Regional Municipality of Peel

# Wellhead Protection Area Delineations and Vulnerability Assessments for Alton 1-2 Standby Wells, Cheltenham PW1/ PW2 Amended PTTW, and Caledon Village Proposed Well 5 (TW2-05).

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Report Submitted to:

Regional Municipality of Peel

AquaResource Inc.

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# EXECUTIVE SUMMARY

This report presents the results of additional wellhead protection area delineations and groundwater vulnerability assessment completed for the groundwater systems located in the Villages of Alton, Caledon Village, and Cheltenham in the Town of Caledon, the Regional Municipality of Peel. The study was completed as part of the Region of Peel's Drinking Source Water Protection initiatives, and it represents a step in the continuous improvement of the hydrogeological characterization of the Region's municipal drinking water sources. This work accomplishes the tasks outlined in the Region of Peel Terms of Reference dated October 29, 2007 and the subsequent workplan by AquaResource Inc. dated November 5, 2007. The project tasks were carried in accordance with the MOE Guidance Module for Groundwater Vulnerability Analysis, Draft Module 3 (MOE, 2006). This supplementary study lays the foundation for further analysis of issues, threats and concerns to municipal drinking water supplies and the subsequent Water Quality Risk Assessment for the stand-by/expended Peel systems in Alton, Caledon Village, and Cheltenham. The specific systems that constituted the subject of this assessment included stand-by Alton Wells 1 and 2; Cheltenham Wells PW1/PW2 (under the PTTW amendment review), and the Caledon Village 3/3A system (subject to potential future expansion through a proposed new well (currently test well TW2-05)).

This study examined the intrinsic vulnerability ranking and scoring of the Region of Peel's water supplies to surficial sources of contamination using three unique methodologies including (i) the intrinsic susceptibility index (ISI) method similar to that conducted for all existing municipal systems in the Credit Valley watershed in 2007 (AquaResource, 2007), (ii) the Surface to Well Advection Time (SWAT) method, and (iii) the Watertable to Well Advective Time (WWAT) method. The vulnerability assessments were completed following the MOE Draft Guidance Module 3, and the vulnerability scores can be carried forward by the Region of Peel in their future Water Quality Risk Assessments. The SWAT and WWAT methodologies provided a more in depth look at the vulnerability of the municipal aquifer based on the physical nature of the groundwater flow system. The study also included the potential contaminant source inventory within the newly delineated WHPAs for these systems.

***Alton 1-2***

Vulnerability within the capture zones delineated for Alton Wells 1-2 is high and there are some potential threats to the groundwater supply at this wellfield. Furthermore, water quality monitoring completed at this wellfield indicate the concentrations of chloride and nitrate have been rising in the past three decades. As outlined in previous studies, the primary threats to the Alton 1-2 wellfield are residential septic systems within the Village of Alton, and road salting practices in the Village. There is also a local automotive service centre within the capture zone that may also pose a threat to the water supply, as the municipal aquifer is largely unconfined and considered to be susceptible to surficial sources of contamination.

***Caledon Village 3- TW2-2005***

Vulnerability within the time of travel capture zones for Caledon Village 3/3A and TW2-2005 (Proposed Well 5) is predominately high, and aggregate extraction activities currently taking place within the capture zones pose the greatest threat to the water quality at the wells. Water quality monitoring completed at the Well 3/3A wellfield show low to moderate concentrations of

chloride, nitrate and sodium, however wells that are screened in the shallow aquifer exhibit higher chloride concentrations than those screened deeper in the aquifer. Road salting practices along Highway 10, residential septic systems, and the nearby aggregate extraction practices are known to be potential contaminant sources within the capture zones.

***Cheltenham PW1/ PW2***

Vulnerability was mapped in this study as moderate throughout all of the Cheltenham PW1/PW2 sensitivity zones. Water quality monitoring completed at the Cheltenham wellfield is generally good, with very few exceedences of the Ontario Drinking Water Standards, and those exceedences are interpreted to be naturally occurring (e.g. iron from underlying Queenston Formation bedrock). The few potential contaminant sources mapped within the capture zones, are largely rural in nature, and include agricultural activities, septic systems, and road salting practices.

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES



## LIST OF APPENDICES

# 1 Introduction

AquaResource Inc. (AquaResource) was retained by the Regional Municipality of Peel (Peel Region) to delineate capture zones, and map the groundwater vulnerability and potential contaminant sources in three municipal water supply systems located within the Credit River Watershed; Alton Wells 1-2, Caledon Village Well 3 and Proposed Well 5 (TW2-2005), and Cheltenham PW1/PW2. This study represents an update to two studies completed in 2007 by AquaResource; the 'Region of Peel WHPA Study' (AquaResource, 2007a), and 'Capture Zone Analysis for Caledon Village – PW3/3A and TW-2-2005' Memo (AquaResource, 2007b). The methodologies and modeling tools used in those previous studies were also used in this study for consistency. A summary of relevant information from the previous studies is outlined throughout this report, however additional details and information can be found in the above noted reports.

## 1.1 Scope of Work

The Terms of Reference for this study (Region of Peel, October 2007) identify the primary objectives of the study as follows:

- Delineate the 2-year, 5-year, and 25-year time-of-travel (TOT) capture zones for Alton Wells 1-2 utilizing currently permitted pumping rate; and for Cheltenham PW1/ PW2 and Caledon Village 3/3A /TW2-2005 utilizing increased pumping rates.
- Delineate and map the 100m fixed radius pathogen security zone for Alton Wells 1-2, Caledon Village 3/3A and TW2-2005 and Cheltenham PW1/PW2.
- Map the WHPA sensitivity zones A, B, C, D as per MOE Guidance Module 3.
- Assess the intrinsic vulnerability within the 25-year TOT capture zones (MOE, 2006a) for the three wellfields noted above utilizing the intrinsic susceptibility index (ISI) and surface to well advective time (SWAT) methods.
- Finalize the vulnerability scores for each sensitive area within the 25-year TOT for each of the updated WHPAs (MOE, 2006a).
- Update the mapping of potential contaminant sources within the updated Alton 1-2, Cheltenham PW1/ PW2 and Caledon Village Well 3/3A /TW2-2005 capture zones; and
- Discuss uncertainties as applicable.

# 2 Previous WHPA and Groundwater Vulnerability Studies

This report is supplementary to the Region of Peel wellhead protection area (WHPA) study and groundwater vulnerability assessment completed in 2007 (AquaResource, 2007a) for the active Peel municipal wellfields located within the Credit River watershed. The previous WHPA delineation and vulnerability assessment were conducted in Alton (Wells 3 and 4), Caledon Village (Wells 3 and 4), Inglewood (Wells 1, 2 and 3), and Cheltenham (PW1/ PW2), located within the Town of Caledon and the Credit River Watershed. The study was completed as part of the 2006 Region of Peel's Source Protection initiatives, and was supported through funding provided by the Ministry of the Environment's 2005-2006 Source Protection Grant Program. The 2007 study (AquaResource, 2007a) and the current study, represent a step forward in the continuous improvement of the hydrogeological characterization of the Region of Peel's municipal groundwater resources and in terms of potential water takings from selected systems. All of the work followed the MOE Guidance Module for Groundwater Vulnerability Analysis, Draft Guidance Module 3 (MOE, 2006) and it forms the basis for future Water Quality Risk Assessments and threats assessments conducted within WHPAs of the Region's municipal drinking water supplies.

## 2.1 Hydrogeologic Characterization

The 2007 WHPA and vulnerability study (AquaResource, 2007a) built upon the existing regional interpretations used to generate the CVC Regional (watershed-scale) Model and improved on the characterization in the vicinity of each of the four Region of Peel wellfields located in the Credit River Watershed. The hydrogeologic characterization benefitted from years of regional characterization and modelling. Local scale characterization in the vicinity of each wellfield was refined with the generation and interpretation of twenty-five local-scale cross-sections, and examination of local scale water level and water quality data.

## 2.2 Numerical Modelling and Wellhead Protection Area Delineation

The CVC Regional Model was developed using the software program FEFLOW, a modelling tool that simulates three-dimensional, groundwater flow conditions. The wellhead protection areas delineated in the 2007 study (AquaResource, 2007a) were notably different in some areas than those zones delineated in previous studies carried out in the 1990s. Boundary conditions and limited extent of regional interpretations posed limitations for earlier models, and groundwater flow in previous models was forced to follow directions imposed by more restrictive interpretations.

Since the 1990s, the Region of Peel's drilling, well testing and data collection programs have provided borehole, water level, water quality, tritium age dating and other sources of information, to help refine the hydrostratigraphic characterization and groundwater flow system within each of the wellhead areas.

WHPA capture zone delineation methods are discussed in Section 4 and Appendix 2 of the MOE's Guidance Module 3 (2006) and the approaches employed in the WHPA study for Peel municipal wells located within the Credit River watershed are discussed in Sections 2.1, 2.2 and 3.5 of the WHPA Study report by AquaResource (2007a). The outputs of the reverse particle tracking carried as part of the WHPA Study reflect the upward projection of the 'time-of-travel' results onto a plan view. As the time of travel delineations do not account for full vertical flow through the subsurface, they are considered to be very conservative. However, this conservatism compensates for potential direct preferential pathways such as improperly abandoned boreholes that can rapidly transmit contaminants from surficial or subsurface sources to underlying aquifers. This method of capture zone delineation is the Ontario Ministry of the Environment recommended method for delineating WHPAs.

### 2.3 Vulnerability Assessment

The vulnerability assessment and scoring were carried out utilizing the ISI method as well as Surface to Well Advection Time (SWAT), and Watertable to Well Advective Time (WWAT) methods. The SWAT and WWAT methodologies provided a more in depth look at the vulnerability of the municipal aquifer based on the physical nature of the groundwater flow system.

### 2.4 Potential Contaminant Sources Mapping

A windshield survey was completed within the four 25-year capture zones as part of the 2007 WHPA Study (AquaResource, 2007a). Land use conditions within the capture zone were recorded based on what could be seen from the road, and judgment calls were made regarding the potential for contaminant sources to exist at a given location.

The rural nature of these wellfields resulted in relatively few potential contaminant sources and those that were identified were mapped and catalogued for use in future Water Quality Risk Assessments.

# 3 Study Methodology

## 3.1 Groundwater Flow Modeling

The numerical groundwater flow model used in this study built upon earlier work completed for the Peel Region (see Section 2.1 of AquaResource Inc. 2007a). The groundwater flow model used to delineate the capture zones was developed using the finite element application FEFLOW (WASY, 2006). The model was originally developed at a regional scale for the Credit Valley Conservation, and it was refined locally in the Alton, Caledon Village, Inglewood, and Cheltenham areas to meet the requirements of the MOE Technical Terms of Reference (2001) and the MOE Guidance Module 3 (2006) for capture zone delineation.

The groundwater flow model used in the previous Region of Peel WHPA Study (AquaResource, 2007a, b) was used in this study, and the only changes made to the groundwater flow model were updates to the capture zone delineation pumping rates for Cheltenham PW1/ PW2 and Alton Wells 1-2. The remaining boundary conditions, input parameters and other model parameters remained unchanged. Table 1 below outlines the capture zone delineation rates applied in this study.

