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7.0 ELGIN COUNTY WATER QUALITY RISK ASSESSMENT

~~There is o~~One municipal drinking water system ~~located within the portion of~~within Elgin County ~~that falls~~is located ~~within~~ in the Long Point Region Source Protection Area, as summarized in ~~(~~**Table 7-1**~~)~~. The village of Richmond drinking water system is located in the Municipality of Bayham. This is a new municipal drinking water system established in 2014. The total annual takings in 2014 were 12,466 cubic meters. The communities of Port Burwell and Vienna have municipal drinking water distribution systems and source their water from Lake Erie via the Elgin Area Primary Water Supply System located in the Kettle Creek Source Protection Area.

Table 7-1: Municipality of Bayham Municipal Residential Drinking Water Systems in the Long Point Region

DWS Number	DWS Name	Operating Authority	GW or SW	System Classification[1]	Number of Users served
260074854	Richmond Community Drinking Water Supply System	Municipality of Bayham	GW	Small municipal residential	51

1 as defined by O. Reg. 170/03 (Drinking Water Systems) made under the *Safe Drinking Water Act, 2002.*

7.1 Municipality of Bayham Richmond Water Supply System

The Municipality of Bayham owns and operates the water supply and distribution system which provides water to residents of the Village of Richmond. The system, which is groundwater-based, consists of three pumping wells: one bedrock backup supply well (TW1-10), and two overburden wells (TW2-12 and TW3-12). The system supplies water to approximately 51 private residences in the Village of Richmond. **Map 7-1** shows the location of the well site and serviced area.

TW1-10 is an 81.4 m deep drilled well with an outside diameter (OD) of 168mm. The well is completed as an open hole into bedrock starting at 72.5 m below grade. ~~The annular space from 72.5 m to ground surface was filled with bentonite slurry to prevent a hydraulic connection from occurring between the overburden formations and the bedrock. Geologic cross sections produced by Stantec (2013) suggest that the bedrock formation is separated from the surface by a thick layer of low permeability clay and other fine grained materials.~~ TW1-10 is not actively pumped as part of the Richmond water supply system because of poor ambient~~the~~ water quality within~~of~~ the deep bedrock aquifer ~~is poor~~.

TW2-12 and TW3-12 are constructed within the shallow overburden sediments to depths of 17.4 and 18.0m below ground surface respectively and screened within an unconfined aquifer. ~~The wells were completed as 168 mm OD holes with screen lengths of 4.9 m. Well TW2-12 is screened from 11.0 to 15.9 m below ground surface and TW3-12 is screened from 11.6 to 16.5 m below ground surface. The annular space between the casing and the formation from 11.0 m below ground surface in TW2-12 and 11.6 m below ground surface in TW3-12 was backfilled with bentonite slurry to prevent a hydraulic connection with the surface. Geologic cross sections produced by Stantec (2013) suggest that the overburden is unconfined in this area.~~

7.1.1 Vulnerability Assessment

Delineation of Wellhead Protection Areas

~~Wellhead Protection Areas (WHPAs) developed for municipal groundwater supplies represent the areas within the aquifer that contribute groundwater to the well over a specified time period. According to the Technical Rules (MOE, 2009a), four Wellhead Protection Areas must be identified.~~

~~The delineation of a Wellhead Protection Area for a municipal well field is based on the delineation of the time of travel capture areas for the municipal well field. Wellhead Protection Areas represent the area projected to land surface where groundwater can be captured by pumping at the municipal wells. It should be noted that the WHPAs represent time of travel within the saturated zone of the aquifer to the well and do not account for travel time from ground surface down to the water table. The pumping rates used to determine the Wellhead Protection Area are based on the allocated quantity of water.~~

~~Wellhead Protection Areas are sub-divided into four time of travel (TOT) zones according to Technical Rule V.3 (47-50):~~

- ~~Zone A (WHPA-A) 100 m radius from wellhead~~
- ~~Zone B (WHPA-B) 2 year time of travel capture zone~~
- ~~Zone C (WHPA-C) 5 year time of travel capture zone~~
- ~~Zone D (WHPA-D) 25 year time of travel capture zone~~

~~Modelling Approach for the Village of Richmond Water Supply~~

The Long Point Tier 3 FEFLOW groundwater flow model (Matrix, 2013) was used to generate the Wellhead Protection Areas (WHPAs) for the Richmond water supply system. The groundwater model was developed to support the development of the Long Point Region water budget and local area risk assessments. ~~Model d~~Development of the Tier 3 groundwater flow model and calibration is discussed in Matrix Solutions (2013). To delineate WHPAs for the Richmond municipal wells, ~~T~~the Tier 3 model was recalibrated in the Richmond area to better represent local conditions (Burnside, 2015).

~~During the calibration process, efforts were made to adjust as few parameters as possible. Recharge distribution, boundary conditions within both the overburden and the bedrock, the hydrostratigraphic structure of the model, and the model layer thickness were all retained in the re-calibrated Tier 3 model. The following adjustments were made to the model to better represent the local conditions in the vicinity of the Richmond supply system:~~

- ~~Horizontal hydraulic conductivities of the overburden were updated based on pumping test data for the Richmond municipal wells (Stantec, 2013),~~
- ~~The vertical hydraulic conductivity of the aquitards between the overburden and the bedrock within the study area was adjusted to better reflect the differences in water levels observed in the wells, and~~
- ~~The parameter controlling the connection between the streams within the study area and the groundwater system was adjusted to better reflect conditions near the streams as described in Stantec (2013) investigations.~~

~~Groundwater levels simulated with the re-calibrated model in the overburden and bedrock are shown to have good agreement with the overburden targets derived from the MOE water well records. The re-calibrated model was further tested by simulating pumping tests completed by~~

~~Stantec (2013). The results of the model testing confirm that the re-calibrated model is suitable for predicting changes in water due to pumping the Richmond supply system wells.~~

~~The particle tracking capabilities of the Tier 3 FEFLOW model were used to delineate the groundwater flow directions and travel times to support the delineation of the Richmond supply system capture zones. The capture zones were delineated assuming long-term average conditions. Average takings from 2006, 2012, and 2013, in addition to the constant rate pumping tests completed in 2013 (Stantec, 2013) were reviewed to determine an appropriate average daily pump rate.~~ A continuous pumping rate of 1.0 L/s for the municipal wells was ~~assumed for the analysis~~used to generate the Richmond WHPAs. This rate~~, which~~ also accommodates the possibility ~~of~~ for~~a~~ future increases in demand.

~~Effective porosities were assumed to be 0.3 for the overburden and 0.01 for the bedrock. The values assumed for the overburden is consistent with analyses of travel times in typical sand and gravel aquifers. The value assumed for the bedrock is relatively low, reflecting the fact that the bedrock may be sparsely fractured. This is a conservative value that accounts for the possibility of preferential pathways in the rock.~~

~~*Delineation of Richmond Wellhead Protection Areas*~~

~~The initial WHPAs produced were elongated and narrow, as are typical of WHPAs produced by wells pumping at low rates. In order to account for the increased uncertainty in the WHPAs away from the Richmond wells, a conservative approach to delineation was undertaken. The initial WHPAs were doubled in their lateral extent in order to incorporate the uncertainty associated with the location of the boundary. T~~The final WHPAs are presented in **Map 7-2**.

Delineation of WHPA-E and WHPA-F

Delineation of additional WHPAs may be required for each well or wellfield that has been identified as groundwater under the direct influence of surface water under subsection 2(2) of O. Reg. 170/03 (referred to as GUDI wells). A WHPA-E is required for GUDI wells where the interaction between surface water and groundwater has the effect of decreasing the travel time of water to the well.

The overburden wells in the Village of Richmond were recommended to be considered GUDI with adequate in-situ filtration. The closest surface water source to these wells is Big Otter Creek. An evaluation of the site geology and topography indicated that Big Otter Creek is located a significant distance below the well intake and is separated from the aquifer in which the wells are constructed by a layer of clay. As a result, a WHPA-E for the Village of Richmond wells was not delineated. Since a WHPA- E was not generated for these wells, a WHPA-F was also not delineated.

Vulnerability Scoring in Wellhead Protection Areas

The completion of aquifer vulnerability scoring is outlined under Part VII of the Technical Rules (MOE, 2009a). Mapping for this study was completed in three stages: i) development of aquifer vulnerability mapping ii) updated aquifer vulnerability to reflect the presence of potential transport pathways and iii) assignment of vulnerability scores.

