# Appendix 5-1

Provincial Permissions for Modifications

Mississippi-Rideau Source Protection Region

Mississippi Valley Conservation

RIDEAU VALLEY CONSERVATION AUTHORITY

**Mississippi – Rideau Source Protection Region**

May 25, 2009

Mary Wooding

Liaison Officer, Source Protection Implementation

Ministry of the Environment

Source Protection Programs Branch

P.O. Box 22032 Kingston, ON

K7M 8S5

Dear Mary:

**RE: REQUEST FOR DIRECTORS APPROVAL TO USE RULE 37(5) & 38(3) FOR HVA DELINEATION, MISSISSIPI-RIDEAU SOURCE PROTECTION REGION**

This letter is a formal request to get Directors approval to use rule 37(5) and 38(3) for the purpose of delineating Highly Vulnerable Aquifers within the Mississippi-Rideau Source Protection Region (MRSPR).

## Specific Request

Rule 37(5) and 38(3) - The MRSPR would like to get Directors approval to use a modified intrinsic vulnerability index (ISI) method to assess the vulnerability of groundwater for the delineation of Highly Vulnerable Aquifers. The modified ISI method would consist of the normal ISI method, plus the incorporation of surficial geology maps. All areas that are mapped as either bare rock or shallow overburden <1.5 m thick (Units R, R), or mapped as being covered by sand or gravel (Units 2, 3, 5, 6, 8, 9, 10, 12) would be classed as highly vulnerable areas.

## Background Information

It is our current intention to use the aquifer vulnerability mapping completed in 2003 by Golder Associated Ltd. as part of the Renfrew County – Mississippi – Rideau

Groundwater Study (2003 Report) to meet the requirements of the Assessment Report for the MRSPR. This aquifer vulnerability mapping is considered to be of high quality and has been included in our Preliminary Draft Watershed Characterization Report, dated May 2008 and has been previously presented to the Mississippi-Rideau Source Protection Committee as well as several other stakeholders. However, upon close review of the methodology in the 2003 Report, it states that a modified ISI method was performed for aquifer vulnerability analysis in consultation with MOE staff and the study's Technical Advisory Group. Specifically, the two modifications were: (1) Incorporating information from surficial geological maps; and (2) Assessing the uncertainty in the vulnerability mapping. With regard to the first modification, incorporating information from surficial geology maps, the following was included in the study:

> As a modification to the MOE protocol an additional step was performed that involved incorporating information from surficial geology maps. All areas that were mapped as either bare rock or shallow overburden <1.5 m thick (Units R, R), or mapped as being covered by sand or gravel (Units 2, 3, 5, 6, 8, 9, 10, 12) were classed as highly vulnerable areas.

It is noted in the 2003 Report that the ISI methodology was originally designed for overburden aquifers. The modified ISI method better suits the unique geology of the study area, namely large expanses of shallow bedrock, and its use as the main potable aquifer in the area.

For additional information, I have attached the Appendix F – Aquifer Vulnerability from the 2003 Report. Please call me at (613) 692-3571 xt 1141 or email me at

Brian.Stratton@mrsourcewater.ca if you have any questions.

Yours truly,

Brian Stratton, P.Eng

Co-Manager, Source Water Protection

Mississippi – Rideau Source Protection Region

Dell Hallett, P.Eng.

General Manager, Rideau Valley Conservation Authority



Box 599, 3889 Rideau Valley Drive Manotick, ON K4M 1A5
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Ontario

Log: ENV1174IT-2009-181

R.V.C.A.
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REFER TO: Sommer
AUG 1 0 2009
INITIALS: DJ

August 4, 2009

Mr. Brian Stratton, P.Eng.
Co-Manager, Drinking Water Source Protection
Mississippi - Rideau Source Protection Region
Box 599, 3889 Rideau Valley Dr
Manotick ON K4M 1A5

Dear Mr. Stratton:

Thank you for your request, under Technical Rule 37 (5), to use an alternate method of determining groundwater (intrinsic) vulnerability for the completion of the assessment report under the Clean Water Act (CWA) for the Mississippi-Rideau Source Protection Region.

As set out in your correspondence, the proposed approach is to use a modified Intrinsic Susceptibility Index method which includes:

1. Addressing the sparse water well data in rural areas of the source protection region located in the northern areas of the region.
2. Incorporating surficial geological mapping where areas that were mapped as either bare rock or shallow overburden of less than 1.5 metres thickness or the bedrock is covered by sand or gravel strata.
3. Such areas of sparse stratigraphic and hydrogeologic data which have bedrock at or near the ground surface or bedrock covered by relatively highly permeable strata will be identified as highly vulnerable aquifers.

In accordance with my authority under section 107(1) of the CWA, I hereby provide Director's approval for the use of this alternate method.

In your request, it was not documented how your approach will be used to determine and delineate the three types of aquifer vulnerability (high, medium, low) in the subject area(s) of the source protection region, as required under Technical Rule 38 (3). This information, along with the methodology discussed herein, and the subsequent results must be included in your assessment report.

…/2

Mr. Brian Stratton
Page 2.

We thank you for your efforts in completing the technical studies in support of the assessment report under the CWA. If you have any questions or require additional information, please contact our office.

Sincerely,

Ian Smith, Director
Source Protection Programs Branch
Ministry of the Environment

cc: Janet Stavinga, Mississippi-Rideau Source Protection Committee Chair
Dell Hallett, General Manager, Mississippi–Rideau Conservation Authority
Sommer Casgrain-Robertson, Drinking Water Source Protection Co-Manager
Heather Malcolmson, Manager, Source Protection Planning
Keith Willson, Manager, Source Protection Approvals
Wendy Lavender, Liaison Officer, Source Protection Implementation

**Brian Stratton**

**From:** Brian Stratton
**Sent:** Monday, December 21, 2009 10:25 AM
**To:** 'Wooding, Mary (ENE)'
**Subject:** Request for Director's approval for an alternate methodology (Grid for Impervious Surface Area)

December 21st, 2009

**Attention:** Mary Wooding, Liaison Officer
Source Protection Implementation
Ministry of the Environment

**Re:** Request for Director's approval for an alternate methodology (Grid for Impervious Surface Area)

Dear Mary:

The Mississippi-Rideau Source Protection Region (MRSPR) is seeking Director's approval for an alternate methodology to **generate the grid** to be used to estimate the Percentage of Impervious Surface Area (Section 17 of the Technical Rules, dated November, 2009). The rationale for the request is outlined below.

1. **Applicable Section of the Technical Rules** – Generation of Grid to estimate Percentage of Impervious Surface Area (Section 17 of the Technical Rules, dated November, 2009.)