**Table 1: Capture Zone Delineation Rates**

| Well | Capture Zone Delineation Pumping Rate ($m^3$/day) | | | |
|---|---|---|---|---|
| | Peel WHPA Study[1] | Caledon Village WHPA Study[2] | | Rates Applicable to Current Study |
| | | Scenario 1 | Scenario 2 | |
| Alton Wells 1-2 | Capture zones not delineated. | | | 1309 |
| Caledon Village 3 | 1964 | 1964 | 1964 | 1964 |
| Caledon Village 3A | 0 | 1305 | 0 | 1305 |
| TW2-2005 | 0 | 0 | 2281 | 2281 |
| Cheltenham PW1/ PW2 | 500 | | | 1469 |

[1] AquaResource, 2007a
[2] AquaResource, 2007b

The capture zones presented for Caledon Village Wells 3/3A and TW2-2005 in this study represent a total capture zone that encompasses the capture zones delineated in the Caledon Village study (AquaResource, 2007b). The capture zones delineated under the two pumping scenarios (Table 1) were very similar in size and shape to the base case capture zones delineated in the AquaResource 2007a study.

## 3.2 Wellhead Protection Area Delineation Methodology

The following time-of-travel capture zones were delineated for Alton Wells 1-2 and Cheltenham PW1/ PW2 using the rates outlined in Table 1 above: 2-year, 5-year, 10-year, and 25-year capture zones as prescribed by the MOE (MOE, 2001 and MOE, 2006a). In addition, a 100 m fixed radius zone was mapped around each municipal well as suggested in the guidance (MOE, 2006a). For additional discussion regarding the delineation of the time of travel capture zones, please refer to Section 2.2 in the Peel WHPA Study (AquaResource, 2007a).

## 3.3 Vulnerability Mapping Within the Capture Zones

The relative vulnerability of an aquifer to contamination can be defined as the tendency or likelihood that a contaminant introduced at a location on the ground surface will reach an aquifer of interest. Vulnerability, therefore, is a relative indication of the degree to which the aquifer is susceptible to contamination introduced at ground surface. The aquifer vulnerability is categorized as high, medium/ moderate or low depending on the geologic and hydrogeologic properties surrounding the aquifer of interest.

An assessment utilizing ISI method was undertaken (see Section 2.4 AquaResource, 2007a) to identify the vulnerability of the groundwater resources to surficial sources of contamination. The same ISI vulnerability assessment was conducted in this study, to map and examine the vulnerability within the updated capture zones. In addition, the current study included relative vulnerability ranking and scoring utilizing the time of travel Surface to Well Advection Time (SWAT), and Watertable to Well Advective Time (WWAT) methods. The SWAT and WWAT methodologies provided a more in depth look at the vulnerability of the municipal aquifer based on the physical nature of the groundwater flow system.

### 3.3.1 Intrinsic Vulnerability Mapping – ISI- Based Method

The Intrinsic Susceptibility Index (ISI) is an index value that estimates the susceptibility of a given aquifer (in this case the municipal aquifer) to contamination at a given point. As outlined in the Region of Peel WHPA study (Section 2.4.1 of AquaResource, 2007a) ISI values were calculated using 2 techniques and Method 2 was recommended as the preferred mapping product to be carried forward to the Water Quantity Risk Assessment. This method was preferred as it 'corrected' individual ISI values based on broader interpretations to provide a more consistent vulnerability assessment across an area.

Discussion on the rationale and methodologies used to map the intrinsic vulnerability are located in Section 2.4.1 of AquaResource, 2007a. ISI values on the maps of the relative vulnerability of the municipal contributing aquifer (Figures 4 to 6 of this report) were classed into one of three groups; high (<30), medium (30-80) or low (>80).

### 3.3.2 Intrinsic Vulnerability Scoring – ISI- Based Method

As outlined in Section 2.4.2 of AquaResource, 2007a, the relative vulnerability map (ISI based vulnerability rating) was overlain on top of the 25-year time-of-travel capture zones and an overall 'intrinsic vulnerability score' was assigned. The scores range from 2 to 10, where 2 represents a low vulnerability to surficial contamination, while 10 represents high vulnerability. For all WHPA sensitivity areas, Zone A, represented by the 100 m fix radius around the municipal wells, was assigned a high intrinsic vulnerability score (score of 10) irrespective of the actual value of the intrinsic vulnerability or the vulnerability rating. Similarly, Zone C (5-year time-of-travel capture zone), which is designated as a 'DNAPL Contaminant Protection Zone', receives an intrinsic vulnerability score of 10 for DNAPL contaminants irrespective of the calculated intrinsic vulnerability, or the vulnerability rating. For pathogens, the intrinsic vulnerability (IV) scoring is 10 within 100m fixed radius zone and is also 10 within Zone B (i.e. 2-year time of travel zone designated as the 'Pathogen Management Zone') where ISI rating is high. The score within Zone B decreases to 8 and 6 where IV rating is medium and low (see Table 2) while Zones C and D were assigned a score of zero since vulnerability scoring is not required for pathogen risk assessment beyond Zone B (2-year capture zone).

Table 2 below (adapted from MOE, 2006a) summarizes the intrinsic vulnerability scores applied to each of the WHPA sensitivity zones for Time of Travel (TOT) capture zones.

**Table 2: Intrinsic Vulnerability (IV) Scoring Using ISI Method**

| WHPA TOT Zone | | Intrinsic Vulnerability Score | | | Comments |
|---|---|---|---|---|---|
| | | IV is HIGH | IV is MEDIUM | IV is LOW | |
| 100 m fixed radius | Zone A: Pathogen Security/ Prohibition Zone | 10 | | | Assigned intrinsic vulnerability score of 10. |
| 0 to 2-year | Zone B: Pathogen Management Zone | 10 | 8 | 6 | Scoring applies to all contaminants but DNAPL's |
| 2 to 5-year | Zone C : DNAPL Contaminant Protection Zone (0-5 yrs) | 10 | | | Assigned intrinsic vulnerability score of 10. |
| | Zone C : All Contaminants Protection Zone (2-5 yrs) | 8 | 6 | 4 | Scoring applies to all contaminants but DNAPLs and Pathogens |
| 5 to 25-year | Zone D: Secondary Protection Zone | 6 | 4 | 2 | Scoring applies to all contaminants but Pathogens |

The ISI method discussed above does not provide estimates of groundwater travel time; it provides means of assessing intrinsic vulnerability based on the geologic characteristics of material overlying the aquifer of interest. The ISI methods are considered by MOE as the minimum standard for vulnerability assessment.

### 3.3.3 Intrinsic Vulnerability Mapping – SWAT/ SAAT Methods

Surface to well advection time (SWAT) and surface to aquifer advection time (SAAT) methods attempt to account for the actual travel times from the surface to the well screen/ aquifer and thus are less conservative. However, these methods incorporate the travel time through both the saturated and unsaturated zones, and are believed to provide a more physically-based estimate of vulnerability. The SWAT/SAAT travel times were calculated and mapped according to the methodologies outlined in the MOE Assessment Report: Draft Guidance Module 3 (MOE, 2006).

Surface to well advection time were calculated as the sum of two components; the saturated travel time (watertable to well advection time; WWAT), and the vertical unsaturated travel time (unsaturated zone advection time; UZAT). The saturated travel pathway includes both vertical and horizontal flow components, and is typically determined through forward particle tracking from the watertable to a municipal well. Information utilized for the SAAT/SWAT methods included digital topographic elevation model (depicted on Figure 2 of the WHPA report; AquaResource, 2007a), surficial geology mapping within each WHPA and vicinity (Figure 6, and Figures 9-12 of the 2007a WHPA Report), depth to watertable mapping (see Figures 4 to 8 of AquaResource, 2008) and recharge values (Figure 13 of the WHPA Report (AquaResource, 2007a)).

*3.3.3.1 Watertable to Well Advection Time - Saturated Zone Travel Time*

The software program FEFLOW was used to conduct the forward particle tracking for the WWAT assessment. Particles were released on the watertable surface at a 50 m grid spacing within (and immediately surrounding) the delineated 25-year capture zones for Alton 1-2, Caledon Village Well 3/3A/TW2-2005 and Cheltenham PW1/PW2. The WWAT travel times were estimated, and the relative vulnerability was categorized based on the WWAT travel times (i.e. High (0-5 years); Medium (5-25 years) and Low (>25 years).

*3.3.3.2 Surface to Watertable Advection Time- Unsaturated Zone Travel Time*

As outlined in the MOE Guidance Module 3 (MOE, 2006) the unsaturated zone advection time (UZAT) is a vertical travel time through the unsaturated zone. It is proportional to the thickness of the unsaturated zone, the degree of saturation, and the estimated rate of groundwater recharge.

The time for a particle to travel through the unsaturated zone from the ground surface to the watertable was calculated using the following equation:

$$\mathrm{UZAT} = \frac{d_{wt} \cdot \theta_m}{q_s}$$

Where $d_{wt}$ is the depth to the watertable (ground surface digital elevation model minus watertable elevation calculated using the calibrated groundwater model), $\Theta_m$ is the mobile moisture content (where lithology is determined from surficial mapping and the groundwater model layers), and the $q_s$ is the recharge rate applied in the calibrated groundwater model (Figure 13 in the WHPA Report; AquaResource, 2007a). The mobile moisture content for unsaturated overburden (as per the surficial geology maps and hydrostratigraphy within each WHPA; AquaResource, 2007a) were assigned values in accordance with Appendix 3f.1 of the Groundwater Vulnerability Guidance Module (MOE, 2006): 10% for sands (material with a K $>10^{-5}$ m/s), 25% for loam (material with a $10^{-7}$ m/s > K > $10^{-5}$ m/s), and 40% for clay (K<$10^{-7}$ m/s). All of the above noted parameters were analyzed in the project GIS and used to calculated the UZAT values on a 50 m grid spacing within the updated 25-year time of travel capture zone.

The concept of unsaturated zone advective travel time is only applicable within portions of a capture zone where water is recharging, as the unsaturated travel time is zero in areas of groundwater discharge where the watertable lies at ground surface. UZAT values are also of primary interest in areas where the watertable is relatively deep, and the vertical travel times can be significant. The unsaturated zone advection time is added to the watertable to well advection time (WWAT) to produce SWAT estimates within the Region of Peel municipal capture zone areas (i.e., UZAT + WWAT = SWAT).

As per the MOE's Guidance Module 3 (Appendix 3g), in some cases the UZAT calculations could be refined or eliminated completely from the assessment depending on the local hydro(geological) conditions and uncertainties, local land uses and potential threats, or areas where shallow soil fractures/disturbances may provide short-circuits to underlying aquifers.

In general, when the UZAT portion is added to the WWAT portion to produce the SWAT times, the calculated SWAT travel times are longer than the WWAT times, and the SWAT zones are also smaller. It is reasonable to include the UZAT times in the SWAT analysis when considering certain contaminants such as road salt or agricultural fertilizers. In other circumstances, such as contaminant spills, the time of travel may be much less than that predicted by the methods outlined in the MOE Guidance Module 3. It is important to recognize the uncertainty associated with the parameters used in the calculations of the various methodologies (SWAT, SAAT, UZAT, etc), and in some instances, it may be pertinent to disregard the UZAT calculations in the SWAT analysis, and for this reason, the results of the WWAT analysis were included in this report.

#### *3.3.3.3 Relative Vulnerability Assessment and Scoring: SWAT and WWAT Method*

Appendix 4 of the MOE's Guidance Module 3 deals with Intrinsic Vulnerability Mapping and Scoring applicable to all vulnerability assessment methods and all 'highly vulnerable areas' defined by the MOE, including the WHPAs (Appendix 4d). In this Appendix, the Guidance outlines how the results of the vulnerability assessments can be used to complete the vulnerability scoring as it is the 'score' that is carried forward into the risk analysis aspects of the Source Protection Assessment Report. The primary MOE reference to relative vulnerability categorization and scoring is Table 4.1 in Appendix 4 (or Table 1) of the MOE Guidance Module 3. In general, the scoring process includes the following steps:

i. categorizing or rating the relative vulnerability of the aquifer as high (H; 0-5 years), medium (M; 5 -25 years), or Low (L; >25 years);
ii. overlying/intersecting the WHPAs TOT/sensitivity zones A, B, C, D with the high, medium or low vulnerability categorization; and
iii. assigning the intrinsic vulnerability scores, which range from 2 (low vulnerability) to 10 (high vulnerability).