Aquifer vulnerability mapping was completed within the Lake Erie Region Source Protection Area using the Surface to Aquifer Advection Time (SAAT) ~~approach~~ method (EarthFX, 2008). The SAAT ~~approach~~ method estimates~~s~~ the average time required for~~by~~ a water particle to travel from a point at the ground surface to the aquifer of interest~~concern~~. The SAAT is approximated by ~~using~~calculating the vertical component of the advective velocity integrated over the vertical distance and the average porosity. ~~The travel times generated are categorized into groups being <5 years, 5 to 25 years and > 25 years.~~

~~Calculation of the SAAT values was based on the use of empirical formulae provided by the MOE (MOE, 2009a). These formulae provide methods for the computation of two separate components of the SAAT, the unsaturated zone advection time (UZAT) and the water table to aquifer advection time (WAAT). The UZAT was computed based on values assumed for depth to water table, mobile water content and infiltration rate. For the study a depth to water map was generated using an interpolated water table map and the elevation of the land surface. Mobile water content was approximated based on the specific yield of each soil type and infiltration was approximated using a GAWSER recharge model in which infiltration was assumed to be equal to the recharge rate. In areas where several layers of varying materials were present the calculations were done for each layer and then summed over the entire unsaturated portion of the sub-surface.~~

~~Where required, the WAAT component of the SAAT was also computed. It is noted by EarthFX that the WAAT was only computed in two instances; the first where the target aquifer was known to be confined and the second where no aquifer material was recognised. The factors included in the computation of the WAAT were aquifer porosity, thickness of the geologic layer, vertical hydraulic conductivity and the difference between the head in the confined aquifer and the water table. Hydraulic conductivities were estimated based on the geologic materials listed in the boreholes logs. Vertical hydraulic gradients were estimated by subtracting the interpolated potentiometric surface from the interpolated water table. The thickness of each layer above the target aquifer and the location of the top of the target aquifer were determined from the borehole logs.~~

The SAAT travel times were grouped based on guidance provided by the MOE to create ratings which were then used to construct an aquifer vulnerability map of the study area. ~~TOT~~ Time-of-travel values less than 5 years ~~are~~ were rated as ~~H~~highly v~~V~~ulnerable~~ility~~. Values between 5 and 25 years ~~are~~ were classified as ~~M~~medium vulnerability, and~~. Any~~ values greater than 25 years ~~is~~were classified as having a l~~L~~ow v~~V~~ulnerability. The vulnerability ratings based on the travel times are shown in **Table 7-2.** The unadjusted intrinsic vulnerability (SAAT aquifer vulnerability) for the Richmond area is shown on **Map 7-3.**

Table 7-2: SAAT Vulnerability Ratings

Time of Travel (years)	Vulnerability Rating
<5	High
5 to 25	Medium
>25	Low

~~***Identification of Transport Pathways and Vulnerability Adjustment***~~

Transport Pathways in the Richmond Wellhead Protection Area

Rules 39 to 41 of the Technical Rules (MOE, 2009b) allow for an increase in the vulnerability rating of an aquifer due to the presence of transport pathways that may increase the vulnerability of the aquifer by providing a conduit for contaminants to bypass the natural protection of the aquifer. ~~The presence of the transport pathways should be accounted for in the vulnerability assessment and these pathways may include private water wells, unused water wells, abandoned water wells, construction of underground services, subsurface excavations, pits and quarries.~~

~~Transport Pathways in the Richmond Wellhead Protection Area~~

The vulnerability mapping as presented in **Map 7-3** accounts for potential transport pathways within the Richmond WHPAs. Further analysis of possible transport pathways within the Richmond WHPA indicated that no further updates to the vulnerability mapping were required. **Map 7-4** shows the final vulnerability scoring for the Richmond Wellhead Protection Areas.

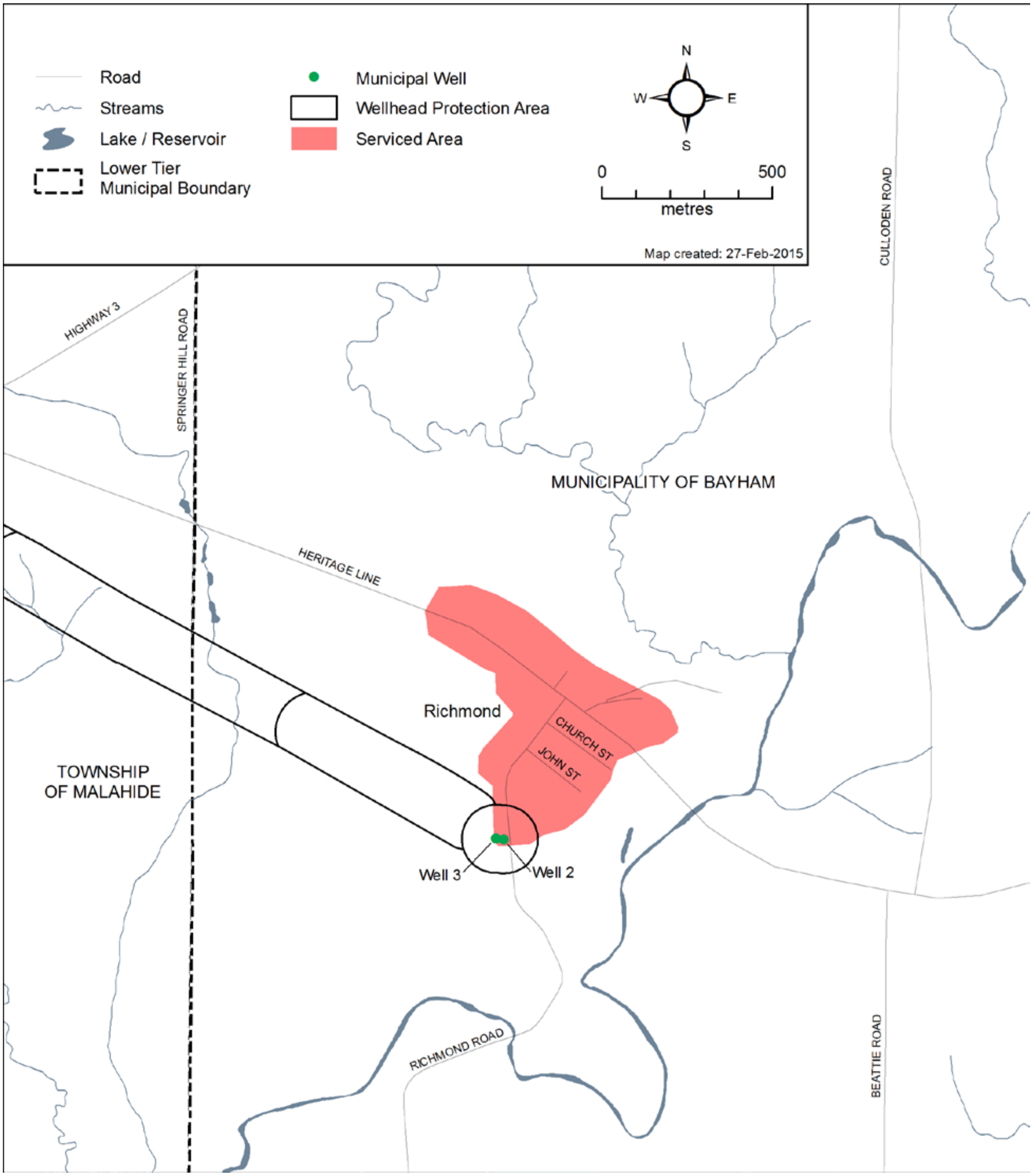
~~Uncertainty in the Wellhead Protection Area Delineation and Vulnerability Scoring for the Richmond Well Supply~~

~~The time-related capture zones that have been delineated in the overburden and bedrock are relatively long and narrow. These results are consistent with a setting in which wells pump at relatively low rates in permeable formations. In light of the fact that the capture zones are so narrow, there is significant uncertainty in their likely lateral extents. In addition to the high uncertainty assigned to the wellhead protection areas, there is also high uncertainty assigned to the vulnerability scores as vulnerability mapping for the Richmond wellfield was completed based on a regional scale SAAT map.~~

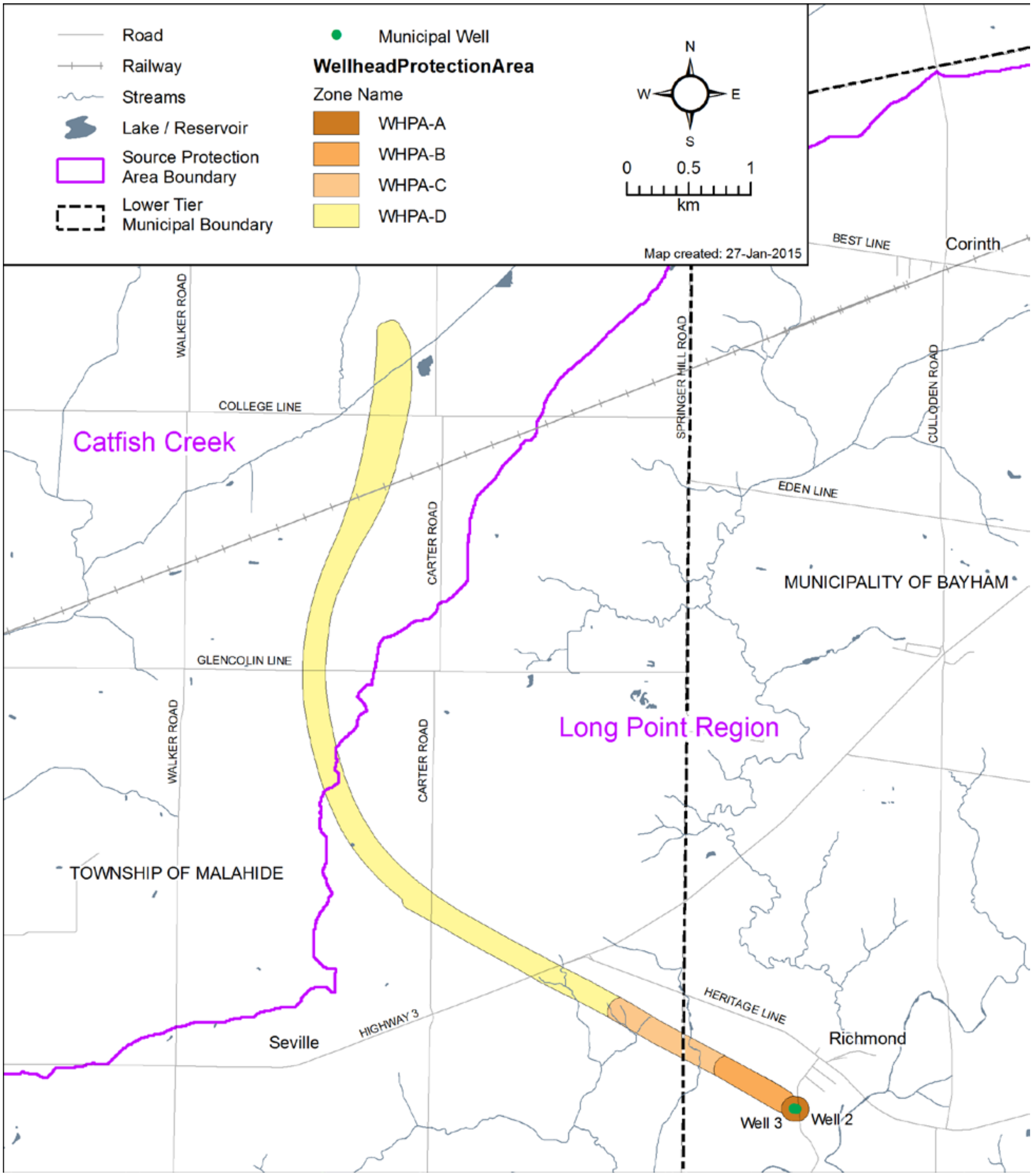
~~In addition, the uncertainties embedded in the Long Point Tier 3 model are carried through the Richmond analysis. Sources of uncertainty identified in the Tier 3 model include gaps in the characterization of the surface and groundwater systems; limitations in the climate and stream flow data; uncertainties associated with water use and in the representation of snow and urban systems; and limitations in the modeling approaches (Matrix Solutions, 2013). Additional sources of uncertainty have been identified in the re-calibrated Tier 3 model; these include uncertainty in the effective porosity of the overburden, gaps in the characterization of subsurface heterogeneity, and spatial and temporal local variations in the regional hydraulic gradient.~~