2. **Description of the Method being Proposed**- Since Highly Vulnerable Aquifers and Significant Groundwater Recharge Areas are being completed on a regional basis (and cross source protection area boundaries) and Intake Protection Zones and Wellhead Protection Areas also cross source protection areas, the MRSPR proposes to create the grid required to calculate the percent Impervious Surface Area based on the centroid of the source protection region instead of each source protection area. The rest of the methodology would be followed as set out in the Technical Rules.

3. **Rationale for the Alternate Method** – The proposed methodology would eliminate the possibility of different results for grids that overlap two or more source protection areas (the grids would not line up because 2 different centroids would be used). The results of the MRSPR proposed method would be cleaner, and easier to present and discuss in the report.

4. **Explanation on how this method satisfies the Percentage of Impervious Surface Area requirements**
It is not anticipated that the proposed methodology would produce any significant differences to the results than the method specified in the Technical Rules. The reason for the request is for easier presentation and elimination of conflicting results where there are two different grids on the boundary between SPAs.

Should you require any further information, please do not hesitate to contact me.

Thank you.

Brian Stratton

**Brian C. Stratton, P.Eng.**
**Co-Manager, Drinking Water Source Protection**
**Mississippi - Rideau Source Protection Region**
Box 599, 3889 Rideau Valley Drive, Manotick, ON K4M 1A5
Phone: (613) 692-3571 ext.1141 Fax: (613) 692-0831
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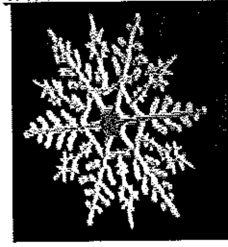

# RVCA Holiday Hours

Our office will close at noon on Thursday, December 24, 2009
and will re-open at 8:30 a.m. on Monday, January 4, 2010.

**Ministry of the Environment**

Source Protection Programs Branch

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**Ministère de l'Environnement**

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Log: ENV1174IT-2009-272

January 18, 2010

R.V.C.A.
RECEIVED
REFER TO: Brian S
JAN 22 2010
INITIALS: DP

Mr. Brian C. Stratton, P.Eng.
Co Project-Manager, Drinking Water Source Protection
Mississippi–Rideau Source Protection Region
Box 599, 3889 Rideau Valley Drive,
Manotick, ON K4M 1A5

Dear Mr. Stratton:

Thank you for your email request of December 21, 2009 to use an alternate method under sub-Rule 15(1) of the Director's Technical Rules (Rules) for the completion of assessment reports under the Clean Water Act (CWA) for the Mississippi-Rideau source protection region.

As set out in your correspondence, your proposal is to use an alternative grid centroid within which you determine the impervious surface percentages for each of your source protection area. As per your email, you are proposing to establish one grid for the complete source protection region, instead of separate grids for each source protection area as required by Rule 17. In our opinion the use of this alternative grid centroid within the source protection region will not impact the implementation of this Rule, other than to move the grid within a 1km square area. Therefore, this approach is equivalent to the method currently required through sub-Rule 16(11) and Rule 17.

In accordance with my authority under sub-Rule 15(1), I hereby provide Director's approval for the use of this alternate method for both source protection areas within the Mississippi-Rideau source protection region.

Your rationale for the use of an alternative grid and how it is being applied must be included in your assessment report.

We thank you for your efforts in completing the technical studies in support of the assessment report under the CWA. If you have any questions or require additional information, please contact our office.

Sincerely,

Ian Smith, Director
Source Protection Programs Branch
Ministry of the Environment

cc: Janet Stavinga, Chair, Source Protection Committee
Heather Malcolmson, Manager, Source Protection Planning
Keith Willson, Manager, Source Protection Approvals
Mary Wooding, Liaison Officer, Source Protection Implementation

# Appendix 5-2

MOE Methodology for Defining

Groundwater Intrinsic Susceptibility

Mississippi-Rideau Source Protection Region

# Appendix 5-2

This methodology is based primarily on the MOE Technical Terms of Reference, March 2002, (MOE TOR p 4 – 8, and Appendix C). Sections of this schedule have been reprinted directly from the MOE Terms of Reference.

**Purpose** - In general, groundwater intrinsic susceptibility maps identify areas where contamination of groundwater is more (or less) likely to occur as a result of surface contamination. It is anticipated that land managers, municipal planners, and facility owners and operators will be able to use groundwater intrinsic susceptibility (GwIS) maps showing the areas of high, medium, and low intrinsic susceptibility and index values at point locations. The GwIS maps can be used as a general guide to preserve existing groundwater resources by diverting potentially harmful land use from areas of higher groundwater susceptibility to areas of lower groundwater susceptibility. Furthermore, recognizing that today's groundwater contamination is tomorrow's surface water contamination, the maps can be effective in preserving the ecosystem functions linked to the groundwater systems.

**Rationale** - The rationale for this method is linked to time of travel. The vulnerability is tied to arrival of a contaminant to the water table and or the shallowest aquifer. The method is not geared to assessing a specific contaminant, contaminant group or human activity. This method assesses intrinsic vulnerability or susceptibility with limited consideration of the specific attributes of the hydrogeologic system or the behaviour of contaminants. The two key attributes considered are the depth to water table and the conductivity of geologic material in the unsaturated zone (or above a confined aquifer). Although the method considers only the intrinsic susceptibility of the shallowest aquifer, deeper aquifers will be of interest to the local municipality. A modification of this method that uses an effective thickness instead of depth to water table, where the effective thickness represents the time of travel to the aquifer, would be a useful first cut at determining the intrinsic susceptibility of aquifers below the shallowest aquifer. This method is also used for determining the intrinsic susceptibility of confined shallow aquifers. Here, the depth to the aquifer is used instead of the depth to water table.

Intrinsically, fine unfractured media retards contaminant migration whereas fractured media, or coarse porous media, provides faster travel times and less retardation and hence more vulnerability. For example 20 m of silt over a confined aquifer would have a low intrinsic susceptibility. But 10 m of clean coarse sand or fractured rock would have a high susceptibility to contamination.

There are other factors that could be used to improve the understanding of a systems intrinsic susceptibility to contamination. Such factors may include gradients, recharge and discharge, flow paths and local geology. This information can be used to adjust the intrinsic susceptibility values.

This method presumes sufficient water well records and topography information are available to predict water table with certainty over the geographic area. In some areas, insufficient water wells, lack of a digital elevation model, or other issues may preclude the use of water table. In these cases, an effective thickness may have to be used that best approximates depth to water table.