In accordance with Table 4.1 of the MOE's Guidance Module 3, the vulnerability scoring applied within the WHPA TOT/capture zones using the SWAT/ WWAT vulnerability assessment method is outlined in Table 3 below.

**Table 3: Intrinsic Vulnerability Scoring Using SWAT and WWAT Methods**

<table>
<tr><th rowspan="2">WHPA TOT Zone</th><th colspan="3">Intrinsic Vulnerability Scoring (IVS): SWAT/ WWAT</th><th colspan="3">Comments</th></tr>
<tr><th>High IVS</th><th>Medium IVS</th><th>Low IVS</th><th>Pathogen</th><th>DNAPLs</th><th>Zone Designation</th></tr>
<tr><td rowspan="2">Zone A (100 m radius)</td><td>10</td><td>10</td><td>10</td><td rowspan="2">10</td><td rowspan="2">10</td><td rowspan="2">Pathogen security/prohibition zone</td></tr>
<tr><td colspan="3">High scoring irrespective of SWAT/WWAT score</td></tr>
<tr><td rowspan="2">Zone B (0-2 yr)</td><td>10</td><td>8</td><td>6</td><td rowspan="2">6-10 (IVS=10 in 100m zone)</td><td rowspan="2">10</td><td rowspan="2">Pathogen management zone: all contaminants but DNAPLs</td></tr>
<tr><td colspan="3">Scoring applies to all contaminants but DNAPLs</td></tr>
<tr><td rowspan="2">Zone C (2-5 yr)</td><td>8</td><td>6</td><td>2</td><td rowspan="2">0</td><td rowspan="2">10</td><td rowspan="2">DNAPL contaminant protection zone</td></tr>
<tr><td colspan="3">Scoring applies to all contaminants but Pathogens & DNAPLs</td></tr>
<tr><td rowspan="2">Zone D (5-25 yr)</td><td>8</td><td>6</td><td>2</td><td rowspan="2">0</td><td rowspan="2">2-8</td><td rowspan="2">Secondary Protection Zone</td></tr>
<tr><td colspan="3">Scoring applies to all contaminants but Pathogens</td></tr>
</table>

In some instances, the vulnerability scores may be increased to account for the presence of preferential pathways that may allow contaminants released at ground surface to bypass the underlying natural protective geologic layers. These constructed pathways include improperly constructed (or improperly decommissioned) wells, pits and quarries, and large diameter pipes. Where applicable, the vulnerability score may be increased from low to moderate or moderate to high to reflect the increased vulnerability.

### 3.3.4 Vulnerability Uncertainty Assessment

As outlined in the Groundwater Vulnerability Guidance Module (MOE, 2006), an uncertainty rating of either 'high' or 'low' must be assigned to each wellhead protection sensitivity area (or subsection of a polygon) within each municipal capture zone. The uncertainty rating applied should consider the uncertainty associated with quantity and quality of data used to assess the vulnerability, with delineating the time-of-travel capture zones, and with determining the relative vulnerability rating (high, medium, low) using ISI or SWAT methods. If a high relative uncertainty rating is applied to a polygon for either assessment (time-of-travel delineation or vulnerability rating), the uncertainty rating for that polygon is defined as 'high' (MOE, 2006). Only if the uncertainty ratings associated with both the time-of-travel and the vulnerability rating were determined to be low would the resultant uncertainty score be defined as 'low'.

#### *3.3.4.1 Uncertainty Associated with Time of Travel Delineations*

Uncertainty in the delineation of the WHPA capture zones, and SWAT or WWAT travel times was minimized through the simulation of multiple sensitivity scenarios. In general, the sensitivity scenarios for WHPA delineation produced similarly shaped capture zones, resulting in a relatively low uncertainty for the capture zone delineation. The uncertainty in SWAT or WWAT travel times was also addressed through multiple model sensitivity runs.

#### *3.3.4.2 Uncertainty Associated with Vulnerability Rating*

There are several levels of uncertainty associated with determining the vulnerability rating (high, medium, low) that vary depending on the method used (ISI or SWAT). One of the main uncertainties associated with the vulnerability rating common to both methods is the quality and quantity of data available to interpret the geologic and numerical model layers. Sparse water well data or poor quality well data can lead to uncertainties in the thicknesses of aquifers and aquitards, which in turn increase the uncertainty associated with the ISI-based vulnerability calculations or the SWAT/ WWAT travel times. (Discussion on the uncertainties associated with the ISI-based vulnerability assessment can be found in Section 2.4.3 of AquaResource, 2007.)

There are several uncertainties associated with the input parameters used to calculate the SWAT and WWAT travel times and categorize the vulnerability (e.g. high, medium or low). Calculating the UZAT times requires estimates of mobile moisture content within the unsaturated zone, recharge values, and depth to watertable, and there are uncertainties associated with each of these parameters. The depth to watertable used was based on the watertable elevation from the calibrated groundwater model, and represents the average annual condition. However, the depth to watertable will vary seasonally as precipitation (and recharge) rise and fall. The recharge estimate used in the UZAT calculation also represents average annual recharge, and also does not take seasonal variations in recharge into account. In addition, the mobile moisture content is assumed to be constant throughout the unsaturated zone, and constant throughout the year. These values change on an event or seasonal basis and as such the unsaturated travel time values are likely overestimated.

Similarly, the hydraulic conductivities applied in the groundwater model also have a similar degree of uncertainty. Decreasing the hydraulic conductivity in the municipal supply aquifer simulated in the model from $2 \times 10^{-5}$ m/s to $1 \times 10^{-5}$ m/s would equate to increases in the SWAT travel times from 3 years to 6 years, or 15 years to 30 years. This minor adjustment to the hydraulic conductivity would in turn lead to a shift in the SWAT vulnerability rating from high to medium, or medium to low.

## 3.4 Potential Contaminant Sources Inventory Methodology

Given the dependence of the population within the Town of Caledon on groundwater for their potable water supply, understanding the quality of groundwater and the locations of potential contaminant sources is of great importance (AquaResource, 2007a).

A ‘windshield’ potential contaminant sources survey was undertaken in December 2006 as part of the Region of Peel WHPA Study (AquaResource, 2007a). The “windshield” survey was completed by driving the roadways within the 25-year capture zone to investigate known and/or potential sources of contamination. The windshield survey completed was intended to be non-invasive and as such residents and businesses were not asked to participate; analysis was limited to what could be deduced by driving through the area.

This windshield survey was updated in February 2008 using the same methodologies used in the earlier study (see Section 2.3 of AquaResource, 2007a). The land use and chemical occurrence inventory (LUCOI) database (AMEC, 2003) was brought into a geographic information system (GIS) and maps were created of the reported potential contaminant sources. AquaResource staff drove through the 25-year time-of-travel capture zones to ground-truth the results presented by AMEC (2003), and to identify any additional land uses that may have the potential to impact the municipal groundwater quality.

When a potential contaminant source was encountered within the 25-year time-of-travel capture zone, digital photographs were taken, and a GPS reading and notes were recorded to describe the potential contaminant and/or the land use on the site. New/additional potential contaminant sources that were not identified in the AMEC (2003) study were photographed and annotated and these are outlined in Appendix A.

A desktop analysis was also undertaken to investigate the potential for improperly abandoned wells to exist within the updated capture zones. Areas that have municipal services (sewer and water) were plotted within a GIS (information provided by Region of Peel) along with MOE water wells and wells that were properly abandoned as part of the Region of Peel’s well abandonment program. Water wells that lie within the municipally serviced area, that have not been decommissioned as part of the Region of Peel program were considered to be a potential threat to the groundwater. Some of these wells may still be used for lawn watering, car washing or other domestic uses, and some may have been decommissioned by the owners. However, a number of existing domestic wells may be open conduits to deeper aquifers and pose a threat to the municipal groundwater quality.

# 4 Study Results

## 4.1 Regional Setting

The following sections outline the regional and local hydrogeologic setting as outlined in the previous WHPA Study report (see Section 3 of AquaResource, 2007a for additional information).

### 4.1.1 Topography

Ground surface in the Town of Caledon varies dramatically from west to east. Surface topography ranges in elevation from approximately 250 m asl south of Cheltenham at the Credit River, to 450 m asl in the Caledon Lake area to the northwest. The most significant topographic features in the Study Area are the north-south trending Niagara Escarpment, and the west-east trending Oak Ridges Moraine. The Niagara Escarpment rises over 100 m above the glacial till plains located east of the Escarpment, and similarly, the hummocky topography associated with the Oak Ridges Moraine rises approximately 50 m above the surrounding till plain.

### 4.1.2 Physiography

There are 5 main physiographic regions within the Town of Caledon: the Guelph Drumlin Field, Hillsburgh Sandhills (Orangeville Moraine), Niagara Escarpment, Oak Ridges Moraine Complex and the South Slope. Each of these regions is discussed in AquaResource, 2007a (Section 3.1.2).

### 4.1.3 Regional Geology

The Town of Caledon, located in the Region of Peel, is underlain by Paleozoic limestone, dolostone, shale and sandstone bedrock formations that are overlain by variable thicknesses of Quaternary aged overburden sediments. Paleozoic bedrock outcrops at surface along the brow of the Niagara Escarpment, and along riverbeds within the Alton area. Overburden thickens dramatically away from the Niagara Escarpment and is thickens substantially within buried bedrock valleys.

#### *4.1.3.1 Bedrock Geology*

Bedrock in the Town of Caledon consists of Paleozoic rocks composed of limestone, dolostone, sandstone and shale formations that have a regional dip of approximately 0.2% to the southwest (Johnson et al, 1992). Bedrock outcrops along the Niagara Escarpment and some river valleys where overburden deposits have been eroded.

Table 4 outlines the Paleozoic rocks that lie within the Study Area (listed from youngest (top) to oldest (bottom)). Figure 4 in the AquaResource, 2007a report illustrates the bedrock geology subcrop locations within the Region of Peel.

**Table 4: Paleozoic Bedrock Formations in the Study Area**

| Bedrock Formation | Description | Aquifer/ Aquitard |
|---|---|---|
| Amabel | Dolostone; shaley dolostone | Excellent regional aquifer |
| Cabot Head (Cataract Gp) | Shale | Aquitard |
| Manitoulin (Cataract Gp) | Dolostone | Local aquifer |
| Whirlpool (Cataract Gp) | Sandstone | Local aquifer |
| Queenston | Shale | Fractured upper portion – poor local aquifer; competent lower portion –aquitard |

Additional information regarding each of the bedrock formations (description, composition, etc) can be found in Section 3.1.4 of AquaResource, 2007a).

#### *4.1.3.2 Bedrock Topography*

There was an extensive period of erosion and weathering (unconformity) in Ontario between the deposition of Paleozoic sedimentary bedrock formations (approximately 350 million years ago) and the earliest record of glacial sediment deposition during the Late Wisconsinan Glaciation (approximately 115,000 years ago). During this period, the bedrock surface was exposed and subjected to glacial, and fluvial erosion and weathering that shaped and eroded the bedrock surface. Differential erosion of carbonates, sandstones and shales resulted in the carving of deep bedrock valleys in the relatively soft shales, and the creation of bedrock highs such as the Niagara Escarpment in areas overlain by resistant carbonate rocks (Karrow, 1973; Johnson et al, 1992). Much of the irregular bedrock topography is attributed to fluvial erosion whereby paleodrainage was focused along the bedrock for extensive periods of time, leading to the erosion of river valleys in the bedrock that have subsequently been infilled with fine and coarse grained sediments (AquaResource, 2007a).