~~The WHPAs have been delineated to represent what is believed to be the long term average conditions based on the available data. High-quality data to support the analysis of groundwater flow conditions in the vicinity of Richmond are limited to one point in time at four wells. To account for the uncertainty in the delineation of the WHPAs it is recommended that a buffer be added to the WHPAs to provide a margin of safety.~~

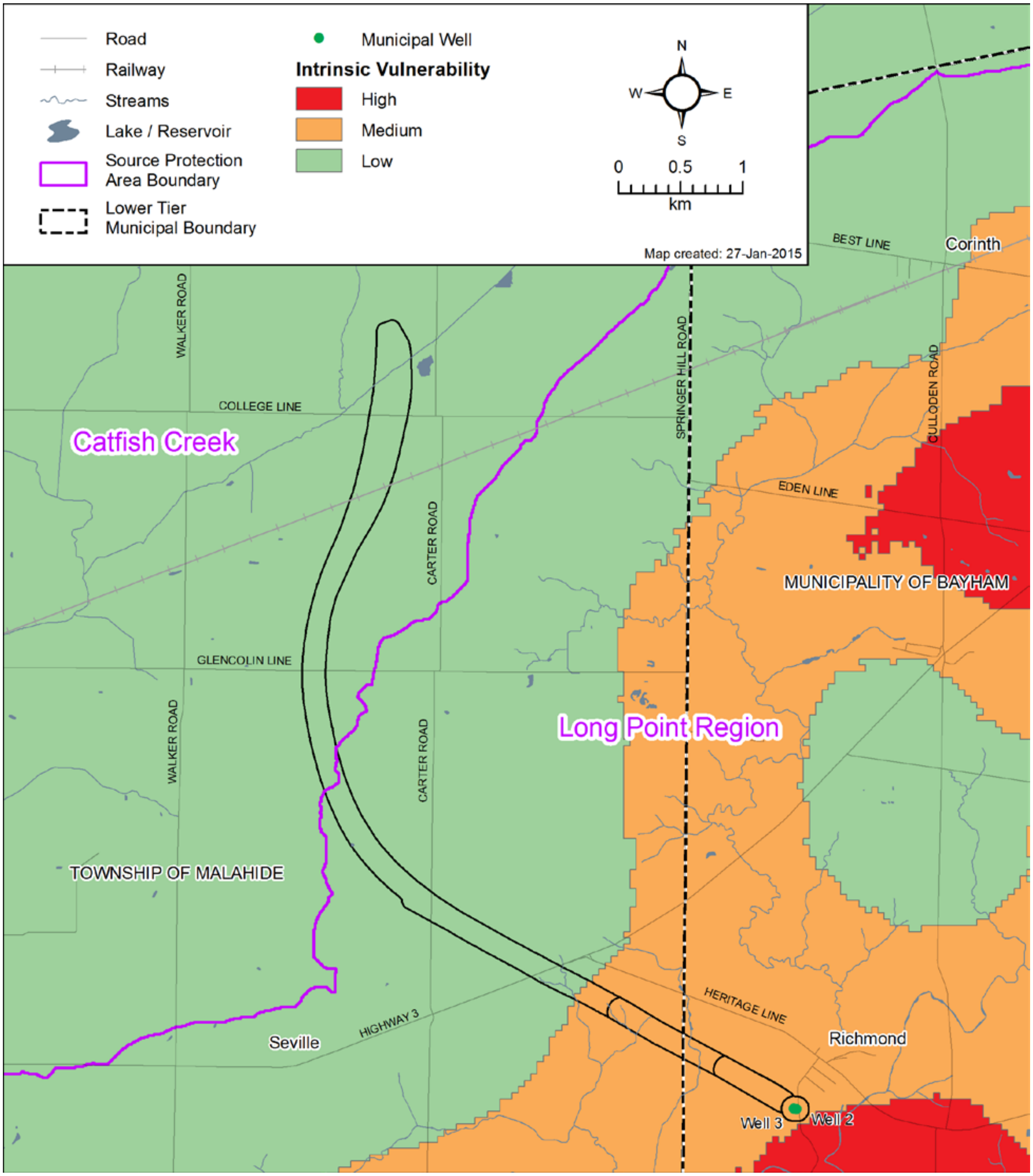
Map 7-1~~7-1~~: Richmond Well Supply Serviced Areas



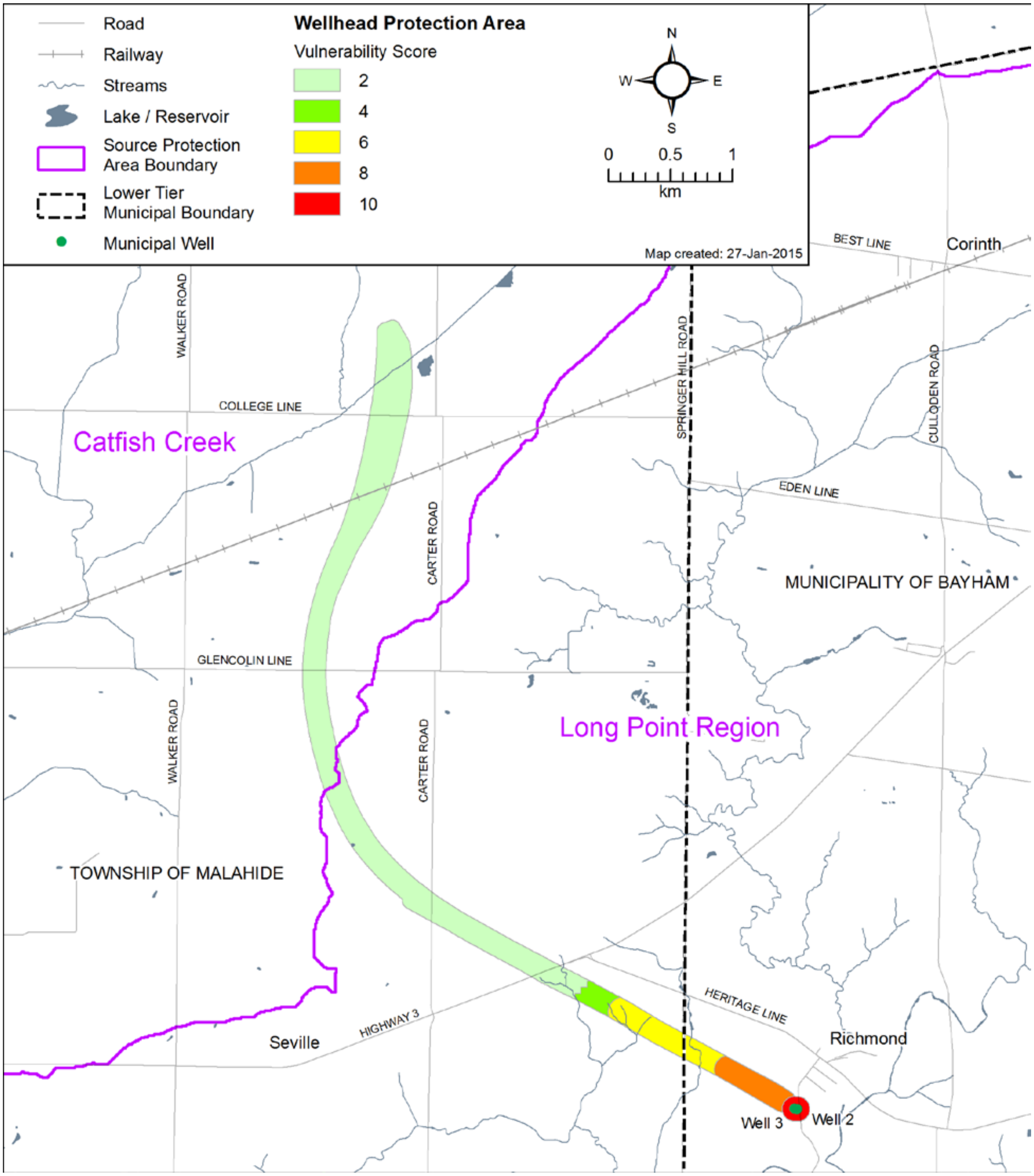
Map 7-2~~7-2~~: Richmond Wellhead Protection Areas