**STEP 1: Data Preparation**

**Geological Descriptions** - The Geological Survey of Canada has developed rules for improving the geological descriptions in the MOE Well Log Database which are presented in *Schedule B (MOE TOR, but reprinted here as Schedule C-2 in Appendix C of this report).* These revised descriptions will be included in the database provided by the MOE or otherwise made available to grant recipients, and should be used for the GwIS map. A list of the GSC terms is included in *Schedule B* of this document. This step has been shown to improve the quality of the geological descriptions used for the GwIS map.

| | |
|---|---|
| Table: | D_GEOLOGY_FORMATION |
| Field: | MAT1-3, MATGSC |
| Notes: | GSC updates provided, use Reference table R_WELL_GSCGEOL. The geo-materials conversion process was developed by the GSC for use on the Oak Ridges Moraine. The GSC is interested in learning about the application of this conversion process to other stratigraphic settings in the province. |

**Well Selection and Screening** - All wells with a MOE Well Log database universal transverse mercaptor (UTM) or Elevation Reliability Code error of more than 6 should be initially filtered out of the analysis. The UTM error code refers to the estimated accuracy of the UTM coordinates for the well; a code of 6 implies an error of at least 300 m. Similarly an Elevation Error Code of 6 implies an elevation error of at least 15 m.

| | |
|---|---|
| Table: | D_LOCATION |
| Field: | COORD1_QA_CODE |
| Notes: | provides estimated accuracy of well position.<br>Note that the UTM QA code in the D_Location table is the >corrected= MOE QA code. The original MOE QA code is found in the D_MOE_WELL_INFO table in field COORD2_QA_CODE. |

**STEP 2: Water Table**

A depth to water table map is a requirement of the groundwater study, and is to be used in the preparation of the GwIS map. The water table depth map should be prepared by interpolating a water table surface based on the static water level depths from shallow wells. The consultant is required to assess the local hydrogeological regime and develop a rationale for selecting shallow wells and other relevant data points for the generation of a water table map. The map will be considered the best available depth to water table surface, and should be updated periodically as new information comes available.

The water table surface is to be developed using the static water levels of a subset of shallow wells from the MOE well log database deemed to represent water table conditions. The rationale for selecting shallow wells (e.g., dug and point wells, wells <20 metres in depth, as an example) should be determined by individual consultants based on local conditions. The inferred water table elevation values are then written back to the database, for all wells, for use in further GwIS calculations.

**Database Updates** - The depth to water table is required at all wells in order to calculate the groundwater Intrinsic Susceptibility Index (ISI) at each well. The consultant is therefore required to add the interpolated depth to water table from the map to all wells in the database for the study area.

| | |
|---|---|
| Table: | D_INTERVAL_TEMPORAL |
| Field: | READING_NAME, READING_VALUE |
| Notes: | provides static elevation (and depth) at time of drilling |

**Inadequate or Unreliable Water Table Data** - For each stratigraphic layer, for selected Effective Thickness or depth from ground surface, which has been derived from the preliminary data analysis, a K-Factor (see MOE *Schedule C: Generic Representative Permeability (K-Factor) Table*, reprinted as attachment to this report schedule) is estimated and is multiplies by the thickness of that layer. The summed value of the K-Factors is then used to classify whether an area is of High, Medium, or Low Intrinsic Susceptibility to Contamination. This method can be used where it can be justified to the MOE, prior to using the method, that the water table information is inadequate and will lead to misleading or unacceptable uncertainty. The rationale will need to be provided to the MOE, as well as the detailed description of the method. The MOE will decide what areas or parts of areas can be mapped using an alternate method. The effective thickness should represent a reasonable surrogate for depth to water table and/or depth to aquifer and should be based on a review of all hydrogeologic information, including the water wells. Histograms of water wells with depth to water table, etc., should be included in the rationale.

**STEP 3: Calculation of Intrinsic Susceptibility Index (ISI) at Each Well**

The preparation of the GwIS map includes calculation of an intrinsic susceptibility index (ISI) for each well. This value is written to the database and used to prepare the final map.

The ISI is calculated by summing the product of the thickness of each unit in the well log and a corresponding K-Factor. The K-Factor (reference table provided in *Schedule C, attached*) is a dimensionless, relative number that can be loosely related to the exponent of the vertical hydraulic conductivity in m/s. The calculation is performed from surface to a lower limit defined by the water table configuration.

The consultant shall assess the geology at each well, distinguishing aquifers from aquitards to properly account for consecutive layers of similar materials.

The consultant shall determine on a well-by-well basis if the aquifer of interest is confined, semi-confined or unconfined. The regional groundwater intrinsic susceptibility (GwIS) map is focused on evaluating the uppermost significant aquifer (to be determined by the consultant and the local study team), and considering:

- the use of the aquifer as a drinking water source;
- the linkage of the uppermost aquifer to any local surface water systems and the sensitivity of these systems; and
- the linkage the aquifer might have to deeper aquifers that are used for drinking water.

| | |
|---|---|
| Table: | D_LOCATION_HYDRAULIC |
| Field: | AVI, QUAT_GEOL, STATIC_CORRECTED_E, CONFINED, DEPTHTOSIGNIFICANTAQUIFER |
| Notes: | update these fields with the values calculated at each well |

**Grouping of consecutive aquifer layers**

Geological material should be generalized as aquifer or aquitard based on the classifications prescribed in Table A (appended - Table A may not be complete for the entire province; in the event of missing descriptions, Table A can serve as a guide to the classification of the missing descriptions). This will serve to group together consecutive aquifer layers, and thus facilitate the selection of the first significant aquifer for the intrinsic susceptibility calculations.

Note:some consideration should be given to the presence of thin aquitard layers in undertaking the grouping exercise. In general, a thin aquitard layer should not be used to separate otherwise consecutive aquifer layers. A suggested threshold to define a thin aquitard layer is <1m, but may be refined to better reflect local conditions.

**Identification of First Significant Aquifer**

The following two steps should be used to identify the first significant aquifer at each well:

1. Starting from ground surface, locate the first aquifer unit that is greater than 2m thick and is at least partially saturated.
2. If no aquifer is detected in step 1, locate the first aquifer unit below ground surface that is greater than 1m thick and at least partially saturated.
3. If no aquifer material is detected in the well log, assume the aquifer is located at the well screen, and the top of the aquifer depth is set to the depth of the screen.

Note:The definition of first significant aquifer according to individual study priorities may vary from the GW studies 2001/2002 standard. In these cases, consultants are encouraged to undertake any aquifer characterization work that may enhance the value of the study for local groundwater management purposes. These analyses, however, must be completed in addition to the analyses prescribed by the technical TOR that are intended to ensure regional consistency. For example, a consultant may choose to determine GwIS for the first significant aquifer, as well as for a deeper water production aquifer in the study area.

