is high enough for it to be listed in the Tables of Drinking Water Threats (MOE, 2009d) as a significant, moderate, or low *threat*.

Land uses associated with *activities* that would be *threats* may or may not be permitted in the current municipal official plan and zoning by-law. An initial review of the relevant planning documents has been completed to assess which land uses are currently permitted in the *vulnerable area*; partial findings are provided below for the information of the reader.

The predominant permitted land uses are residential and agricultural uses that are associated prescribed *drinking water threats* (Novatech Engineering Consultants Ltd. for Township of Rideau Lakes, 2004 and 2005). The rural designation and zone permit uses that are associated with prescribed *drinking water threats* will need to be reviewed to determine if changes to the permitted uses in general or to specific properties should be recommended as part of the *source protection plan*.

### 5.2.5.6 Conclusions and Next Steps

Malroz Engineering Inc. (2009) completed a study of the Westport *drinking water system* to delineate a WHPA around the supply well. A corresponding *drinking water issues* evaluation and a *threats* assessment were conducted for the Mississippi-Rideau Source Protection Region. These efforts have investigated the areas from where the groundwater potentially travels to reach the supply well and have also evaluated potential *activities* and *conditions* which can affect the groundwater quality.