Map 7-3~~7-3~~: Richmond Wellhead Protection Area Intrinsic Vulnerability



Map 7-4~~7-4~~: Richmond Wellhead Protection Area Vulnerability Scoring



7.1.2 Managed Lands and Livestock Density

Managed Lands are lands to which nutrients are applied. Managed lands can be categorised into two groups: agricultural managed land and non-agricultural managed land. Agricultural managed land incudes areas of cropland, fallow and improved pasture that may receive nutrients. Non-agricultural managed land included golf courses, sports fields, lawns and other grassed areas that may receive nutrients. Managed lands in the Richmond area were mapped based on a field visit (**Map 7-5**).

Livestock density is defined as nutrient units per acre of agricultural managed land within a vulnerable area. A nutrient unit is defined as the number of animals that will give the fertilizer replacement value of the lesser of 43 kilograms of nitrogen or 55 kilograms of phosphate per year as nutrients.

Livestock density was calculated using the MOE 2009 guidance "Calculating Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers". Using aerial photography, livestock buildings were identified and square metre areas were measured for each structure. Each category of livestock was calculated into Nutrient Units as per the Barn/Nutrient Unit Relationship Table provided by the GRCA (2009) and area weighted given the amount of agricultural managed land that fell within each Wellhead Protection Area zone. The sum of the total Nutrient Units for each Wellhead Protection Area zone was then divided by the agricultural managed land area acreage to arrive at the NU/acre density for each Wellhead Protection Area zone. The Livestock Density values for the Village of Richmond are provided in **Map 7-6** and **Table 7-4**.

Table 7-3: Managed Lands Percentage in the Richmond Wellhead Protection Areas

Municipality	Location	Well	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Bayham	Richmond	TW2-12 and TW3-12	60%	90%	60%	N/A

Table 7-4: Livestock Density in the Richmond Wellhead Protection Area (Nutrient Units/Acre)

Municipality	Location	Well	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Bayham	Richmond	TW2-12 and TW3-12	0.0	1.1	0.0	N/A

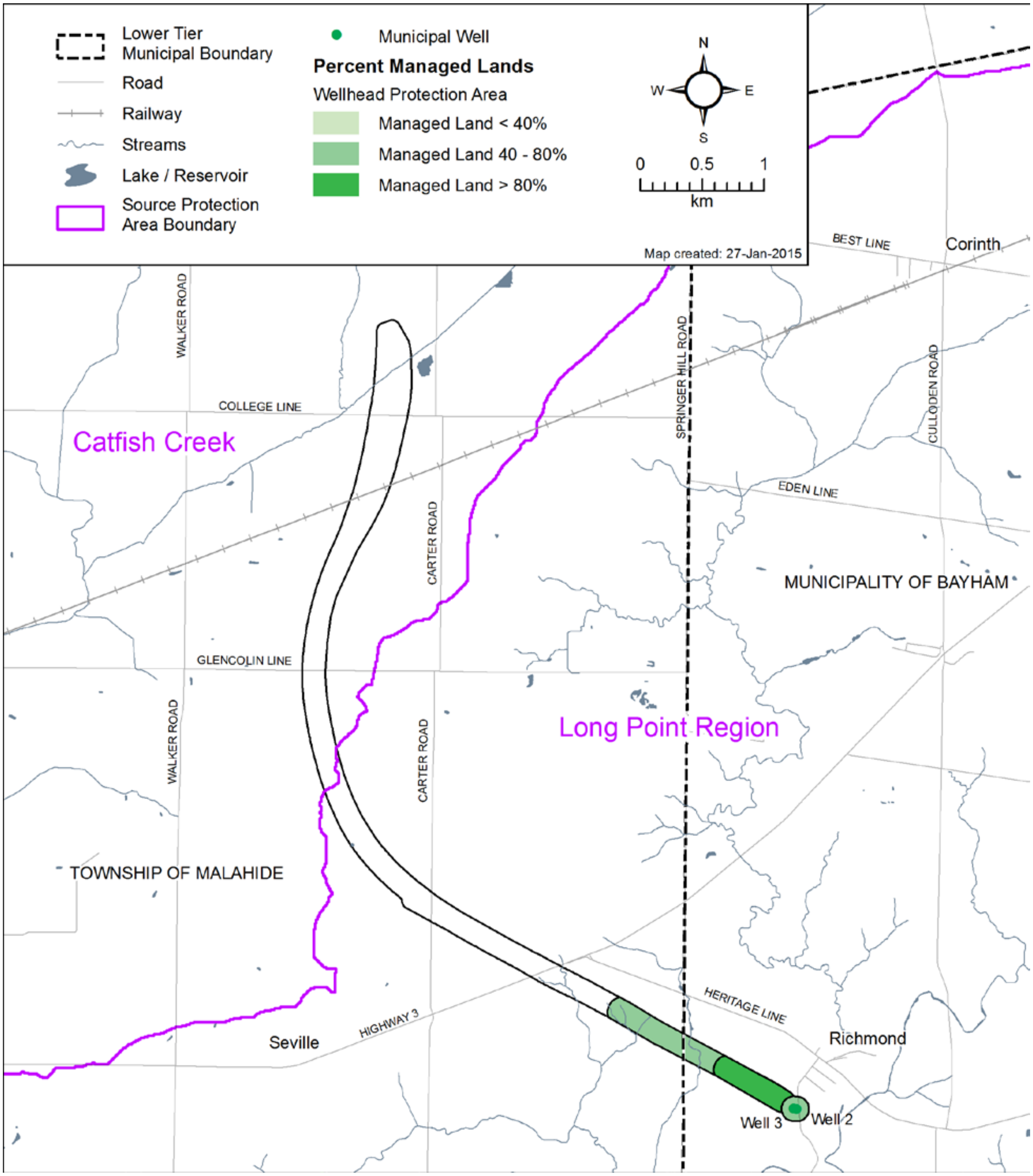
7.1.3 Percent Impervious Surface in Wellhead Protection Areas

To calculate the percent impervious surface, information on land cover classification from the Southern Ontario Land Resource Information system (SOLRIS) was used. This provided land use information, including road and highway transportation routes, as continuous 15x15 metre grid cells across the entire Source Protection Area. All the cells that represent highways and other impervious surfaces used for vehicular traffic were re-coded with a cell value of 1 and all other land cover classifications were given a value of 0, to identify impervious surface areas.