**Determining confined and unconfined aquifers**

**Confined Aquifers** - For confined aquifers, it is reasonable to assume that contaminants from the surface must migrate through the confining layer and reach the aquifer to cause potential impact. The first significant aquifer is considered confined if it is fully saturated with the water table located at least 4 m above the top of the aquifer. Four metres accounts for the typical range in seasonal groundwater fluctuations. **For confined aquifers, GwlS is calculated from ground surface to the top of the aquifer.**

**Unconfined Aquifers** - For unconfined aquifers, it is reasonable to assume that contaminants from the surface must only migrate to the water table to cause potential impact If the water table is located less than 4m above an aquifer, the aquifer is considered partially saturated and should be classified as unconfined. **For unconfined aquifers, GwlS is calculated from ground surface to the water table or the top of the aquifer, whichever is lower.**

**Semi-confined Aquifers** - For semi-confined aquifers or where there is doubt about the integrity of the confining layer, it is reasonable to assume that contaminants from surface must migrate through a leaky layer and reach the aquifer to cause potential impact. Expert judgement is needed to evaluate the hydrogeological and hydrological information collected for the groundwater studies. Determining if a field of wells should have a modified K_Factor should be based on best professional judgement. The ISI is calculated by summing the product of the thickness of each geological unit in the well and an appropriate K-Factor (refer to *Schedule C*), from ground surface to the top of the water table.

**Missing Aquifers** - For wells where no aquifer material is detected, based on the codes provided in *Schedule B*, the ISI will be calculated as the sum of the product of the unit thickness and the K-Factor from the ground surface to 15 metres below the ground surface.

**Data Reliability Issues** - Where the data and well density are too low to confidently produce the mapping of the water table and geologic materials an alternate method must be proposed which is as faithful as possible to the MOE suggested method. Unreliable wells can be screened out.

Adjustments might also be appropriate where it is clear that certain information sources consistently misrepresent a geological feature of significance. The methods used must be clearly documented for dealing with data reliability issues and interpolation methods between water wells. Adjustments may be used as they arise during the derivation of enhanced local groundwater intrinsic susceptibility maps through the use of local expertise.

**Definitions** - The specific definitions of the first significant aquifer and what qualifies as a semi-confined aquifer, confined aquifer will be defined by the consultant in the context of local hydrogeological conditions.

### STEP 4: Categorizing Intrinsic Susceptibility Index (ISI) Values

For final mapping purposes, the ISI value at each well is categorized into Low (<30), Medium (30 to 80), and High (>80) groupings. The thresholds defining the limits of these categories will be established by the consultant to best reflect local hydrogeological resources and functions.

Once the initial classification has been applied and shown on a preliminary map, the classification limits may be adjusted to reflect local conditions by the consultant to produce the final derived map. The threshold rationale must be clearly described and justified, and account not only for water supply aquifers, but also the ecosystem functions as related to wetlands, rivers, etc.

### STEP 5: Mapping

The final map is developed by interpolating the categorized ISI values at each well. Although the selection of an interpolation method shall be at the discretion of the consultant, a kriging algorithm is recommended, using a grid cell size of 500m or less with a preference for a lower grid spacing.

**Boundary Harmonization** - Consultants must identify how boundary issues with adjoining municipalities will be harmonized. Adjacent study areas must work together for the harmonization of the thresholds where they have been modified from the original classification. Harmonization issues include: geomaterial coding, water table and confined or unconfined aquifer definitions, and intrinsic susceptibility evaluations. The MOE may provide ground rules on harmonization where there are circumstances of unresolvable harmonization of threshold tiers.

### Intrinsic Susceptibility Thresholds

- Low intrinsic susceptibility values will be greater than 80;
- Low to moderate intrinsic susceptibility values will be between 30 and 80; and
- High intrinsic susceptibility values will be less than 30.

**Table A: Classification of Geological Materials**

(Based on the MOE well records following the GSC conversion)

| GSC Protocol Description | K Number | Aquifer |
|---|---|---|
| clay, silty clay | 6 | No |
| clay, silty clay, topsoil | 6 | No |
| clay, silty clay, with muck, peat, wood frags. | 6 | No |
| clay, silty clay, with rhythmic/graded bedding | 6 | No |
| covered, missing, previously bored | 3 | No |
| diamicton: cl to cl/si matrix | 5 | No |
| diamicton: cl to cl/si with gr/sa/si/cl interbeds | 5 | No |
| diamicton: cl to cl/si, stoney | 5 | No |
| diamicton: cl to cl/si, topsoil | 5 | No |
| diamicton; si to sa/si with muck, peat, wood frags. | 5 | No |
| diamicton: si/sa to sa matrix | 5 | No |
| diamicton: si/sa to sa with gr/sa/si/cl interbeds | 5 | No |
| diamicton: cl to cl/si, with muck, peat, wood frags. | 5 | No |
| diamicton: si/sa to sa, stoney | 5 | No |
| diamicton: cl to cl/si, topsoil | 5 | No |
| diamicton: si/sa to sa matrix | 5 | No |
| diamicton: si/sa to sa with gr/sa/si/cl interbeds | 5 | No |
| diamicton: cl to cl/si, with muck, peat, wood frags. | 5 | No |

| GSC Protocol Description | K Number | Aquifer |
|---|---|---|
| diamicton: si/sa to sa, stoney | 5 | No |
| diamicton: texture unknown | 5 | No |
| dolomite | 2 | Yes |
| fill (incl. topsoil, waste) | 3 | No |
| granite (poss. bedrock, prob. boulder) | 4 | Yes |
| gravel, gravelly sand | 1 | Yes |
| gravel, gravelly sand, topsoil | 2 | Yes |
| gravel, gravelly sand, with muck, peat, wood frags. | 2 | Yes |
| gravel, gravelly sand, with rhythmic/graded bedding | 1 | Yes |
| interbedded limestone/shale | 2 | Yes |
| limestone | 1 | Yes |
| miscellaneous; no obvious material code | 3 | No |
| organic | 3 | No |
| organic, topsoil | 3 | No |
| potential bedrock | 3 | Yes |
| rock | 3 | Yes |
| sand, silty sand | 2 | Yes |
| sand, silty sand, topsoil | 3 | Yes |
| sand, silty sand, with muck peat, wood frags. | 3 | Yes |
| sand, silty sand, with rhythmic/graded bedding | 3 | Yes |
| sandstone | 3 | Yes |

| GSC Protocol Description | K Number | Aquifer |
|---|---|---|
| shale | 8 | No |
| silt, sandy silt, clayey silt | 4 | No |
| silt, sandy silt, clayey silt, topsoil | 4 | No |
| silt, sandy silt, clayey silt, with muck, peat, wood frags. | 4 | No |
| silt, sandy silt, clayey silt, with rhythmic/graded bedding | 4 | No |