Several buried bedrock valley systems lie within the Credit River Watershed, and some of these valleys host municipal water supplies for Alton, Inglewood, and Cheltenham. Additional discussion on these bedrock valleys and the interpreted bedrock topography within the Region of Peel is provided in Section 3.1.4 of AquaResource, 2007a.

#### *4.1.3.3 Quaternary Geology*

Quaternary aged overburden sediments provide a complex record of glacial and interglacial events throughout the most recent glaciation (Wisconsinan Glaciation). The last major ice advance began approximately 25,000 years ago, and glacial ice retreated for the last time from the area approximately 10,000 years ago. Figures 6 to 10 of the AquaResource, 2007a report illustrated the surficial distribution of Quaternary deposits within the Study Area and the wellhead protection areas. Discussion of the conceptual understanding of the Quaternary sediments within the Study Area, and the depositional environments under which the Quaternary deposits were laid down is also provided in the previous WHPA report (AquaResource, 2007a).

### 4.1.4 Regional Hydrogeology

Region of Peel has utilized both overburden and bedrock aquifers to provide water supplies for communities. Overburden aquifers include sand and gravel aquifers contained within buried bedrock valleys, outwash sand and gravels, and kame deposits, while bedrock aquifers include carbonate aquifers associated with the Niagara Escarpment (AquaResource, 2007a).

#### *4.1.4.1 Bedrock Aquifers*

The Amabel Formation is a highly transmissive bedrock aquifer that lies west of the Niagara Escarpment. The high transmissivity is due to significant secondary porosity features such as fractures, joints, and vugs. The formation was widely used as a municipal aquifer in the Region of Peel in the past however water quality and quantity issues forced the shut down of many of the wells (Caledon Village 1 and 2, McLeodville, Skywood Park, and Mono Mills). In many of these areas overburden overlying the Amabel Formation is thin and the aquifer was highly susceptible to surficial sources of contamination. In other areas, shallow wells intercepting this watertable aquifer were impacted by significant seasonal water level fluctuations (AquaResource, 2007a).

East of the Escarpment, the Queenston Formation is used for domestic water supply by residents where there are limited productive overburden aquifers. The weathered portion of the Queenston Formation is able to transmit low amounts of water (5 to 15 L/min) suitable for domestic supply, but it is unsuitable for communal or municipal supply.

#### *4.1.4.2 Overburden Aquifers*

Overburden aquifers provide an excellent source of water within the Town of Caledon despite their variable spatial distribution. The Oak Ridges Moraine is a regionally significant overburden aquifer within the Town of Caledon. The overburden geology of the moraine is very complex, and consists of interbedded aquifer and aquitard materials referred to as ‘stratified drift’. There are no municipal wells extracting water from the mapped extent of the Oak Ridges Moraine within the Credit River Watershed.

Below the Escarpment, the Cheltenham municipal wells derive their groundwater from an aquifer that was deposited during the same time period as the Oak Ridges Moraine (Mackinaw Interstadial), and these sediments are buried within a bedrock valley feature. Above the Escarpment, the Alton Wells and Caledon Village Wells derive their groundwater from sediments laid down during this period.

Buried bedrock valleys are common within the Town of Caledon, and the overburden aquifers within these features are important from a municipal water supply perspective. The bedrock valleys contain variable thicknesses of coarse-grained aquifer deposits interbedded with fine-grained confining units. These valley features are linear and narrow but are capable of transmitting large volumes of water compared to the till plains that surround them.

### 4.1.5 Surface Water Features

Surface water features in the Study Area include the main branch of the Credit River, and its many tributaries. Shaws Creek, a tributary of the Credit River, merges with the main branch of the Credit River at Alton. In the Caledon Village area, the main surface water feature is Caledon Creek, a Credit River tributary, which joins with the main branch southwest of Caledon Village. The Credit River travels south through Cheltenham to Glen Williams where it trends southeast to its outlet in Lake Ontario.

#### 4.1.6 Natural Features

Natural areas are critical features that act as refuges for rare flora and fauna, but they are also important to the hydrologic regime as they play a key role in groundwater recharge, discharge, and/or flow attenuation. Some natural areas act as headwater discharge points, while others function as water storage or flood detention areas, and provide sinks for sediments and contaminants. On a regional scale, ecological land use, interpreted from ELC mapping, is dominated by intensive agriculture (25% of the land area) followed by cultural meadow (13.2%), non-intensive agriculture (10.5%), deciduous forest (10.1%), coniferous forest (4.8%), coniferous plantation (4.3%), cultural savannah (3.6%) and mixed forest (3.5%). The remaining 20% of the land area is classified as rural development (2.1%), active aggregate (3.1%) and various other various woodland, swamp and open space parcels of land.

#### 4.1.7 Land Use

Agricultural land use dominates within the Town of Caledon and accounts for just over half (51%) of the land uses within the Town of Caledon that lies within the Credit River Watershed. An additional 18.2% of this land area is designated as residential, 14% as vacant land or park land, 3.3% is industrial uses, and 1.6% is designated as commercial use. The remaining 12% includes unclassified land uses, institutional, government lands, special purpose lands, streets, railroads and other various land uses.

## 4.2 Local Settings

#### 4.2.1 Alton

The Village of Alton lies west of the Niagara Escarpment, and south of the Orangeville Moraine. The community has 4 municipal wells; Alton 1-2, and Alton 3- 4. The capture zones for Alton 3-4 were delineated as part of the earlier WHPA Study (AquaResource, 2007a). The capture zones for Alton 1-2 (currently Region of Peel stand-by wells) were not delineated in the previous study, however they were delineated in this update study. Discussion on the local settings surrounding the Village of Alton is provided in AquaResource, 2007a (Section 3.2.1) and below.

##### *4.2.1.1 Geology and Hydrogeology*

The uppermost bedrock formation in this area is the Amabel Formation which is described as a porous crystalline dolostone with significant secondary porosity arising from solution cavities and fractures (Singer et al., 2003). Below the Amabel Formation are shale, sandstone and dolostone formations of the Clinton-Cataract Group, and the Queenston Formation shale at depth.

Overburden in the Alton area includes subglacial tills, glaciofluvial sands and gravels, and ice contact stratified drift. The sandy silt Port Stanley Till lies south and east of the Credit River (mapped as silty sand to sandy silt till on Figure 9 of AquaResource, 2007a), ice contact sands and gravels west of Alton, and glaciofluvial outwash sands and gravels beneath Alton and along Shaws Creek (i.e. Orangeville Moraine).

Bedrock topography in this area is variable, and water well records indicate the presence of a buried bedrock valley extending beneath the modern day Credit River from Orangeville towards the Forks of the Credit. The valley lies just east of Alton, and in places, the base of the valley reaches up to 80 m below ground surface. The bedrock valley is infilled with fine and coarse-grained sediments, and Caledon Village Well 4 is completed within a coarse-grained aquifer of this buried bedrock valley feature. Additional information regarding the local geology and hydrogeology in the Alton area can be found in Section 3.2.1 and 3.4.1 of AquaResource, 2007a.

#### *4.2.1.2 Surface Water and Natural Features*

Alton Wells 1-2 are located approximately 350 m southeast of Shaws Creek, a tributary to the Credit River. A GUDI study was performed by Stantec (2002a) and this study determined these wells are GUDI with effective in situ filtration. The 'Credit River at Alton Provincially Significant Wetland (PSW) Complex' lies north and east of the Village of Alton near Alton Wells 1-2 along the banks of the Credit River and portions of Shaws Creek near the confluence with the Credit River (see Figure 1).

Groundwater discharges to both Shaws Creek and the Credit River as well as the many riparian wetlands located along the banks and floodplain of the Credit River. Further west of the capture zones, portions of Shaws Creek may lose water to the groundwater system (i.e. recharge the groundwater system), however the tributary is primarily characterized as a coldwater reach.

ELC mapping within the Alton area classifies the majority of the land surrounding the Village of Alton as rural, consisting of non-intensive agriculture with lesser areas of intensive agriculture, manicured open space, and woodlands (mixed, coniferous and deciduous swamp and forest, cultural meadow, and plantation).

#### *4.2.1.3 Groundwater Flow and Recharge Conditions*

Shallow groundwater flow in the Alton area is influenced by local topography and surface water features including Shaws Creek and the Credit River with shallow groundwater discharging through the Amabel Formation to these features. Groundwater flow in the deeper bedrock system flows along the bedrock valley towards the Credit River and as a result, potentiometric contours in the area (See Figure 19) indicate flow directions perpendicular to the axis of the buried bedrock valley.

Recharge in the Alton and Caledon Village Well 4 area ranges from 360 mm/yr on the Orangeville moraine to 0 mm/yr where groundwater discharges into the Credit River and associated wetlands. Recharge to the groundwater system is estimated to be 175 to 220 mm/yr on the Port Stanley Till Plain.

### 4.2.2 Caledon Village

Caledon Village is located approximately 6 km east of Alton, and 3 km west of the Niagara Escarpment (see Figure 10, AquaResource, 2007a). Ground surface topography in the area surrounding Wells 3/3A and TW2-2005 has been modified dramatically by local aggregate operations. Regionally, the topography in this area slopes away from the Niagara Escarpment towards Lake Ontario from a high of 460 m asl north of Caledon Village to a low of 405 m asl in the Caledon Creek valley. Locally, the ground surface near Well 3/ 3A/TW2-2005 lies at an elevation of approximately 417 m asl (estimated from the MNR 5 m DEM), with water level elevations in the ponds varying from 400 to 405 m asl (GeoKamp, 2006).

### *4.2.2.1 Geology and Hydrogeology*

The Amabel Formation (dolostone) is the uppermost bedrock unit beneath Caledon Village. Beneath the Amabel Formation are the dolostones, sandstones and shales of the Cataract Group, and shales of the Queenston Formation. The majority of bedrock wells in this area are completed in the Amabel Formation or the dolostones and sandstones of the Manitoulin and Whirlpool Formations (Cataract Group).

Surficial geology in the Caledon Village area consists of Wentworth Till, glaciofluvial sand and gravel outwash, and ice contact stratified drift (see Figure 10 of AquaResource, 2007a). Well 3/ 3A and TW2-2005 are completed in the sands and gravels of the Caledon Meltwater Channel, which directly overlies Amabel Formation bedrock. The hydrostratigraphy surrounding Caledon Village 3/ 3A and TW2-2005 is highly variable. Overburden thickness varies dramatically from less than one metre to over 80 m thick along the flank of the Escarpment.

Groundwater flow in the shallow overburden is from north to south and is influenced by the Caledon Meltwater Channel and the man-made ponds associated with below watertable aggregate extraction. Groundwater flow in the deep groundwater system is also from the north and trends toward the Credit River and the crest of the Niagara Escarpment. Additional information regarding the local geology and hydrogeology in the Caledon Village area can be found in Section 3.2.2 and 3.4.2 of AquaResource, 2007a.

### *4.2.2.2 Surface Water and Natural Features*

Large sand and gravel pits exist adjacent to the Caledon Village pumping wells, and within these gravel pit lands lie four large ponds used for aggregate processing and washing. The ponds are the result of extraction below the watertable within the same aquifer as the Caledon Village Well 3 and TW2-2005. Caledon Creek, a tributary of the Credit River, lies approximately 650 m northwest of the Caledon Village Well 3, and losing conditions along this creek have been reported.