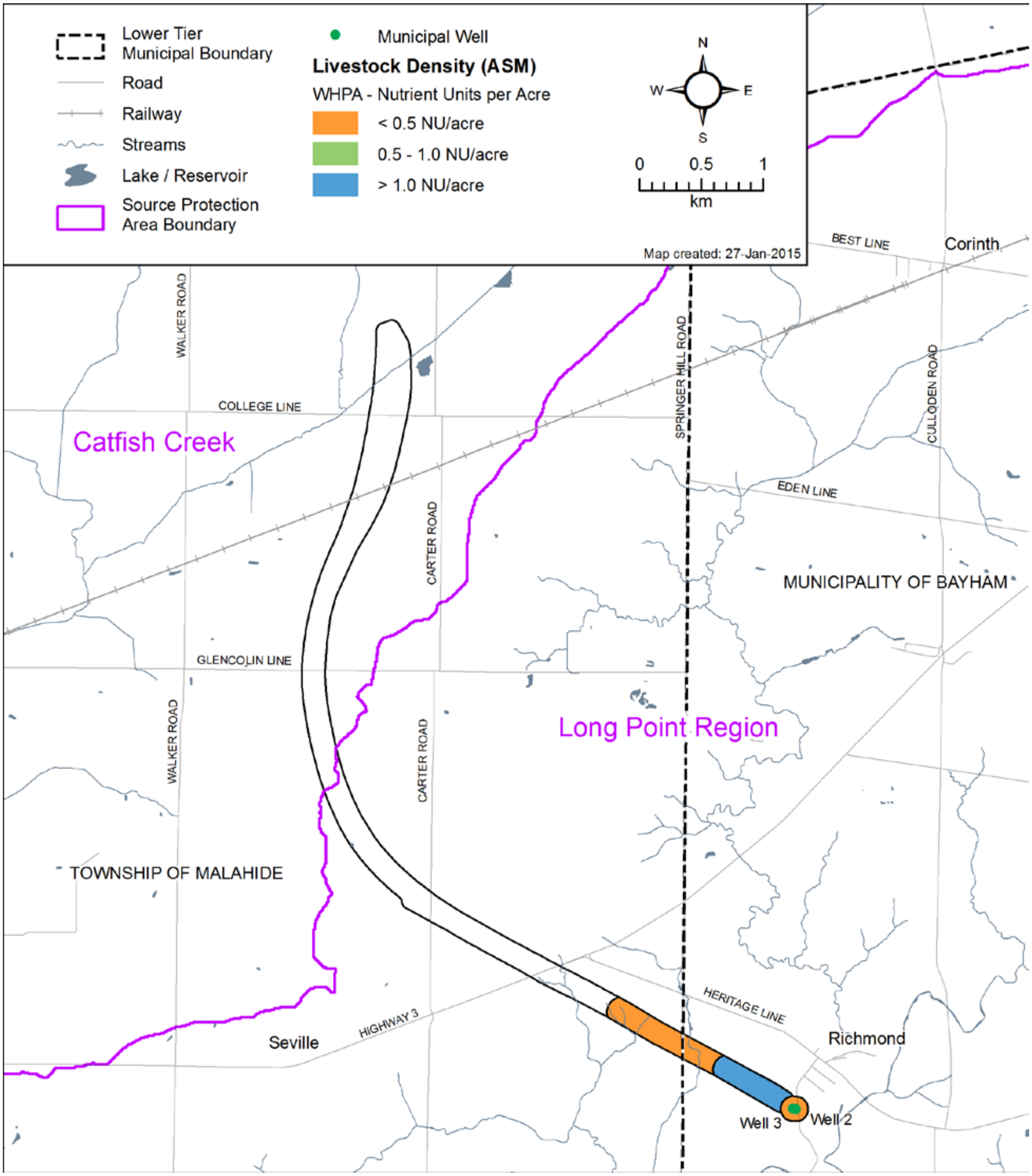
Then, a focal sum moving window average was applied using the Spatial Analyst module of the ArcGIS software. For each 15x15 metre cell, the total number of neighbouring grid cells coded as impervious, within a 1x1 kilometre search area, was calculated. This total was then converted into the percentage of impervious surface by land area, using the area of each cell (225 sq. m) and the area of the moving window (1 sq. km). This provides a 1x1 kilometre moving window calculation of percent impervious surface, represented in 15x15 metre spatial increments. This dataset was calculated for the entire Source Protection Area, but for Richmond was clipped to show those results only where the vulnerability score was 6 or above. The analysis is more representative of road density and is better than the method described in the Technical Rules. As per Technical Rule 15.1, the Director has confirmed his agreement with the departure. The Director‘s letter of confirmation can be found in **Appendix B**.

See **Map 7-7** for the impervious area percentages for the Richmond wellhead protection area.

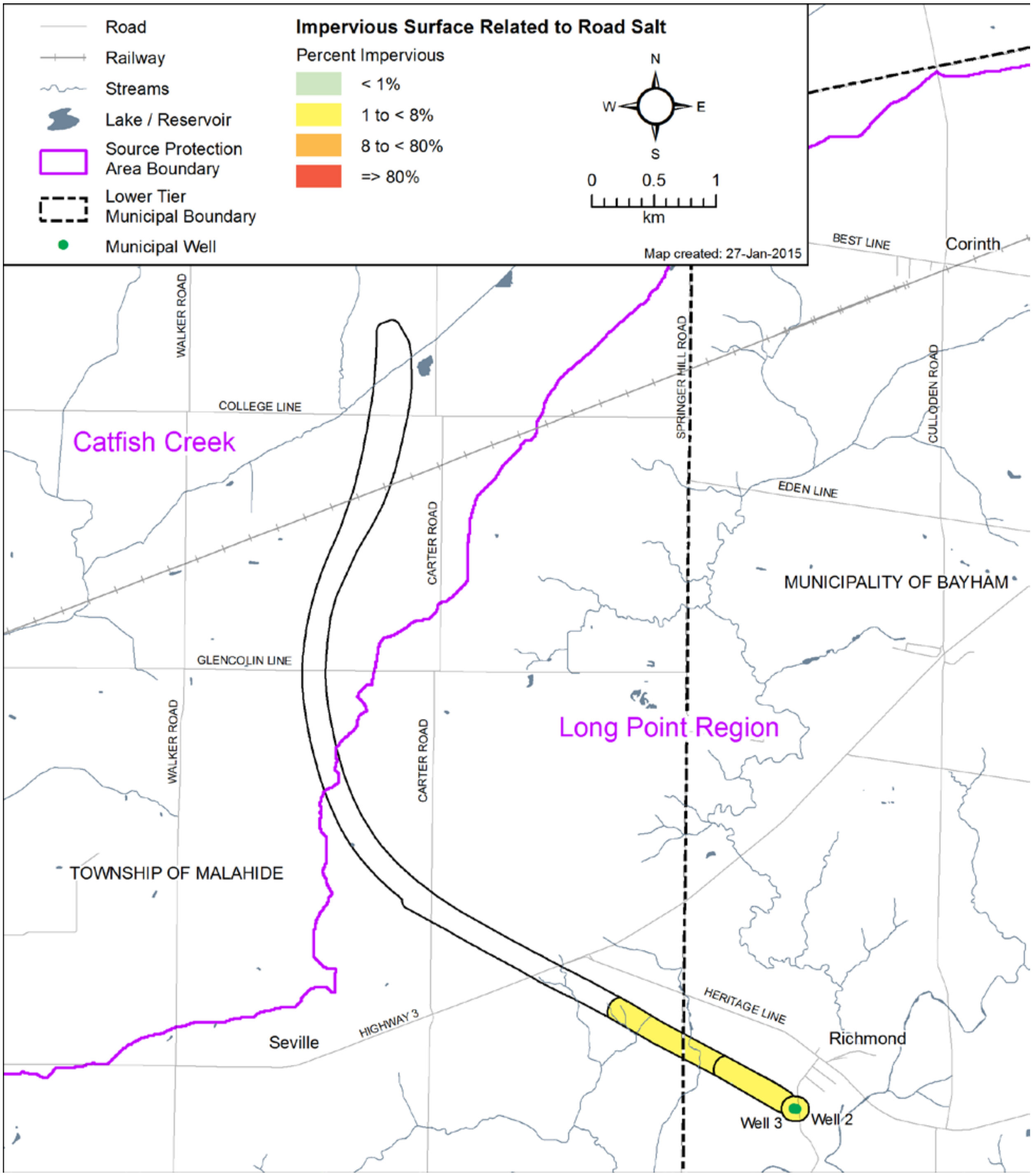
Map 7-5~~7-5~~: Percent Managed Land within the Richmond Wellhead Protection Area



Map 7-6~~7-6~~: Livestock Density within the Richmond Wellhead Protection Area



Map 7-7~~7-7~~: Percent Impervious Surface within the Richmond Wellhead Protection Area



7.1.4 Richmond Water Quality Threats Assessment

The Ontario *Clean Water Act, 2006* defines a Drinking Water Threat as “an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat.”

The Technical Rules (MOE, 2009a) list five ways in which to identify a drinking water threat:

a) Through an activity prescribed by the Act as a Prescribed Drinking Water Threat;

b) Through an activity identified by the Source Water Protection Committee as an activity that may be a threat and (in the opinion of the Director) a hazard assessment confirms that the activity is a threat;

c) Through a condition that has resulted from past activities that could affect the quality of drinking water;

d) Through an activity associated with a drinking water issue; and

e) Through an activity identified through the events based approach (this approach has not been used in this Assessment Report).

Threats can fall into one of the following four categories:

- Chemical threats can include toxic metals, pesticides, fertilizers, petroleum products and industrial solvents;

- Pathogenic threats are microorganisms that could cause illness; and

- Dense non-aqueous phase liquids (DNAPLs) are chemicals which are denser than water and do not dissolve in water, such as chlorinated solvents.

- Through a condition that has resulted from past activities that could affect the quality of drinking water.

Significant threats to the Richmond water supply were assessed through the development of a desktop land use inventory. Following preliminary research a field assessment to verify the initial threats inventory was completed.

Activities that Are or Would be Drinking Water Threats in the Wellhead Protection Areas

Ontario Regulation 287/07, pursuant to the *Clean Water Act*, *2006* provides a list of Prescribed Drinking Water Quality Threats that could constitute a threat to drinking water sources. **Table 7-5** lists the activities that are prescribed drinking water threats. Listed beside the prescribed drinking water threats are the typical land use activities that are associated with the threat.

In addition, there is one local threat that has been identified in the Lake Erie Source Protection Region: the transportation of oil and fuel products through a pipeline.

A spill of oil and fuel products could result in the presence of petroleum hydrocarbons or BTEX in groundwater. The conveyance of oil by way of an underground pipeline that would be designated as transmitting or distributing “liquid hydrocarbons”, including “crude oil”, "condensate", or "liquid petroleum products", and not including "natural gas liquids" or "liquefied petroleum gas", within the meaning of Ontario Regulation 210/01 under the *Technical Standards and Safety Act* or is subject to the *National Energy Board Act,* was approved as a local threat. The letter of approval from the Director of the Source Protection Programs Branch and table of hazard ratings is found in **Appendix C**.