**Schedule C**

**Generic Representative Permeability (K-Factor) Table**

| Geomaterial | Representative K-Factor (dimensionless)* | K-Value (m/s @75% range** | Highest K-Value (m/s) |
|---|---|---|---|
| gravel<br>weathered dolomite/limestone<br>karst<br>permeable basalt | 1 | 1.00E-01<br>1.00E-06<br>1.00E-03<br>1.00E-03 | 0.1 |
| sand | 2 | 0.01 | 1.00E-02 |
| peat (organics)<br>silty sand<br>weathered clay (<5m below surface)<br>shrinking/fractured & aggregated clay<br>fractured igneous metamorphic rock<br>weathered shale | 3 | 1.00E-03<br>1.00E-04<br>1.00E-04***<br>1.00E-04***<br>1.00E-05<br>1.00E-05*** | 1.00E-03 |

| **Geomaterial** | **Representative K-Factor (dimensionless)*** | **K-Value (m/s @75% range**** | **Highest K-Value (m/s)** |
|---|---|---|---|
| Silt<br>loess<br>limestone/dolomite | 4 | 1.00E-06<br>1.00E-06<br>1.00E-06 | 1.00E-06 |
| weathered/fractured till<br>diamicton (sandy, silty)<br>diamicton (silty, clayey)<br>sandstone | 5 | 1.00E-07<br>1.00E-07***<br>1.00E-08***<br>1.00E-07 | 1.00E-07 |
| clay till<br>clay (unweathered marine) | 8 | 1.00E-09***<br>1.00E-10 | 1.00E-09 |
| unfractured igneous and metamorphic rock | 9 | 1.00E-13 | 1.00E-13 |

* Representative K-Factors are relative numbers and do not correspond directly to the exponent or index of the observed K-Values for the geomaterial in the group.

**Correspondence with descriptors of observed K-Values in Freeze & Cherry 1979, Prentice-Hall. Derived using the length of the line to determine the 75% value and rounding to the highest K-Value.

***Estimated value based on field studies in Ontario.

**NOTE**: When actual study area data is available, this chart should be used to assign the corresponding K-Values for locally defined geomaterial (e.g., Mayhill Till) and then apply the appropriate Representative K-Factor in the calculation of the index of the groundwater intrinsic susceptibility to contamination.

N:\Active\2700\021-2736 MVCA GW Study\8000 Reporting\FINAL REPORT\VOLUME 2\ScheduleF_1.doc

Source: Renfrew Count – Mississippi – Rideau Groundwater Study, Volume 2. Schedule F.1. MOE Methodology for defining Groundwater Intrinsic Susceptibility.

# Appendix 5-3

City of Ottawa Rationale for Carp Pumping Rates

Mississippi-Rideau Source Protection Region

Ottawa

21 July 2010

Mr. Brian Stratton, P.Eng
Co-Manager, Drinking Water source Protection
Mississippi-Rideau Source Protection Region
Box 599
3889 Rideau Valley Drive
Manotick, Ontario
K4M 1A5

Dear Mr. Stratton

**Re: Flow Rates for Carp Municipal Drinking Water System**

I understand that you require confirmation by the City of Ottawa (City) regarding the average flow that was used by Golder Associates Ltd. (Golder) in their most recent model for the delineation of the capture zones for the municipal well in the Village of Carp.

The original Wellhead Protection Study, prepared by Golder in April 2003, used an average pumping rate of 467 $m^3$/d. This flow rate was the 20-year growth potential based on the best information available at the time. In June 2004, the City completed a Community Design Plan (CDP) for Carp, which showed a substantial increase for the projected growth in the village. At approximately the same time, the City was being approached regarding a large-scale residential/industrial development for the Carp Airport, which would significantly increase the flows for the Carp municipal water system. Due to the recent changes in the population projection in the CDP, and because of the potential increase in flows for the Carp Airport, Golder was asked to prepare a technical memorandum (dated August 9, 2004) that would outline two new scenarios—one for the increase in the Village of Carp (to 4,200 people) and one for the increase in the village and that would also include the Carp Airport development. These two scenarios were 1,150 $m^3$/d and 2,000 $m^3$/d respectively.

The Carp Airport development continued to advance, with the completion of an Environmental Assessment report in April 2007 and a subdivision application that received Draft Approval by the City on May 4, 2007, and final approval by the Ontario Municipal Board on August 16, 2007. On the strength of this approval it was decided to opt for the 2,000 $m^3$/d scenario, as shown in the August 2004 technical memorandum.

The next milestone in the planning process for the Village of Carp was the completion of an Environmental Assessment report for Carp in May 2009, which included the increase for the village and the development at the Carp Airport. The Carp EA projected flows up to the year 2031, and calculated that the flow for the village will be 1,340 $m^3$/d and the flow for the Carp Airport (taken from the Carp EA) will be 1,050 $m^3$/d, for a total flow of 2,390 $m^3$/d. These flows are slightly different than those in the Golder technical memorandum, but this has more to do with a refinement in the per capita flow rates than in discrepancies in population projections.

In summary, a flow of 2,000 $m^3$/d is considered to be reasonable for the delineation of the capture zones for the municipal well in Carp. The Carp EA predicts slightly higher flows, but this is not considered to be an issue, as the Wellhead Protection Study will be reviewed as time progresses and refined as necessary.

Best regards,

Michel Kearney, P.Geo.
Sr. Hydrogeologist
Infrastructure Planning Unit
Policy Development & Urban Design Branch

# Appendix 5-4

Rationale for Defining Shallow Bedrock Aquifers as Inherently Highly Vulnerable: Source Protection Areas in Eastern Ontario

Mississippi-Rideau Source Protection Region

# Rationale for Defining Shallow Bedrock Aquifers as Inherently Highly Vulnerable: Source Protection Areas in Eastern Ontario

(Revised September 1, 2010)

## Introduction

Aquifers in eastern Ontario require special consideration as highly vulnerable aquifers (HVA) due to the inherent vulnerability of unprotected fractured rock aquifers. Aquifer vulnerability has been assessed under the Ontario *Clean Water Act, 2006* and associated findings are being included in technical assessment reports by source protection committees during 2010. The purpose of this document is to provide a detailed scientific rationale for the identification of extensive HVAs in eastern Ontario.

Several of the source protection area / regions across eastern Ontario (the Cataraqui, Mississippi-Rideau, and Quinte) share similar hydrogeological conditions. Our source protection areas are situated on and adjacent to the Frontenac Axis portion of the Canadian Shield, and therefore feature a blend of Precambrian and Paleozoic bedrock conditions.

There is minimal cover by soil, sand, and gravel (collectively called "overburden") throughout the majority of our source protection areas. We maintain that fractured rock aquifers are vulnerable to contamination without a sufficient protective layer of overburden. To provide a protection, the layer of overburden should ideally be composed of at least five metres of relatively impermeable soil and sediment (i.e. clay, silty clay, or till).

Assessments of aquifer vulnerability in our source protection areas / regions have been completed using variations of the Intrinsic Susceptibility Index (ISI) method. These assessments share a common finding, consistent with earlier research (e.g. Dillon Consulting Ltd., 2001), that extensive HVAs exist and should be mapped across eastern Ontario. The sections below provide evidence from each of our source protection areas / regions in support of the methods and assumptions used to define aquifer vulnerability.