Most of the area north, east and west of Caledon Village is classified as intensive agriculture with lesser pockets of non-intensive agriculture, and coniferous and mixed forest. Much of the area surrounding Wells 3/ 3A and TW2-2005 is classified as active aggregate with the surrounding areas classified as agricultural, and residential (within Caledon Village).

### *4.2.2.3 Groundwater- Surface Water Interactions and Recharge Conditions*

The most abundant surface water features in the vicinity of the Caledon Village Well 3/ 3A and TW2-2005 are man-made aggregate ponds that lie within the Caledon Meltwater Channel. Caledon Creek, a tributary to the Credit River, exhibits some groundwater discharge in the spring when the watertable is elevated however the creek is classified as hosting warm water fish communities.

Recharge was estimated in this area to be approximately 365 mm/yr along the meltwater channel/ outwash deposits and the Caledon Meltwater Channel where thick sand and gravel deposits lie at surface. Recharge is estimated to be 260 mm/yr on the sandy Wentworth Till Plain, and slightly lower on the slope of the Escarpment (approximately 180 mm/yr).

### 4.2.3 Cheltenham

The Village of Cheltenham lies at the base of the Niagara Escarpment, approximately 10 km north of Georgetown. Water supply for Cheltenham is derived from two wells located within a few metres of one another; Cheltenham PW1 and PW2 (Figure 12). Both wells are located in Cheltenham, adjacent to Creditview Road, east of the Credit River. Topography east of Cheltenham slopes gently southeastward towards Lake Ontario, and west of the village, ground surface rises abruptly out of the Credit River Valley (250 m asl) to the top of the Niagara Escarpment (350 m asl).

#### *4.2.3.1 Geology and Hydrogeology*

Overburden thickness varies in the Cheltenham area from 5 m at the Escarpment to over 50 m in the buried bedrock valley. The stony and sandy Wentworth Till blankets the Amabel Formation (dolostone) bedrock above the Escarpment and below (east of) the Escarpment, the silty clay-rich Halton Till overlies the municipal aquifer system and the Queenston Formation shale bedrock.

A bedrock valley extends along the path of the modern day Credit River near Cheltenham. The eastern edge of the valley trends roughly north-south, east of the village between King Street and Old School Roads, and the valley is interpreted to contain interbedded coarse and fine-grained material, including the coarse-grained aquifer that is intersected by Cheltenham PW1/PW2. Outside the buried valley, on the eastern side of the Credit River, thick fine and coarse-grained overburden deposits (20 to 40 m) overlie Queenston Formation bedrock. On the west side of the Credit River, there is a variable thickness of overburden that ranges from only a few metres to over 20 m on top of the bedrock slopes of the Niagara Escarpment. Additional information regarding the local geology and hydrogeology in the Cheltenham area can be found in Section 3.2.4 and 3.4.4 of AquaResource, 2007a.

Groundwater flow in Cheltenham is greatly influenced by the Credit River and the nearby buried bedrock valley (see Figures 18 and 19 of AquaResource, 2007a). Shallow and deep groundwater flows from the west and east into the River or the underlying buried bedrock valley. Groundwater flow within the bedrock valley is interpreted to be from north to south; however local discharge from the valley into the Credit River may occur where the confining units have been eroded away.

#### *4.2.3.2 Surface Water and Natural Features*

The Credit River lies approximately 460 m west of the Cheltenham production wells. A small tributary to the Credit River lies approximately 500 m east of the wells, and a small pond which is associated with that tributary also lies in the area (approximately 550 m to the southeast – see Figure 12 of AquaResource, 2007a). There are very few wetlands in the Cheltenham area. A locally significant wetland complex (the Cheltenham Wetland Complex) lies approximately 800 m south of the municipal wells.

The vast majority of wetland and woodland natural areas are associated with the Credit River, and outside this area the ecological land use is dominated by intensive agriculture with lesser plots of land designated as non-intensive agriculture, cultural meadow and deciduous forest (Figure 7 of AquaResource, 2007a).

#### *4.2.3.3 Groundwater Surface Water Interactions and Recharge Conditions*

Groundwater discharges to the Credit River and the riparian wetlands located within the river floodplain in the Cheltenham area. The main branch of the Credit River contains coldwater fisheries that are dependent on groundwater discharge for spawning and survival.

Groundwater recharge in the Cheltenham area was estimated to be approximately 125 to 160 mm/yr. Recharge along the slope of the Escarpment, to the east of Cheltenham is estimated to be approximately 180 mm/yr and recharge is believed to be negligible along the Credit River and its associated wetlands where groundwater discharge conditions are reported to exist.

## 4.3 Numerical Model Results

The setup, calibration and utilization of the FEFLOW groundwater model for capture zone delineation in the Region of Peel was discussed in Section 3.5 of AquaResource, 2007a. The only changes made to the numerical model for use in this study, were the pumping rates used to delineate the capture zones (Table 1).

The same particles release points were used to delineate time-of-travel capture zones in each of the model scenarios. The resulting backward particle paths for each simulation were compared against the base case. Composite time-of-travel capture zones were delineated using the particles from each of the various sensitivity scenarios.

Backward tracking particles were released at the top, bottom and middle of the model layer containing the municipal supply aquifer. These particles were tracked backwards in time through the subsurface to the top of aquifer and/or watertable, and at the various time of travels, a horizontal projection was made to the surface through overlying overburden to delineate the plan view capture zones depicted in Figures 1 to 3. This methodology is consistent with the Technical Terms of Reference for Groundwater Studies (MOE, 2001) as well as the Draft Provincial Guidance Module 3 (MOE, 2006).

The size and extent of the capture zones delineated in this study are discussed below.

### 4.3.1 Alton 1-2 Capture Zones

Figure 1 illustrates the current delineations for the 2, 5, 10 and 25-year time-of-travel capture zones for the Alton Wells 1-2 as well as the 100 m fixed radius zone around the wells. The capture zones extend to the southwest beneath the Village of Alton towards 4$^{th}$ Line West. The capture zones are broad in shape and follow the local groundwater flow path from the southwest towards the Credit River and associated wetlands. The capture zones delineated in this study are very similar in size and shape to the capture zone previously delineated by Dames and Moore (1995).

### 4.3.2 Caledon Village Capture Zones

The capture zone delineations for Caledon Village Wells 3/3A and TW2-2005 (Figure 2) represent the composite capture zones for two municipal pumping scenarios (see Table 1 and AquaResource, 2007b). The capture zones extend in a northerly direction beneath Highway 10 and Caledon Sand and Gravel into Caledon Village. The 25-year capture zone extends north and west of Charleston Sideroad into a residential neighbourhood in Caledon Village. Compared to the Caledon Village 3/3A capture zone delineations (AquaResource, 2007a) the combined 3/3A and TW2-05 capture zones are broader by about 200m east and west of the wells and include a slightly larger area at the northern limit of the 25-year zone.

#### 4.3.3 Cheltenham Capture Zones

The revised capture zones for Cheltenham are illustrated on Figure 3. The municipal wells are completed in a sand and gravel aquifer within the north-south trending buried bedrock valley, that lies east of the modern day Credit River. Groundwater flow is towards the Credit River (a local groundwater discharge zone) from the east and west (i.e. from the Niagara Escarpment). The Cheltenham capture zones extend eastward from the municipal wells toward and south of King Sideroad. The capture zones delineated in this study using a higher a pumping rate (1469 $m^3$/day; Table 1) are broader than those delineated in the previous study (AquaResource, 2007a) under a lower pumping rate (500 $m^3$/day).

#### 4.3.4 Uncertainties in Capture Zone Delineation

The uncertainty associated with the delineation of the capture zones were addressed by simulating multiple scenarios that modified model input parameters within the range of uncertainty while maintaining a calibrated condition (see AquaResource, 2007a for additional details). In addition, the conceptualization of bedrock valley depth, local aquitard continuity and the conductivity of aggregate operations were also evaluated in alternative scenarios to assess the uncertainty associated with the effect of those features on the resulting capture zones. All of these scenarios were run in this study with the revised pumping rates and the capture zones presented on Figures 1 to 3 represent the composite capture zones for those scenarios.

### 4.4 Wellhead Protection Area Implementation

#### 4.4.1 Vulnerability Rating – ISI Method 2

The methodologies used to map the vulnerability within the 25-year time-of-travel capture zones are discussed in Section 2.4 of AquaResource, 2007a and are outlined in Section 3.3 of this report. The ISI categories (from MOE, 2001) include high (aquifer vulnerability less than 30), medium (30 to 80), and low (greater than 80). The following sections outline the resulting vulnerability as determined through the use of ISI Method 2 (AquaResource, 2007a).

##### *4.4.1.1 Alton*

Within the 25 year capture zone for Alton Wells 1-2, the intrinsic susceptibility values calculated using the interpreted groundwater model surfaces (Method 2) is dominated by high and medium vulnerability areas (Figure 4). These ratings are a result of the abundant coarse-grained sand and gravel overlying shallow dolostone bedrock, as well as the discontinuous, or absent, confining layer overlying the municipal aquifer.

The ISI-based vulnerability mapping is consistent with the water quality data collected in the Alton 1-2 well, and the early warning wells located within the capture zones. Water quality testing on the early warning wells (Beatty, 2007a) reported elevated concentrations of sodium, chloride, and nitrate. The source of these elevated concentrations is interpreted to be rural land use activities that may include road salting practices, high density residential septic systems, and fertilizer application (Beatty, 2007a). Stantec (2002a) attributed the elevated nitrates concentrations to the residential septic systems within the village. Tritium isotopic dating conducted by Stantec (2002a) also supports the vulnerability mapping, and estimated the water in the Alton 1-2 municipal well was on average, less than 30 years old.

#### *4.4.1.2 Caledon Village*

The ISI-based vulnerability within the capture zones for Caledon Village Well 3/3A and TW2-2005 is predominately high (Figure 5), which is attributed to the thick accumulations of sand across much of the area. There are a few small areas of moderate vulnerability, including the area surrounding the wellfield, and this slightly lower vulnerability is due to the increase in overburden thickness, surrounding the wells. As the vulnerability in this unconfined aquifer is calculated as the sum of the thickness of the units by their respective K-factor for all units overlying the watertable, the increased thickness leads to a decreased vulnerability in this area.

The water quality within Caledon Village 3/3A is good considering the vulnerability and the aggregate activities taking place on the surface surrounding the well. Concentrations of chloride, nitrate and sodium are generally low to moderate, however wells screened in the shallow sands and gravels (e.g. EW 3-3s) exhibit higher chloride concentrations (134 mg/L) than wells screened deeper below the ground surface (e.g. EW 3-3d; < 60 mg/L chloride in 2005; Beatty, 2005), and the chloride concentrations have been increasing since 1998 (see Stantec, 2002b). Tritium analysis conducted on water pumped from Wells 3/3A (Stantec, 2002b) estimated the age of the water to be, on average, less than 30 years. This is consistent with the high overall vulnerability of the contributing aquifer.

#### *4.4.1.3 Cheltenham*

Figure 6 illustrates the ISI based vulnerability within the Cheltenham PW1/PW2 capture zones. Although the area is overlain with a clay-rich Halton Till, the underlying sand and gravel municipal aquifer remains fairly close to ground surface (see Cheltenham A-A' in Appendix A of AquaResource, 2007a), which produces the moderate vulnerability rating for the majority of the capture zone. There is a small zone of high vulnerability in the eastern reaches of the capture zone at the edge of the 25-year time-of-travel capture zone (Figure 6) and this high value corresponds to an area where sand and gravel are mapped at surface (Karrow, 1991).