Table 7-5: Drinking Water Threats

Prescribed Drinking Water Threat Ontario Regulation 287/07 s.1.1.(1)		**Land Use / Activity**
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act.*	Landfills – Active, Closed Hazardous Waste Disposal Liquid Industrial Waste
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage Infrastructures Septic Systems, etc.
3	The application of agricultural source material to land.	e.g. manure, whey, etc.
4	The storage of agricultural source material.	e.g. manure, whey, etc.
5	The management of agricultural source material.	aquaculture
6	The application of non-agricultural source material to land.	Organic Soil Conditioning Biosolids
7	The handling and storage of non-agricultural source material.	Organic Soil Conditioning Biosolids
8	The application of commercial fertilizer to land.	Agriculture Fertilizer
9	The handling and storage of commercial fertilizer.	General Fertilizer Storage
10	The application of pesticide to land.	Pesticides
11	The handling and storage of pesticide.	General Pesticide Storage
12	The application of road salt.	Road Salt Application
13	The handling and storage of road salt.	Road Salt Storage
14	The storage of snow.	Snow Dumps
15	The handling and storage of fuel.	Petroleum Hydrocarbons
16	The handling and storage of a dense non-aqueous phase liquid.	DNAPLs
17	The handling and storage of an organic solvent	Organic Solvents
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	De-icing
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.	Private water taking
20	An activity that reduces the recharge of an aquifer.	Impervious Surfaces
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Agricultural Operations
Local Drinking Water Threat		**Land Use / Activity**
The conveyance of oil by way of an underground pipeline that would be designated as transmitting or distributing "liquid hydrocarbons", including "crude oil", "condensate", or "liquid petroleum products", and not including "natural gas liquids" or "liquefied petroleum gas", within the meaning of the Ontario Regulation 210/01 under the *Technical Standards and Safety Act* or is subject to the *National Energy Board Act.* [1]		Oil pipeline

[1]: As confirmed by the letter from the Director of the Source Protection Programs Branch in **Appendix C**.

Identification of Significant, Moderate and Low Drinking Water Quality Threats for the Richmond Well Supply

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the Tables of Drinking Water Threats available through www.sourcewater.ca. Information on drinking water threats is also accessible through the Source Water Protection Threats Tool: http://swpip.ca. For local threats, the risk score is calculated as per the Director's Approval Letter, as shown in **Appendix C**. The information above can be used with the vulnerability scores shown in **Map 7-4** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 7-6 provides a summary of the threat levels possible in the Richmond Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL), Pathogen, and Local Threats (Oil Pipelines). A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not. The colours shown for each vulnerability score correspond to those shown in **Map 7-4**.

Table 7-6: Identification of Drinking Water Quality Threats in the Richmond Well Supply Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Threat Classification Level		
			Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	WHPA-A	10	✔	✔	✔
	WHPA-B	8	✔	✔	✔
	WHPA-C	6		✔	✔
	WHPA-D	2 & 4			
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	✔		
	WHPA-D	2 & 4			
Pathogens	WHPA-A	10	✔	✔	
	WHPA-B	8		✔	✔
	WHPA-C/D	Any Score			
Local Threat (Oil Pipelines)	WHPA-A	10	✔		
	WHPA-B	8		✔	
	WHPA-C	6			✔
	WHPA-D	2 & 4			

7.1.5 Conditions Assessment

Conditions are contamination that already exist and are a result of past activities that could affect the quality of drinking water. To identify a Condition, Part XI.3, Rule 126 of the CWA Technical Rules, lists the following two criteria for groundwater sources:

- The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or wellhead protection area.

- The presence of a contaminant in groundwater in a highly vulnerable area, significant groundwater recharge area or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Groundwater and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table.

The above listed criteria were used to evaluate potentially contaminated sites within the WHPAs to determine if such a Condition was present at a given site.

~~***Conditions Assessment for the Richmond Well Supply***~~

A review of available data regarding potential contamination within the WHPAs was completed. Data available included databases such as the National Environmental Emergencies System, Record of Site Condition and the Ontario Spills database. The search of available databases did not provide any evidence of a condition site within the Richmond ~~water supply~~ WHPAs.

7.1.6 Drinking Water Quality Issues Evaluation

~~The objective of the Issues evaluation is to identify drinking water Issues where the existing or trending concentration of a parameter or pathogen at an intake, municipal well or monitoring well would result in the deterioration of the quality of water for use as a source of drinking water. The parameter or pathogen must be listed in Schedule 1, 2 or 3 of the Ontario Drinking Water Quality Standards (ODWQS) or Table 4 of the Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines (Technical Rules XI.1 (114 – 117)).~~

~~Once a drinking water Issue is identified, the objective is to identify all sources and threats that may contribute to the issue within an Issue contributing area and manage these threats appropriately. If at this time the Issue contributing area cannot be identified or the Issue cannot be linked to threats then a work plan must be provided to assess the possible link.~~

~~If an Issue is identified for an intake, municipal well or monitoring well, then all threats related to a particular Issue within the issue contributing areas are significant drinking water threats, regardless of the vulnerability.~~

~~***Water Quality Issues Evaluation for the Richmond Water Supply***~~

Raw water quality data obtained during pumping tests completed in 2013 was reviewed to determine if any parameters were in exceedance of the Ontario Drinking Water Quality Standards (ODWQS) (Stantec, 2013). It is worth noting when reviewing the following sections that TW1-10 is an 81.4 m deep well completed in a confined bedrock aquifer, whereas wells TW2-12 and TW3-12 are shallow overburden wells completed 17.4 m and 18.0 m below ground surface.

Microbiological Parameters

Samples were analyzed for *Escherichia coli (E. coli*.), fecal coliform, total coliforms, background bacteria and total aerobic spore formers. No bacteriological parameters exceeded the ODWQS ~~(Ontario Drinking Water Quality Standards)~~ Maximum Acceptable Concentration (MAC).

Inorganic Parameters

Results of the general chemistry/inorganic analysis indicated the following parameters exceeded the ODWQS MAC, the ODWQS Aesthetic Objectives (AO), the ODWQS Operation

Guidelines (OG) and/or the Medical officer of Health Reporting Limit (MOH). These results are based on samples taken in 2010 for TW1-10, and 2012 for TW2-12 and TW3-12.

<u>TW1-10</u>

- Selenium (0.014 mg/L) slightly exceeded the ODWQS MAC of 0.01 mg/L.
- Hardness (550 mg/L) exceeded the ODWQS OG of 80 to 100 mg/L.
- Organic nitrogen (3.7 mg/L) exceeded the ODWQS OG of 0.15 mg/L.
- Chloride (450 mg/L) and sodium (300 mg/L) exceeded the ODWQS AO of 250 mg/L and 200 mg/L, respectively.
- Total dissolved solids (TDS) (1,300 mg/L) exceeded the ODWQS AO of 500 mg/L.
- Sulfide (150 mg/L) exceeded the ODWQS AO of 0.05 mg/L.
- Dissolved Methane (3.2 L/m^3) exceeded the ODWQS AO of 3 L/m^3.
- Turbidity (24 NTU) exceeded the ODWQS AO of 5.0 NTU.

<u>TW2-12</u>

- Nitrate (17 mg/L) exceeded the ODWQS MAC of 10 mg/L.
- Hardness (310 mg/L) exceeded the ODWQS OG of 80 to 100 mg/L.

<u>TW3-12</u>

- Nitrate (17 mg/L) exceeded the ODWQS MAC of 10 mg/L.
- Hardness (370 mg/L) exceeded the ODWQS OG of 80 to 100 mg/L.
- Organic nitrogen (0.3 mg/L) exceeded the ODWQS OG of 0.15 mg/L.
- Total dissolved solids (523 mg/L) exceeded the ODWQS AO of 500 mg/L.
- Sodium (41 mg/L) exceeded the ODWQS MOH of 20 mg/L.

Hardness concentrations were exceeded in groundwater pumped from each of the test wells, with these elevated concentrations being caused by dissolved calcium and magnesium. Water supplies having hardness concentrations greater than 200 mg/L are considered poor from a taste perspective; however, no aesthetic guideline has been established as the public acceptance of hardness may vary considerably according to the local conditions. Overall, elevated hardness concentrations are common to groundwater throughout southern Ontario and are not considered by the ODWS to be a health concern.

One sample was collected from each of the wells TW2-12 and TW3-12 in 2012 to be analyzed for nitrate along with other suites of parameters. Both wells had nitrate concentrations of 17 mg/L which exceeded the ODWQS of 10 mg/L. Additional samples were collected in 2013 and again in 2015 from both wells. TW2-12 had nitrate concentrations of 16.0 mg/L in 2013 and 16.7 mg/L in 2015. TW3-12 had nitrate concentrations of 6.99 mg/L in 2013 and 7.52 mg/L in 2015. The elevated concentrations in TW2-12 may be the result of nitrate leaching to the groundwater system from manure and/or fertilizers applied to the local agricultural lands, which are prevalent throughout the wellhead protection area. These agricultural practices may also be the source of the elevated concentration of organic nitrogen (0.3 mg/L) also detected in the water sampled from TW3-12.

Nitrate concentrations which exceed 10 mg/L in drinking water may cause blood related problems (i.e., methaemoglobinaemia); however, this condition has been shown to be restricted to babies and small children, whereas older children and adults drinking the same water are unaffected. Excess organic nitrogen in a water supply can result in operational difficulties in water treatment equipment (i.e., chlorination) and may be responsible for taste and odour problems; however, the presence of this parameter at elevated concentrations in the water supply is not considered to be a health-related risk. Organic nitrogen was also found to be notably high in the groundwater sampled from TW1-10 (3.7 mg/L).