## Flow and Transport in Fractured Rock Aquifers

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

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

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

Contaminant transport in any aquifer can be considered in terms of the source, pathway, and receptor. Potential sources of contamination include agricultural nutrients and pathogens, industrial solvents (DNAPLs), oil and gas (LNAPLs), cemeteries, and septic tanks. The pathway is governed by the groundwater flow path and geological structure of the aquifer. The receptor is the water body or drinking water well where contaminants are discharged and potentially consumed. Though recharge to fractured bedrock aquifers can be limited, any open vertical fracture creates a high velocity conduit for contamination to reach the drinking water aquifer. Thus rapid recharge to fractured rock aquifers is particularly important, since even small quantities of water are capable of transporting potentially detrimental contaminants to the drinking water source (Gleeson et al., 2009).

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

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

## Examples of Vulnerability in Fractured Rock Aquifers

### Tay River field site

The Department of Civil Engineering at Queen's University has studied groundwater flow and transport in fractured rock aquifers since 2004 in the Tay River area of the Mississippi-Rideau Source Protection Region. The study area is characterized by sparsely-fractured Precambrian syenite-migmatite overlain by 0-3m of sandstone. Rock outcrops are common in this terrain, but overburden thickness can be greater than 4m. Twenty-two bedrock wells were drilled between 2004 and 2008 to depths from 30-45m below ground surface (bgs) in a 40 $km^2$ area. Hydraulic testing to identify horizontal fracture features was completed on each well and most were instrumented with multilevel piezometers. Results from a regional monitoring program indicate that areas of minimal overburden create direct transport pathways for pathogens, such as *E. coli*. Bacteria occur most often in shallow piezometer sections indicating direct connection to the surface. However, bacteria were also found in deep piezometers (~30m bgs) suggesting that vertical fractures encourage transport to deeper horizontal fractures (Levison and Novakowski, 2009).

### Rapid recharge and fluctuating water levels

At the Tay River field site, several research projects focused on recharge to bedrock aquifers and water table fluctuations (Milloy, 2007; Gleeson et al., 2009; Praamsma et al., 2009). Initial water level monitoring and application of the Water Table Fluctuation Method (Healy and Cook, 2002) showed that recharge to the aquifer is approximately five percent for bedrock wells, but that recharge occurs very quickly causing significant changes in water levels (Milloy, 2007). Similar studies were completed in the Quinte Source Protection Region, where recharge contributions are approximately ten percent for bedrock wells. Subsequent studies, at the Tay River field site, using isotopes of hydrogen and oxygen, deuterium and oxygen-18, indicate that precipitation infiltrates the bedrock aquifer very quickly, changing the composition of the groundwater over a short span of time (Gleeson et al., 2009; Praamsma et al., 2009). This research clearly indicates that a contaminant source adjacent to such a well would infiltrate into the aquifer very quickly.

### Surface to fracture tracer experiments

To further verify the recharge work, a surface to fracture tracer experiment was completed using microspheres and lissamine dye to simulate bacteria and nitrate flow. The tracer was applied to a dammed area on the surface (rock outcrop) and samples were collected from a nearby well. Tracer experiments indicate that transport times can be very fast, with arrival times between 30 minutes to five hours after tracer application on the rock outcrop. Microspheres arrive earlier than the conservative flow, but straining is evident. The dominant flow likely occurs through a semi-vertical fracture from the pond area and trickles down into the closest well (5m from the pond). Some of the tracer is flowing downwards to a larger fracture deeper in the deeper interval in the same well. Significant tracer reaches the nearby well (15m from the pond) through shallow horizontal and vertical fractures. All results from the tracer experiments indicate that wells drilled on rock outcrops are extremely vulnerable to surface contamination from agricultural processes.

### Sydenham, Ontario

Sydenham is located north of Kingston on the edge of the Canadian Shield (in the Cataraqui Source Protection Area). Individual private homeowner’s wells have been plagued with nitrate and bacteriological contamination for many years due to connections between septic tanks and drinking water wells. Of the 210 private wells in Sydenham, 25 wells are drilled directly on bedrock, while 185 contain an average of three metres of overburden. Lot sizes are on average 0.1 hectares. Water quality surveys were completed in 1966, 1970, 1972, 1981, 1983, and 1997, where the 1983 and 1997 studies exceeded the Ontario Drinking Water Standards (ODWS) in up to 50% of wells sampled. Through these studies, TSH (2001) concluded that that a drinking water treatment plant with an intake from Sydenham Lake would solve the drinking water contamination issues. The drinking water treatment plant has been online since 2006, however septic tanks remain in use, suggesting that nitrate and bacterial loading is still occurring in the fractured rock aquifer.

### Lanark, Ontario

The village of Lanark is located in the Mississippi-Rideau Source Protection Region. The village is situated in the Precambrian shield and has very limited overburden. Water quality surveys were completed in the village in 1978, 1987, 1990, and 2000, indicating that up to 75% of private homeowner's wells were impacted by nitrate and up to 16% of the wells were impacted by bacteria. Well contamination is attributed to local septic tank contamination and transport through the fractured rock aquifer.

### Portland, Ontario

A detailed well and septic study was completed in Portland by the Department of Civil Engineering at Queen's University. Portland is located in a geologically complex area on Big Rideau Lake (in the Mississippi-Rideau Source Protection Region), where Paleozoic rock outcrops exist in the southern regions of the village and the northern portion of the village has more than ten metres of soil, glacial till, and fill overlying the bedrock aquifer. In this location, the nitrate and bacteriological data suggests that the area with overburden is protected from contamination from local septic tanks, but is subject to contamination sources upgradient of this area that do not have sufficient overburden cover to protect the drinking water aquifer (Kozuskanich, pers. comm, 2010).

### Lansdowne, Ontario

Lansdowne is a small community in the Cataraqui Source Protection Area. The drinking water supply wells in Lansdowne were drilled through 2 metres of clay, 13 metres of sandstone, and 35 metres of syenite migmatite. The wells are cased to 3.5 metres below ground surface. There is significant evidence that suggests a direct connection from ground surface to the supply wells. Intera (2010) has classified the wells as GUDI, even though there are no adjacent water bodies, because of continued positive bacteriological results in the supply wells. Cascading water has also been reported in the supply wells at a depth of 6 metres below ground surface at a rate of 45 litres per minute (Malroz, 2003). It is suspected that this fracture represents a direct pathway from ground surface to the well.

### Rural villages within the City of Ottawa

A review of groundwater characterization reports of rural villages within the jurisdiction of the City of Ottawa by Michel Kerney, P.Geo, shows correlation between soil cover type/thickness and indicators of surface impact. All of the reports are less than ten years old; typically between 10-20% of residential wells were sampled in each village. Summaries of each report are included in Appendix 'A' to this document.