Water quality in the Cheltenham wells is fairly good and the only exceedences of the ODWS are for iron, manganese and sodium, which may have been derived from the Queenston shale bedrock as opposed to surficial sources of contamination.

### 4.4.2 Vulnerability Rating – SWAT/ SAAT Methods

Based on Appendix 4, Guidance Module 3 (MOE, 2006), the advective travel times obtained through SWAT methods are to be translated into relative measures of intrinsic vulnerability which are then utilized in the vulnerability scoring (Section 4.4.5). The relative intrinsic vulnerability rating for the SWAT and WWAT method is carried as follows:

- High Relative Vulnerability: 0 years < SWAT (or WWAT only) < 5years
- Medium Relative Vulnerability: 5years < SWAT (or WWAT only) < 25 years
- Low Relative Vulnerability: SWAT (or WWAT only) > 25 years

As it may be appropriate in some instances to ignore the unsaturated zone travel times, the High, Medium, and Low vulnerability ranking and scoring were carried forward for both the WWAT and SWAT times.

*4.4.2.1 Alton 1-2 – UZAT/ SAAT*

In the area surrounding Alton Wells 1-2, the municipal supply aquifer is largely unconfined and therefore, the top of the municipal aquifer was considered to be the watertable position. As a result, the SAAT within the 25-year capture zone of Alton Wells 1-2 was interpreted to be coincident with the UZAT.

Figure 7 illustrates the unsaturated zone travel times within the 25-year capture zone for Alton Wells 1-2. The majority of the unsaturated times are between 2 and 5 years, and less than 2 years north of the well due to the shallow watertable in close proximity to the Credit River and the associated wetland complex.

*4.4.2.2 Alton 1-2 - WWAT*

The forward particle tracking travel times from watertable to well (WWAT) for Alton 1-2 are illustrated on Figure 8 alongside the resulting vulnerability rating (high, medium and low). As illustrated on the figure, the WWAT-based vulnerability is predominately ranked as high to moderate, with a small area of low vulnerability in the southern reaches of the capture zone. This vulnerability mapping is fairly consistent with the ISI-based vulnerability mapping conducted in the area (Figure 4), and the water quality data reported in the municipal well, and the Region of Peel Early Warning Wells.

*4.4.2.3 Alton 1-2 - SWAT*

The surface to well advection time for particles released within the Alton 1-2 capture zone were calculated as the summation of the unsaturated zone and the saturated zone travel times (UZAT + WWAT). As plain-view capture zone delineations are based primarily on saturated travel time through the municipal aquifer, in instances where the reverse particle tracking terminated at a significant depth beneath the watertable and/or ground surface, the SWAT travel times could be considerably longer than the capture zone travel time as they account for the complete travel times from surface to well screen. As a result, SWAT may provide a less conservative approximation of the intrinsic vulnerability of the municipal well than the ISI method.

The forward particle tracking travel times from surface to the well (SWAT) for Alton 1-2 capture zone are illustrated on Figure 9 alongside the resulting SWAT vulnerability rating (high, medium and low). The SWAT travel times are longer than the WWAT travel times, due to the addition of the UZAT travel times, and as such the high (SWAT time of 0 to 5 years) and medium (SWAT times of 5 to 25 years) vulnerability areas are smaller in size than the corresponding high and medium WWAT vulnerability areas. In general, the SWAT vulnerability (Figure 9) is primarily moderate to high within the 25 year WHPA TOT zone.

*4.4.2.4* Caledon Village Well 3/3A, TW2-2005 – UZAT/ SAAT

The shallow unconfined hydrostratigraphic setting and the lack of an overlying aquitard results in relatively low UZAT values (see Figure 10). The UZAT within the 25-year capture zone ranges from 0 days (where groundwater lies at ground surface on the gravel pit ponds) up to 10 years in the area located south and southeast of the wellfield (Figure 10) where the UZAT value corresponds to an increase in ground surface elevation associated with an increased thickness in the sand aquifer at surface. This increased thickness which translates to a greater depth to watertable in the area, and therefore a longer UZAT travel time. The same zone is mapped as a medium vulnerability in the ISI vulnerability mapping in AquaResource (2007), whereas the remainder of the wellfield was mapped as high intrinsic vulnerability. Consequently the ISI and UZAT evaluations suggest similar results.

As the municipal well is completed in an unconfined aquifer, the top of the municipal aquifer for this wellfield is considered to be the watertable position, and therefore, the SAAT times are considered to be equivalent to the UZAT travel times. The majority of the capture zone area is simulated to have unsaturated travel times less than 5 years, and this type of low attenuation capacity within the unsaturated zone is expected at this location due to the coarse-grained nature of the surficial materials.

#### *4.4.2.5 Caledon Village Well 3/3A, TW2-2005 – WWAT*

The WWAT travel times for Caledon Village Well 3/3A/TW2-2005 are illustrated on Figure 11, and are very similar to the reverse particle tracking travel times obtained in the capture zones delineation. This is consistent with unconfined aquifer systems that recharge locally. The WWAT vulnerability rating (high, medium, low) within the 25-year TOT capture zone is also illustrated on Figure 11, and is mapped as predominately high to moderate with only a few small areas with low vulnerability in the northern reaches of the capture zone.

#### *4.4.2.6 Caledon Village Well 3/3A, TW2-2005 – SWAT*

Figure 12 illustrates the SWAT travel times and corresponding SWAT vulnerability rating (high, medium, low) for Caledon Village Well 3/3A and TW2-2005. As illustrated on this figure, the area immediately surrounding the wells, and extending north to Caledon Creek are mapped as having a high vulnerability (SWAT times of less than 5 years). The majority of the remaining portion of the 25-year capture zone is medium vulnerability (SWAT times of 5 to 25 years) and similar to the WWAT mapping, there is only a small portion of the capture zone mapped as low vulnerability (Figure 12). This relative vulnerability mapping is consistent with the expected high intrinsic vulnerability of this unconfined aquifer; the majority of the recharge for the wellfield takes place locally and there is limited protection against potential contaminants entering the municipal aquifer within the capture zone.

The water quality within the municipal well is good considering the high vulnerability. Concentrations of chloride, nitrate and sodium reported in Peel's Early Warning Wells are generally low to moderate, however monitoring wells screened in the shallow sands and gravels (e.g. EW 3-3s) exhibit higher chloride concentrations (119-134 mg/L in 2005) than wells screened at greater depths (e.g. EW 3-3d; 8 mg/L to < 60 mg/L; Beatty, 2005), and the chloride concentrations appear to be increasing since 1998 (Stantec, 2002b). Tritium analysis (Stantec, 2002) estimated the age of the water at less than 30 years, which is within the range calculated in the SWAT analysis.

#### *4.4.2.4 Cheltenham PW1/PW2 - UZAT*

As the Cheltenham PW1/PW2 wells are completed in a confined aquifer, the UZAT values are not coincident with the SAAT values, and SAAT values are calculated as the sum of UZAT values and watertable to aquifer advection times (WAAT).

The UZAT values (Figure 13) calculated within the 25-year capture zone are relatively low across the area due to the low mobile moisture content assumed for the Halton Till, as well as the modest depth to watertable in the area. As illustrated in Figure 13, UZAT values within the 25-year capture zone commonly range between 5 and 25-years. There is a zone in the southeastern portion of the 25-year capture zone (Figure 13) which was calculated to have shorter UZATs, and this is due to the presence of a sand unit mapped at surface (Karrow, 1991). This sand layer is represented as having a lower soil moisture content and higher recharge in the UZAT calculation, which produces the faster UZAT travel times.

#### *4.4.2.5 Cheltenham PW1/PW2 - WWAT*

Figure 14 illustrates the WWAT travel times and WWAT vulnerability rating for the Cheltenham PW1/PW2 wellfield. There is a small area of high WWAT vulnerability mapped in the area surrounding the wellfield. The remainder of the 25-year TOT WHPA is mapped as medium vulnerability, decreasing to low vulnerability with increasing distance to the well.

#### *4.4.2.6 Cheltenham PW1/PW2 - SWAT*

Figure 15 illustrates the SWAT times and the corresponding SWAT vulnerability rating (high, medium, low) delineated for the Cheltenham PW1/PW2 wellfield. Cheltenham PW1/ PW2 is screened in a confined aquifer and the depth of the well and the fine-grained material overlying the municipal aquifer contribute to the long SWAT times. None of the forward tracking particles extend from ground surface to the well in less than 5 years, and as such there are no high vulnerability areas within the 25-year capture zone. A medium vulnerability area is mapped surrounding the municipal well, while the remainder of the capture zone is dominated by low vulnerability (SWAT times greater than 25 years).

### 4.4.3 Uncertainty in Vulnerability Rating

As noted earlier there are several contributing factors to the uncertainty associated with the vulnerability assessment. Those factors include uncertainty associated with the time of travel delineation and uncertainties associated with the relative vulnerability rating.

Uncertainty with the vulnerability rating is often due to uncertainty associated with the understanding and conceptualization of the hydrostratigraphic groundwater system. These uncertainties as well as uncertainties associated with the delineation of the UZAT, SWAT and WWAT times will be the focus of this discussion.

#### *4.4.3.1 Alton 1-2*

Uncertainty considerations relating the ISI and SWAT/ WWAT vulnerability mapping and rating undertaken within the Alton 1-2 capture zones are as follows:

- A number of the wells within the 5-year TOT capture zone (Zones C) report ISI values that are very close to the threshold between high and moderate intrinsic susceptibility (vary from 25 to 35). As such this zone was given a high uncertainty value for the relative vulnerability mapping using the ISI method.
- While there are several wells within 500 m of the municipal wells (Figure 4), there are very few wells in the southern limits of 5-year and 25-year time-of-travel capture zones, and as such ISI vulnerability assessment within Zones C and D were also assigned high uncertainty values.

- Results of the capture zone modeling, and their similarities to previous delineations give good confidence in the trend and mapping of the time-of-travel capture zones, and as such the time-of-travel delineations were given low uncertainty values.
- The results of the forward particle tracking were fairly consistent with the conceptualization of the area, and with the reverse particle tracking results, and as such there is a low uncertainty with respect to the longer term SWAT and WWAT travel times (e.g. 5 to 25 years, > 25 years). The potential variability of the hydraulic conductivity of the municipal aquifer leads to a high uncertainty in the 0 to 5 year WWAT and SWAT travel times and relating vulnerability ranking.

#### *4.4.3.2 Caledon Village*

Uncertainty considerations relating the ISI and SWAT/ WWAT vulnerability mapping and rating undertaken within the Caledon Village 3/3A/ TW2-2005 capture zones are as follows:

- Caledon Village Well 3/3A and TW2-2005 lie within an area that is known to contain significant quantities of coarse-grained sediment on top of bedrock. This understanding leads to a low level of uncertainty with respect to the conceptualization of the relative vulnerability ratings.
- There are very few high quality wells within the 25-year time of travel capture zone with which to calculate the ISI values, and validate the conceptual understanding of the onsite geology, and watertable position. Therefore there is a high uncertainty with respect to the data quality and distribution across the capture zones.
- The results of the forward particle tracking were consistent with the conceptualization of the area, and with the reverse particle tracking results. As such there is a low uncertainty with respect to the longer term SWAT and WWAT travel times. However, the potential variability of the hydraulic conductivity (e.g. $1x10^{-4}$ vs $2x10^{-4}$ m/s) of the municipal aquifer leads to a high uncertainty in terms of the 0 to 5 year WWAT and SWAT travel times and relating vulnerability rating.
- The uncertainties in the time-of-travel capture zone delineations are low given the hydrostratigraphic understanding of the area.