The presence of elevated concentrations of total alkalinity (380 mg/L to 555 mg/L), ammonia (2.2 mg/L to 2.4 mg/L), iron (0.2 mg/L to 1 mg/L), methane (3.2 l/m_3), sulfide (150 mg/L) and non-detect concentrations of nitrate (<0.10 mg/L) in TW1-10 suggest that the groundwater system is characterized by anaerobic (i.e., reducing) conditions, providing further evidence that the bedrock aquifer is under confined conditions. Although a selenium concentration of 0.014 mg/L was detected in a groundwater sample that was obtained from TW1-10 during the pumping test, this concentration was only slightly over the MAC of 0.010 mg/L and, technically, could be considered to be at the ODWS.

Elevated concentrations of sodium were detected in the groundwater samples obtained from TW1-10 (300 mg/L) and TW3-12 (41 mg/L). These concentrations are in excess of the Medical Officer of Health Report Limit of 20 mg/L and may pose a concern for individuals consuming the well water who are on a sodium-restricted diet.

Turbidity concentrations of 0.8 NTU and 24 NTU were detected in the groundwater samples obtained from TW3-12 and TW1-10, respectively. Where possible, water supplies that are treated should be equipped with filtration systems that are designed and operated to reduce turbidity levels to a target of less than 0.1 NTU.

Nitrate Assessment for the Richmond Water Supply

An additional nitrate investigation has been completed for municipal wells TW2-12 and TW3-12~~,~~. As of February, 2015, both wells have been sampled on a monthly basis for nitrate and an annual monitoring report completed as per policy EC-CW-1.14 of the Long Point Source Protection Plan (BluMetric, 2017).

During the ~~sampling~~ period between February 2015 to June 2017, TW2-12 nitrate concentrations have ranged from 12.2 mg/L to 17.9 mg/L ~~and~~while TW3-12 nitrate concentrations have ranged from 5.58 mg/L to 17.2 mg/L. ~~Both wells had n~~Nitrate concentrations in both wells have ~~which~~ exceeded the ODWS of 10 mg/L on a consistent basis. Two raw water samples were submitted for isotope and artificial sweetener analysis in early 2015. Results ~~which~~ indicated that nitrate is derived from the nitrification of ammonium;~~m and that~~ no artificial sweeteners were identified. The annual nitrate monitoring report (BluMetric, 2017), concluded that ~~the~~ nitrate in ~~municipal~~ wells TW2-12 and TW3-12 is most likely associated with ~~synthetic~~nitrified fertilizers applied to the field immediately adjacent to the wells. It was recommended that monthly samples continue to be collected at both municipal wells to determine how pumping rates and total daily volumes being drawn at each well will influence nitrate levels at each well.

Nitrate Issue Contributing Area for the Richmond Water Supply

As nitrate concentrations at the wells regularly exceed the nitrate MAC of 10 mg/L, nitrate was identified as a ~~On the basis of the exceedances of the ODWS and with support from the Lake~~

~~Erie Region Source Protection Committee, nitrate was identified as a~~ Drinking Water Issue under Technical Rule 114 of the *Clean Water Act, 2006,* and an Issue Contributing Area (ICA) delineated for the Richmond wellfield as shown on **Map 7-8**. Since wells TW2-12 and TW3-12 are screened in an unconfined overburden aquifer and classified as GUDI without effective in-situ filtration, and the pumping rate for the wellfield is comparatively small for a municipal wellfield, it is likely that the land uses located adjacent to the wells have the largest impact on nitrate concentrations in the groundwater. Therefore, the ICA for the Richmond wells extends to include only WHPAs A and B. The extent of the ICA was developed in consultation with the Municipality of Bayham's Risk Management Official and municipal staff, based on conclusions from the annual monitoring report.

~~The extent of the ICA was developed in consultation with the Risk Management Official for the Municipality of Bayham and municipal staff and based on the conclusions of the annual monitoring report. The Issue Contributing Area for the Richmond well supply is shown in **Map 7-8**.~~

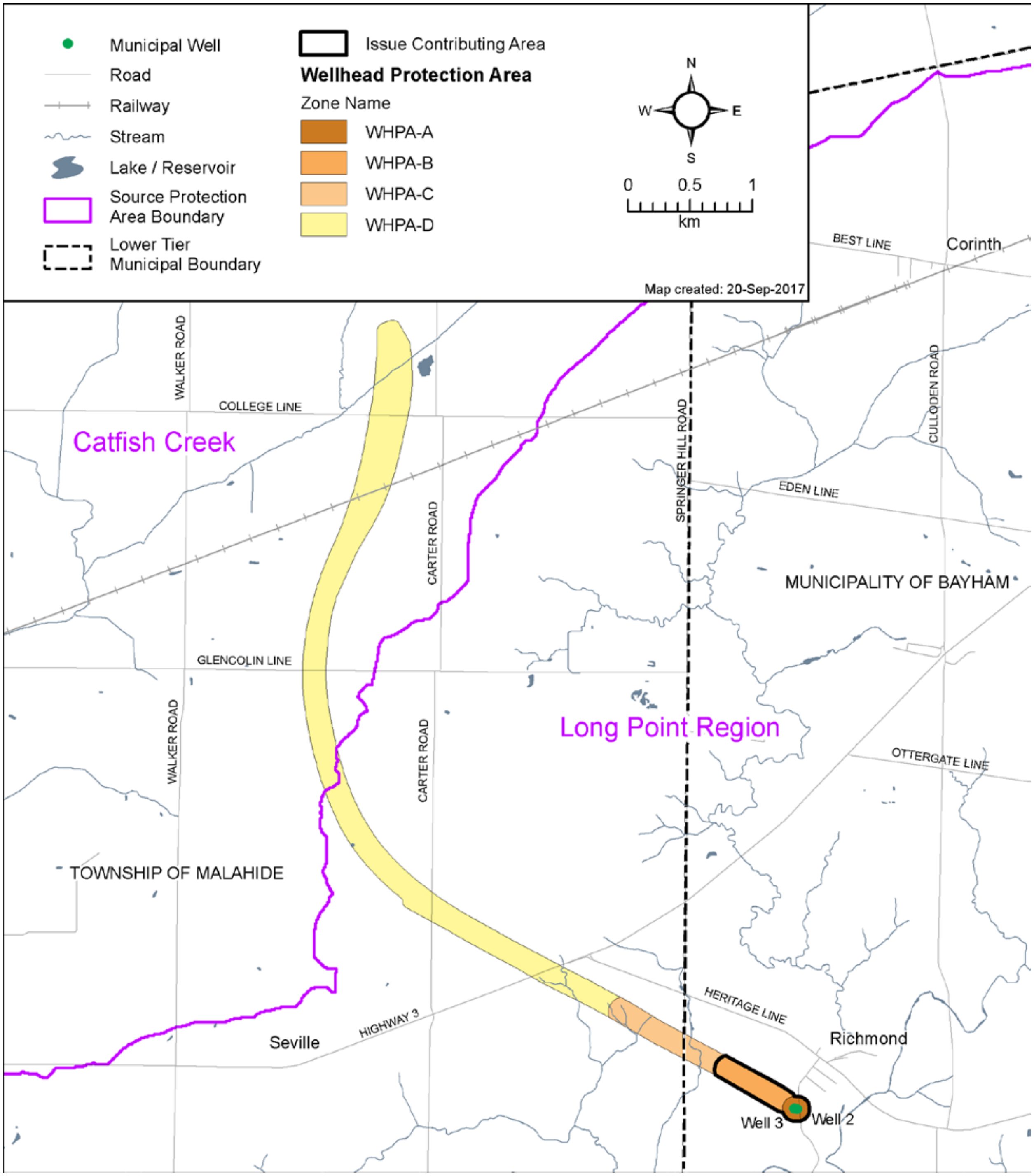
~~***Summary of Drinking Water Issues Evaluation***~~

~~Although the nitrate concentration in well TW2-12 is elevated, there is limited monitoring data available as both wells were drilled in August, 2012. Only three rounds of water quality results were available at the time of this report; 2012 data from when the well was drilled, 2013 and 2015 data. The Preliminary nitrate investigations 2012 data shows both wells to have nitrate concentrations ranging from 5.99 mg/L toof 17 mg/L. 2013 data shows nitrate concentrations of 5.99 mg/L for TW3-12 and 16 mg/L for TW2-12, whereas 2015 data shows nitrate concentrations of 7.52 mg/L for TW3-12, and 16.7 mg/L for TW2-12. It isThese preliminary investigations recommended that the elevatedincreased nitrate concentrations at wells TW2-12 and TW3-12 be described as a drinking water issue per Technical Rule 115.1 under Section 15 (2) (f) of the *Clean Water Act, 2006*. Under this Technical Rule, an Issues Contributing Area is not delineated and therefore there can be no significant threat activities identified associated with this issue. The only applicable policies would relate to the monitoring of the nitrate issue.~~

~~Recent and more detailed nitrate data (monthly samples in 2015 and 2016) show similar results as the preliminary study with elevated nitrate levels above the ODWS of 10 mg/L at both municipal wells. The nitrate monitoring report concluded that with further investigation of nitrate levels and pumping rates and volumes, determination of managing fertilizer applications on the nearby field within WHPA A could result in an improvement in water quality with respect to nitrate over time (BluMetric, 2017). Nitrate was identified as an Drinking Water Issue and an ICA was delineated for the Richmond wellfield in WHPA-A and B in response to results of 2017 nitrate monitoring report.~~

~~Since nitrate concentrations are high, the issues approach allows the Municipality time to complete further sampling and study into the sources of nitrates at these wells.~~

Map 7-8 Richmond Well Supply Issue Contributing Area



7.1.7 Enumeration of Significant Drinking Water Quality Threats

The Technical Rules require an estimation of the number of locations at which an Activity is a significant drinking water threat and the number of locations at which a Condition resulting from past activity is a significant drinking water threat.