## Regional Groundwater Studies

A description of the methods, assumptions, and limitations of the Groundwater Studies that were prepared by Dillon Consulting Ltd. in the early 2000s is included in Appendix 'B' to this document.

Aquifer vulnerability was addressed in those provincially-funded studies in a manner that is similar to more recent work under the Ontario *Clean Water Act, 2006*.

## Rationale for Extensive HVAs in Assessment Reports

In summary, we believe that our common finding of extensive HVAs in the assessment reports for eastern Ontario is appropriate from a scientific perspective, since:

(1) In most locations there is a limited cover of overburden to prevent contaminants from entering into the groundwater;

(2) Although our knowledge is incomplete, fracturing has been observed in the shallow and deep bedrock of eastern Ontario, including the Canadian Shield, and it is reasonable to assume as part of groundwater vulnerability assessments that fractures may exist under any location across our source protection areas and that the bedrock is an unconfined aquifer; and

(3) Research to-date in eastern Ontario has demonstrated that the presence of vertical fractures creates a direct, high velocity conduit to the drinking water aquifer.

Further, from a policy and process perspective:

(1) Drinking water source protection under the Ontario *Clean Water Act, 2006* is intended to follow a conservative approach, which is consistent with the above assumption related to the extent of fracturing;

(2) Caveats can be added to our assessment reports to indicate that: (a) a conservative approach has been followed in our assessments of groundwater vulnerability, (b) that some individual water wells and locations in our source protection areas may not have a high vulnerability, and (c) that therefore site-specific confirmation of aquifer vulnerability is recommended;

(3) Extensive HVAs were included in each of the provincially-funded regional groundwater studies that were prepared prior to the drinking water source protection initiative (such that the overall finding is familiar to the province, municipalities, and other stakeholders);

(4) Findings with extensive HVAs have been endorsed by each of the source protection committees responsible for our areas/regions and have been received as 'reasonable' in the municipal and public consultation processes for draft assessment reports in the Cataraqui and Quinte; and

(5) The source protection plans that will be prepared under the *Act* and its regulations may include only voluntary policies for highly vulnerable aquifers (such as those related to public education, incentive-based programs, and land use planning), which are conducive to implementation on a broad geographic scale.

We acknowledge that further research on aquifer vulnerability in eastern Ontario will be appropriate over time in order to learn more about the geology and hydrogeology of our source protection areas /

regions.  Continuous improvement may refine the extent of HVAs in future editions of our assessment reports.

The above rationale has been endorsed by the technical staff at the following source protection areas/regions:

- Cataraqui Source Protection Area;
- Mississippi-Rideau Source Protection Region; and
- Quinte Source Protection Region

Letters of support from Dr. Kent Novakowski and Dr. Michel Robin for the above rationale are included in Appendix 'C'.

## Conclusions

Most landowners in the rural portions of the Cataraqui, Mississippi-Rideau, and Quinte source protection areas / regions rely on fractured rock aquifers as their primary drinking water source. Current research indicates that fractured rock aquifers should be considered as inherently vulnerable where insufficient overburden protection exists. The provincial Drinking Water Source  Protection initiative provides a unique opportunity to protect these important aquifers

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# Appendix 'A'

This appendix outlines a review of groundwater characterization reports of rural villages within the jurisdiction of the City of Ottawa by Michel Kerney, P.Geo, shows correlation between soil cover type/thickness and indicators of surface impact.

### *Fitzroy Harbour*

- Champlain Sea clay in areas;
- Thin soil veneer over bedrock in the east and west parts of the village;
- Wells are mostly finished in limestone or granite;
- Nitrate was found to be elevated in the thinly veneered bedrock areas; and
- Chloride was found to be elevated in areas, with the data indicating the possibility of road salt impact.

### *Ashton*

- Central area of the village has less than one metre of soil cover;
- Elevated nitrate; and
- Elevated chloride, with evidence that the source is road salt.

### *Richmond*

- Predominantly clay overburden (up to 10 m in thickness); and
- No indicators of surface impact.

### *North Gower*

- Till with a high clay content; and
- No indicators of surface impact.

### *Cumberland*

- Highly variable geology;
- Clay in some areas (up to 39 m);
- Central and north portions of the village have less than 1 m of soil cover over bedrock;
- Nitrate in thin overburden areas reaching 6.8 mg/L; and
- Chloride average is 464 mg/L.

### *Vernon*

- Shallow soils (<1 m in central area); and
- 19% of wells have Total Coliform presence.

### *Metcalfe*

- Extensive study of this village over more than 20 years;
- Fairly complex geology;
- Areas with less than one metre of soil;
- Most of the village is underlain with till that is very hard and fractured (locally known as "hardpan");
- "Hardpan" makes well seals more challenging, and thus many wells are improperly sealed;
- Studies in 1983/84 indicated 34% of wells contaminated with bacteria;
- Study in 2003 indicated 28% of wells contaminated with bacteria; and
- Elevated chloride, nitrate and ammonia.

# Appendix 'B'

## Regional Groundwater Studies

### Background

Aquifer vulnerability mapping was performed as part of the regional groundwater studies that were undertaken in the watersheds that comprise much of the Cataraqui, Mississippi-Rideau, and Quinte Source Protection Areas / Regions. Vulnerability mapping performed in these watersheds followed the methodology developed during the Renfrew County – Mississippi-Rideau Groundwater Study (Golder and Dillon, 2003). Documentation of the methodology is provided in the following MOE Terms of Reference (TOR) documents:

a) Ontario Ministry of the Environment and Energy, 2002; Groundwater Studies, 2001/2002, Technical Terms of Reference with Database Field References, 2002;

b) Ontario Ministry of the Environment and Energy, 2002; Groundwater Studies, 2001/2002, Clarification for TOR section 2.2.2 and 2.2.3 – GwIS calculation, July 12, 2002; and,

c) Ontario Ministry of the Environment and Energy, 2002; Groundwater Studies 2001/2002 – Methods for GwIS and water table mapping in bedrock areas, August 26, 2002.

### Aquifer Vulnerability Method and Assumptions

Mapping of groundwater vulnerability in the Cataraqui, Quinte and Mississippi-Rideau watersheds involved the following steps:

1. Intrinsic Susceptibility Index (ISI) values at wells were generated following the 2001/2002 MOE TOR, and its subsequent amendments. For bedrock wells where little overburden existed, the assumption was made that the top portion of the bedrock aquifer was potentially unconfined. The water table was generated based on kriging the elevation of static water levels in all wells that were less than 15 m deep, and overlain by less than 5 m of overburden, and conditioning this surface to the elevation of surface water features. This assumption was based on the geological model developed for the applicable watersheds, and presented in the regional groundwater study reports (Dillon, 2004; Golder and Dillon, 2003) and the Cataraqui Groundwater Vulnerability Report (Dillon, 2008). Aquifer vulnerability between the wells was determined by interpolation of water well ISI values.