#### *4.4.3.3 Cheltenham*

Uncertainty considerations relating the SWAT/ WWAT methods undertaken within the Cheltenham PW1/ PW2 capture zones are as follows:

- The conceptual setting for this area is fairly well understood, although there is a poor understanding of the spatial and lateral continuity of sand lenses within the Halton Till, that may lead to higher than predicted travel times in the SWAT/ WWAT assessment. Therefore the uncertainty associated with the conceptualization is high.
- Given the uncertainty with the conceptualization, and the uncertainty associated with the hydraulic conductivity (within half an order of magnitude) of the municipal supply aquifer, the SWAT/ WWAT travel times and the resulting vulnerability ranking is considered to have a high uncertainty.

### 4.4.4 Summary of Uncertainty Rankings

The uncertainty ratings established above for the capture zones may be used in the Region of Peel's future Water Quality Risk Assessment as per the guidance modules (MOE, 2006). The uncertainty ranking, along with the risk assessment score, will be used to determine the need for (and spatial extent of) additional data collection and/or analysis. If the uncertainty is so high that there is insufficient confidence in the assigned vulnerability scores to use them as a basis for prioritizing and developing risk management activities, then the collection of additional field data may be required prior to establishing the risk and assessing potential threats.

The above analysis has shown that many of the vulnerability zones surrounding the municipal wells are lacking in data, primarily away from the municipal wells themselves. Thus this lack of data generally results in a high degree of uncertainty associated with the vulnerability mapping and ranking performed. Generally, the Region of Peel's early warning sentry wells are contained within Zone A and B and do not reduce the uncertainty in Zones C and D located further away from the wellfields.

### 4.4.5 Application of Vulnerability Scoring to WHPA Sensitivity Zones

The vulnerability scoring was undertaken by intersecting the relative vulnerability categories (high, medium, low) with the delineated 2-, 5-, and 25-year TOT capture zones and the 100m radius zone. The intersection of the relative vulnerability rating (developed using the ISI or SWAT/WWAT based methods) with the time-of-travel capture zones (i.e. sensitivity areas) was carried as per the MOE guidance document (MOE, 2006).

Zone A, the 100 m fixed radius zone that surrounds the municipal wells is mapped as one continuous sensitivity area, and this area applies for all potential contaminants. This zone is considered to be a "Pathogen Security/ Prohibition Zone", whereby there is no consideration given to the results of the vulnerability assessment; the intrinsic vulnerability score is based solely on the proximity to the well.

Pathogen consideration for the risk assessment is limited to the 2-year time-of-travel capture zone (Zone B), referred to as the "Pathogen Management Zone", unless the pathogens threats inventory identifies the need to apply a risk assessment to a specific drinking water threat or threats beyond this zone.

The 5-year time-of-travel capture zone (Zone C) is referred to as the "DNAPL Contaminant Protection Zone". The vulnerability score for DNAPLs within this zone is 10, irrespective of the intrinsic vulnerability values/rating in that zone. For all contaminants other than DNAPLs and pathogens within this zone, consideration *is* given to the results of the vulnerability rating.

The 5-year to 25-year time-of-travel capture zone is referred to as the "Secondary Protection Zone" (Zone D). The scoring for this zone takes into account the high, medium or low vulnerability rating.

### 4.4.6 Vulnerability Scoring

Vulnerability scores were applied to the wellhead protection sensitivity areas A, B, C, D as noted above. The vulnerability scores will be used by Region of Peel to complete a Water Quality Risk Assessment within the wellhead protection areas in the future. In general terms, the Risk Assessment brings together the results (scores) of the groundwater vulnerability assessment, and a Threats Assessment (also conducted within the capture zones) to direct risk management activities that will mitigate the risks to water quality. The vulnerability scoring is based on the premise that the vulnerability of the aquifer decreases as the time-of-travel to the well increases. In other words, under identical geologic conditions, a higher vulnerability score will be assigned within the 2-year time-of-travel capture zone than the 25-year time-of-travel capture zone. As outlined in Tables 2 and 3, the vulnerability scores assigned within the sensitivity zones varied from 2 (low vulnerability) to 10 (high vulnerability).

As outlined in the Draft Guidance Module (MOE, 2006a), Zone C is referred to as the 'DNAPL Contaminant Protection Zone', whereby Zones A, B and C are assigned a vulnerability score of 10 regardless of the intrinsic vulnerability score when there is a DNAPL present within these zones. Similarly, within Zone A, referred to as 'Pathogen Security/ Prohibition Zone' a vulnerability score of 10 was applied for all pathogens that lie within this zone. Zone B, referred to as the 'Pathogen Management Zone' is assigned scores from 6 to 10 depending on the relative vulnerability within the zone (as per Tables 2 and 3 in this report).

### 4.4.7 ISI-Based Vulnerability Scoring

Figures 16 to 18 illustrate the ISI-based vulnerability scores for all contaminants, Pathogens and DNAPL's respectively within the 25-year TOT capture zone for Alton 1-2. Figures 19 to 21 illustrate the vulnerability scores within the 25-year capture zone for Caledon Village Wells 3/3A and TW2-2005, and Figures 22 to 24 illustrate the scores within 25-year capture zone for the Cheltenham wellfield. Each of these scores are discussed below.

As a score of 10 was assigned for pathogens within Zone B (Pathogen Management Zone) regardless of the ISI-based vulnerability rating as per Table 2 and Figures 4-6. This approach was applied for consistency with the standards applied in the main WHPA study report (AquaResource 2007a) and to account for ISI uncertainties, areas sensitivity or the presence of potential contaminant sources/preferential pathways within the Zone B areas.

#### *4.4.7.1 Alton 1-2 – ISI Based Vulnerability Scoring*

Figure 4 illustrates the ISI vulnerability rating (H, M, L) for Alton Wells 1-2, and Figures 16 to 18 illustrate the vulnerability scores within the WHPA sensitivity zones (Zones A to D). The vulnerability rating within the 5 to 25-year capture zone (Zone D) is mapped as ranging from high to medium, leading to vulnerability scores of 8 to 4 respectively, depending on the contaminant of concern.

#### *4.4.7.2 Caledon Village Well 3/3A, TW5-2005 – ISI Based Vulnerability Scoring*

Figure 5 illustrates the ISI vulnerability rating (H, M, L) for Caledon Village Wells 3/3A and TW2-2005, and Figures 19 to 21 illustrate the vulnerability scores within the WHPA sensitivity zones (Zones A to D). The vulnerability rating within the 5 to 25-year capture zone (Zone D) is mapped primarily as high to medium leading to vulnerability scores of 8 to 6 respectively, depending on the contaminant of concern.

#### *4.4.7.3 Cheltenham PW1/ PW2 – ISI Based Vulnerability Scoring*

Figure 6 illustrates the ISI vulnerability rating (H, M, L) for Cheltenham Wells PW1/PW2, and Figures 22 to 24 illustrate the vulnerability scores within the WHPA sensitivity zones (Zones A to D). The vulnerability rating within the 5 to 25-year capture zone (Zone D) is mapped primarily as medium leading to vulnerability scores of 4 within the majority of this zone, depending on the contaminant of concern.

### 4.4.8 SWAT/ WWAT Based Vulnerability Scores

The vulnerability scoring was conducted within the 25-year time of travel capture zones for three distinct classes of contaminants; general contaminants, pathogens, and DNAPLs, as outlined in Table 3 of this report and Table 4.1 of MOE's Guidance Module 3 (MOE, 2006). The vulnerability was scored within the 25-year TOT capture zone using the intrinsic vulnerability rating (High, Moderate, Low) obtained from both the WWAT results as well as the SWAT results. Table 3 of this report outlines the scoring methodology used for this portion of the vulnerability assessment.

#### *4.4.8.1 Alton 1-2 - WWAT and SWAT Based Vulnerability Scoring*

Figure 8 illustrates the vulnerability rating (H, M, L) based on WWAT travel times for Alton Wells 1-2, and Figures 25 to 27 illustrate the WWAT vulnerability scores within the WHPA sensitivity zones (Zones A to D). Similarly, Figure 9 illustrates the SWAT vulnerability rating (H, M, L) and Figures 28 to 30 illustrate the SWAT vulnerability scores within those zones. The vulnerability rating within the 5 to 25-year SWAT and WWAT polygons (Zone D) are primarily mapped as moderate to low, leading to vulnerability scores of 6 and 2 respectively, depending on the contaminant of concern. Vulnerability score for pathogens and DNAPLs were assigned a score of '10' within the 5-year capture zone and 100m radius for the respective contaminants. However, the pathogen score outside the 100 m radius within Zone B is dependent on the WWAT/SWAT vulnerability rating and ranged from 8 to 10 similar to the scores for 'general contaminants'.

#### *4.4.8.2 Caledon Village Well 3/3A, TW5-2005 - WWAT and SWAT Based Vulnerability Scoring*

Figure 11 illustrates the vulnerability rating (H, M, L) based on WWAT travel times for Caledon Village Well 3/3A and TW5-2005. Figures 31 to 33 illustrate the WWAT vulnerability scores within the WHPA sensitivity zones (Zones A to D). Similarly, Figure 12 illustrates the vulnerability rating based on SWAT travel times, and Figures 34 to 36 illustrate the SWAT vulnerability scores within those zones. The vulnerability rating within the 25-year WHPA TOT zone (Zone D) is mapped primarily as moderate with lesser zones of low, leading to vulnerability scores of 6 and 2 respectively, depending on the contaminant of concern.

Caledon Village Wells 3/3A and TW2-2005 are completed in a shallow unconfined aquifer, and as such the vast majority of the capture zone is mapped as having a high SWAT and WWAT vulnerability rating. The relatively homogeneous conditions surrounding the Caledon Village Well 3/3A/ TW2-2005, the SWAT analysis has produced results that are consistent with the field observations and our understanding of the geology and hydrogeology of the Caledon Village Well 3 area.

#### *4.4.8.3 Cheltenham PW1/ PW2 - WWAT and SWAT Based Vulnerability Scoring*

Figure 14 illustrates the vulnerability rating (H, M, L) based on WWAT travel times for Cheltenham PW1/ PW2. Figures 37 to 39 illustrate the WWAT vulnerability scores within the WHPA sensitivity zones (Zones A to D). Similarly, Figure 15 illustrates the vulnerability rating based on SWAT travel times, and Figures 40 to 42 illustrate the SWAT vulnerability scores within those zones. The vulnerability ranking based on SWAT and WWAT travel times is mapped predominately as moderate to low, leading to vulnerability scores that range from of 6 to 2 within the Zone D polygon.

The SWAT analysis for Cheltenham Wells PW1/PW2 suggests a slightly lower intrinsic vulnerability than the ISI mapping completed earlier (AquaResource, 2007). This lower intrinsic vulnerability is consistent with available chemistry data; water quality in the Cheltenham wells is fairly good and the only exceedences of the Ontario Drinking Water Standards are for iron, manganese and sodium, which are interpreted to be derived from the underlying shale bedrock as opposed to surficial sources of contamination.

### 4.4.9 Modifications to Vulnerability Scoring

The vulnerability scores are based on physical or natural protection above the municipal aquifers, however anthropogenic activities such as excavations, or pits and quarries, can compromise the natural protection and increase the vulnerability of the aquifers to surficial contamination. Therefore, vulnerability scores can be increased or decreased accordingly. Storm water management (SWM) ponds may also increase the vulnerability of a municipal aquifer however no SWM ponds were noted on the windshield survey within the capture zones.