The threats inventory was compiled using the data from various sources that were reviewed as part of this study. Following the preliminary research, field assessments were conducted to verify and complete the threats inventory process. As a conservative measure no effort to include the impact of management techniques that may be employed at any threat location was considered. It can therefore be concluded that the level of uncertainty associated with this inventory is high. It is through a re-evaluation of the prioritized threats that the level of uncertainty associated with the current results will be reduced.

Data Sources for the Activity Threats Assessment of the Richmond Well Supply

The threats inventory was compiled using the data and information sources outlined below. Following the preliminary research field assessments were completed to complete the threats inventory. All threats were recorded in a database provided by the MOE.

EcoLog Environmental Risk Information Services Ltd. (EcoLog ERIS) is a national database service, which provides specific environmental and real estate information for locations across Canada. A review of all available provincial, federal and private environmental databases was requested for the areas within a prescribed radius around the wells' Wellhead Protection Areas. The search included the following databases:

Federal Government Source Databases

- National PCB Inventory 1988-2008
- National Pollutant Release Inventory 1994-2012
- Environmental Issues Inventory System 1992-2001
- Federal Convictions 1988-June 2007
- Contaminated Sites on Federal Land June 2000-September 2015
- Environmental Effects Monitoring 1992-2007
- Fisheries & Oceans Fuel Tanks 1964-September 2003
- Indian & Northern Affairs Fuel Tanks 1950-August 2003
- National Analysis of Trends in Emergencies System (NATES) 1974-1994
- National Defense & Canadian Forces Fuel Tanks Up to May 2001
- National Defense & Canadian Forces Spills March 1999-August 2010
- National Defense & Canadian Forces Waste Disposal Sites 2001 – April 2007
- National Environmental Emergencies System (NEES) 1974-2003
- Parks Canada Fuel Storage Tanks 1920-January 2005
- Transport Canada Fuel Storage Tanks 1970-March 2007

Provincial Government Source Databases

- Certificates of Approval: 1985 – October 30, 2011
- Ontario Regulation 347 Waste Generators Summary: 1986 – April 2014
- Ontario Regulation 347 Waste Receivers Summary: 1986 - 2013
- Private and Retail Fuel Storage Tanks: 1989 - 1996
- TSSA Commercial Fuel Oil Tanks: 1948 – April 2013

- TSSA Fuel Storage Tanks: 2010 – May 2013
- Ontario Inventory of PCB Storage Sites: 1987 - Oct 2004
- Compliance and Convictions: 1989 – February 2014
- Waste Disposal Sites - MOE CA Inventory: 1970 – October 2014
- Waste Disposal Sites - MOE 1991 Historical Approval Inventory: Up to October 1990
- Pesticide Register: 1988 – June 2013
- Wastewater Discharger Registration Database: 1990 - 2011
- Non-Compliance Reports: 1992 (water only), 1994 - 2014
- Aggregate Inventory: Up to August 2012
- Abandoned Aggregate Inventory: Up to September 2002
- Record of Site Condition: 1997 - September 2001, October 2004 – October 2014
- Environmental Registry: 1994 – October 2014
- Ontario Spills: 1988- February 2014
- Abandoned Mine Information System: 1800 - January 2014
- Borehole: 1875 – August 2011
- Inventory of Coal Gasification Plants and Coal Tar Sites: April 1987 – November 1988
- Certificates of Property Use: 1994 – October 2014
- Drill Hole Database: 1886 – January 2014
- Environmental Activity and Sector Registry: October 31 2011 – October 2014
- Environmental Compliance Approval: October 31, 2011 – October 2104
- List of TSSA Expired Facilities: Current to May 2013
- Fuel Storage Tank Historic: Pre – January 2010
- TSSA Historic Incidents: 2006 – June 2009
- TSSA Incidents: June 2009 – April 2013
- Landfill Inventory Management Ontario: 2012
- Mineral Occurrences: 1846 – April 2013
- Ontario Oil and Gas Wells: 1800-2013
- Orders: 1994 – October 2014
- TSSA Pipeline Incidents June 2009 – March 2012
- Permit to Take Water: 1994 – October 2014
- TSSA Variances for Abandonment of Underground Storage Tanks: Current to June 2013
- Water Well Information System: 1955 – March 2014

Private Sources Databases

- Retail Fuel Storage Tanks: 1989 – July 2014
- Andersen's Waste Disposal Sites: 1860s to Present
- Scott's Manufacturing Directory: 1992 – March 2011
- Chemical Register: 1992,1999 – July 2014
- Automobile Wrecking & Supplies: 2001 – July 2014
- ERIS Historical Searches: 1999 – August 2014
    - Canadian Mine Locations: 1998 - 2009
    - Oil and Gas Wells: 1988 – September 2014
    - Canadian Pulp and Paper: 1999, 2002, 2004, 2005, 2009
    - Anderson’s Storage Tanks: 1915 – 1953

The database search identified numerous items within the search area. All threats identified have been mapped and compiled into the project database. Items identified by Ecolog ERIS included Certificates of Approval for municipal sewage, fuel storage tanks, registered waste generators under O.Reg. 347, registered pesticide vendors, manufacturing businesses and spills (Ecolog ERIS, 2014).

Site Reconnaissance and Inspection

Burnside conducted a drive-by roadside inspection of the WHPAs on November 10, 2014 to verify and compliment the dataset compiled during the records review portion of the assessment. The inspection consisted of a fence line/roadside documentation of the properties and their land uses included in the WHPA. Land uses within the WHPA include large areas of agricultural land and open space.

Significant Drinking Water Quality Threats for the Richmond Well Supply

As per the Technical Rules (MOE, 2009a), the enumeration of significant threats is required for the completion of the Assessment Report. **Table 7-7** summarizes the significant threats identified in the Richmond WHPAs as of September 2017.

Table 7-7: Richmond Well Supply Significant Drinking Water Quality Threats

PDWT #[1]	Threat Subcategory[2]	Number of Activities	Vulnerable Area
~~1~~	~~Application Of Untreated Septage To Land~~	~~1~~	~~WHPA-A~~
2	Sewage System Or Sewage Works - Septic System	2	WHPA-A
2	Sewage System Or Sewage Works - Septic System Holding Tank	2	WHPA-A
3	Application Of Agricultural Source Material (ASM) To Land	1	WHPA-A
6	Application Of Non-Agricultural Source Material (NASM) To Land (Including Treated Septage)	1	WHPA-A
8	Application Of Commercial Fertilizer to Land	1	WHPA-A ICA
10	Application Of Pesticide To Land	1	WHPA-A
Total Number of Properties		**3**	
Total Number of Activities		**8**	

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in O.Reg 287/07 s.1.1.(1).

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: Certain types of activities on residential properties that are incidental in nature and that are significant drinking water threats are not enumerated. These threats include the application of commercial fertilizer on residential properties, the storage of organic solvents (dense non-aqueous phase liquids) on residential properties, and the storage of fuel (e.g., heating fuel tanks) on residential properties in natural gas serviced areas.

Note: Storm sewer piping is not considered to be part of a storm water management facilty.

Limitations and Uncertainty for the Enumeration of Significant Drinking Water Threats for the Richmond Well Supply

As part of the Richmond study, several databases were reviewed for the study area to collect information on the land use activities in the study area. There was no information available from the databases and the threats identified were enumerated solely on air photography interpretation and field reconnaissance. Both of these methods have a certain level of uncertainty as they are collected during a specific day and do not account for seasonal changes in land use. They also do not identify activities that are located within buildings or areas of the property not seen from the road.

In addition to the uncertainty associated with the threats inventory, the process of assigning a threat ranking was undertaken based on a number of simplifying assumptions. The uncertainty associated with the threat ranking is related to knowledge and understanding of the circumstances under which activities are conducted on a particular site. For this analysis, it was assumed that any possible threats associated with an activity were present and that all potential chemicals were present. This information was provided by the MOE in the form of look-up tables. The circumstances and quantity for each threat were assigned based on available knowledge such as typical storage practices, typical chemical quantities and typical waste disposal practices for that particular land use activity.

Based on the uncertainty involved in the threats inventory and the threat ranking for this study, the uncertainty for all of the threats has been classified as high. This level of uncertainty is expected in a desk top study. It is anticipated that additional information that is collected over time will allow for the uncertainty related to this assessment to be reduced.

The Technical Guidance outlines that each vulnerable area should be assigned an uncertainty of 'high' or 'low' to identify where information gaps exist. This process will assist in addressing data quality problems in future source water protection planning. **Table 7-8** summarizes the uncertainty assigned to each vulnerability area within the Richmond WHPAs.

Table 7-8: Richmond Wellhead Protection Area Vulnerability Uncertainty

	Uncertainty Type	**WHPA-A**	**WHPA-B**	**WHPA-C**	**WHPA-D**
Threats Uncertainty	Location of Threats	Low	Low	High	High
	Circumstances of Threats	High	High	High	High
	Overall – Threats Uncertainty	High	High	High	High

Uncertainty of location of threats in the WHPAs is generally low as most were field verified. More effort was used to locate threats located in close proximity to the wells, therefore the uncertainty of locations of threats increases away from the wells.

The uncertainty of circumstances associated to threats located within the WHPAs can be decreased through additional threat verification and communication with land owners.