2. Areas of thin (<1.5 m) and absent overburden were identified as highly vulnerable as per the August 26, 2002 MOE amended mapping methodology. Information on overburden thickness was based on water well records, digital elevation model data, satellite imagery and information from surficial geology maps. It is noted that the August 26, 2002 methodology recommended identifying areas having <6 m of overburden as highly vulnerable. This filter was not applied as it did not significantly affect the assessment results and only added additional uncertainty into the evaluation.

3. For areas that were mapped as being covered by permeable soils such as sandy till, surficial sand or gravel, a high vulnerability designation was given.

Key assumptions made in the vulnerability assessment that are specific to areas of shallow bedrock are as follows:

*Unconfined Conditions are Potentially present in Shallow Bedrock Aquifers* – It is assumed that a water table aquifer may exist in shallow bedrock aquifers, and that this aquifer would represent the first aquifer encountered in the ISI methodology. It is realized that individual wells may tap deeper confined fractured zones; however, these zones are not considered the shallow most aquifer. These assumptions are supported by the geological model which assumes that fractures are often connected in varying degrees and that fractures observed at depth in a well may be connected to shallower fractures. Examples of scientific evidence in support of this model are presented in earlier sections of this letter. While it is realized that these assumptions are not valid at every well, it is postulated that the quality of most water well records is insufficient to prove the absence of unconfined conditions.

*Bedrock is Potentially Fractured from Surface to base of Well* – Water well records are often the only information source available to identify fractures at depth; however, these records are not considered reliable to identify all water bearing fractures. In the absence of reliable data, it is conservatively assumed that other fractures are present in the bedrock in addition to those recorded in the well record. The accuracy of the well log will depend upon drilling technique, lithology and logging approach taken by the driller. As an example, fracture zones are often more easily identified via rotary drilling as the drill action becomes rougher; however, water bearing zones are often more easily observed using cable tool technology. With respect to log descriptions, water well drillers focus on the identification of larger water bearing fractures, and will not necessarily be able to identify smaller fracture zones. Lastly, the vertical nature of the water well is of use in identifying the presence/absence of nearby vertical fractures.

*Errors in Interpolation of ISI values between Wells* – Interpolation of ISI values between bedrock wells is problematic because the correlation of fracture zones between wells using the Water Well Information System (WWIS) as the prime data source is highly unreliable. Firstly, the description of fracture zones in the WWIS is simplistic and often of poor quality. Secondly, the geological processes that control fracture characteristics are very complex and produce a highly heterogeneous fracture pattern that has greater spatial variability than the frequency of the observation points (wells).

*Shallow Fractured Rock is Intrinsically Highly Vulnerable* – This conservative assumption is based on the geological model of groundwater flow in bedrock through fracture networks. These networks are controlled by a combination of various geological processes such as sheeting, solution weathering and geotectonic influences. These processes are highly complex, and the resulting fracture characteristics are not readily mappable or predictable based on the quality and resolution of the available information. While broad characterizations can be made for fracture patterns in different rock types, such general descriptions are of limited use for aquifer vulnerability mapping where a single vertical fracture can make a well susceptible to impacts.

## Limitations

The main limitation to this approach is that all areas of shallow bedrock were conservatively identified as highly vulnerable, when in reality this will not always be the condition. As a result, some land parcels in the study areas will be identified as high vulnerability areas, when they are not. Determination of lower vulnerability conditions would require much more sophisticated input data than is currently available for these regional analyses.

## Appendix 'C'

This appendix includes two letters of support for this rationale document by Drs. Kent Novakowski and Michel Robin from the Department of Civil Engineering at Queen's University and the Earth Sciences Department at the University of Ottawa, respectively.

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Tuesday, 22 June 2010

Ian Smith
Source Water Protection Branch
Ontario Ministry of the Environment
2 St. Clair Avenue West
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Dear Ian,

I am writing to offer a letter of support to the Source Water Protection Areas/Regions in eastern Ontario where many citizens acquire their drinking water from shallow bedrock aquifers with very little protective soil or overburden cover. I have read the report prepared by this group entitled "Rationale for Defining Shallow Bedrock Aquifers as Inherently Highly Vulnerable: Source Protection Areas in Eastern Ontario" and concur with their arguments.

I have 25 years of research and consulting in the field of fractured rock hydrogeology, and in my experience, it is impossible to characterize bedrock aquifers with techniques developed for porous media. This is because the aquifer has a much smaller storage volume (by several orders of magnitude), much higher groundwater velocities (also by several orders of magnitude), and typically much less protection from overlying sediments than sand and gravel aquifers of equivalent permeability. Groundwater recharge tends to be low, and contaminant migration very rapid and heterogeneous in these settings. Vertical fractures which may be sparsely distributed provide very rapid pathways to the underlying fracture networks. Once bedrock aquifers are contaminated, clean up is rarely if ever successful. Thus as a source of either municipal or domestic drinking water, there is none other that is riskier or more vulnerable. I strongly believe that an important distinction for these sources of water should be made perhaps best via the source water protection process.

Please do not hesitate to contact me if I can offer any assistance in this matter.

Sincerely,

Kent S. Novakowski

Kent S. Novakowski, PhD, P.Geo., LEL
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24 June, 2010

**Brian C. Stratton, P.Eng.**
Co-Manager, Drinking Water Source Protection
Mississippi - Rideau Source Protection Region
Box 599, 3889 Rideau Valley Drive, Manotick, ON K4M 1A5

RE: Mississippi – Rideau HVA designation

Brian,

As you requested by phone on June 22nd , I reviewed the Eastern Ontario HVA rationale document and its amended Appendix A; a letter of support for the HVA designation in eastern Ontario by Dr Kent Novakowski; and *Appendix F – Aquifer Vulnerability Analysis* of the *2003 Renfrew County – Mississippi – Rideau Groundwater Study*.

My views concur with those of Dr Novakowski: I my opinion, the shallow, fractured bedrock aquifers of Eastern Ontario are highly vulnerable, purely based on hydrogeological considerations: as pointed out by Dr Novakowski, fractured systems are typically of low storage, high groundwater velocities and consequently they are very fast-responding and vulnerable to contamination; in Eastern Ontario, the fracture network is poorly characterized, but it is present; and there is ample circumstantial evidence provided in the HVA rationale document.

From a methodological stand-point, the ISI method for characterizing vulnerability suffers a number of shortcomings, not the lease of which is that it ignores the magnitude and direction of the driving force, the hydraulic gradient. In the case of the fractured rock aquifers of Eastern Ontario, the hydraulic gradient is highly variable in space and in time, and consequently highly unpredictable. Even if it were measured in the field the spatial and temporal variability would remain. In this particular case, therefore, I believe that the ISI methodology will provide a level of conservatism that is justified.

Sincerely,

Michel Robin

Michel J.L. Robin, PhD, P.Geo