In the Region of Peel, improperly abandoned wells, or sand and gravel aggregate extraction operations near the capture zones may impact the vulnerability of the municipal aquifer. Improperly abandoned wells were not recognizable through windshield surveys, so database and GIS tools were used to determine the potential presence of these features. MOE water wells that lie within a municipally-serviced portion of a capture zone were considered to be potentially improperly-abandoned; the exception is those wells that were properly abandoned through the Region of Peel well abandonment program.

#### *4.4.9.1 Alton*

As illustrated on Figure 1, there are a number of MOE domestic water wells that lie within Alton's 25-year capture zone, and the majority of these wells lie within a municipally serviced area of Alton. The MOE water wells are not on record as being properly abandoned by the Region of Peel private well decommissioning program (or other program that has reported the well status to the MOE). These wells may provide a direct conduit from the surface to the underlying municipal aquifer if they have not been properly decommissioned, or are not currently being properly maintained by the homeowner. The integrity of the well casing is of primary concern, and review of the over 20 private well records shows that the majority of the wells were drilled in the 1960s and 1970s, and some more recently. Given this, the well casings are expected to be in reasonable shape. As part of the Region of Peel's Microbial Contamination Plan, residents within the pre-existing capture zones were surveyed on their water wells, and it was determined that there were residents within the municipally serviced area that were still using their private wells for water supply. Based on this information, it is not believed that these wells, or Region of Peel monitoring wells, are increasing the vulnerability of the municipal aquifer to surficial contaminants.

There are currently no active aggregate or quarrying operations within the 25-year time-of-travel zone for the Alton Wells 1-2; however portions of the 2-, 5- and 25-year time-of-travel zones have been designated as Caledon High Potential Mineral Aggregate Resource Areas (CHPMARA; Town of Caledon, 2004; See Figure 1). CHPMARA areas are designated within Caledon's Official Plan as areas that have been identified to protect significant areas of mineral aggregate resources (sand, gravel or bedrock) that are not constrained by the Core Greenlands System in Peel, the Niagara Escarpment Plan, registered plans of subdivision, or approved settlement areas. Given this designation it is possible that sand and gravel aggregate extraction may take place within this area in the future, potentially removing the protective overburden and altering the intrinsic vulnerability within the aggregate extraction area. Vulnerability mapping should be updated if such a land use change occurs in this area.

Watermains were also identified within portions of the 2-, and 5- year capture zones. These utilities have the potential to act as horizontal preferential pathways through the subsurface, and as such site specific assessments should be conducted where water quality threats are identified, to determine if the vulnerability score should be increased to account for the presence of these potential preferential pathways.

#### *4.4.9.2 Caledon Village*

According to the MOE water well database there are less than 15 wells within the Caledon Village Well 3/3A and TW2-2005 capture zones that could pose a threat to the water quality (Figure 2). Of those wells, most are municipal supply wells, Region of Peel observation wells, or monitoring wells related to the nearby aggregate extraction operations. Given the nature of these wells, they are expected to be well maintained and are not interpreted to pose a threat to the municipal aquifer. All of the Peel Region monitoring wells within their municipal capture zones have been drilled or upgraded in accordance with the requirements of Regulation 903 and have secure locking systems. Therefore, these wells are not considered to increase the vulnerability of the municipal aquifer. There are two wells located in the municipally serviced subdivision within Caledon Village that may no longer be used by the homeowners however they are not expected to be a serious threat to the municipal aquifer.

Surrounding the Caledon Village Well 3/3A and TW2-2005 are active sand and gravel aggregate operations that are actively removing overburden layers above the municipal aquifer which would otherwise resist migration to the watertable. While the migration resistance of the sand and gravel materials being removed is relatively minor, extraction operations moderately increase the vulnerability of the underlying aquifers. It is recommended that the ISI based, and SWAT based vulnerability scores in the 2-year capture zone area surrounding the wellfield be increased from 8 to 10 to account for these activities. (Note: the WWAT vulnerability score is already 10 in the 2-year TOT capture zone, and a score of 10 was applied to pathogens within the entire 2-year capture zone as noted in Section 4.4.7).

#### *4.4.9.3 Cheltenham*

Overlaying the capture zones and wells in the MOE database shows that there are seven water wells within the 2-year capture zones that lie in municipally serviced areas (Figure 3); two of these wells are municipal supply wells, two are observation wells and three are private domestic wells. There are several additional water wells within the 2 to 25-year capture zone and these well are likely being used by rural landowners as they lie outside the municipally serviced area of Cheltenham. The observation wells within the capture zones are monitored and maintained by the Region of Peel, and as such are not considered to increase the vulnerability of the municipal aquifer. There are no CHPMARA areas or areas designated as sand and gravel resources areas of significance within the Cheltenham capture zones.

#### *4.4.9.4 Summary*

Examination of the various potential for anthropogenic constructed pathways within the municipal capture zone showed that consideration of modification of the vulnerability scores should only be considered in the area surrounding Caledon Village Well 3/3A and TW2-2005.

The presence of sand and gravel extraction activities in this area may warrant an increase in the vulnerability rating within the capture zones. The majority of the capture zones for Caledon Village Well 3 are mapped as high and it is recommended that consideration be given to increasing the moderate vulnerability portions of the capture zones to high vulnerability. Table 8 below summarizes the results of the preferential pathways examination within the capture zones.

**Table 5: Summary of Constructed Pathways**

| **Threat** | **Alton 1-2** | **CV 3/3A, TW2-2005** | **CH PW1/2** |
|---|---|---|---|
| | Does the threat exist in the 25 yr capture zone? | | |
| Significant number of boreholes over 50 years old within municipally serviced area | No | No | No |
| Active sand and gravel operations | No | Yes | No |
| Large diameter buried utilities (e.g. sewer main) | No | No | No |
| Large construction projects (e.g. high rise, underground parking lot) requiring excavation | No | No | No |
| Storm water infiltration ponds | No | No | No |
| **Adjustment Necessary?** | **No** | **Yes** | **No** |

### 4.4.10 Contaminant Sources Inventory Assessment

The objective of the windshield survey was to prepare an updated inventory of potential contaminant sources within the 25-year time-of-travel capture zones in Alton, Caledon Village and Cheltenham. Existing databases (AMEC, 2003), results of previous windshield surveys (AquaResource, 2007a) and other sources of information were used to supplement the windshield survey completed in February 2008. Figures 43 to 46 outline the results of the potential contaminant sources inventory windshield survey, while Appendix A contains photographs of the potential contaminant sources encountered during the windshield survey.

One potential contaminant source that may be common to all wellfields is the storage of chemicals associated with the treatment or filtration of water within the pump houses. Potential contaminants of concern that may be stored include chlorine, chloramine, or sodium thiosulfate.

The following sections discuss the results of the contaminant sources inventory within each of the capture zones.

#### *4.4.10.1 Alton*

The capture zones for the Alton Wells 1-2 contain a number of potential point source contaminants (Figure 43). Within the two year capture zone, there is a library, an elementary school, a small retail store, an assisted care facility for the elderly and the fire and emergency services building for the village of Alton.

Also within the 2 year capture zone is an automotive garage which has the potential to contaminate the underlying groundwater aquifer. Potential contaminants associated with automotive garages may include fuel, engine and transmission oils (containing paraffin-like hydrocarbons), paints, battery acids, and other related contaminants.

A greenhouse was also noted to lie within the 2 year capture zone. Potential contaminant sources associated with greenhouses include herbicides, pesticides, and fertilizers. A cemetery was also noted within the 2 year time of travel capture zone. Contaminants associated with cemeteries range from arsenic, preservatives in the wood caskets, and organic nitrogen, viruses, bacteria and pathogens associated with the decay of human remains (Ucisik and Ryshbrook, 1998).

The southern portions of the 25-year capture zone, and the southeastern portion of the 5 year capture zone include agricultural lands. The windshield survey was undertaken in the winter (Feb. 2008) and as such, the nature of the agricultural activities was not determined, however, the majority of the area appears to be low intensity agriculture and no large livestock operations were observed. Contaminants of concern associated with agricultural lands include nitrate and phosphate and potential pathogens from manure, fertilizers, or non-agricultural biosolids. Agriculture-derived contaminant sources could be both point (i.e. storage areas) and non-point (i.e. spreading areas) sources.

#### *4.4.10.2 Caledon Village*

The dominant land use surrounding Caledon Village well 3/3A and TW2-2005 is aggregate extraction operations. There is sand and gravel extraction actively taking place on the lands surrounding the wellfield, and the pump house lies less than 50 m from Highway 10 (Figures 44 and 45). The windshield survey was undertaken again in February 2008 however there were no additional contaminant sources noted that had not already been reported during the previous windshield survey (see Section 3.6.6 of AquaResource, 2007a).

#### *4.4.10.3 Cheltenham*

The capture zone for Cheltenham has relatively few potential contaminant sources as the capture zones lies predominately in a residential and agricultural area (Figure 46). The windshield survey was undertaken again in February 2008 however there were no additional contaminant sources noted that had not already been reported during the previous windshield survey (see Section 3.6.6 of AquaResource, 2007a).

# 5 Summary of Findings

This study represents another step in the continuous improvement of the hydrogeological characterization of the Region of Peel's municipal water resources. This work accomplishes the tasks outlined in the MOE Guidance Module for Groundwater Vulnerability Analysis, Draft Module 3 (MOE, 2006a) and lays the foundation for further Water Quality Risk Assessment and analysis of threats to municipal drinking water supplies.

## 5.1 Vulnerability Assessment

The vulnerability assessments completed herein followed the MOE Guidelines for Groundwater Vulnerability Analyses (Guidance Module 3) and build upon earlier concepts of intrinsic vulnerability mapping and also included the SWAT/WWAT vulnerability assessment methods. The current methodology incorporates a scoring system that links the intrinsic vulnerability and the delineated capture zones from the numerical model, as well as the SWAT and WWAT based vulnerability rating with WHPA TOT zones.

Relative vulnerability maps and vulnerability scoring was undertaken and is presented in this report. Vulnerability assessments were compared with available water quality data to support or refute the mapping results.

## 5.2 Uncertainty Assessment

Uncertainty was considered throughout the vulnerability assessment. There are many potential sources of uncertainty in a hydrogeologic assessment and this analysis considered that uncertainty in the delineation of the capture zones, in the mapping of intrinsic vulnerability and in the mapping of the vulnerability scores.

Uncertainty from the relative vulnerability mapping and conceptual model was variable depending upon the knowledge available in the vicinity of each wellfield. Uncertainty related to the available data within each vulnerability zone was also evaluated.

As a further evaluation, the potential for constructed preferential contaminant migration pathways within each vulnerability zone was also considered. In general, this potential is low except in those areas where aggregate extraction operations exist or are planned. Such operations remove soil that could otherwise resist infiltration of potential contaminants. In the case of shallow unconsolidated sand and gravel deposits, the protection reduction by removing these deposits is relatively minor (above watertable extraction).

## 5.3 Contaminant Sources Mapping

A windshield survey was completed within the 25-year capture zones and built upon information collected in the previous study. The windshield survey was designed to observe land use conditions within the capture zone and based on what could be seen from the road, make a judgment call regarding the potential for contaminant sources.

The rural nature of these wellfields resulted in relatively few potential contaminant sources. Those identified were mapped and catalogued for potential use in future risk assessments. The windshield survey performed in this study built upon earlier contaminant sources mapping and field verified the contamination potential.

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# Figures

# APPENDIX A

## Contaminant Sources Inventory Windshield Survey Results